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SHYSTER: The Program

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Introduction

Most legal expert systems attempt to implement complex models of legal reasoning. Yet the utility of a legal expert system lies not in the extent to which it simulates a lawyer's approach to a legal problem, but in the quality of its predictions and of its arguments. A complex model of legal reasoning is not necessary: a successful legal expert system can be based upon a simplified model of legal reasoning.

Some researchers have based their systems upon a jurisprudential approach to the law, yet lawyers are patently able to operate without any jurisprudential insight. A useful legal expert system should be capable of producing advice similar to that which one might get from a lawyer, so it should operate at the same pragmatic level of abstraction as does a lawyer—not at the more philosophical level of jurisprudence.

A legal expert system called SHYSTER has been developed to demonstrate that a useful legal expert system can be based upon a pragmatic approach to the law. SHYSTER has a simple representation structure which simplifies the problem of knowledge acquisition. Yet this structure is complex enough for SHYSTER to produce useful advice.

SHYSTER is a case-based legal expert system (although it has been designed so that it can be linked with a rule-based system to form a hybrid legal expert system). Its advice is based upon an examination of, and an argument about, the similarities and differences between cases. SHYSTER attempts to model the way in which lawyers argue with cases, but it does not attempt to model the way in which lawyers decide which cases to use in those arguments. Instead, it employs statistical techniques to quantify the similarity between cases. It decides which cases to use in argument, and what prediction it will make, on the basis of that similarity measure.

<i>Module</i>	<i>lines of code</i>		<i>Total</i>
	<i>.h</i>	<i>.c</i>	
SHYSTER	64	347	411
STATUTES	19	40	59
CASES	274	639	913
TOKENIZER	56	385	441
PARSER	4	947	951
DUMPER	20	784	804
CHECKER	6	268	274
SCALES	13	284	297
ADJUSTER	7	227	234
CONSULTANT	19	260	279
ODOMETER	14	830	844
REPORTER	12	1523	1535
<i>Total</i>	508	6534	7042

Figure 1: Lines of C code in SHYSTER, by module. Each module comprises two files: a definition (.h) file and an implementation (.c) file.

SHYSTER is of a general design: it provides advice in areas of case law that have been specified by a legal expert using a specification language, indicating the cases and attributes of importance in those areas. Four different, and disparate, areas of law have been specified for SHYSTER, and its operation has been tested in each of those legal domains.

Testing of SHYSTER in these four domains indicates that it is exceptionally good at predicting results, and fairly good at choosing cases with which to construct its arguments. SHYSTER demonstrates the viability of a pragmatic approach to legal expert system design.

* * *

SHYSTER is implemented using a dozen modules, written in ISO C.¹ (A breakdown, by module, of the number of lines of C code in SHYSTER is given in figure 1.) This report provides complete code listings of all twelve modules. This code, and the case law specifications used to test SHYSTER, are available on the worldwide web.² Full details of the design, implementation, operation and testing of SHYSTER are given elsewhere.³

->	structure/union pointer	→
*	indirection	*
*	multiplication	×
==	equal to	≡
!=	not equal to	≠
<=	less than or equal to	≤
>=	greater than or equal to	≥
!	logical negation	¬
&&	logical AND	∧
	logical OR	∨

Figure 2: Special symbols used in the listings of C code that appear in this report. The operators on the left are represented by the symbols on the right.

The SHYSTER module (§1) is the top-level module for the whole system. The STATUTES module (§2) is the top-level module for a rule-based system, presently unimplemented. The CASES module (§3) is the top-level module for the case-based system. The TOKENIZER and PARSER modules (§4 and §5) tokenize and parse a program written in SHYSTER's case law specification language. The DUMPER module (§6) displays the information that has been parsed. The CHECKER module (§7) checks for evidence of dependence between the attributes. The SCALES module (§8) determines the weight of each attribute. The ADJUSTER module (§9) allows the legal expert to adjust the weights of the attributes. The CONSULTANT module (§10) interrogates the user as to the attribute values in the instant case. The ODOMETER module (§11) determines the distances between the leading cases and the instant case, and the REPORTER module (§12) writes SHYSTER's legal opinion.

* * *

The format used for the display of C code in this report is based on that of the CWEB system.⁴ Reserved words and preprocessor commands are set in boldface type. Identifiers are set in italics. String constants and character constants are set in a typewriter font, with “`□`” representing a space. Some operators are represented by special symbols, as explained in figure 2.⁵

SHYSTER's external identifiers are made up of upper- and lower-case letters. Static identifiers consist only of lower-case letters. Identifiers in all upper-case are enumerated identifiers and other constants.

An index to all of the identifiers which appear in the code listings, and which are not reserved words or preprocessor commands, is at the end of this report.

* * *

Much of SHYSTER's output is in \LaTeX format: i.e. it is suitable for processing by the \LaTeX document processor.⁶ This contributes to SHYSTER's portability, as \LaTeX is widely available on many platforms. Using \LaTeX simplifies the footnoting of text (`\footnote{...}`), allows some data to be displayed in a clear and economical tabular format (`\begin{tabular}...`), and ensures the aesthetic quality of the output.

¹International standard ISO/IEC 9899: 1990; Australian standard AS 3955–1991. Kernighan and Ritchie 1988 describe ANSI C which is the same as ISO C.

²<http://cs.anu.edu.au/software/shyster>

³Popple 1993, 1996.

⁴Knuth and Levy 1994. CWEB is a version of Knuth's WEB system (1986a, 1986b) adapted to C. The CWEB system of structured documentation was not used in the development of SHYSTER, but CWEB's approach to "pretty-printing" C code has been adopted for this report. This report was prepared using the \LaTeX document processor; \LaTeX code was generated from SHYSTER's C code using a preprocessor constructed by the author.

⁵All of the special symbols in figure 2 are used by CWEB, except for \times : CWEB uses $*$ for both indirection and multiplication.

⁶Lamport 1986 describes \LaTeX which is a set of macros for Knuth's \TeX system (1984, 1986a). SHYSTER's \LaTeX output is suitable for processing by \LaTeX version 2.09 (25 March 1992) and \TeX version 3.141. It can also be processed, in "compatibility mode," by $\text{\LaTeX} 2_{\epsilon}$ which is described by Lamport 1994.

1

The SHYSTER module

shyster.h

```
/* This is the header file for the SHYSTER module. It is included by all twelve modules. */
/* version and copyright information */
#define Shyster_Version "SHYSTER_version_1.0"
#define Copyright_Message "Copyright_James_Popple_1993"
/* a string which is written to stderr if SHYSTER is invoked without arguments */
#define usage_string \
    "usage:\t" \
    "shyster[_a][_c_filename][_d_filename][_D_filename][_e]\n" \
    "\t\t[_h_number_number][_i][_l_filename][_p_filename]\n" \
    "\t\t[_q][_r_filename][_w_filename]\n"
/* the versions of LATEX and TEX for which SHYSTER has been developed */
#define LaTeX_Version "LaTeX_version_2.09<25_March_1992>"
#define TeX_Version "TeX_version_3.141"
/* maxima */
#define Max_Filename_Length 256
#define Max_Error_Message_Length 256
#define Max_LaTeX_Line_Width 64
/* other constants */
#define Empty_String ""
#define Null_Character '\0'
#define Space_Character '_'
#define Carriage_Return_Character '\n'
#define Top_Level 0
#define No_Hang 0
#define Hang 1
```

```

/* functions whose returned values are always ignored */
#define fprintf (void) fprintf
#define free (void) free
#define gets (void) gets
#define sprintf (void) sprintf

/* simple types */
typedef unsigned int cardinal;
typedef float floating_point;
typedef char *string;
typedef FILE *file;

/* enumerated type */
typedef enum {
    FALSE,
    TRUE
} boolean;

/* external functions */
extern void
Indent(
    file stream,
    cardinal level);

extern void
Write(
    file stream,
    string write_string,
    const string suffix,
    const cardinal level,
    const boolean hanging_indent);

extern void
Write_Error_Message_And_Exit(
    file stream,
    const string module_name,
    string message);

extern void
Write_Warning_Message(
    file stream,
    const string module_name,
    string message,
    const cardinal level);

extern void
Write_LaTeX_Header(
    file stream,
    boolean inputable_latex);

extern void
Write_LaTeX_Trailer(
    file stream,
    boolean inputable_latex);

```

```
extern boolean
Is_Digit(
    int ch);
```

shyster.c

```
/* This is the implementation file for the SHYSTER module. */
```

```
#include <stdio.h>
#include <stdlib.h>
#include "shyster.h"
#include "cases.h"
#include "statutes.h"
```

```
extern void
```

```
Indent(
    file stream,
    cardinal level)
```

```
/* Writes the equivalent of  $4 \times level$  spaces (1 tab = 8 spaces). */
```

```
{
    while (level > 1) {
        fprintf(stream, "\t");
        level -= 2;
    }
    if (level == 1)
        fprintf(stream, "    ");
}
```

```
static void
```

```
write_line(
    file stream,
    string *write_string,
    const cardinal level,
    const boolean hanging_indent,
    cardinal count)
```

```
/* Writes a line of characters from *write_string. Writes characters up to the last space in the next count characters, then breaks the line and indents the next line by  $4 \times level$  spaces (plus an extra two spaces if hanging_indent is TRUE). Leaves *write_string pointing to the character after the space at which the line was broken. */
```

```
{
    /* find the last space that will fit on the line */
    while ((*write_string + count) != Space_Character) ^ (count != 0)
        count--;
```

```

if (count == 0) {

    /* there is no convenient place to break this line, so write as much as will fit, with a %
       character at the end of the line, and don't indent the next line */

    for (count = Max_LaTeX_Line_Width - level × 4 - 1; count ≠ 0; count--)
        fprintf(stream, "%c", *((write_string)++));
    fprintf(stream, "%%\n");

} else {

    /* there is (at least) one space in this line, so write each of the characters up to the
       last space, break the line, and indent the next line */

    while (count ≠ 0) {
        fprintf(stream, "%c", *((write_string)++));
        count--;
    }
    (*write_string)++;
    fprintf(stream, "\n");
    Indent(stream, level);
    if (hanging_indent)
        fprintf(stream, "\u00a0");
}
}

```

extern void

```

Write(
    file stream,
    string write_string,
    const string suffix,
    const cardinal level,
    const boolean hanging_indent)

/* Writes write_string plus suffix. Breaks lines (at spaces) so that they are no longer than
   Max_LaTeX_Line_Width characters. Indents lines by 4 × level spaces. Indents lines after the
   first by a further two spaces, if hanging_indent is TRUE. (Assumes that suffix is less than
   Max_LaTeX_Line_Width - level × 4 characters long.) */

{
    cardinal count = 0,
    suffix_length = 0,
    line_length = Max_LaTeX_Line_Width - level × 4;
    boolean hanged = FALSE;

    if (write_string == NULL)

        /* there is no string to write */

        fprintf(stream, "%s", Null_String);

```

```

else {
    /* there is a string to write */
    if (suffix ≠ NullString)
        /* there is a suffix, so set suffix_length to the number of characters in the suffix, up
        to (but not including) the first carriage return (if there is one) */
        while ((* (suffix + suffix_length) ≠ NullCharacter) ∧
            (* (suffix + suffix_length) ≠ Carriage_Return_Character))
            suffix_length++;
        Indent(stream, level);
        while (* (write_string + count) ≠ NullCharacter) {
            if (count ≡ line_length) {
                /* there are more characters left in the string than will fit on this line, so write
                as much as will fit */
                write_line(stream, &write_string, level, hanging_indent, count);
                if (¬hanged ∧ hanging_indent) {
                    line_length -= 2;
                    hanged = TRUE;
                }
                count = 0;
            }
            count++;
        }
        /* the rest of the string will fit on a line */
        if (count + suffix_length > line_length) {
            /* ... but the rest of the string plus the suffix will be too long to fit on a line, so
            write as much as will fit */
            write_line(stream, &write_string, level, hanging_indent, count);

            /* the rest of the string plus the suffix will fit on the new line; set count to be the
            number of characters still to be written */
            count = 0;
            while (* (write_string + count) ≠ NullCharacter)
                count++;
        }
        /* write the rest of the string */
        while (count ≠ 0) {
            fprintf(stream, "%c", *write_string++);
            count--;
        }
    }
    /* write the suffix */
    fprintf(stream, "%s\n", suffix);
}

```

extern void

```

Write_Error_Message_And_Exit(
    file stream,
    const string module_name,
    string message)

/* Writes "ERROR (module_name): message." to stderr and to stream. Exits with a value of
EXIT_FAILURE (defined in stdlib.h). */

{
    static char full_message[Max_Error_Message_Length];

    sprintf(full_message, "ERROR_□(%s) : □%s", module_name, message);

    Write(stderr, full_message, ".\n", Top_Level, Hang);

    /* write to stream only if stream ≠ stdout (the error message has already been written to
stderr) */

    if ((stream ≠ NULL) ∧ (stream ≠ stdout))
        Write(stream, full_message, ".\n", Top_Level, Hang);

    exit(EXIT_FAILURE);
}

```

extern void

```

Write_Warning_Message(
    file stream,
    const string module_name,
    string message,
    const cardinal level)

/* Writes "WARNING (module_name): message." to stderr and to stream. */

{
    static char full_message[Max_Error_Message_Length];

    if (stream ≠ NULL) {

        sprintf(full_message, "WARNING_□(%s) : □%s", module_name, message);

        Write(stderr, full_message, ".\n", Top_Level, Hang);

        /* write to stream only if stream ≠ stdout (the warning message has already been
written to stderr) */

        if (stream ≠ stdout)
            Write(stream, full_message, ".\n", level, Hang);
    }
}

```


extern void

Write_LaTeX_Header(

file stream,

boolean inputable_latex)

/ Writes L^AT_EX code to go at the start of a L^AT_EX document. Writes code that can be included in another L^AT_EX document (i.e. not stand-alone code), if inputable_latex is TRUE. */*

```
{
    fprintf(stream, "%_Produced_by_s\n\n"
             "%_s\n\n", Shyster_Version, Copyright_Message);
    if (!inputable_latex)
        fprintf(stream, "%_This_is_a_stand-alone_LaTeX_file.\n");
    else
        fprintf(stream, "%_This_is_not_a_stand-alone_LaTeX_file.\n"
                "%_Include_it_in_a_LaTeX_document_using_the_\input_command.\n");
    fprintf(stream, "%_Use_s_and_s.\n\n", LaTeX_Version, TeX_Version);
    if (!inputable_latex)
        fprintf(stream, "\\documentstyle[12pt]{article}\n"
                "\\oddsidemargin=-5.4mm\n"
                "\\evensidemargin=-5.4mm\n"
                "\\topmargin=-5.4mm\n"
                "\\headheight=0mm\n"
                "\\headsep=0mm\n"
                "\\textheight=247mm\n"
                "\\textwidth=170mm\n"
                "\\footskip=15mm\n"
                "\\pagestyle{plain}\n\n"
                "\\begin{document}\n\n");
}
```

extern void

Write_LaTeX_Trailer(

file stream,

boolean inputable_latex)

/ Writes L^AT_EX code to go at the end of a L^AT_EX document. Writes code that can be included in another L^AT_EX document (i.e. not stand-alone code), if inputable_latex is TRUE. */*

```
{
    if (!inputable_latex)
        fprintf(stream, "\\end{document}\n");
}
```

extern boolean

Is_Digit(

int ch)

/ Returns TRUE, iff ch is a digit (0 ... 9). */*

```
{
    return ((ch ≥ Zero_Character) ∧ (ch ≤ Nine_Character));
}
```

```

static void
error_exit(
    const string message)
{
    Write_Error_Message_And_Exit(NULL, "Shyster", message);
}

static void
parse_arguments(
    int argc,
    string *argv,
    boolean *adjust,
    boolean *echo,
    cardinal *hypothetical_reports,
    cardinal *hypothetical_changes,
    boolean *inputable_latex,
    boolean *verbose,
    string *specification_filename,
    string *distances_filename,
    string *log_filename,
    string *probabilities_filename,
    string *report_filename,
    string *dump_filename,
    string *weights_filename)
/* Parses the UNIX command line arguments (argv[1] ... argv[argc - 1]) and stores the in-
   information in the variables pointed to by the 13 other parameters. */
{
    string argument;
    char message[Max_Error_Message_Length];

    if (argc < 2) {
        /* no argument was provided, so write usage_string to stderr and exit with a value of
           EXIT_FAILURE (defined in stdlib.h) */
        fprintf(stderr, usage_string);
        exit(EXIT_FAILURE);
    }

    /* skip over the first argument (the name by which SHYSTER was invoked) */
    argc--;
    argv++;

    /* while there are still arguments to parse ... */
    while (argc > 0) {
        argument = *argv;
        if (*argument++ ≠ '-')
            /* this argument is not a switch */
            break;
    }
}

```

```
switch (*argument++) {  
  
    case 'a':  
  
        /* -a: enable weight adjustment */  
  
        *adjust = TRUE;  
        break;  
  
    case 'c':  
  
        /* -c specification: read the case law specification from "specification.cls" */  
  
        if (argc > 1) {  
            argc--;  
            argv++;  
            *specification_filename = *argv;  
        } else  
            error_exit("must supply a filename with -c");  
        break;  
  
    case 'd':  
  
        /* -d distances: write distances to "distances-area.tex" */  
  
        if (argc > 1) {  
            argc--;  
            argv++;  
            *distances_filename = *argv;  
        } else  
            error_exit("must supply a filename with -d");  
        break;  
  
    case 'D':  
  
        /* -D dump: write dump to "dump.tex" */  
  
        if (argc > 1) {  
            argc--;  
            argv++;  
            *dump_filename = *argv;  
        } else  
            error_exit("must supply a filename with -D");  
        break;  
  
    case 'e':  
  
        /* -e: enable echo mode */  
  
        *echo = TRUE;  
        break;  
  
}
```

```

case 'h':

    /* -h r c: hypothesize, reporting on r hypotheticals per result with a limit of c
       changes */

    if (argc > 2) {
        argc--;
        argv++;
        while (**argv ≠ Null_Character) {
            if (¬Is_Digit(**argv))
                error_exit("argument_to_h_must_be_two_numbers");
            *hypothetical_reports = (10 × *hypothetical_reports) +
                (cardinal) **argv - (cardinal) Zero_Character;
            (*argv)++;
        }
        argc--;
        argv++;
        *hypothetical_changes = 0;
        while (**argv ≠ Null_Character) {
            if (¬Is_Digit(**argv))
                error_exit("argument_to_h_must_be_two_numbers");
            *hypothetical_changes = (10 × *hypothetical_changes) +
                (cardinal) **argv - (cardinal) Zero_Character;
            (*argv)++;
        }
    } else
        error_exit("must_supply_two_numbers_with_h");
    break;

case 'i':

    /* -i: write LATEX code that can be included in another LATEX document
       (i.e. not stand-alone code) */

    *inputable_latex = TRUE;
    break;

case 'l':

    /* -l log: write log to "log.log" */

    if (argc > 1) {
        argc--;
        argv++;
        *log_filename = *argv;
    } else
        error_exit("must_supply_a_filename_with_l");
    break;

```

```

case 'p':
    /* -p probabilities: write probabilities to "probabilities.tex" */
    if (argc > 1) {
        argc--;
        argv++;
        *probabilities_filename = *argv;
    } else
        error_exit("must supply a filename with -p");
    break;

case 'q':
    /* -q: enable quiet mode (don't summarize cases, etc.) */
    *verbose = FALSE;
    break;

case 'r':
    /* -r report: write report to "report-area.tex" */
    if (argc > 1) {
        argc--;
        argv++;
        *report_filename = *argv;
    } else
        error_exit("must supply a filename with -r");
    break;

case 'w':
    /* -w weights: write weights to "weights.tex" */
    if (argc > 1) {
        argc--;
        argv++;
        *weights_filename = *argv;
    } else
        error_exit("must supply a filename with -w");
    break;

default:
    sprintf(message, "unrecognized option -%s", argument - 1);
    error_exit(message);
    break;
}
argc--;
argv++;
}
}

```

```

extern int
main(
    int argc,
    string *argv)
/* Extracts the options and arguments from the UNIX command line, initializes the rule-based
system and the case-based system, then invokes the rule-based system. */
{
    char filename[Max_Filename_Length],
        message[Max_Error_Message_Length];
    statute_law_specification statute_law;
    case_law_specification case_law;
    file log_stream;
    boolean adjust = FALSE,
        echo = FALSE,
        inputable_latex = FALSE,
        verbose = TRUE;
    cardinal hypothetical_reports = 0,
        hypothetical_changes;
    string specification_filename = NULL,
        distances_filename = NULL,
        log_filename = NULL,
        probabilities_filename = NULL,
        report_filename = NULL,
        dump_filename = NULL,
        weights_filename = NULL;

    /* extract the options and arguments from the UNIX command line */
    parse_arguments(argc, argv, &adjust, &echo, &hypothetical_reports, &hypothetical_changes,
        &inputable_latex, &verbose, &specification_filename, &distances_filename,
        &log_filename, &probabilities_filename, &report_filename, &dump_filename,
        &weights_filename);

    /* write version and copyright information to stdout */
    fprintf(stdout, "%s\n\n", Shyster_Version, Copyright_Message);
    if (log_filename == NULL)
        /* no log filename was specified, so log information will be written to stdout */
        log_stream = stdout;
    else {
        /* open the log file */
        sprintf(filename, "%s%s", log_filename, Log_File_Extension);
        if ((log_stream = fopen(filename, "w")) == NULL) {
            sprintf(message, "can't open log file \"%s\"", filename);
            error_exit(message);
        }
        /* write version and copyright information to the log file */
        fprintf(log_stream, "%s\n\n"
            "%s\n\n", Shyster_Version, Copyright_Message);
    }
}

```

```
/* initialize the rule-based system */
statute_law = Initialize_Statutes();
/* initialize the case-based system */
case_law = Initialize_Cases(log_stream, inputable_latex, verbose, specification_filename,
                           dump_filename, probabilities_filename, weights_filename);
/* invoke the rule-based system */
Statute_Law(log_stream, statute_law, case_law, adjust, echo, inputable_latex, verbose,
            hypothetical_reports, hypothetical_changes, distances_filename, weights_filename,
            report_filename);
/* write "Finished." to the log file (if there is one) and to stdout */
if (log_filename != NULL)
    fprintf(log_stream, "Finished.\n");
fprintf(stdout, "Finished.\n");
/* close the log file */
if (fclose(log_stream) == EOF) {
    sprintf(message, "can't close log file \"%s\"", filename);
    error_exit(message);
}
/* everything worked, so exit with a value of EXIT_SUCCESS (defined in stdlib.h) */
return EXIT_SUCCESS;
}
```


2

The STATUTES module

statutes.h

```
/* This is the header file for the STATUTES module. It is also included by the SHYSTER
   module. */

/* structure type */

typedef struct {
    void *dummy;
} statute_law_specification;

/* external functions */

extern statute_law_specification
Initialize_Statutes();

extern void
Statute_Law(
    file log_stream,
    statute_law_specification statute_law,
    case_law_specification case_law,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    string distances_filename,
    string weights_filename,
    string report_filename);
```

statutes.c

```

/* This is the implementation file for the STATUTES module. */

#include <stdio.h>
#include "shyster.h"
#include "cases.h"
#include "statutes.h"

extern statute_law_specification
Initialize_Statutes()

/* Returns a pointer to a dummy structure. (If implemented, it would initialize the rule-based
system, by reading a statute law specification, and return a pointer to SHYSTER's internal
representation of that specification.) */

{
    statute_law_specification statute_law;

    statute_law.dummy = NULL;
    return statute_law;
}

extern void
Statute_Law(
    file log_stream,
    statute_law_specification statute_law,
    case_law_specification case_law,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    string distances_filename,
    string weights_filename,
    string report_filename)

/* Prompts the user for an identifier, then invokes the case-based system seeking advice in
the area corresponding to that identifier. The result that the case-based system returns is
written to log_stream. */

{
    char area_identifier[Max_Identifier_Length];
    string result_identifier;

    /* prompt the user for a case law area identifier */

    fprintf(stdout, "Case_Law_area_identifier:");
    gets(area_identifier);

    fprintf(log_stream, "Case-based_system_called_with_area_identifier \"%s\".\n\n",
        area_identifier);
}

```

```
/* invoke the case-based system */
result_identifier = Case_Law(log_stream, case_law, area_identifier, adjust, echo,
    inputable_latex, verbose, hypothetical_reports, hypothetical_changes, Top_Level,
    distances_filename, weights_filename, report_filename);
/* write the result identifier to the log file */
if (result_identifier ≠ NULL)
    fprintf(log_stream,
        "Case-based_system_returned_result_identifier\"%s\".\n\n",
        result_identifier);
}
```


3

The CASES module

cases.h

```
/* This is the header file for the CASES module. It is included by all twelve modules. */
/* maxima */
#define Max_Identifier_Length 16
#define Max_Attribute_Options 4
/* the number of characters first allocated for a string, and the number of extra characters
   allocated if that string has to be extended */
#define String_Increment 256
/* a "pseudo-infinite" weight for the calculation of weighted correlation coefficients */
#define Very_Heavy_Indeed 1000000.0
/* the threshold of likelihood, below which a given number of YES/YES pairs is considered
   unusually high or unusually low */
#define Threshold 0.05
/* arithmetic is precise to (log Precision) decimal places */
#define Precision 100.0
/* distance and weight comparisons are precise to (log Distance_Precision) decimal places (this
   is the threshold within which two cases are considered equidistant, or two weights are
   considered equal) */
#define Distance_Precision 100.0
/* the format for the display of floating point numbers (the number of decimal places should
   be (log Distance_Precision)) */
#define Floating_Point_Format "%.2f"
```

```

/* string constants for output to LATEX files */

#define Raise_Height "0.6\ht\strutbox"
#define Column_Separation "\tabcolsep"
#define Matrix_Column_Separation "0.4em"
#define Heading "\subsection*"
#define Subheading "\subsubsection*"
#define Skip "\medskip\noindent"
#define Identifier_Font "\sf"
#define Null_String "{\it\string\}"

/* special LATEX symbols:
    • Yes_Symbol
    × No_Symbol
      Unknown_Symbol

    ■ Functional_Dependence_Symbol
    • Stochastic_Dependence_Symbol

    ⇒ Specified_Direction_Symbol
     $\overset{I}{\Rightarrow}$  Ideal_Point_Direction_Symbol
     $\overset{\mu}{\Rightarrow}$  Centroid_Direction_Symbol
     $\overset{*}{\Rightarrow}$  All_Directions_Symbol

    ⇔ External_Area_Symbol
    ← External_Result_Symbol

    ∨ Disjunction_Symbol */

#define Yes_Symbol "$\bullet$"
#define No_Symbol "$\times$"
#define Unknown_Symbol ""
#define Functional_Dependence_Symbol "\rule[0.25ex]{0.35em}{0.35em}"
#define Stochastic_Dependence_Symbol "$\bullet$"
#define Specified_Direction_Symbol "$\rightarrow$"
#define Ideal_Point_Direction_Symbol \
    "$\stackrel{\scriptscriptstyle I}{\rightarrow}$"
#define Centroid_Direction_Symbol \
    "$\stackrel{\scriptscriptstyle \mu}{\rightarrow}$"
#define All_Directions_Symbol \
    "$\stackrel{\scriptscriptstyle \star}{\rightarrow}$"
#define External_Area_Symbol "$\Leftrightarrow$"
#define External_Result_Symbol "$\leftarrow$"
#define Disjunction_Symbol "$\vee$"

/* file extensions */

#define LaTeX_File_Extension ".tex"
#define Log_File_Extension ".log"
#define Specification_File_Extension ".cls"

```

```

/* character constants */
#define Attribute_Vector_Begin_Character '('
#define Attribute_Vector_End_Character ')'
#define Little_A_Character 'a'
#define Little_Z_Character 'z'
#define Big_A_Character 'A'
#define Big_Z_Character 'Z'
#define Zero_Character '0'
#define Nine_Character '9'
#define Yes_Character 'Y'
#define No_Character 'N'
#define Unknown_Character 'U'
#define Help_Character 'H'
#define Quit_Character 'Q'

/* other constants */
#define Year_Digits 4
#define Yes_Value 1.0
#define No_Value 0.0

/* enumerated types */
typedef enum {
    NO,
    YES,
    UNKNOWN
} attribute_value_type;

typedef enum {
    NEARER,
    EQUIDISTANT,
    FURTHER
} relative_distance_type;

/* structure types */
typedef struct {
    boolean infinite;
    floating_point finite;
} weight_type;

typedef struct {
    cardinal infinite;
    floating_point finite;
} distance_subtype;

typedef struct {
    distance_subtype known;
    distance_subtype unknown;
} distance_type;

typedef struct {
    boolean meaningless;
    floating_point unweighted;
    floating_point weighted;
} correlation_type;

```

```

typedef struct {
    distance_type distance;
    cardinal number_of_known_differences,
        number_of_known_pairs;
    floating_point weighted_association_coefficient;
    correlation_type correlation_coefficient;
} metrics_type;

```

```

typedef struct vector_element {
    attribute_value_type attribute_value;
    struct vector_element *next;
} vector_element;

```

```

typedef struct matrix_element {
    attribute_value_type attribute_value;
    struct matrix_element *case_next,
        *attribute_next;
} matrix_element;

```

```

typedef struct centroid_element {
    boolean unknown;
    floating_point value;
    struct centroid_element *next;
} centroid_element;

```

```

typedef struct probability_element {
    boolean unknown,
        functional_dependence;
    floating_point probability_that_or_fewer,
        probability_that_or_more;
    struct probability_element *next;
} probability_element;

```

```

typedef struct identifier_list_element {
    string identifier;
    struct identifier_list_element *next;
} identifier_list_element;

```

```

typedef struct weight_list_element {
    weight_type weight;
    struct weight_list_element *next;
} weight_list_element;

```

```

typedef struct hypothetical_list_element {
    vector_element *hypothetical_head;
    distance_type nearest_neighbour_distance;
    struct hypothetical_list_element *next;
} hypothetical_list_element;

```



```

/* the structure type kase is so-named because the more obvious case is a reserved word */
typedef struct kase {
    cardinal number;
    string name;
    string short_name;
    string citation;
    cardinal year;
    string court_string;
    cardinal court_rank;
    matrix_element *matrix_head;
    string summary;
    boolean summarized;
    metrics_type metrics;
    struct kase *equidistant_known_next,
        *equidistant_unknown_next,
        *next;
} kase;

typedef struct result {
    string identifier,
        string;
    kase *case_head,
        *nearest_known_case,
        *nearest_unknown_case;
    relative_distance_type nearest_known_compared_with_unknown;
    distance_subtype specified_direction;
    struct result *equidistant_specified_direction_next;
    vector_element *ideal_point_head;
    metrics_type ideal_point_metrics;
    struct result *equidistant_ideal_point_next;
    distance_subtype ideal_point_direction;
    struct result *equidistant_ideal_point_direction_next;
    centroid_element *centroid_head;
    metrics_type centroid_metrics;
    struct result *equidistant_centroid_next;
    distance_subtype centroid_direction;
    struct result *equidistant_centroid_direction_next;
    hypothetical_list_element *hypothetical_list_head;
    struct result *equidistant_next,
        *next;
} result;

typedef struct direction_list_element {
    result *result;
    struct direction_list_element *next;
} direction_list_element;

typedef struct local_attribute_type {
    string question,
        help;
} local_attribute_type;

```

```

typedef struct external_attribute_type {
    string area_identifier;
    identifier_list_element *yes_identifier_head,
        *no_identifier_head,
        *unknown_identifier_head;
} external_attribute_type;

typedef struct attribute {
    cardinal number;
    boolean external_attribute;
    union {
        local_attribute_type local;
        external_attribute_type external;
    } details;
    string yes;
    direction_list_element *yes_direction_head;
    string no;
    direction_list_element *no_direction_head;
    string unknown;
    direction_list_element *unknown_direction_head;
    matrix_element *matrix_head;
    floating_point mean;
    weight_type weight;
    weight_list_element *weights_head;
    probability_element *probability_head;
    struct attribute *next;
} attribute;

typedef struct area {
    string identifier,
        opening,
        closing;
    result *result_head;
    cardinal number_of_results;
    attribute *attribute_head;
    cardinal number_of_attributes;
    boolean infinite_weight;
    boolean correlation_coefficients;
    result *nearest_result;
    result *nearest_ideal_point;
    result *nearest_centroid;
    result *strongest_specified_direction;
    result *strongest_ideal_point_direction;
    result *strongest_centroid_direction;
    struct area *next;
} area;

typedef struct court {
    string identifier,
        string;
    cardinal rank;
    struct court *next;
} court;

```

```
typedef struct {
    court *court_head;
    area *area_head;
} case_law_specification;

/* external functions */

extern boolean
Is_Zero(
    floating_point x);

extern boolean
Is_Equal(
    floating_point x,
    floating_point y,
    floating_point precision);

extern boolean
Is_Less(
    floating_point x,
    floating_point y,
    floating_point precision);

extern boolean
Is_Zero_Subdistance(
    distance_subtype x);

extern boolean
Is_Zero_Distance(
    distance_type x);

extern boolean
Attribute_Value(
    attribute_value_type attribute_value,
    floating_point *value);

extern attribute_value_type
Nearest_Attribute_Value(
    floating_point value);

extern void
Write_Floating_Point(
    file stream,
    floating_point number,
    string warning_string);

extern case_law_specification
Initialize_Cases(
    file log_stream,
    boolean inputable_latex,
    boolean verbose,
    string specification_filename,
    string dump_filename,
    string probabilities_filename,
    string weights_filename);
```

```

extern string
Case_Law(
    file log_stream,
    case_law_specification case_law,
    string area_identifier,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    cardinal level,
    string distances_filename,
    string weights_filename,
    string report_filename);

```

CASES.C

```

/* This is the implementation file for the CASES module. */

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>
#include "shyster.h"
#include "cases.h"
#include "tokenizer.h"
#include "parser.h"
#include "dumper.h"
#include "checker.h"
#include "scales.h"
#include "adjuster.h"
#include "consultant.h"
#include "odometer.h"
#include "reporter.h"

static void
error_exit(
    file stream,
    const string message)
{
    Write_Error_Message_And_Exit(stream, "Cases", message);
}

static void
warning(
    file stream,
    const string message,
    cardinal level)
{
    Write_Warning_Message(stream, "Cases", message, level);
}

```

```

extern boolean
Is_Zero(
    floating_point x)

/* Returns TRUE, iff  $x = 0$  precise to  $(\log Precision)$  decimal places. */
{
    return floor((double) x  $\times$  Precision + 0.5)  $\equiv$  0.0;
}

extern boolean
Is_Equal(
    floating_point x,
    floating_point y,
    floating_point precision)

/* Returns TRUE, iff  $x = y$  precise to  $(\log precision)$  decimal places. */
{
    return floor((double) x  $\times$  precision + 0.5)  $\equiv$  floor((double) y  $\times$  precision + 0.5);
}

extern boolean
Is_Less(
    floating_point x,
    floating_point y,
    floating_point precision)

/* Returns TRUE, iff  $x < y$  precise to  $(\log precision)$  decimal places. */
{
    return floor((double) x  $\times$  precision + 0.5)  $<$  floor((double) y  $\times$  precision + 0.5);
}

extern boolean
Is_Zero_Subdistance(
    distance_subtype x)

/* Returns TRUE, iff both of  $x$ 's infinite and finite components are zero. */
{
    return (x.infinite  $\equiv$  0)  $\wedge$  Is_Zero(x.finite);
}

extern boolean
Is_Zero_Distance(
    distance_type x)

/* Returns TRUE, iff both of  $x$ 's known and unknown components are zero. */
{
    return Is_Zero_Subdistance(x.known)  $\wedge$  Is_Zero_Subdistance(x.unknown);
}

```

```

extern boolean
Attribute_Value(
    attribute_value_type attribute_value,
    floating_point *value)

/* Sets *value to 1, if attribute_value is YES; to 0, if attribute_value is NO. Returns TRUE, iff
attribute_value is known. */

{
    switch (attribute_value) {
        case YES:
            *value = Yes_Value;
            return TRUE;
        case NO:
            *value = No_Value;
            return TRUE;
        default:
            return FALSE;
    }
}

extern attribute_value_type
Nearest_Attribute_Value(
    floating_point value)

/* Returns the nearest attribute value to value ( $0 \leq \textit{value} < 0.5$ : NO;  $0.5 \leq \textit{value} \leq 1$ : YES) */

{
    if (value < 0.5)
        return NO;
    else
        return YES;
}

extern void
Write_Floating_Point(
    file stream,
    floating_point number,
    string warning_string)

/* Writes number, precise to (log Precision) decimal places. If warning_string is not empty, it
is written after number. */

{
    if (Is_Less(number, 0.0, Precision))
        fprintf(stream, "$-$");

    fprintf(stream, Floating_Point_Format,
        floor(fabs((double) number)  $\times$  Precision + 0.5) / Precision);

    if (strcmp(warning_string, Empty_String))
        fprintf(stream, "\r\nlap{\makebox[\tabcolsep]{%s}}", warning_string);
}

```

```

extern case_law_specification
Initialize_Cases(
    file log_stream,
    boolean inputable_latex,
    boolean verbose,
    string specification_filename,
    string dump_filename,
    string probabilities_filename,
    string weights_filename)

/* Calls the TOKENIZER and PARSER to read the case law specification in specification_filename
and build an internal representation of that specification. Invokes the DUMPER to dump
that internal representation to dump_filename. Uses the CHECKER to check for attribute de-
pendence, and to write the probabilities to probabilities_filename. Calls the SCALES module
to assign weights to all the attributes, and to write those weights to weights_filename. Re-
turns a pointer to SHYSTER's internal representation of the specification with all attributes
weighted. */

{
    file specification_stream = NULL,
    dump_stream = NULL,
    probabilities_stream = NULL,
    weights_stream = NULL;
    char filename[Max_Filename_Length];
    char message[Max_Error_Message_Length];
    case_law_specification case_law;
    area *area_pointer;
    result *result_pointer;

    if (specification_filename == NULL)
        /* there is no specification filename */
        error_exit(log_stream, "no_case_law_specification_file_specified");

    /* open the case law specification file */
    sprintf(filename, "%s%s", specification_filename, Specification_File_Extension);
    if ((specification_stream = fopen(filename, "r")) == NULL) {
        sprintf(message, "can't_open_case_law_specification_file_%s", filename);
        error_exit(log_stream, message);
    }
    fprintf(log_stream,
        "Reading_case_law_specification_from_%s"... \n\n", filename);
    case_law = Parse_Specification(specification_stream, log_stream);
    if (case_law.area_head == NULL)
        /* no areas were specified in the specification file */
        error_exit(log_stream, "no_case_law_specified");

    /* close the case law specification file */
    if (fclose(specification_stream) == EOF) {
        sprintf(message, "can't_close_case_law_specification_file_%s", filename);
        error_exit(log_stream, message);
    }
}

```

```

fprintf(log_stream, "Case_law_specification_is_invalid.\n\n");

/* check that every result in every area has either a case or an ideal point */

for (area_pointer = case_law.area_head; area_pointer ≠ NULL;
     area_pointer = area_pointer→next)
  for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
       result_pointer = result_pointer→next)
    if (result_pointer→case_head ≡ NULL)
      if (result_pointer→ideal_point_head ≡ NULL) {
        sprintf(message, "%s_result_in_%s_area_has_neither_cases"
                  "\nor_an_ideal_point", result_pointer→identifier,
                  area_pointer→identifier);
        warning(log_stream, message, Top_Level);
      } else {
        sprintf(message, "%s_result_in_%s_area_has_no_cases",
                  result_pointer→identifier, area_pointer→identifier);
        warning(log_stream, message, Top_Level);
      }
    }

if (dump_filename ≠ NULL) {
  /* a dump filename was specified, so open the dump file */

  sprintf(filename, "%s%s", dump_filename, LaTeX_File_Extension);
  if ((dump_stream = fopen(filename, "w")) ≡ NULL) {
    sprintf(message, "can't_open_dump_file_%s", filename);
    error_exit(log_stream, message);
  }
  fprintf(log_stream, "Writing_dump_to_%s.\n\n", filename);

  Dump_Specification(dump_stream, log_stream, case_law, inputable_latex, verbose);

  /* close the dump file */

  if (fclose(dump_stream) ≡ EOF) {
    sprintf(message, "can't_close_dump_file_%s", filename);
    error_exit(log_stream, message);
  }
}

if (probabilities_filename ≠ NULL) {
  /* a probabilities filename was specified, so open the probabilities file */

  sprintf(filename, "%s%s", probabilities_filename, LaTeX_File_Extension);
  if ((probabilities_stream = fopen(filename, "w")) ≡ NULL) {
    sprintf(message, "can't_open_probabilities_file_%s", filename);
    error_exit(log_stream, message);
  }
  fprintf(log_stream, "Writing_probabilities_to_%s.\n\n",
          filename);
}

Check_for_Attribute_Dependence(probabilities_stream, log_stream, case_law, inputable_latex);

```



```

if (probabilities_filename ≠ NULL)
    /* a probabilities filename was specified, so close the probabilities file */
    if (fclose(probabilities_stream) ≡ EOF) {
        sprintf(message, "can't close probabilities file \"%s\"", filename);
        error_exit(log_stream, message);
    }
if (weights_filename ≠ NULL) {
    /* a weights filename was specified, so open the weights file */
    sprintf(filename, "%s%s", weights_filename, LaTeX_File_Extension);
    if ((weights_stream = fopen(filename, "w")) ≡ NULL) {
        sprintf(message, "can't open weights file \"%s\"", filename);
        error_exit(log_stream, message);
    }
    fprintf(log_stream, "Writing weights to \"%s\".\n\n", filename);
}
Weight_Attributes(weights_stream, log_stream, case_law, inputable_latex);

if (weights_filename ≠ NULL)
    /* a weights filename was specified, so close the weights file */
    if (fclose(weights_stream) ≡ EOF) {
        sprintf(message, "can't close weights file \"%s\"", filename);
        error_exit(log_stream, message);
    }
return case_law;
}

static void
write_facts(
    file log_stream,
    vector_element *vector_pointer)
/* Writes the fact vector pointed to by vector_pointer. Uses Y, N and U characters to represent
YES, NO and UNKNOWN, respectively. */
{
    fprintf(log_stream, "(");
    while (vector_pointer ≠ NULL) {
        switch (vector_pointer→attribute_value) {
            case YES:
                fprintf(log_stream, "Y");
                break;
            case NO:
                fprintf(log_stream, "N");
                break;
            case UNKNOWN:
                fprintf(log_stream, "U");
                break;
        }
    }
}

```

```

    vector_pointer = vector_pointer→next;
}
fprintf(log_stream, "");
}

static vector_element *
copy_facts(
    file log_stream,
    vector_element *vector_pointer)

/* Returns a pointer to a copy of the fact vector pointed to by vector_pointer. */
{
    vector_element *temp_pointer;

    /* allocate memory for this vector element */
    if ((temp_pointer =
        (vector_element *) malloc(sizeof(vector_element))) ≡ NULL)
        error_exit(log_stream, "malloc_failed_during_fact_copying");

    temp_pointer→attribute_value = vector_pointer→attribute_value;
    if (vector_pointer→next ≡ NULL)
        temp_pointer→next = NULL;
    else
        temp_pointer→next = copy_facts(log_stream, vector_pointer→next);

    return temp_pointer;
}

static void
remove_facts(vector_element *vector_pointer)

/* Frees the memory taken up by the fact vector pointed to by vector_pointer. */
{
    if (vector_pointer ≠ NULL) {
        remove_facts(vector_pointer→next);
        free(vector_pointer);
    }
}

static void
mark_differences(
    file log_stream,
    vector_element *vector_pointer_X,
    vector_element *vector_pointer_Y)

/* Marks, with carets, the differences between the two fact vectors pointed to by vec-
tor_pointer_X and vector_pointer_Y (one of which has already been written on the previous
line of log_stream). */

```

```

{
  if (vector_pointer_X ≠ NULL) {
    if (vector_pointer_X→attribute_value ≠ vector_pointer_Y→attribute_value)
      fprintf(log_stream, "^");
    else
      fprintf(log_stream, "□");
    mark_differences(log_stream, vector_pointer_X→next, vector_pointer_Y→next);
  }
}

static void
instantiate(
  file log_stream,
  file distances_stream,
  file report_stream,
  case_law_specification case_law,
  area *area_pointer,
  vector_element *instantiated_head,
  vector_element *facts_head,
  result *nearest_result,
  boolean verbose,
  cardinal *instantiation_number,
  cardinal *different_results,
  cardinal level)
/* Instantiates the unknown attribute values in the fact vector pointed to by instantiated_head
to create instantiations of the instant case in which all the attribute values are known.
Treats each instantiation as if it were a new instant case, and invokes the ODOMETER and
the REPORTER to recalculate the distances and argue with the instantiation. */
{
  vector_element *vector_pointer;
  static char message[Max_Error_Message_Length];
  boolean all_known = TRUE;
  cardinal temp_cardinal = *instantiation_number / 10;

  /* make a copy of the fact vector pointed to by instantiated_head */
  instantiated_head = copy_facts(log_stream, instantiated_head);

  for (vector_pointer = instantiated_head; (vector_pointer ≠ NULL) ∧
      (all_known = vector_pointer→attribute_value ≠ UNKNOWN);
      vector_pointer = vector_pointer→next);

  if (all_known ∧ (*instantiation_number ≠ 0)) {
    /* all of the attribute values in the instantiation are known, and the instantiation is
not the instant case itself, so treat it as if it were a new instant case */

    Indent(log_stream, level);
    fprintf(log_stream, "Instantiation□%u□is□", *instantiation_number);
    write_facts(log_stream, instantiated_head);
    fprintf(log_stream, ".\n");

    Indent(log_stream, level + 5);
  }
}

```

```

while (temp_cardinal ≠ 0) {
    fprintf(log_stream, " ");
    temp_cardinal = temp_cardinal / 10;
}

mark_differences(log_stream, instantiated_head, facts_head);
fprintf(log_stream, "\n");

Calculate_Distances(distances_stream, log_stream, area_pointer, case_law,
    instantiated_head, FALSE, *instantiation_number, level + 1);

if (area_pointer→nearest_result ≡ nearest_result) {

    /* the same result was reached as was reached in the instant case, so write a report
       to a NULL report file (nothing will be added to the report, although information
       will still be added to the log file) */

    Write_Report(NULL, log_stream, area_pointer, instantiated_head, facts_head,
        verbose, FALSE, FALSE, *instantiation_number, level + 1);

} else {

    /* a different result was reached, so write a full report on the instantiation */

    Write_Report(report_stream, log_stream, area_pointer, instantiated_head, facts_head,
        verbose, FALSE, FALSE, *instantiation_number, level + 1);

    sprintf(message, "Instantiation %u in %s area has a different result
        "to that of the uninstantiated instant case",
        *instantiation_number, area_pointer→identifier);
    warning(log_stream, message, level);

    (*different_results)++;

}

(*instantiation_number)++;
}
if (*instantiation_number ≡ 0)
    *instantiation_number = 1;
if (¬all_known) {

    /* vector_pointer points to the first UNKNOWN attribute value in the instantiation, so
       set it to YES and instantiate the whole fact vector then set it to NO and instantiate
       the whole fact vector again */

    vector_pointer→attribute_value = YES;
    instantiate(log_stream, distances_stream, report_stream, case_law, area_pointer,
        instantiated_head, facts_head, nearest_result, verbose, instantiation_number,
        different_results, level);

    vector_pointer→attribute_value = NO;
    instantiate(log_stream, distances_stream, report_stream, case_law, area_pointer,
        instantiated_head, facts_head, nearest_result, verbose, instantiation_number,
        different_results, level);

}

/* free the memory taken up by the instantiation */
remove_facts(instantiated_head);
}

```

```

static void
add_to_hypothetical_list(
    file log_stream,
    vector_element *new_head,
    distance_type new_distance,
    hypothetical_list_element **hypothetical_list_pointer,
    cardinal count,
    cardinal hypothetical_reports)

/* Inserts the hypothetical pointed to by new_head into the list of hypotheticals pointed to by
 *hypothetical_list_pointer. The list is kept sorted: the nearer a hypothetical is to the instant
 case, the closer it is to the head of the list (the new hypothetical is new_distance from the
 instant case). *hypothetical_list_pointer points to hypothetical number count in the list.
 The total number of hypotheticals in the list is not allowed to exceed hypothetical_reports.
 Removes the last hypothetical in the list if inserting the new hypothetical makes the list
 too long. */

{
    hypothetical_list_element *temp_pointer;

    if (count > hypothetical_reports)

        /* *hypothetical_list_pointer points past the end of the list, so return without inserting
         anything into the list */

        return;

    if ((*hypothetical_list_pointer == NULL) ∨ (Relative_Distance(new_distance,
        (*hypothetical_list_pointer)→nearest_neighbour_distance) ==
        NEARER)) {

        /* the new hypothetical belongs at the head of the list, so allocate memory for it, make
         a copy of it, and put that copy at the head of the list */

        if ((temp_pointer =
            (hypothetical_list_element *) malloc(sizeof(hypothetical_list_element))) ==
            NULL)
            error_exit(log_stream, "malloc_failed_during_hypothetical_handling");

        temp_pointer→hypothetical_head = copy_facts(log_stream, new_head);
        temp_pointer→nearest_neighbour_distance = new_distance;
        temp_pointer→next = *hypothetical_list_pointer;
        *hypothetical_list_pointer = temp_pointer;

        /* skip through to the end of the list */

        while ((temp_pointer→next ≠ NULL) ∧ (count < hypothetical_reports)) {
            temp_pointer = temp_pointer→next;
            count++;
        }
    }
}

```

```

if (temp_pointer→next ≠ NULL) {
    /* there's now one more hypothetical in the list than will be required when reports
       are written, so remove the last hypothetical from the list and free the memory it
       takes up */
    remove_facts(temp_pointer→next→hypothetical_head);
    free(temp_pointer→next);
    temp_pointer→next = NULL;
}
else
    /* the hypothetical does not go at the head of the list, so check whether it belongs
       somewhere in the rest of the list */
    add_to_hypothetical_list(log_stream, new_head, new_distance,
        &(hypothetical_list_pointer)→next, count + 1, hypothetical_reports);
}

```

static void

```

hypothesize(
    file log_stream,
    case_law_specification case_law,
    area *area_pointer,
    attribute *attribute_pointer,
    vector_element *hypothetical_head,
    vector_element *facts_head,
    result *instant_result,
    distance_type instant_distance,
    cardinal *hypothetical_number,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    cardinal level)

```

/* Makes hypothetical variations to the fact vector pointed to by *hypothetical_head*, allowing no more than *hypothetical_changes* differences (in the known attribute values) between the hypothetical and the instant case (the fact vector of which is pointed to by *facts_head*). Treats each hypothetical as if it were a new instant case, and invokes the ODOMETER to recalculate the distances.

Builds (for each result) a list of those hypotheticals which are eligible to be reported on. A hypothetical is considered eligible to be reported on if its nearest result is different to that of the instant case (pointed to by *instant_result*), or if it has the same nearest result but its nearest neighbour is nearer the instant case than is that of the instant case (which is *instant_distance* from the instant case). Lists only the nearest *hypothetical_reports* hypotheticals for each result. */

```

{
    vector_element *vector_pointer = facts_head,
    *hypothetical_pointer,
    *new_head;
    cardinal count;
if (attribute_pointer ≡ NULL)
    return;

```

```

/* count the known differences between the hypothetical and the instant case */
count = 0;
for (hypothetical_pointer = hypothetical_head; hypothetical_pointer ≠ NULL;
     hypothetical_pointer = hypothetical_pointer→next) {
  if ((vector_pointer→attribute_value ≠ UNKNOWN) ∧
      (hypothetical_pointer→attribute_value ≠ vector_pointer→attribute_value))
    count++;
  vector_pointer = vector_pointer→next;
}
if ((hypothetical_changes ≠ 0) ∧ (count ≡ hypothetical_changes))
  /* the maximum number of changes has already been made */
  return;
new_head = copy_facts(log_stream, hypothetical_head);
/* find the attribute to change in the new hypothetical */
count = 1;
for (hypothetical_pointer = new_head; count < attribute_pointer→number;
     hypothetical_pointer = hypothetical_pointer→next)
  count++;
if (hypothetical_pointer→attribute_value ≡ UNKNOWN) {
  /* the value of the attribute to change in the new hypothetical is UNKNOWN, so ignore
  it—UNKNOWN values have already been instantiated by instantiate()—and continue
  hypothesizing using the next attribute */
  hypothesize(log_stream, case_law, area_pointer, attribute_pointer→next,
              new_head, facts_head, instant_result, instant_distance,
              hypothetical_number, hypothetical_reports, hypothetical_changes, level);
} else {
  (*hypothetical_number)++;
  /* change the (known) value of the attribute in the new hypothetical */
  if (hypothetical_pointer→attribute_value ≡ YES)
    hypothetical_pointer→attribute_value = NO;
  else
    hypothetical_pointer→attribute_value = YES;
  /* calculate distances without writing anything to the log file or the distances file */
  Calculate_Distances(NULL, NULL, area_pointer, case_law, new_head, TRUE, 0, level + 1);
  if (area_pointer→nearest_result ≡ instant_result) {
    /* the hypothetical has the same result as that of the instant case, so only add it
    to the hypothetical list if its nearest neighbour is nearer than was that of the
    instant case */
    if (instant_result→nearest_known_compared_with_unknown ≠ FURTHER) {
      /* the nearest known neighbour is the nearest neighbour (although there may
      be an equidistant case with an unknown distance) */

```

```

    if (Relative_Distance(instant_result→nearest_known_case→metrics.distance,
                          instant_distance) ≡ NEARER)
        add_to_hypothetical_list(log_stream, new_head,
                                instant_result→nearest_known_case→metrics.distance,
                                &instant_result→hypothetical_list_head, 1, hypothetical_reports);
} else {
    /* the nearest unknown neighbour is the nearest neighbour */
    if (Relative_Distance(instant_result→nearest_unknown_case→metrics.distance,
                          instant_distance) ≡ NEARER)
        add_to_hypothetical_list(log_stream, new_head,
                                instant_result→nearest_unknown_case→metrics.distance,
                                &instant_result→hypothetical_list_head, 1, hypothetical_reports);
}
} else {
    /* the hypothetical has a different result to that of the instant case */
    if (area_pointer→nearest_result→nearest_known_compared_with_unknown ≠
        FURTHER)

        /* the nearest known neighbour is the nearest neighbour (although there may
           be an equidistant case with an unknown distance) */
        add_to_hypothetical_list(log_stream, new_head,
                                area_pointer→nearest_result→nearest_known_case→metrics.distance,
                                &area_pointer→nearest_result→hypothetical_list_head, 1,
                                hypothetical_reports);

    else

        /* the nearest unknown neighbour is the nearest neighbour */
        add_to_hypothetical_list(log_stream, new_head,
                                area_pointer→nearest_result→nearest_unknown_case→metrics.distance,
                                &area_pointer→nearest_result→hypothetical_list_head, 1,
                                hypothetical_reports);
}
/* hypothesize, using the next attribute, with the unchanged hypothetical */
hypothesize(log_stream, case_law, area_pointer, attribute_pointer→next,
            hypothetical_head, facts_head, instant_result, instant_distance,
            hypothetical_number, hypothetical_reports, hypothetical_changes, level);
/* ... and with the new hypothetical */
hypothesize(log_stream, case_law, area_pointer, attribute_pointer→next,
            new_head, facts_head, instant_result, instant_distance,
            hypothetical_number, hypothetical_reports, hypothetical_changes, level);
}
/* free the memory taken up by the hypothetical */
remove_facts(new_head);
}

```



```

static void
write_hypotheticals(
    file log_stream,
    file distances_stream,
    file report_stream,
    case_law_specification case_law,
    area *area_pointer,
    vector_element *facts_head,
    boolean verbose,
    boolean same_result,
    hypothetical_list_element *hypothetical_list_pointer,
    cardinal *hypothetical_number,
    cardinal level)

/* Writes reports on the hypotheticals in the list, the head of which is pointed to by
   hypothetical_list_pointer. */
{
    cardinal temp_cardinal;

    /* while there are still hypotheticals in the list ... */
    while (hypothetical_list_pointer  $\neq$  NULL) {
        /* treat the hypothetical as if it were the instant case */
        (*hypothetical_number)++;
        Indent(log_stream, level);
        fprintf(log_stream, "Hypothetical %u is ", *hypothetical_number);
        write_facts(log_stream, hypothetical_list_pointer  $\rightarrow$  hypothetical_head);
        fprintf(log_stream, ".\n");

        Indent(log_stream, level + 4);
        fprintf(log_stream, "   ");
        temp_cardinal = *hypothetical_number / 10;
        while (temp_cardinal  $\neq$  0) {
            fprintf(log_stream, " ");
            temp_cardinal = temp_cardinal / 10;
        }

        mark_differences(log_stream, hypothetical_list_pointer  $\rightarrow$  hypothetical_head, facts_head);
        fprintf(log_stream, "\n");

        /* calculate the distances again (when they were calculated in hypothesize(), nothing
           was written to the log file or the distances file) and write a report on this hypothetical
           (which also writes to the log file) */
        Calculate_Distances(distances_stream, log_stream, area_pointer, case_law,
            hypothetical_list_pointer  $\rightarrow$  hypothetical_head, TRUE, *hypothetical_number,
            level + 1);

        Write_Report(report_stream, log_stream, area_pointer,
            hypothetical_list_pointer  $\rightarrow$  hypothetical_head, facts_head, verbose, TRUE,
            same_result, *hypothetical_number, level + 1);

        hypothetical_list_pointer = hypothetical_list_pointer  $\rightarrow$  next;
    }
}

```

extern *string*

```
Case_Law(
    file log_stream,
    case_law_specification case_law,
    string area_identifier,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    cardinal level,
    string distances_filename,
    string weights_filename,
    string report_filename)
```

/* Determines the “likely result” of the instant case in the *area_identifier* area of the *case_law* specification, and constructs an argument supporting that conclusion.

Calls the ADJUSTER, if *adjust* is *TRUE*. Invokes the CONSULTANT to interrogate the user as to the attribute values in the instant case. (The CONSULTANT recursively invokes *Case_Law()*, if required, to resolve open textured—external—attributes.) Calls the ODOMETER to calculate the distances between the instant case and the leading cases, and to determine the nearest neighbours and results. Invokes the REPORTER to write a report about the instant case.

Returns the identifier of the “likely result.” */

```
{
    file distances_stream = NULL,
    report_stream = NULL;
    static char filename[Max_Filename_Length];
    static char message[Max_Error_Message_Length];
    vector_element *facts_head;
    area *area_pointer;
    result *result_pointer,
    *instant_result = NULL;
    kase *case_pointer;
    distance_type instant_distance;
    cardinal instantiation_number = 0,
    hypothetical_number = 0,
    different_results = 0,
    hypothetical_count = 0;

    /* find the area with an identifier matching area_identifier */
    for (area_pointer = case_law.area_head;
        (area_pointer != NULL) ^ strcmp(area_pointer->identifier, area_identifier);
        area_pointer = area_pointer->next);

    if (area_pointer == NULL) {
        /* area_identifier does not match the identifier of any area */
        sprintf(message, "%s area not found", area_identifier);
        error_exit(log_stream, message);
    }
}
```

```

Indent(log_stream, level);
fprintf(log_stream, "Area_is_%s.\n\n", area_identifier);

if (distances_filename ≠ NULL) {
    /* a distances filename was specified, so open a distances file for this area */
    sprintf(filename, "%s-%s%s", distances_filename,
            area_identifier, LaTeX_File_Extension);
    if ((distances_stream = fopen(filename, "w")) ≡ NULL) {
        sprintf(message, "can't open distances file \"%s\"", filename);
        error_exit(log_stream, message);
    }
    Indent(log_stream, level);
    fprintf(log_stream, "Writing_distances_to_%s\n\n", filename);
}
if (report_filename ≠ NULL) {
    /* a report filename was specified, so open a report file for this area */
    sprintf(filename, "%s-%s%s", report_filename,
            area_identifier, LaTeX_File_Extension);
    if ((report_stream = fopen(filename, "w")) ≡ NULL) {
        sprintf(message, "can't open report file \"%s\"", filename);
        error_exit(log_stream, message);
    }
    Indent(log_stream, level);
    fprintf(log_stream, "Writing_report_to_%s\n\n", filename);
}
if (adjust)
    Adjust_Attributes(log_stream, area_pointer, weights_filename, level, inputable_latex);

/* interrogate the user as to the facts in the instant case */
if ((facts_head = Get_Facts(log_stream, case_law, area_pointer, adjust, echo, inputable_latex,
    verbose, hypothetical_reports, hypothetical_changes, level,
    distances_filename, weights_filename, report_filename)) ≠ NULL) {
    /* the user has entered some facts */
    if (distances_stream ≠ NULL) {
        /* a distances file is open for this area, so write its header */
        fprintf(distances_stream, "%_Distances_file\n\n");
        Write_LaTeX_Header(distances_stream, inputable_latex);
    }
    if (report_stream ≠ NULL) {
        /* a report file is open for this area, so write its header */
        fprintf(report_stream, "%_Report_file\n\n");
        Write_LaTeX_Header(report_stream, inputable_latex);
    }
    Indent(log_stream, level);
    fprintf(log_stream, "Fact_vector_is");
    write_facts(log_stream, facts_head);
    fprintf(log_stream, ".\n\n");
}

```

```

Calculate_Distances(distances_stream, log_stream, area_pointer,
                   case_law, facts_head, FALSE, 0, level + 1);

/* mark all cases as unsummarized */

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
  for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
       case_pointer = case_pointer→next)
    case_pointer→summarized = FALSE;

Write_Report(report_stream, log_stream, area_pointer, facts_head,
            NULL, verbose, FALSE, FALSE, 0, level + 1);

instant_result = area_pointer→nearest_result;

if (instant_result→nearest_known_compared_with_unknown ≠ FURTHER)

  /* the nearest known neighbour is the nearest neighbour (although there may be
     an equidistant case with an unknown distance) */

  instant_distance = instant_result→nearest_known_case→metrics.distance;

else

  /* the nearest unknown neighbour is the nearest neighbour */

  instant_distance = instant_result→nearest_unknown_case→metrics.distance;

/* instantiate the unknown attribute values in the instant case */

instantiate(log_stream, distances_stream, report_stream, case_law, area_pointer,
            facts_head, facts_head, instant_result, verbose, &instantiation_number,
            &different_results, level);

instantiation_number--;

if (hypothetical_reports ≠ 0) {

  /* the user requested hypothesizing */

  hypothesize(log_stream, case_law, area_pointer, area_pointer→attribute_head,
              facts_head, facts_head, instant_result, instant_distance,
              &hypothetical_number, hypothetical_reports, hypothetical_changes, level);

  /* write the hypotheticals for this result */

  write_hypotheticals(log_stream, distances_stream, report_stream,
                      case_law, area_pointer, facts_head, verbose, TRUE,
                      instant_result→hypothetical_list_head, &hypothetical_count, level);

  /* write the hypotheticals for all other results */

  for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
       result_pointer = result_pointer→next)
    if (result_pointer ≠ instant_result)
      write_hypotheticals(log_stream, distances_stream, report_stream,
                          case_law, area_pointer, facts_head, verbose, FALSE,
                          result_pointer→hypothetical_list_head, &hypothetical_count, level);
}

```

```

/* write details of the instantiations to the log file */
if (instantiation_number == 0)
    sprintf(message, "No instantiations");
else if (different_results == 0) {
    if (instantiation_number == 2)
        sprintf(message, "Both");
    else
        sprintf(message, "All %u", instantiation_number);
    sprintf(message, "%s instantiations have the same nearest result"
        " as does the instant case", message);
} else
    sprintf(message, "%u of the %u instantiations s a nearest result"
        " different to that of the instant case", different_results,
        instantiation_number, different_results == 1 ? "has" : "have");
Write(log_stream, message, ".\n", level, Hang);

/* write details of the hypothesizing to the log file */

Indent(log_stream, level);
if (hypothetical_reports == 0)
    fprintf(log_stream, "No hypotheticals.\n\n");
else {
    fprintf(log_stream, "Reported on %u hypothetical %s of %u",
        hypothetical_count, hypothetical_count == 1 ? "" : "s", hypothetical_number);
    if (hypothetical_changes != 0)
        fprintf(log_stream, " (limit of %u change %s)", hypothetical_changes,
            hypothetical_changes == 1 ? "" : "s");
    fprintf(log_stream, ".\n\n");
}

if (distances_stream != NULL)
    /* a distances file is open for this area, so write its trailer */
    Write_LaTeX_Trailer(distances_stream, inputable_latex);

if (report_stream != NULL)
    /* a report file is open for this area, so write its trailer */
    Write_LaTeX_Trailer(report_stream, inputable_latex);
}
if (distances_filename != NULL) {
    /* a distances filename was specified, so close the distances file */
    sprintf(filename, "%s-%s%s", distances_filename,
        area_identifier, LaTeX_File_Extension);
    if (fclose(distances_stream) == EOF) {
        sprintf(message, "can't close distances file \"%s\"", filename);
        error_exit(log_stream, message);
    }
}
}

```

```
if (report_filename ≠ NULL) {
    /* a report filename was specified, so close the report file */
    sprintf(filename, "%s-%s%s", report_filename,
            area_identifier, LaTeX_File_Extension);
    if (fclose(report_stream) ≡ EOF) {
        sprintf(message, "can't close report file \"%s\"", filename);
        error_exit(log_stream, message);
    }
}
/* return the identifier of the "likely result" */
if (instant_result ≡ NULL)
    return NULL;
else
    return instant_result→identifier;
}
```

4

The TOKENIZER module

tokenizer.h

```
/* This is the header file for the TOKENIZER module. It is also included by the CASES and
   PARSER modules. */

/* string and character constants */

#define Quoted_LaTeX_Characters "$&%"
#define Comment_Character '%'
#define Quote_Character '"'
#define Equals_Character '='
#define Hyphen_Character '-'
#define Tab_Character '\t'
#define Vertical_Tab_Character '\v'
#define Form_Feed_Character '\f'
#define Backslash_Character '\\'

/* enumerated types */

typedef enum {
    TK_KEYWORD,
    TK_IDENTIFIER,
    TK_STRING,
    TK_YEAR,
    TK_ATTRIBUTE_VECTOR,
    TK_EQUALS,
    TK_EOF
} token_type;
```

```

typedef enum {
    KW_AREA,
    KW_ATTRIBUTE,
    KW_CASE,
    KW_CITATION,
    KW_CLOSING,
    KW_COURT,
    KW_EXTERNAL,
    KW_FACTS,
    KW_HELP,
    KW_HIERARCHY,
    KW_IDEAL,
    KW_NO,
    KW_OPENING,
    KW_QUESTION,
    KW_RESULT,
    KW_RESULTS,
    KW_SUMMARY,
    KW_UNKNOWN,
    KW_YEAR,
    KW_YES
} keyword_type;

/* structure type */
typedef struct {
    cardinal line_number,
    column_number;
    token_type token;
    union {
        keyword_type keyword;
        string identifier,
        string;
        cardinal year;
        matrix_element *matrix_head;
    } details;
} token_details;

/* external function */
extern token_details
Get-Token(
    file in_stream,
    file log_stream);

```

tokenizer.c

```

/* This is the implementation file for the TOKENIZER module. */
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "shyster.h"
#include "cases.h"
#include "tokenizer.h"

```



```

static void
error_exit(
    file stream,
    string message,
    token_details *token)
{
    char full_message[Max_Error_Message_Length];

    sprintf(full_message, "%s_[%u,%u]", message, token->line_number,
            token->column_number);
    Write_Error_Message_And_Exit(stream, "Tokenizer", full_message);
}

static void
warning(
    file stream,
    const string message,
    const token_details *token)
{
    char full_message[Max_Error_Message_Length];

    sprintf(full_message, "%s_[%u,%u]", message, token->line_number,
            token->column_number);
    Write_Warning_Message(stream, "Tokenizer", full_message, Top_Level);
}

static int
get_char(
    file in_stream,
    cardinal *line_number,
    cardinal *column_number,
    boolean *eof)

/* Returns the next character from in_stream. Adjusts *line_number and *column_number
   appropriately. Sets *eof to TRUE, if the end of in_stream has been encountered (i.e. the
   character returned is EOF). */

{
    int ch;

    if (!(*eof = (ch = getc(in_stream))  $\equiv$  EOF))
        if (ch  $\equiv$  Carriage_Return_Character) {
            (*line_number)++;
            *column_number = 0;
        } else
            (*column_number)++;
    return ch;
}

```

static void

```

unget_char(
    file in_stream,
    file log_stream,
    int ch,
    token_details *token,
    cardinal *line_number,
    cardinal *column_number)

```

/ Pushes `ch` back onto `in_stream`. Adjusts `*line_number` and `*column_number` appropriately. **/**

```

{
    char message[Max_Error_Message_Length];

    if (ch == Carriage_Return_Character)
        (*line_number)--;
    else
        (*column_number)--;
    if (ch != EOF)
        if (ungetc((int) ch, in_stream) == EOF) {
            sprintf(message, "ungetc failed with character '%c'", ch);
            error_exit(log_stream, message, token);
        }
}

```

static boolean

```

is_whitespace(
    int ch)

```

/ Returns `TRUE`, iff `ch` is a whitespace character (a space, a tab, a vertical tab, a carriage return, or a form feed). **/**

```

{
    return ((ch == Space_Character) ∨ (ch == Tab_Character) ∨
            (ch == Vertical_Tab_Character) ∨ (ch == Carriage_Return_Character) ∨
            (ch == Form_Feed_Character));
}

```

static boolean

```

is_alpha(
    int ch)

```

/ Returns `TRUE`, iff `ch` is an alphabetic character (A ... Z, a ... z). **/**

```

{
    return (((ch ≥ Big_A_Character) ∧ (ch ≤ Big_Z_Character)) ∨
            ((ch ≥ Little_A_Character) ∧ (ch ≤ Little_Z_Character)));
}

```

```

static void
get_keyword_or_ident(
    file in_stream,
    file log_stream,
    int ch,
    token_details *token,
    cardinal *line_number,
    cardinal *column_number,
    boolean *eof)

/* Gets an identifier, which may be a keyword (the first character of the identifier—ch—
has just been read). Changes the structure pointed to by token: sets token→token to
TK_KEYWORD or TK_IDENTIFIER, and sets token→details appropriately.

EBNF: identifier = letter { letter | digit | "-" }. */

{
    cardinal length = 1;
    string identifier;
    char message[Max_Error_Message_Length];

    /* allocate memory for the identifier */

    if ((identifier = (string) malloc((Max_Identifier_Length + 1) × sizeof(char))) ≡ NULL)
        error_exit(log_stream, "malloc_failed_during_keyword/identifier_handling",
            token);

    /* put up to Max_Identifier_Length characters into the identifier */

    identifier[0] = ch;
    ch = get_char(in_stream, line_number, column_number, eof);
    while ((length < Max_Identifier_Length) ∧
        (is_alpha(ch) ∨ Is_Digit(ch) ∨ (ch ≡ Hyphen_Character))) {
        identifier[length++] = ch;
        ch = get_char(in_stream, line_number, column_number, eof);
    }
    identifier[length] = Null_Character;

    if (is_alpha(ch) ∨ Is_Digit(ch) ∨ (ch ≡ Hyphen_Character)) {

        /* there is more of the identifier, so warn the user and skip over the rest of it */

        sprintf(message, "identifier_truncated_to_%s", identifier);
        warning(log_stream, message, token);
        while (is_alpha(ch) ∨ Is_Digit(ch) ∨ (ch ≡ Hyphen_Character))
            ch = get_char(in_stream, line_number, column_number, eof);
    } else

        /* reallocate (just enough) memory for the identifier */

        if ((identifier = (string) realloc((void *) identifier, length × sizeof(char))) ≡
            NULL)
            error_exit(log_stream, "realloc_failed_during_keyword/identifier_handling",
                token);

    /* push the first character after the identifier back onto in_stream */
    unget_char(in_stream, log_stream, ch, token, line_number, column_number);

```

```

/* check whether the identifier is a keyword */
if (¬strcmp(identifier, "AREA")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_AREA;
} else if (¬strcmp(identifier, "ATTRIBUTE")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_ATTRIBUTE;
} else if (¬strcmp(identifier, "CASE")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_CASE;
} else if (¬strcmp(identifier, "CITATION")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_CITATION;
} else if (¬strcmp(identifier, "CLOSING")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_CLOSING;
} else if (¬strcmp(identifier, "COURT")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_COURT;
} else if (¬strcmp(identifier, "EXTERNAL")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_EXTERNAL;
} else if (¬strcmp(identifier, "FACTS")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_FACTS;
} else if (¬strcmp(identifier, "HELP")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_HELP;
} else if (¬strcmp(identifier, "HIERARCHY")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_HIERARCHY;
} else if (¬strcmp(identifier, "IDEAL")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_IDEAL;
} else if (¬strcmp(identifier, "NO")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_NO;
} else if (¬strcmp(identifier, "OPENING")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_OPENING;
} else if (¬strcmp(identifier, "QUESTION")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_QUESTION;
} else if (¬strcmp(identifier, "RESULT")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_RESULT;
} else if (¬strcmp(identifier, "RESULTS")) {
    token→token = TK_KEYWORD;
    token→details.keyword = KW_RESULTS;
}

```

```

} else if (!strcmp(identifier, "SUMMARY")) {
    token->token = TK_KEYWORD;
    token->details.keyword = KW_SUMMARY;
} else if (!strcmp(identifier, "UNKNOWN")) {
    token->token = TK_KEYWORD;
    token->details.keyword = KW_UNKNOWN;
} else if (!strcmp(identifier, "YEAR")) {
    token->token = TK_KEYWORD;
    token->details.keyword = KW_YEAR;
} else if (!strcmp(identifier, "YES")) {
    token->token = TK_KEYWORD;
    token->details.keyword = KW_YES;
} else {

    /* the identifier is not a keyword */

    token->token = TK_IDENTIFIER;
    token->details.identifier = identifier;
}
}

static void
get_string(
    file in_stream,
    file log_stream,
    token_details *token,
    cardinal *line_number,
    cardinal *column_number,
    boolean *eof)

/* Gets a string (a " character has just been read). Treats a pair of consecutive " characters as
a single " character. Treats consecutive whitespace characters as a single space character.
Sets token->details appropriately (token->token has already been set to TK_STRING).
EBNF: string = "" character { character } "" */
{
    int ch,
        next_ch;
    string temp_string;
    cardinal allocated_length,
        actual_length;

    allocated_length = String_Increment;
    actual_length = 0;

    /* allocate memory for the string */

    if ((temp_string = (string) malloc(allocated_length * sizeof(char))) == NULL)
        error_exit(log_stream, "malloc failed during string handling", token);

    /* get the first character of the string */

    ch = get_char(in_stream, line_number, column_number, eof);

```

```

for (;) {
  if (ch  $\equiv$  EOF)
    error_exit(log_stream, "end_of_file_in_string", token);
  if (strchr(Quoted_LaTeX_Characters, ch)  $\neq$  NULL) {
    /* the character is one of those in Quoted_LaTeX_Characters (i.e. it is $, & or %);
       it has a special meaning in LATEX and needs to be prefixed in the string by a
       \ character */
    temp_string[actual_length++] = Backslash_Character;
    if (actual_length  $\equiv$  allocated_length)
      /* the string is too long for temp_string, so reallocate some more memory */
      if ((temp_string = (string) realloc((void *) temp_string,
        (allocated_length += String_Increment)  $\times$ 
        sizeof(char))  $\equiv$  NULL)
        error_exit(log_stream, "realloc_failed_during_string_handling",
          token);
  }
  if (ch  $\equiv$  Quote_Character)
    /* the character is a " character */
    if ((next_ch = get_char(in_stream, line_number, column_number, eof))  $\neq$ 
      Quote_Character) {
      /* the next character is not a " character so this is the end of the string; push
         the first character after the string back onto in_stream */
      unget_char(in_stream, log_stream, next_ch, token, line_number, column_number);
      if (actual_length  $\equiv$  0)
        error_exit(log_stream, "empty_string", token);
      else {
        temp_string[actual_length++] = Null_Character;
        if (actual_length < allocated_length)
          /* reallocate (just enough) memory for the string */
          if ((temp_string = (string) realloc((void *) temp_string,
            actual_length  $\times$  sizeof(char))  $\equiv$  NULL)
            error_exit(log_stream, "realloc_failed_during_string_handling",
              token);
      }
      token $\rightarrow$ details.string = temp_string;
      return;
    }
  }
  if (is_whitespace(ch)) {
    /* skip to the next non-whitespace character */
    for (ch = get_char(in_stream, line_number, column_number, eof);
      is_whitespace(ch);
      ch = get_char(in_stream, line_number, column_number, eof));

```

```

    if (ch == EOF)
        error_exit(log_stream, "end_of_file_in_string", token);

    /* put a single space character in the string for all of the whitespace */
    temp_string[actual_length++] = Space_Character;

    /* push the non-whitespace character back onto in_stream */
    unget_char(in_stream, log_stream, ch, token, line_number, column_number);
} else
    temp_string[actual_length++] = ch;
if (actual_length == allocated_length)
    /* the string is too long for temp_string, so reallocate some more memory */
    if ((temp_string = (string) realloc((void *) temp_string,
        (allocated_length + String_Increment) *
        sizeof(char))) == NULL)
        error_exit(log_stream, "realloc_failed_during_string_handling", token);

    /* get the next character */
    ch = get_char(in_stream, line_number, column_number, eof);
}
}

static void
get_year(
    file in_stream,
    file log_stream,
    int ch,
    token_details *token,
    cardinal *line_number,
    cardinal *column_number,
    boolean *eof)

/* Gets a year (the first digit of the year—ch—has just been read). Sets token→details appropriately (token→token has already been set to TK_YEAR).

EBNF: year = digit [digit] [digit] [digit]. */
{
    cardinal digits = 1,
        year = (cardinal) ch - (cardinal) Zero_Character;

    for (ch = get_char(in_stream, line_number, column_number, eof);
        (Is_Digit(ch) ^ (digits < Year_Digits));
        ch = get_char(in_stream, line_number, column_number, eof)) {
        year = (10 × year) + (cardinal) ch - (cardinal) Zero_Character;
        digits++;
    }
    if (Is_Digit(ch))
        error_exit(log_stream, "year_has_too_many_digits", token);
    unget_char(in_stream, log_stream, ch, token, line_number, column_number);
    token→details.year = year;
}

```

static void

```

get_attribute_vector(
    file in_stream,
    file log_stream,
    token_details *token,
    cardinal *line_number,
    cardinal *column_number,
    boolean *eof)

/* Gets an attribute vector (a left parenthesis character has just been read). Sets token→
details appropriately (token→token has already been set to TK_YEAR).

EBNF: attribute-vector = "(" attribute-value { attribute-value } ")".
    attribute-value = "Y" | "N" | "U". */

{
    int ch;
    matrix_element *matrix_head,
        *matrix_pointer;
    boolean empty = TRUE;
    char message[Max_Error_Message_Length];

    /* allocate memory for this matrix element (the first in the list) */

    if ((matrix_head = (matrix_element *) malloc(sizeof(matrix_element))) ≡ NULL)
        error_exit(log_stream, "malloc_failed_during_attribute_vector_handling",
            token);

    matrix_pointer = matrix_head;

    /* for every character that is not a right parenthesis ... */

    for (ch = get_char(in_stream, line_number, column_number, eof);
        ch ≠ Attribute_Vector_End_Character;
        ch = get_char(in_stream, line_number, column_number, eof)) {

        if (¬empty) {

            /* allocate memory for this matrix element */

            if ((matrix_pointer→case_next =
                (matrix_element *) malloc(sizeof(matrix_element))) ≡ NULL)
                error_exit(log_stream, "malloc_failed_during_attribute_vector_handling",
                    token);
            matrix_pointer = matrix_pointer→case_next;
        }

        switch (ch) {
            case Yes_Character:
                matrix_pointer→attribute_value = YES;
                break;
            case No_Character:
                matrix_pointer→attribute_value = NO;
                break;
        }
    }
}

```



```

        case Unknown_Character:
            matrix_pointer→attribute_value = UNKNOWN;
            break;
        default:
            sprintf(message, "invalid_attribute_value_ '%c'", ch);
            error_exit(log_stream, message, token);
            break;
    }
    empty = FALSE;
    matrix_pointer→case_next = NULL;
    matrix_pointer→attribute_next = NULL;
}
if (empty)
    error_exit(log_stream, "empty_attribute_vector", token);
token→details.matrix_head = matrix_head;
}

static void
skip_to_end_of_line(
    file in_stream,
    cardinal *line_number,
    cardinal *column_number,
    boolean *eof)

/* Skips over characters until the end of the line, or the end of the file, is reached. */
{
    int ch;

    for (;;) {
        ch = get_char(in_stream, line_number, column_number, eof);
        if ((ch ≡ EOF) ∨ (ch ≡ Carriage_Return_Character))
            return;
    }
}

extern token_details
Get-Token(
    file in_stream,
    file log_stream)

/* Returns details of the next token from in_stream. */
{
    token_details token;
    int ch;
    static cardinal line_number = 1,
        column_number = 0;
    static boolean eof = FALSE;
    char message[Max_Error_Message_Length];

```

```

for (;) {
    if (eof) {
        token.token = TK_EOF;
        return token;
    }

    /* skip to the next non-whitespace character */
    for (ch = get_char(in_stream, &line_number, &column_number, &eof);
        is_whitespace(ch);
        ch = get_char(in_stream, &line_number, &column_number, &eof));

    token.line_number = line_number;
    token.column_number = column_number;

    if (is_alpha(ch)) {
        get_keyword_or_ident(in_stream, log_stream, ch, &token,
            &line_number, &column_number, &eof);
        return token;
    } else if (ch ≡ Quote_Character) {
        token.token = TK_STRING;
        get_string(in_stream, log_stream, &token, &line_number, &column_number, &eof);
        return token;
    } else if (Is_Digit(ch)) {
        token.token = TK_YEAR;
        get_year(in_stream, log_stream, ch, &token, &line_number, &column_number, &eof);
        return token;
    } else if (ch ≡ Attribute_Vector_Begin_Character) {
        token.token = TK_ATTRIBUTE_VECTOR;
        get_attribute_vector(in_stream, log_stream, &token,
            &line_number, &column_number, &eof);
        return token;
    } else if (ch ≡ Equals_Character) {
        token.token = TK_EQUALS;
        return token;
    } else if (ch ≡ EOF) {
        token.token = TK_EOF;
        return token;
    } else if (ch ≡ Comment_Character)
        skip_to_end_of_line(in_stream, &line_number, &column_number, &eof);
    else {
        sprintf(message, "invalid character '%c'", ch);
        error_exit(log_stream, message, &token);
    }
}
}

```

5

The PARSER module

parser.h

```
/* This is the header file for the PARSER module. It is also included by the CASES module. */  
  
/* external function */  
  
extern case_law_specification  
Parse_Specification(  
    file in_stream,  
    file log_stream);
```

parser.c

```
/* This is the implementation file for the PARSER module. */  
  
#include <stdio.h>  
#include <stdlib.h>  
#include <string.h>  
#include "shyster.h"  
#include "cases.h"  
#include "parser.h"  
#include "tokenizer.h"  
  
static void  
error_exit(  
    file stream,  
    string message,  
    token_details *token)
```

```

{
    char full_message[Max_Error_Message_Length];

    if (token ≠ NULL) {
        sprintf(full_message, "%s [%u,%u] ", message, token→line_number,
            token→column_number);
        Write_Error_Message_And_Exit(stream, "Parser", full_message);
    } else
        Write_Error_Message_And_Exit(stream, "Parser", message);
}

static void
warning(
    file stream,
    const string message)
{
    Write_Warning_Message(stream, "Parser", message, Top_Level);
}

static void
parse_court_pair(
    file in_stream,
    file log_stream,
    court *court_pointer,
    token_details *token,
    cardinal *count,
    cardinal *rank)

/* Parses a court identifier/string pair, and puts details in the court pointed to by court_pointer.
A court identifier has just been read, and its details are pointed to by token. *count is the
number of courts already parsed. *rank is the rank of this court.

EBNF: hierarchy-block = court-identifier string
                        { [ "=" ] court-identifier string }.
    court-identifier = identifier. */

{
    court_pointer→identifier = token→details.identifier;

    /* get the next token (it should be a string) */
    *token = Get-Token(in_stream, log_stream);

    if (token→token ≠ TK_STRING)
        error_exit(log_stream, "string expected in hierarchy block after identifier",
            token);

    court_pointer→string = token→details.string;

    court_pointer→rank = (*rank)++;
}

```

```

/* get the next token (it should be an =, another court identifier, or the keyword AREA) */
*token = Get-Token(in_stream, log_stream);

if (token->token == TK_EQUALS) {
    /* this court, and the next, are of equal rank */
    (*rank)--;

    /* get the next token (it should be another court identifier, or the keyword AREA) */
    *token = Get-Token(in_stream, log_stream);
}
(*count)++;
court_pointer->next = NULL;
}

static court *
parse_hierarchy(
    file in_stream,
    file log_stream,
    token_details *token,
    cardinal *count)

/* Parses a hierarchy, and returns a pointer to a list of courts. The keyword HIERARCHY has
just been read, and the details of the token that followed it are pointed to by token. Sets
*count to the number of courts in the hierarchy.

EBNF: hierarchy      = hierarchy-header hierarchy-block.
      hierarchy-header = "HIERARCHY".
      hierarchy-block  = court-identifier string
                        { [ "=" ] court-identifier string }.
      court-identifier = identifier. */
{
    cardinal rank = 1;
    court *court_head = NULL,
        *court_pointer = NULL,
        *temp_court_pointer;
    char message[Max_Error_Message_Length];

    while (token->token == TK_IDENTIFIER) {
        if (court_head == NULL) {
            /* allocate memory for this court (the first in the list) */
            if ((court_head = (court *) malloc(sizeof(court))) == NULL)
                error_exit(log_stream, "malloc_failed_during_hierarchy_handling",
                    token);

            court_pointer = court_head;

```

```

} else {
    /* go to the end of the list of courts, checking that this court has not already been
       specified */
    for (temp_court_pointer = court_head; temp_court_pointer ≠ NULL;
         temp_court_pointer = temp_court_pointer→next)
        if (¬strcmp(token→details.identifier, temp_court_pointer→identifier)) {
            sprintf(message, "%s□court□already□specified",
                    token→details.identifier);
            error_exit(log_stream, message, token);
        }

    /* allocate memory for this court */

    if ((court_pointer→next = (court *) malloc(sizeof(court))) ≡ NULL)
        error_exit(log_stream, "malloc□failed□during□hierarchy□handling",
                  token);

        court_pointer = court_pointer→next;
    }
    parse_court_pair(in_stream, log_stream, court_pointer, token, count, &rank);
}
return court_head;
}

```

static void

```

parse_result_pair(

```

```

    file in_stream,
    file log_stream,
    result *result_pointer,
    token_details *token,
    cardinal *count)

```

*/** Parses a result identifier/string pair, and puts details in the result pointed to by *result_pointer*. A result identifier has just been read, and its details are pointed to by *token*. **count* is the number of results already parsed in this area.

```

EBNF: results-block    = result-identifier string
                        result-identifier string
                        { result-identifier string }.
result-identifier     = identifier.

```

```

{
    result_pointer→identifier = token→details.identifier;

    /* get the next token (it should be a string) */
    *token = Get-Token(in_stream, log_stream);

    if (token→token ≠ TK_STRING)
        error_exit(log_stream, "string□expected□in□results□block□after□identifier",
                  token);

    result_pointer→string = token→details.string;

```

```

    result_pointer→case_head = NULL;
    result_pointer→ideal_point_head = NULL;
    result_pointer→centroid_head = NULL;
    result_pointer→hypothetical_list_head = NULL;
    (*count)++;

    /* get the next token (it should be a result identifier, or the keyword ATTRIBUTE) */
    *token = Get-Token(in_stream, log_stream);

    result_pointer→next = NULL;
}

static result *
parse_results(
    file in_stream,
    file log_stream,
    token_details *token,
    cardinal *count)

/* Parses results, and returns a pointer to a list of results. The keyword RESULTS has just been
read, and the details of the token that followed it are pointed to by token. Sets *count to
the number of results in the area.

EBNF: results          = results-header results-block.
     results-header    = "RESULTS".
     results-block     = result-identifier string
                       result-identifier string
                       { result-identifier string }.
     result-identifier = identifier. */
{
    result *result_head = NULL,
    *result_pointer = NULL,
    *temp_result_pointer;
    char message[Max_Error_Message_Length];
    while (token→token ≡ TK_IDENTIFIER) {
        if (result_head ≡ NULL) {
            /* allocate memory for this result (the first in the list) */
            if ((result_head = (result *) malloc(sizeof(result))) ≡ NULL)
                error_exit(log_stream, "malloc_failed_during_result_handling", token);

            result_pointer = result_head;
        } else {
            /* go to the end of the list of results, checking that this result has not already been
            specified */
            for (temp_result_pointer = result_head; temp_result_pointer ≠ NULL;
                temp_result_pointer = temp_result_pointer→next)
                if (¬strcmp(token→details.identifier, temp_result_pointer→identifier)) {
                    sprintf(message, "%s_result_already_specified",
                        token→details.identifier);
                    error_exit(log_stream, message, token);
                }
        }
    }
}

```

```

    /* allocate memory for this result */
    if ((result_pointer->next = (result *) malloc(sizeof(result))) == NULL)
        error_exit(log_stream, "malloc_failed_during_result_handling", token);

    result_pointer = result_pointer->next;
}
parse_result_pair(in_stream, log_stream, result_pointer, token, count);
}
return result_head;
}

static void
add_to_direction_list(
    file log_stream,
    direction_list_element **list_head,
    result *result_pointer,
    token_details *token)

/* Adds result_pointer to the list of directions pointed to by *list_head. */

{
    direction_list_element *list_pointer,
        *last_list_pointer;
    char message[Max_Error_Message_Length];

    if (*list_head == NULL) {
        /* allocate memory for this direction (the first in the list) */
        if ((*list_head =
            (direction_list_element *) malloc(sizeof(direction_list_element))) ==
            NULL)
            error_exit(log_stream, "malloc_failed_during_result_list_handling", token);

        list_pointer = *list_head;
    } else {

        /* go to the end of the list of directions, checking that this result has not already been
        specified for this attribute value */

        for (list_pointer = *list_head; list_pointer != NULL;
            list_pointer = list_pointer->next) {
            if (list_pointer->result == result_pointer) {
                sprintf(message,
                    "%s_result_already_specified_for_this_attribute_value",
                    token->details.identifier);
                error_exit(log_stream, message, token);
            }
        }
        last_list_pointer = list_pointer;
    }
}

```



```

    /* allocate memory for this direction */
    if ((last_list_pointer->next =
        (direction_list_element *) malloc(sizeof(direction_list_element))) ==
        NULL)
        error_exit(log_stream, "malloc_failed_during_result_list_handling", token);

    list_pointer = last_list_pointer->next;
}
list_pointer->result = result_pointer;

list_pointer->next = NULL;
}

static void
add_to_identifier_list(
    file log_stream,
    identifier_list_element **list_head,
    string identifier,
    token_details *token)

/* Adds identifier to the list of identifiers pointed to by *list_head. */
{
    identifier_list_element *list_pointer,
    *last_list_pointer;
    char message[Max_Error_Message_Length];

    if (*list_head == NULL) {
        /* allocate memory for this identifier list element (the first in the list) */
        if ((*list_head = (identifier_list_element *) malloc(sizeof(identifier_list_element))) ==
            NULL)
            error_exit(log_stream, "malloc_failed_during_identifier_list_handling",
                token);

        list_pointer = *list_head;
    } else {
        /* go to the end of the list of identifiers, checking that this identifier has not already
        been specified for this attribute value */
        for (list_pointer = *list_head; list_pointer != NULL;
            list_pointer = list_pointer->next) {
            if (!strcmp(list_pointer->identifier, identifier)) {
                sprintf(message,
                    "%s_identifier_already_specified_for_this_attribute_value",
                    token->details.identifier);
                error_exit(log_stream, message, token);
            }
        }
        last_list_pointer = list_pointer;
    }
}

```

```

/* allocate memory for this identifier list element */
if ((last_list_pointer→next =
    (identifier_list_element *) malloc(sizeof(identifier_list_element))) ≡
    NULL)
    error_exit(log_stream, "malloc_failed_during_identifier_list_handling",
              token);

list_pointer = last_list_pointer→next;
}
list_pointer→identifier = identifier;
list_pointer→next = NULL;
}

static attribute *
parse_attributes(
    file in_stream,
    file log_stream,
    result *result_head,
    token_details *token,
    string area_identifier,
    cardinal *count)

/* Parses attributes, and returns a pointer to a list of attributes. The keyword ATTRIBUTE
has just been read, and the details of the token that followed it are pointed to by token.
*result_head is the head of the list of results for this area. Sets *count to the number of
attributes in the area.

EBNF: attribute          = attribute-header attribute-block.
attribute-header        = "ATTRIBUTE".
attribute-block         = local-attribute | external-attribute.
local-attribute         = "QUESTION" string
                        [ "YES" string { result-identifier } ]
                        [ "NO" string { result-identifier } ]
                        [ "UNKNOWN" string { result-identifier } ]
                        [ "HELP" string ].
external-attribute     = "AREA" area-identifier
                        [ "YES" string { result-identifier }
                        [ "EXTERNAL" result-identifier { result-identifier } ] ]
                        [ "NO" string { result-identifier }
                        [ "EXTERNAL" result-identifier { result-identifier } ] ]
                        [ "UNKNOWN" string { result-identifier }
                        [ "EXTERNAL" result-identifier { result-identifier } ] ] ]. */

{
    attribute *attribute_pointer;
    result *result_pointer = result_head;
    boolean found = FALSE;
    char message[Max_Error_Message_Length];

/* allocate memory for this attribute */
if ((attribute_pointer = (attribute *) malloc(sizeof(attribute))) ≡ NULL)
    error_exit(log_stream, "malloc_failed_during_attribute_handling", token);

```

```

if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_QUESTION))
    attribute_pointer→external_attribute = FALSE;
else if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_AREA))
    attribute_pointer→external_attribute = TRUE;
else
    error_exit(log_stream, "keyword_QUESTION_or_AREA_expected_in_attribute",
              token);

/* get the next token (if the attribute is local, it should be a string; if the attribute is
   external, it should be an area identifier) */
*token = Get-Token(in_stream, log_stream);

if (attribute_pointer→external_attribute) {
    if (token→token ≠ TK_IDENTIFIER)
        error_exit(log_stream,
                  "identifier_expected_in_attribute_after_keyword_AREA", token);

    if (¬strcmp(token→details.string, area_identifier)) {
        sprintf(message, "Recursive_external_attribute_in_%s_area",
                area_identifier);
        error_exit(log_stream, message, token);
    }
    attribute_pointer→details.external.area_identifier = token→details.string;
} else {
    if (token→token ≠ TK_STRING)
        error_exit(log_stream,
                  "string_expected_in_attribute_after_keyword_QUESTION", token);

    attribute_pointer→details.local.question = token→details.string;
}

/* get the next token (it should be the keyword YES, the keyword NO, or the keyword
   UNKNOWN) */
*token = Get-Token(in_stream, log_stream);

if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_YES)) {
    /* get the next token (it should be a string) */
    *token = Get-Token(in_stream, log_stream);

    if (token→token ≠ TK_STRING)
        error_exit(log_stream, "string_expected_in_attribute_after_keyword_YES",
                  token);

    attribute_pointer→yes = token→details.string;

    /* get the next token (it should be a result identifier, the keyword NO, the keyword
       UNKNOWN, the keyword HELP, the keyword ATTRIBUTE, or the keyword CASE; if the
       attribute is external the token could also be the keyword EXTERNAL) */
    *token = Get-Token(in_stream, log_stream);

    attribute_pointer→yes_direction_head = NULL;
}

```

```

/* while there are result identifiers to parse ... */
while (token→token ≡ TK_IDENTIFIER) {

    /* find the result matching the result identifier, and add that result to the list of
       directions for YES for this attribute */

    do {
        if (result_pointer ≡ NULL) {
            sprintf(message, "%s result not found",
                    token→details.identifier);
            error_exit(log_stream, message, token);
        }
        found = ¬strcmp(token→details.identifier, result_pointer→identifier);
        if (found)
            add_to_direction_list(log_stream, &attribute_pointer→yes_direction_head,
                                   result_pointer, token);
        else
            result_pointer = result_pointer→next;
    } while (¬found);

    result_pointer = result_head;

    /* get the next token (it should be a result identifier, the keyword NO, the keyword
       UNKNOWN, the keyword HELP, the keyword ATTRIBUTE, or the keyword CASE; if
       the attribute is external the token could also be the keyword EXTERNAL) */

    *token = Get-Token(in_stream, log_stream);
}

if (attribute_pointer→external_attribute) {

    attribute_pointer→details.external.yes_identifier_head = NULL;

    if ((token→token ≡ TK_KEYWORD) ∧
        (token→details.keyword ≡ KW_EXTERNAL)) {

        /* get the next token (it should be a result identifier) */

        *token = Get-Token(in_stream, log_stream);

        while (token→token ≡ TK_IDENTIFIER) {

            /* add the result identifier to the list of external result identifiers for YES for
               this attribute */

            add_to_identifier_list(log_stream,
                                    &attribute_pointer→details.external.yes_identifier_head,
                                    token→details.identifier, token);

            /* get the next token (it should be a result identifier, the keyword NO, the
               keyword UNKNOWN, the keyword HELP, the keyword ATTRIBUTE, or the
               keyword CASE) */

            *token = Get-Token(in_stream, log_stream);
        }
    }
}

```

```

        if (attribute_pointer->details.external.yes_identifier_head == NULL)
            error_exit(log_stream,
                "identifier_expected_in_attribute_after_keyword_EXTERNAL",
                token);
    }
} else
    attribute_pointer->yes = NULL;
if ((token->token == TK_KEYWORD) ^ (token->details.keyword == KW_NO)) {
    /* get the next token (it should be a string) */
    *token = Get-Token(in_stream, log_stream);
    if (token->token != TK_STRING)
        error_exit(log_stream, "string_expected_in_attribute_after_keyword_NO",
            token);
    attribute_pointer->no = token->details.string;
    /* get the next token (it should be a result identifier, the keyword UNKNOWN, the keyword
    HELP, the keyword ATTRIBUTE, or the keyword CASE; if the attribute is external the
    token could also be the keyword EXTERNAL) */
    *token = Get-Token(in_stream, log_stream);
    attribute_pointer->no_direction_head = NULL;
    /* while there are result identifiers to parse ... */
    while (token->token == TK_IDENTIFIER) {
        /* find the result matching the result identifier, and add that result to the list of
        directions for NO for this attribute */
        do {
            if (result_pointer == NULL) {
                sprintf(message, "%s_result_not_found",
                    token->details.identifier);
                error_exit(log_stream, message, token);
            }
            found = !strcmp(token->details.identifier, result_pointer->identifier);
            if (found)
                add_to_direction_list(log_stream, &attribute_pointer->no_direction_head,
                    result_pointer, token);
            else
                result_pointer = result_pointer->next;
        } while (!found);
        result_pointer = result_head;
        /* get the next token (it should be a result identifier, the keyword UNKNOWN, the
        keyword HELP, the keyword ATTRIBUTE, or the keyword CASE; if the attribute is
        external the token could also be the keyword EXTERNAL) */
        *token = Get-Token(in_stream, log_stream);
    }
}

```

```

if (attribute_pointer→external_attribute) {
    attribute_pointer→details.external.no_identifier_head = NULL;

    if ((token→token ≡ TK_KEYWORD) ∧
        (token→details.keyword ≡ KW_EXTERNAL)) {

        /* get the next token (it should be a result identifier) */

        *token = Get-Token(in_stream, log_stream);

        while (token→token ≡ TK_IDENTIFIER) {

            /* add the result identifier to the list of external result identifiers for NO for
               this attribute */

            add_to_identifier_list(log_stream,
                &attribute_pointer→details.external.no_identifier_head,
                token→details.identifier, token);

            /* get the next token (it should be a result identifier, the keyword UNKNOWN,
               the keyword HELP, the keyword ATTRIBUTE, or the keyword CASE) */

            *token = Get-Token(in_stream, log_stream);
        }
        if (attribute_pointer→details.external.no_identifier_head ≡ NULL)
            error_exit(log_stream,
                "identifier_expected_in_attribute_after_keyword_EXTERNAL",
                token);
    }
}
else
    attribute_pointer→no = NULL;

if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_UNKNOWN)) {

    /* get the next token (it should be a string) */

    *token = Get-Token(in_stream, log_stream);

    if (token→token ≠ TK_STRING)
        error_exit(log_stream,
            "string_expected_in_attribute_after_keyword_UNKNOWN", token);

    attribute_pointer→unknown = token→details.string;

    /* get the next token (it should be a result identifier, the keyword HELP, the keyword
       ATTRIBUTE, or the keyword CASE; if the attribute is external the token could also be
       the keyword EXTERNAL) */

    *token = Get-Token(in_stream, log_stream);

    attribute_pointer→unknown_direction_head = NULL;

```

```

/* while there are result identifiers to parse ... */
while (token→token ≡ TK_IDENTIFIER) {
    /* find the result matching the result identifier, and add that result to the list of
    directions for UNKNOWN for this attribute */
    do {
        if (result_pointer ≡ NULL) {
            sprintf(message, "%s result not found",
                    token→details.identifier);
            error_exit(log_stream, message, token);
        }
        found = !strcmp(token→details.identifier, result_pointer→identifier);
        if (found)
            add_to_direction_list(log_stream, &attribute_pointer→unknown_direction_head,
                                result_pointer, token);
        else
            result_pointer = result_pointer→next;
    } while (!found);
    result_pointer = result_head;

    /* get the next token (it should be a result identifier, the keyword HELP, the keyword
    ATTRIBUTE, or the keyword CASE; if the attribute is external the token could also
    be the keyword EXTERNAL) */
    *token = Get-Token(in_stream, log_stream);
}

if (attribute_pointer→external_attribute) {
    attribute_pointer→details.external.unknown_identifier_head = NULL;
    if ((token→token ≡ TK_KEYWORD) ∧
        (token→details.keyword ≡ KW_EXTERNAL)) {
        /* get the next token (it should be a result identifier) */
        *token = Get-Token(in_stream, log_stream);
        while (token→token ≡ TK_IDENTIFIER) {
            /* add the result identifier to the list of external result identifiers for
            UNKNOWN for this attribute */
            add_to_identifier_list(log_stream,
                                &attribute_pointer→details.external.unknown_identifier_head,
                                token→details.identifier, token);

            /* get the next token (it should be a result identifier, the keyword HELP, the
            keyword ATTRIBUTE, or the keyword CASE) */
            *token = Get-Token(in_stream, log_stream);
        }
        if (attribute_pointer→details.external.unknown_identifier_head ≡ NULL)
            error_exit(log_stream,
                      "identifier expected in attribute after keyword EXTERNAL",
                      token);
    }
}

```

```

} else
    attribute_pointer→unknown = NULL;

if ((attribute_pointer→yes ≡ NULL) ∧ (attribute_pointer→no ≡ NULL) ∧
    (attribute_pointer→unknown ≡ NULL))
    error_exit(log_stream, "keyword_YES, NO_or_UNKNOWN_expected_in_attribute",
              token);

if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_HELP)) {

    if (attribute_pointer→external_attribute)
        error_exit(log_stream, "keyword_HELP_not_allowed_in_external_attribute",
                  token);

    /* get the next token (it should be a string) */

    *token = Get-Token(in_stream, log_stream);

    if (token→token ≠ TK_STRING)
        error_exit(log_stream, "string_expected_in_attribute_after_keyword_HELP",
                  token);

    attribute_pointer→details.local.help = token→details.string;

    /* get the next token (it should be the keyword ATTRIBUTE, or the keyword CASE) */

    *token = Get-Token(in_stream, log_stream);

} else if (¬attribute_pointer→external_attribute)
    attribute_pointer→details.local.help = NULL;

attribute_pointer→number = ++(*count);
attribute_pointer→matrix_head = NULL;
attribute_pointer→weights_head = NULL;
attribute_pointer→probability_head = NULL;

if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_ATTRIBUTE)) {

    /* get the next token (it should be the keyword QUESTION, or the keyword AREA) */

    *token = Get-Token(in_stream, log_stream);

    /* parse the next attribute */

    attribute_pointer→next = parse_attributes(in_stream, log_stream, result_head, token,
                                             area_identifier, count);

} else
    attribute_pointer→next = NULL;

return attribute_pointer;
}

```



```

static boolean
is_more_important(
    kase *x,
    kase *y)

/* Returns TRUE, iff case x is more important than case y: i.e. case x was a decision of a
more important court, or of an equally important court at a later date (if neither case x
nor case y has a court then the more recent of the two is the more important). */

{
    if (x→court_string ≡ NULL)
        if (y→court_string ≡ NULL)

            /* neither case x nor case y has a court, so return TRUE if case x is a more recent
            decision than case y */

            return x→year > y→year;

        else

            /* case y has a court and case x doesn't, so case y is assumed to be more important
            than case x */

            return FALSE;

        else if (y→court_string ≡ NULL)

            /* case x has a court and case y doesn't, so case x is assumed to be more important
            than case y */

            return TRUE;

        else {

            /* both case x and case y have a court */

            if (x→court_rank < y→court_rank)

                /* case x was a decision of a more important court then was case y */

                return TRUE;

            else if (x→court_rank ≡ y→court_rank)

                /* case x and case y were decisions of an equally important court, so return TRUE
                if case x is a more recent decision than case y */

                return x→year > y→year;

            else

                /* case x was a decision of a less important court than was case y */

                return FALSE;

        }
}

```

```

static void
rank_cases(
    kase **case_head)

/* Reorders the list of cases pointed to by *case_head so that the cases are listed in order of
their importance (more important cases first). */

{
    boolean changed;
    kase *case_pointer,
        *previous_case_pointer,
        *next_case_pointer,
        *temp_case_pointer;

    do {
        changed = FALSE;
        previous_case_pointer = NULL;
        case_pointer = *case_head;

        /* while there are still cases in the list ... */
        while (case_pointer ≠ NULL) {
            next_case_pointer = case_pointer→next;

            if (next_case_pointer ≠ NULL) {
                if (is_more_important(next_case_pointer, case_pointer)) {
                    /* swap this case and the next */
                    if (previous_case_pointer ≡ NULL)
                        /* case_pointer points to the first case in the list */
                        *case_head = next_case_pointer;
                    else {
                        /* case_pointer points to a case which is not the first in the list */
                        previous_case_pointer→next = next_case_pointer;
                    }
                    case_pointer→next = next_case_pointer→next;
                    next_case_pointer→next = case_pointer;
                    temp_case_pointer = case_pointer;
                    case_pointer = next_case_pointer;
                    next_case_pointer = temp_case_pointer;

                    changed = TRUE;
                }
            }
            previous_case_pointer = case_pointer;
            case_pointer = next_case_pointer;
        }
    } while (changed);
}

```

```

static void
number_cases(
    result *result_head)

/* Assigns a number to each case for each result in the list pointed to by result_head. */

{
    result *result_pointer;
    case *case_pointer;
    cardinal count = 1;

    /* for every result ... */

    for (result_pointer = result_head; result_pointer ≠ NULL; result_pointer =
        result_pointer→next)

        /* for every case ... */

        for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
            case_pointer = case_pointer→next)
            case_pointer→number = count++;
}

static void
cross_link(
    result *result_head,
    attribute *attribute_head)

/* Links attribute values by attribute (they are already linked by case). */

{
    result *result_pointer;
    case *case_pointer;
    attribute *attribute_pointer;
    matrix_element *case_matrix_pointer,
        *attribute_matrix_pointer;

    /* for every result ... */

    for (result_pointer = result_head; result_pointer ≠ NULL; result_pointer =
        result_pointer→next)

        /* for every case ... */

        for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
            case_pointer = case_pointer→next) {

            attribute_pointer = attribute_head;
            case_matrix_pointer = case_pointer→matrix_head;

            if (attribute_pointer→matrix_head ≡ NULL)

                /* this is the first attribute value for this (or any other) attribute, so each
                 attribute value for this case becomes the head of the appropriate attribute's
                 list */

                while ((attribute_pointer ≠ NULL) ∧ (case_matrix_pointer ≠ NULL)) {
                    attribute_pointer→matrix_head = case_matrix_pointer;
                    case_matrix_pointer = case_matrix_pointer→case_next;
                    attribute_pointer = attribute_pointer→next;
                }
        }
}

```

```

else

    /* this is not the first attribute value for this attribute, so add each attribute
       value for this case to the end of the appropriate attribute's list */

    while (attribute_pointer ≠ NULL) {

        for (attribute_matrix_pointer = attribute_pointer→matrix_head;
             attribute_matrix_pointer→attribute_next ≠ NULL;
             attribute_matrix_pointer =
             attribute_matrix_pointer→attribute_next);

        attribute_matrix_pointer→attribute_next = case_matrix_pointer;
        case_matrix_pointer = case_matrix_pointer→case_next;
        attribute_pointer = attribute_pointer→next;
    }
}

static void
check_for_identical_cases(
    file log_stream,
    area *area_pointer)

/* Checks every case in the area_pointer area against every other case in that area and warns
   if two cases are identical, or identical but for UNKNOWN values. */

{
    result *result_pointer_X,
        *result_pointer_Y;
    kase *case_pointer_X,
        *case_pointer_Y;
    matrix_element *matrix_pointer_X,
        *matrix_pointer_Y;
    boolean identical,
        possibly_identical;
    char message[Max_Error_Message_Length];

    /* for every result ... */

    for (result_pointer_X = area_pointer→result_head; result_pointer_X ≠ NULL;
         result_pointer_X = result_pointer_X→next)

        /* for every case X ... */

        for (case_pointer_X = result_pointer_X→case_head; case_pointer_X ≠ NULL;
             case_pointer_X = case_pointer_X→next) {

            case_pointer_Y = case_pointer_X;
            result_pointer_Y = result_pointer_X;

```

```

/* for every case Y (i.e. every case after case X) ... */
while (case_pointer_Y ≠ NULL) {
    if (case_pointer_X ≠ case_pointer_Y) {
        /* X and Y are not the same case */
        identical = TRUE;
        possibly_identical = TRUE;
        matrix_pointer_X = case_pointer_X→matrix_head;
        matrix_pointer_Y = case_pointer_Y→matrix_head;
        while (possibly_identical ∧
            (matrix_pointer_X ≠ NULL) ∧ (matrix_pointer_Y ≠ NULL)) {
            /* look for differences between case X and case Y */
            if (matrix_pointer_X→attribute_value ≠
                matrix_pointer_Y→attribute_value) {
                identical = FALSE;
                if ((matrix_pointer_X→attribute_value ≠ UNKNOWN) ∧
                    (matrix_pointer_Y→attribute_value ≠ UNKNOWN))
                    possibly_identical = FALSE;
            }
            matrix_pointer_X = matrix_pointer_X→case_next;
            matrix_pointer_Y = matrix_pointer_Y→case_next;
        }
        if (identical) {
            sprintf(message,
                "C%u and C%u in %s area have "
                "identical attribute vectors",
                case_pointer_X→number, case_pointer_Y→number,
                area_pointer→identifier);
            if (result_pointer_X ≠ result_pointer_Y)
                sprintf(message, "%s and different results", message);
            warning(log_stream, message);
        } else if (possibly_identical) {
            sprintf(message,
                "C%u and C%u in %s area have "
                "identical attribute values (except for unknowns)",
                case_pointer_X→number, case_pointer_Y→number,
                area_pointer→identifier);
            if (result_pointer_X ≠ result_pointer_Y)
                sprintf(message, "%s and different results", message);
            warning(log_stream, message);
        }
    }
    case_pointer_Y = case_pointer_Y→next;
}

```

```

    while ((case_pointer_Y ≡ NULL) ∧ (result_pointer_Y ≠ NULL)) {
        /* the next case Y is not of this result, so move to the next result */
        result_pointer_Y = result_pointer_Y→next;
        if (result_pointer_Y ≠ NULL)
            case_pointer_Y = result_pointer_Y→case_head;
    }
}

static void
parse_case(
    file in_stream,
    file log_stream,
    court *court_pointer,
    area *area_pointer,
    token_details *token,
    cardinal *count)

/* Parses a case, and adds it to the list of cases for the appropriate result in the area pointed
to by area_pointer. The keyword CASE has just been read, and the details of the token that
followed it are pointed to by token. Increments *count (the number of cases already parsed
in this area).

EBNF: case          = case-header case-block.
      case-header   = "CASE" string [string].
      case-block    = "CITATION" string
                    "YEAR" year
                    ["COURT" court-identifier]
                    "FACTS" attribute-vector
                    "RESULT" result-identifier
                    ["SUMMARY" string]. */

{
    result *result_pointer = area_pointer→result_head;
    kase *case_pointer,
        *temp_case_pointer;
    attribute *attribute_pointer;
    matrix_element *matrix_pointer;
    boolean found = FALSE;
    char message[Max_Error_Message_Length];

    if (token→token ≠ TK_STRING)
        error_exit(log_stream, "string_expected_in_case_after_keyword_CASE", token);

    /* allocate memory for this case */

    if ((case_pointer = (kase *) malloc(sizeof(kase))) ≡ NULL)
        error_exit(log_stream, "malloc_failed_during_case_handling", token);

    case_pointer→name = token→details.string;

    /* get the next token (it should be a string or the keyword CITATION) */
    *token = Get-Token(in_stream, log_stream);

```

```

if (token→token ≡ TK_STRING) {
    case_pointer→short_name = token→details.string;
    /* get the next token (it should be the keyword CITATION) */
    *token = Get-Token(in_stream, log_stream);
} else
    case_pointer→short_name = case_pointer→name;
if ((token→token ≠ TK_KEYWORD) ∨ (token→details.keyword ≠ KW_CITATION))
    error_exit(log_stream, "keyword_CITATION_expected_in_case", token);
/* get the next token (it should be a string) */
*token = Get-Token(in_stream, log_stream);
if (token→token ≠ TK_STRING)
    error_exit(log_stream, "string_expected_in_case_after_keyword_CITATION",
                token);
case_pointer→citation = token→details.string;
/* get the next token (it should be the keyword YEAR) */
*token = Get-Token(in_stream, log_stream);
if ((token→token ≠ TK_KEYWORD) ∨ (token→details.keyword ≠ KW_YEAR))
    error_exit(log_stream, "keyword_YEAR_expected_in_case", token);
/* get the next token (it should be a year) */
*token = Get-Token(in_stream, log_stream);
if (token→token ≠ TK_YEAR)
    error_exit(log_stream, "year_expected_in_case_after_keyword_YEAR", token);
case_pointer→year = token→details.year;
/* get the next token (it should be the keyword COURT, or the keyword FACTS) */
*token = Get-Token(in_stream, log_stream);
if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_COURT)) {
    /* get the next token (it should be a court identifier) */
    *token = Get-Token(in_stream, log_stream);
    if (token→token ≠ TK_IDENTIFIER)
        error_exit(log_stream, "identifier_expected_in_case_after_keyword_COURT",
                    token);
    /* find the court identifier in the list of courts, and link the case to that court */
    do {
        if (court_pointer ≡ NULL) {
            sprintf(message, "%s_court_not_found", token→details.identifier);
            error_exit(log_stream, message, token);
        }
    }
}

```

```

    found = ¬strcmp(token→details.identifier, court_pointer→identifier);
    if (found) {
        case_pointer→court_string = court_pointer→string;

        case_pointer→court_rank = court_pointer→rank;
    } else
        court_pointer = court_pointer→next;
} while (¬found);

/* get the next token (it should be the keyword FACTS) */
*token = Get-Token(in_stream, log_stream);

} else

/* no court specified */
case_pointer→court_string = NULL;

if ((token→token ≠ TK_KEYWORD) ∨ (token→details.keyword ≠ KW_FACTS))
    error_exit(log_stream, "keyword_FACTS_expected_in_case", token);

/* get the next token (it should be an attribute vector) */
*token = Get-Token(in_stream, log_stream);

if (token→token ≠ TK_ATTRIBUTE_VECTOR)
    error_exit(log_stream,
        "attribute_vector_expected_in_case_after_keyword_FACTS", token);

case_pointer→matrix_head = token→details.matrix_head;

/* check that there are as many values in the attribute vector as there are attributes */
matrix_pointer = case_pointer→matrix_head;
for (attribute_pointer = area_pointer→attribute_head;
    (attribute_pointer ≠ NULL) ∧ (matrix_pointer ≠ NULL);
    attribute_pointer = attribute_pointer→next)
    matrix_pointer = matrix_pointer→case_next;
if (attribute_pointer ≠ NULL)
    error_exit(log_stream, "too_few_values_in_attribute_vector", token);
if (matrix_pointer ≠ NULL)
    error_exit(log_stream, "too_many_values_in_attribute_vector", token);

/* get the next token (it should be the keyword RESULT) */
*token = Get-Token(in_stream, log_stream);

if ((token→token ≠ TK_KEYWORD) ∨ (token→details.keyword ≠ KW_RESULT))
    error_exit(log_stream, "keyword_RESULT_expected_in_case", token);

/* get the next token (it should be a result identifier) */
*token = Get-Token(in_stream, log_stream);

if (token→token ≠ TK_IDENTIFIER)
    error_exit(log_stream, "identifier_expected_in_case_after_keyword_RESULT",
        token);

```



```

/* find the result identifier in the list of results, and add the case to the list of cases for
that result */

do {
  if (result_pointer == NULL) {
    sprintf(message, "%s result not found", token->details.identifier);
    error_exit(log_stream, message, token);
  }
  found = !strcmp(token->details.identifier, result_pointer->identifier);
  if (found) {
    if (result_pointer->case_head == NULL)
      result_pointer->case_head = case_pointer;
    else {
      for (temp_case_pointer = result_pointer->case_head;
           temp_case_pointer->next != NULL;
           temp_case_pointer = temp_case_pointer->next);
      temp_case_pointer->next = case_pointer;
    }
  } else
    result_pointer = result_pointer->next;
} while (!found);

(*count)++;

case_pointer->summary = NULL;

/* get the next token (it should be the keyword SUMMARY, the keyword CASE, the keyword
IDEAL, the keyword AREA, or the end of the file) */

*token = Get-Token(in_stream, log_stream);

if ((token->token == TK_KEYWORD) ^ (token->details.keyword == KW_SUMMARY)) {

  /* get the next token (it should be a string) */

  *token = Get-Token(in_stream, log_stream);

  if (token->token != TK_STRING)
    error_exit(log_stream, "string expected in case after keyword SUMMARY",
              token);

  case_pointer->summary = token->details.string;

  /* get the next token (it should be the keyword CASE, the keyword IDEAL, the keyword
AREA, or the end of the file) */

  *token = Get-Token(in_stream, log_stream);
}
case_pointer->next = NULL;
}

```

```

static vector_element *
vector_from_matrix(
    file log_stream,
    matrix_element *matrix_pointer,
    token_details *token)

/* Returns a pointer to a new list of vector elements whose values correspond to those in the
list of matrix elements pointed to by matrix_pointer (linked by case). Frees the memory
taken up by the list of matrix elements. */

{
    vector_element *vector_head,
        *vector_pointer;
    matrix_element *next_matrix_pointer;

    /* allocate memory for the first vector element in the list */

    if ((vector_head = (vector_element *) malloc(sizeof(vector_element)))  $\equiv$  NULL)
        error_exit(log_stream, "malloc_failed_during_matrix/vector_conversion", token);

    vector_pointer = vector_head;

    /* while there are still matrix elements in the list ... */

    while (matrix_pointer  $\neq$  NULL) {

        /* copy the attribute value into the vector element */

        vector_pointer→attribute_value = matrix_pointer→attribute_value;
        next_matrix_pointer = matrix_pointer→case_next;

        /* free the memory taken up by the matrix element */

        free(matrix_pointer);
        if (next_matrix_pointer  $\equiv$  NULL)
            vector_pointer→next = NULL;
        else {

            /* allocate memory for the next vector element */

            if ((vector_pointer→next = (vector_element *) malloc(sizeof(vector_element)))  $\equiv$ 
                NULL)
                error_exit(log_stream, "malloc_failed_during_matrix/vector_conversion",
                    token);

            vector_pointer = vector_pointer→next;
        }
        matrix_pointer = next_matrix_pointer;
    }
    return vector_head;
}

```

```

static void
parse_ideal_point(
    file in_stream,
    file log_stream,
    result *result_pointer,
    attribute *attribute_pointer,
    token_details *token,
    cardinal *count)

/* Parses an ideal point, and makes it the ideal point for the appropriate result in the list of
results pointed to by result_pointer. The keyword IDEAL has just been read, and the details
of the token that followed it are pointed to by token. *attribute_pointer is the head of the
list of attributes for this area. Increments *count (the number of ideal points already parsed
in this area).

EBNF: ideal-point      = ideal-point-header ideal-point-block.
      ideal-point-header = "IDEAL".
      ideal-point-block  = "FACTS" attribute-vector
                          "RESULT" result-identifier.
*/

{
    vector_element *temp_vector_head;
    matrix_element *matrix_pointer;
    boolean found = FALSE;
    char message[Max_Error_Message_Length];

    if ((token->token != TK_KEYWORD) ∨ (token->details.keyword != KW_FACTS))
        error_exit(log_stream, "keyword_FACTS_expected_in_ideal_point", token);

    /* get the next token (it should be an attribute vector) */

    *token = Get-Token(in_stream, log_stream);

    if (token->token != TK_ATTRIBUTE_VECTOR)
        error_exit(log_stream,
            "attribute_vector_expected_in_ideal_point"
            "after_keyword_FACTS", token);

    /* check that there are as many values in the attribute vector as there are attributes */

    matrix_pointer = token->details.matrix_head;
    for (;
        (attribute_pointer != NULL) ∧ (matrix_pointer != NULL);
        attribute_pointer = attribute_pointer->next)
        matrix_pointer = matrix_pointer->case_next;
    if (attribute_pointer != NULL)
        error_exit(log_stream, "too_few_values_in_attribute_vector", token);
    if (matrix_pointer != NULL)
        error_exit(log_stream, "too_many_values_in_attribute_vector", token);
}

```

```

/* convert the attribute vector from a list of matrix elements into a list of vector
elements */

temp_vector_head = vector_from_matrix(log_stream, token->details.matrix_head, token);

/* get the next token (it should be the keyword RESULT) */

*token = Get-Token(in_stream, log_stream);

if ((token->token != TK_KEYWORD) ∨ (token->details.keyword != KW_RESULT))
    error_exit(log_stream, "keyword_RESULT_expected_in_ideal_point", token);

/* get the next token (it should be a result identifier) */

*token = Get-Token(in_stream, log_stream);

if (token->token != TK_IDENTIFIER)
    error_exit(log_stream,
               "identifier_expected_in_ideal_point_after_keyword_RESULT", token);

/* find the result identifier in the list of results, and link that result to the ideal point */

do {
    if (result_pointer == NULL) {
        sprintf(message, "%s_result_not_found", token->details.identifier);
        error_exit(log_stream, message, token);
    }
    found = !strcmp(token->details.identifier, result_pointer->identifier);
    if (found) {
        if (result_pointer->ideal_point_head == NULL)
            result_pointer->ideal_point_head = temp_vector_head;
        else {
            sprintf(message,
                    "ideal_point_for_%s_result_already_specified",
                    token->details.identifier);
            error_exit(log_stream, message, token);
        }
    } else
        result_pointer = result_pointer->next;
} while (!found);

(*count)++;

/* get the next token (it should be the keyword IDEAL, the keyword AREA, or the end of
the file) */

*token = Get-Token(in_stream, log_stream);
}

```

```

static void
parse_area_block(
    file in_stream,
    file log_stream,
    area *area_pointer,
    token_details *token,
    court *court_head)

/* Parses an area block, and puts details in the area pointed to by area_pointer. The keyword
AREA and an area identifier have just been read; the identifier's details are pointed to by
token.

EBNF: area          = area-header area-block.
      area-header   = "AREA" area-identifier.
      area-block    = [opening] [closing]
                    results
                    attribute { attribute }
                    case { case }
                    { ideal-point }.
      area-identifier = identifier.
      opening        = "OPENING" string.
      closing        = "CLOSING" string. */

{
    cardinal number_of_cases = 0,
    number_of_ideal_points = 0;
    result *result_pointer;

    area_pointer->identifier = token->details.identifier;

    Indent(log_stream, 1);
    fprintf(log_stream, "%s area:\n\n", area_pointer->identifier);

    /* get the next token (it should be the keyword OPENING, the keyword CLOSING, or the
    keyword RESULTS) */

    *token = Get-Token(in_stream, log_stream);

    if ((token->token == TK_KEYWORD) ^ (token->details.keyword == KW_OPENING)) {

        /* get the next token (it should be a string) */

        *token = Get-Token(in_stream, log_stream);

        if (token->token != TK_STRING)
            error_exit(log_stream, "string expected after keyword OPENING", token);

        area_pointer->opening = token->details.string;

        /* get the next token (it should be the keyword CLOSING, or the keyword RESULTS) */

        *token = Get-Token(in_stream, log_stream);
    } else
        area_pointer->opening = NULL;
}

```

```

if ((token→token ≡ TK_KEYWORD) ∧ (token→details.keyword ≡ KW_CLOSING)) {
    /* get the next token (it should be a string) */
    *token = Get-Token(in_stream, log_stream);

    if (token→token ≠ TK_STRING)
        error_exit(log_stream, "string_expected_after_keyword_CLOSING", token);

    area_pointer→closing = token→details.string;

    /* get the next token (it should be the keyword RESULTS) */
    *token = Get-Token(in_stream, log_stream);
} else
    area_pointer→closing = NULL;

if ((token→token ≠ TK_KEYWORD) ∨ (token→details.keyword ≠ KW_RESULTS))
    error_exit(log_stream, "keyword_RESULTS_expected_in_results_header", token);

/* get the next token (it should be a result identifier) */
*token = Get-Token(in_stream, log_stream);

area_pointer→number_of_results = 0;
area_pointer→result_head = parse_results(in_stream, log_stream, token,
    &area_pointer→number_of_results);

switch (area_pointer→number_of_results) {
    case 0:
        error_exit(log_stream,
            "no_results_(at_least_two_are_required)", NULL);
        break;
    case 1:
        error_exit(log_stream,
            "only_one_result_(at_least_two_are_required)", NULL);
        break;
    default:
        Indent(log_stream, 2);
        fprintf(log_stream,
            "%u_results\n", area_pointer→number_of_results);
        break;
}

if ((token→token ≠ TK_KEYWORD) ∨ (token→details.keyword ≠ KW_ATTRIBUTE))
    error_exit(log_stream, "keyword_ATTRIBUTE_expected_in_attribute_header",
        token);

/* get the next token (it should be the keyword QUESTION, or the keyword AREA) */
*token = Get-Token(in_stream, log_stream);

area_pointer→number_of_attributes = 0;
area_pointer→attribute_head = parse_attributes(in_stream, log_stream,
    area_pointer→result_head, token, area_pointer→identifier,
    &area_pointer→number_of_attributes);

```

```

    Indent(log_stream, 2);
    fprintf(log_stream, "%u_attribute%s\n", area_pointer->number_of_attributes,
            area_pointer->number_of_attributes == 1 ? Empty_String : "s");

    if ((token->token != TK_KEYWORD) ∨ (token->details.keyword != KW_CASE))
        error_exit(log_stream, "keyword_CASE_expected_in_case_header", token);

    while ((token->token == TK_KEYWORD) ∧ (token->details.keyword == KW_CASE)) {

        /* get the next token (it should be a string) */

        *token = Get-Token(in_stream, log_stream);

        parse_case(in_stream, log_stream, court_head, area_pointer, token, &number_of_cases);
    }
    Indent(log_stream, 2);
    fprintf(log_stream, "%u_case%s\n", number_of_cases,
            number_of_cases == 1 ? Empty_String : "s");

    for (result_pointer = area_pointer->result_head; result_pointer != NULL;
         result_pointer = result_pointer->next)
        rank_cases(&result_pointer->case_head);

    number_cases(area_pointer->result_head);

    cross_link(area_pointer->result_head, area_pointer->attribute_head);

    while ((token->token == TK_KEYWORD) ∧
           (token->details.keyword == KW_IDEAL)) {

        /* get the next token (it should be the keyword FACTS) */

        *token = Get-Token(in_stream, log_stream);

        parse_ideal_point(in_stream, log_stream, area_pointer->result_head,
                         area_pointer->attribute_head, token, &number_of_ideal_points);
    }

    if (number_of_ideal_points != 0) {
        Indent(log_stream, 2);
        fprintf(log_stream, "%u_ideal_point%s\n", number_of_ideal_points,
                number_of_ideal_points == 1 ? Empty_String : "s");
    }
    fprintf(log_stream, "\n");
    area_pointer->correlation_coefficients = FALSE;
    area_pointer->next = NULL;

    check_for_identical_cases(log_stream, area_pointer);
}

```

```

static area *
parse_areas(
    file in_stream,
    file log_stream,
    court *court_head)
/* Parses areas, and returns a pointer to a list of areas. The keyword AREA has just been
read. */
{
    area *area_head = NULL,
    *area_pointer = NULL,
    *temp_area_pointer;
    token_details token;
    char message[Max_Error_Message_Length];
    do {
        /* get the next token (it should be an area identifier) */
        token = Get-Token(in_stream, log_stream);
        if (token.token ≠ TK_IDENTIFIER)
            error_exit(log_stream,
                "identifier_expected_in_area_header_after_keyword_AREA", &token);
        if (area_head ≡ NULL) {
            /* allocate memory for this area (the first in the list) */
            if ((area_head = (area *) malloc(sizeof(area))) ≡ NULL)
                error_exit(log_stream, "malloc_failed_during_area_handling", &token);
            area_pointer = area_head;
        } else {
            /* go to the end of the list of areas, checking that an area with this identifier has
            not already been specified */
            for (temp_area_pointer = area_head; temp_area_pointer ≠ NULL;
                temp_area_pointer = temp_area_pointer→next)
                if (¬strcmp(token.details.identifier, temp_area_pointer→identifier)) {
                    sprintf(message, "%s_area_already_specified",
                        token.details.identifier);
                    error_exit(log_stream, message, &token);
                }
            /* allocate memory for this area */
            if ((area_pointer→next = (area *) malloc(sizeof(area))) ≡ NULL)
                error_exit(log_stream, "malloc_failed_during_area_handling", &token);
            area_pointer = area_pointer→next;
        }
        parse_area_block(in_stream, log_stream, area_pointer, &token, court_head);
    } while ((token.token ≡ TK_KEYWORD) ∧ (token.details.keyword ≡ KW_AREA));
    if (token.token ≠ TK_EOF)
        error_exit(log_stream, "end_of_file_expected", &token);
    return area_head;
}

```



```

extern case_law_specification
Parse_Specification(
    file in_stream,
    file log_stream)

/* Parses the specification file in_stream, and returns a case law specification.
   EBNF: specification = [hierarchy]
                               area { area }. */
{
    case_law_specification case_law;
    token_details token;
    cardinal number_of_courts = 0;

    /* get the first token */
    token = Get-Token(in_stream, log_stream);

    if ((token.token == TK_KEYWORD) ^ (token.details.keyword == KW_HIERARCHY)) {
        /* get the next token (it should be a court identifier) */
        token = Get-Token(in_stream, log_stream);

        case_law.court_head = parse_hierarchy(in_stream, log_stream, &token,
            &number_of_courts);

        if (case_law.court_head == NULL)
            error_exit(log_stream,
                "identifier_expected_in_hierarchy_block"
                "after_keyword_HIERARCHY", &token);
        else {
            Indent(log_stream, 1);
            fprintf(log_stream, "%u_court%s_in_the_hierarchy.\n\n",
                number_of_courts, number_of_courts == 1 ? Empty_String : "s");
        }
    } else
        case_law.court_head = NULL;

    if ((token.token != TK_KEYWORD) v (token.details.keyword != KW_AREA))
        error_exit(log_stream, "keyword_AREA_expected_in_area_header", &token);

    case_law.area_head = parse_areas(in_stream, log_stream, case_law.court_head);

    return case_law;
}

```


6

The DUMPER module

dumper.h

```
/* This is the header file for the DUMPER module. It is also included by the CASES, ODOMETER  
and REPORTER modules. */
```

```
/* external functions */
```

extern void

```
Write_Matrix(  
    file stream,  
    area *area_pointer,  
    vector_element *facts_head,  
    court *court_head,  
    boolean hypothetical,  
    cardinal number);
```

extern void

```
Write_Year_and_Court(  
    file stream,  
    kase *case_pointer,  
    cardinal level);
```

extern void

```
Dump_Specification(  
    file dump_stream,  
    file log_stream,  
    case_law_specification case_law,  
    boolean inputable_latex,  
    boolean verbose);
```

dumper.c

```

/* This is the implementation file for the DUMPER module. */

#include <stdio.h>
#include "shyster.h"
#include "cases.h"
#include "dumper.h"
#include "odometer.h"

static void
warning(
    file stream,
    const string message)
{
    Write_Warning_Message(stream, "Dumper", message, Top_Level);
}

static void
write_hierarchy_table(
    file dump_stream,
    court *court_pointer)

/* Writes a table of courts, with their ranks */

{
    boolean same_rank = FALSE;

    fprintf(dump_stream, "%s{Hierarchy}\n\n", Heading);
    Indent(dump_stream, 1);
    fprintf(dump_stream, "\\begin{small}\n");
    Indent(dump_stream, 2);
    fprintf(dump_stream, "\\begin{trivlist}\\item[]\n");
    Indent(dump_stream, 3);
    fprintf(dump_stream, "\\begin{tabular}{r|l}\\hline\n");
    Indent(dump_stream, 4);
    fprintf(dump_stream,
        "\\multicolumn{1}{|c|}{c$}&"
        "\\multicolumn{1}{c|}{\\it_Court\\}/\\\\\\\\\\hline\\hline");

    /* while there are still courts to list ... */

    while (court_pointer != NULL) {
        fprintf(dump_stream, "\n");
        Indent(dump_stream, 4);
        if (!same_rank)
            fprintf(dump_stream, "%u", court_pointer->rank);
        fprintf(dump_stream, "&%s\\", court_pointer->string);
        if (court_pointer->next != NULL)
            same_rank = (court_pointer->rank == court_pointer->next->rank);
        court_pointer = court_pointer->next;
    }
}

```

```

    fprintf(dump_stream, "\\hline\n");
    Indent(dump_stream, 3);
    fprintf(dump_stream, "\\end{tabular}\n");
    Indent(dump_stream, 2);
    fprintf(dump_stream, "\\end{trivlist}\n");
    Indent(dump_stream, 1);
    fprintf(dump_stream, "\\end{small}\n\n");
}

static void
write_distance(
    file stream,
    distance_subtype distance,
    boolean centre,
    boolean rule_at_right)

/* Writes distance as a cell in a table of distances, centred (if centre is TRUE) and with a
vertical rule at the right (if rule_at_right and centre are both TRUE). */

{
    if (distance.infinite != 0) {
        if (Is_Zero(distance.finite)) {
            /* the distance has an infinite component, but no finite component */
            if (distance.infinite == 1)
                if (centre)
                    fprintf(stream, "\\multicolumn{1}{c%s}{${\\infty$}",
                        rule_at_right ? "|" : "");
                else
                    fprintf(stream, "${\\infty$}");
            else if (centre)
                fprintf(stream, "\\multicolumn{1}{c%s}{%u\\infty$}",
                    rule_at_right ? "|" : "", distance.infinite);
            else
                fprintf(stream, "%u\\infty$", distance.infinite);
        } else {
            /* the distance has both a finite component and an infinite component */
            if (distance.infinite == 1) {
                fprintf(stream, "${\\infty$+");
                Write_Floating_Point(stream, distance.finite, Empty_String);
            } else {
                fprintf(stream, "%u\\infty$+", distance.infinite);
                Write_Floating_Point(stream, distance.finite, Empty_String);
            }
        }
    }
}

```

```

} else {

    if (Is_Zero(distance.finite)) {

        /* the distance has neither a finite component nor an infinite component */

        if (centre)
            fprintf(stream, "\\multicolumn{1}{c%s}{--}", rule_at_right ? "|" : "");
        else
            fprintf(stream, "--");

    } else

        /* the distance has a finite component, but no infinite component */

        Write_Floating_Point(stream, distance.finite, Empty_String);
}
}

static void
write_metrics(
    file stream,
    metrics_type metrics,
    boolean weighted_association_coefficient,
    boolean correlation_coefficients)

/* Writes, as cells in a table of distances, each of the metrics in metrics: the known distance  $d_K$ ,
the unknown distance  $d_U$ , the unweighted distance  $\Delta$ , the association coefficient  $S$ , the
weighted association coefficient  $S'$  (if weighted_association_coefficient is TRUE), the cor-
relation coefficient  $r$  (if correlation_coefficients is TRUE), and the weighted correlation
coefficient  $r'$  (if correlation_coefficients is TRUE). */

{
    write_distance(stream, metrics.distance.known, TRUE, FALSE);
    fprintf(stream, "&");
    write_distance(stream, metrics.distance.unknown, TRUE, TRUE);
    fprintf(stream, "&");

    if (metrics.number_of_known_pairs  $\equiv$  0) {

        /* there are no known pairs, so write zeroes (“-”) for  $\Delta$ ,  $S$  and  $S'$ , and nothing for  $r$ 
and  $r'$  */

        fprintf(stream, "--&--&");
        if (weighted_association_coefficient)
            fprintf(stream, "--&");
        if (correlation_coefficients)
            fprintf(stream, "&&");
    }
}

```

```

} else {

    if (metrics.number_of_known_differences == 0) {

        /* there are no known differences, so write zeroes (“-”) for  $\Delta$ ,  $S$  and  $S'$  */

        fprintf(stream, "--&--&");
        if (weighted_association_coefficient)
            fprintf(stream, "--&");

    } else {

        /* there are known differences, so write values for  $\Delta$ ,  $S$  and  $S'$  */

        fprintf(stream, "%u&", metrics.number_of_known_differences);
        Write_Floating_Point(stream,
            (floating_point) metrics.number_of_known_differences /
            metrics.number_of_known_pairs, Empty_String);
        fprintf(stream, "&");
        if (weighted_association_coefficient) {
            Write_Floating_Point(stream,
                metrics.weighted_association_coefficient, Empty_String);
            fprintf(stream, "&");
        }
    }
}
if (correlation_coefficients)
    if (metrics.correlation_coefficient.meaningless)

        /* either this case (or ideal point or centroid) or the instant case has all attribute
           values equal: the correlation coefficients  $r$  and  $r'$  are meaningless */

        fprintf(stream, "&&");

    else {

        /* write values for  $r$  and  $r'$  */

        Write_Floating_Point(stream,
            metrics.correlation_coefficient.unweighted, Empty_String);
        fprintf(stream, "&");
        Write_Floating_Point(stream,
            metrics.correlation_coefficient.weighted, Empty_String);
        fprintf(stream, "&");
    }
}
}

```

```

static boolean
all_three_equal(
    distance_subtype x,
    distance_subtype y,
    distance_subtype z)

/* Returns TRUE, iff distances x, y and z are equal. */
{
    return ((x.infinite  $\equiv$  y.infinite)  $\wedge$ 
        Is_Equal(x.finite, y.finite, Distance_Precision)  $\wedge$ 
        (x.infinite  $\equiv$  z.infinite)  $\wedge$ 
        Is_Equal(x.finite, z.finite, Distance_Precision));
}

static void
write_result(
    file stream,
    cardinal count,
    cardinal first_result_row,
    boolean write_directions,
    result *result_pointer)

/* Writes the identifier, and the strength of every non-zero direction (if write_directions is
TRUE), for the result pointed to by result_pointer, as cells in a table of distances. Writes
the identifier, then the directions, in consecutive rows of the "Result" column, starting with
row first_result_row so that the information is centred vertically. */
{
    static boolean specified_to_be_written,
        ideal_point_to_be_written,
        centroid_to_be_written,
        all_to_be_written;

    if (count  $\equiv$  first_result_row) {
        /* the result identifier should be written in this row */
        fprintf(stream, "%s□%s", Identifier_Font, result_pointer→identifier);

        if (write_directions) {
            /* determine which directions will be written (on subsequent invocations of this
            function) */

            specified_to_be_written =
                ¬Is_Zero_Subdistance(result_pointer→specified_direction);
            ideal_point_to_be_written =
                ¬Is_Zero_Subdistance(result_pointer→ideal_point_direction);
            centroid_to_be_written =
                ¬Is_Zero_Subdistance(result_pointer→centroid_direction);
            all_to_be_written = (specified_to_be_written  $\wedge$ 
                ideal_point_to_be_written  $\wedge$  centroid_to_be_written  $\wedge$ 
                all_three_equal(result_pointer→specified_direction,
                    result_pointer→ideal_point_direction,
                    result_pointer→centroid_direction));
        }
    }
}

```



```

} else if (write_directions ^ (count > first_result_row)) {
    /* write the strength of the next non-zero direction: a ⇒ symbol is used for specified
    direction; a  $\xrightarrow{I}$  symbol for ideal point direction; a  $\xrightarrow{C}$  symbol for centroid direction;
    a  $\xrightarrow{S}$  symbol if all three directions are of the same strength */
    if (all_to_be_written) {
        fprintf(stream, "%s\\", All_Directions_Symbol);
        write_distance(stream, result_pointer→specified_direction, FALSE, FALSE);
        all_to_be_written = FALSE;
        specified_to_be_written = FALSE;
        ideal_point_to_be_written = FALSE;
        centroid_to_be_written = FALSE;
    } else if (specified_to_be_written) {
        fprintf(stream, "%s\\", Specified_Direction_Symbol);
        write_distance(stream, result_pointer→specified_direction, FALSE, FALSE);
        specified_to_be_written = FALSE;
    } else if (ideal_point_to_be_written) {
        fprintf(stream, "%s\\", Ideal_Point_Direction_Symbol);
        write_distance(stream, result_pointer→ideal_point_direction, FALSE, FALSE);
        ideal_point_to_be_written = FALSE;
    } else if (centroid_to_be_written) {
        fprintf(stream, "%s\\", Centroid_Direction_Symbol);
        write_distance(stream, result_pointer→centroid_direction, FALSE, FALSE);
        centroid_to_be_written = FALSE;
    }
}
}
}

```

extern void

```

Write_Matrix(
    file stream,
    area *area_pointer,
    vector_element *facts_head,
    court *court_head,
    boolean hypothetical,
    cardinal number)

/* Writes a matrix of attribute values and (if facts_head is TRUE) metric information, for the
instant case, the cases in the area pointed to by area_pointer, the ideal points in that area,
and each result's centroid (if they have been calculated). If number is not zero then the
instant case is actually a hypothetical (if hypothetical is TRUE) or an instantiation, and
number is its number. */

{
    result *result_pointer;
    kase *case_pointer;
    matrix_element *matrix_pointer;
    vector_element *vector_pointer;
    centroid_element *centroid_pointer;
    cardinal count,
    first_result_row;

```

```

    Indent(stream, 1);
    fprintf(stream, "\\begin{small}\n");
    Indent(stream, 2);
    fprintf(stream, "\\begin{tabular}{*{2}{|c}}");

    if (area_pointer→number_of_attributes > 1)
        fprintf(stream, "*{u}{@{\hspace{s}}c}|",
            area_pointer→number_of_attributes - 1, Matrix_Column_Separation);

    if (court_head ≠ NULL)

        /* there will be a column for the rank of each case's court */

        fprintf(stream, "r|");

    if (facts_head ≠ NULL) {

        /* there will be columns for metric information */

        fprintf(stream, "r@{\hspace{s}}r|r|", Column_Separation);

        if (area_pointer→infinite_weight)

            /* at least one of the attribute's weights is infinite, so the values obtained for S' are
            meaningless: there will be no S' column */

            fprintf(stream, "c|");
        else

            /* there will be an S' column */

            fprintf(stream, "c@{\hspace{s}}c|", Column_Separation);

        if (area_pointer→correlation_coefficients)

            /* the instant case does not have all attribute values the same, and not every case,
            ideal point and centroid has all attribute values the same: there will be columns
            for the correlation coefficients r and r' (if either of these conditions does not
            hold, all the values of r and r' are meaningless) */

            fprintf(stream, "r@{\hspace{s}}r|", Column_Separation);
    }
    fprintf(stream, "c|}\hline\n");

    /* write the column headings */

    Indent(stream, 3);
    fprintf(stream, "&\\multicolumn{u}{|c|}{\\it_Attributes\\}/&",
        area_pointer→number_of_attributes);

    if (court_head ≠ NULL)
        fprintf(stream, "&");

```

```

if (facts_head ≠ NULL) {
    fprintf(stream, "&&&&");
    if (¬area_pointer→infinite_weight)
        fprintf(stream, "&");
    if (area_pointer→correlation_coefficients)
        fprintf(stream, "&&");
}
fprintf(stream, "\\\\n");
Indent(stream, 3);

fprintf(stream, "\\smash{\\raisebox{%s}{\\it_Case\\}}&", Raise_Height);

for (count = 1; count ≤ area_pointer→number_of_attributes; count++)
    fprintf(stream, "$A_{%u}$&", count);

if (court_head ≠ NULL)
    fprintf(stream, "\\multicolumn{1}{c|}{\\smash{\\raisebox{%s}{c}}}&",
        Raise_Height);

if (facts_head ≠ NULL) {
    fprintf(stream,
        "\\multicolumn{1}{c}{\\smash{\\raisebox{%s}{d_{\\rm_K}}}}&"
        "\\multicolumn{1}{c|}{\\smash{\\raisebox{%s}{d_{\\rm_U}}}}&"
        "\\multicolumn{1}{c|}{\\smash{\\raisebox{%s}{\\Delta}}}&"
        "\\smash{\\raisebox{%s}{S}}&",
        Raise_Height, Raise_Height, Raise_Height, Raise_Height);

    if (¬area_pointer→infinite_weight)
        fprintf(stream, "\\smash{\\raisebox{%s}{S'}}&",
            Raise_Height);

    if (area_pointer→correlation_coefficients)
        fprintf(stream, "\\multicolumn{1}{c}{\\smash{\\raisebox{%s}{r}}}&"
            "\\multicolumn{1}{c|}{\\smash{\\raisebox{%s}{r'}}}&",
            Raise_Height, Raise_Height);
}
fprintf(stream, "\\smash{\\raisebox{%s}{\\it_Result\\}}\\\\\\hline",
    Raise_Height);

if (facts_head ≠ NULL) {

    /* write details of the instant case */

    fprintf(stream, "\\hline\\n");
    Indent(stream, 3);

    if (number ≡ 0)

        /* the instant case is the uninstantiated and unhypothesized instant case */

        fprintf(stream, "$C_{\\rm_Instant}$&");
}

```

```

else if (hypothetical)
    /* the instant case is hypothetical number */
    fprintf(stream, "$C_{\mbox{\scriptsize Hypo-%u}}$$", number);
else
    /* the instant case is instantiation number */
    fprintf(stream, "$C_{\mbox{\scriptsize Inst-%u}}$$", number);

/* write the attribute values for the instant case: a • symbol for YES; a × symbol for
NO; a blank space for UNKNOWN */

for (vector_pointer = facts_head; vector_pointer ≠ NULL;
     vector_pointer = vector_pointer→next)
    fprintf(stream, "%s&",
           vector_pointer→attribute_value ≡ YES ? Yes_Symbol :
           vector_pointer→attribute_value ≡ NO ? No_Symbol :
           Unknown_Symbol);

/* leave an appropriate number of columns empty */
fprintf(stream, "\multicolumn{u}{c|}{\hline",
        court_head ≡ NULL ?
        area_pointer→infinite_weight ?
        area_pointer→correlation_coefficients ? 7 : 5 :
        area_pointer→correlation_coefficients ? 8 : 6 :
        area_pointer→infinite_weight ?
        area_pointer→correlation_coefficients ? 8 : 6 :
        area_pointer→correlation_coefficients ? 9 : 7);
}

/* for every result ... */

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next) {

    /* determine the first row in which information should appear, for this result, in the
    "Result" column so that the information is centred vertically */

    first_result_row = 0;
    for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
         case_pointer = case_pointer→next)
        first_result_row++;
    if (result_pointer→ideal_point_head ≠ NULL)
        first_result_row++;
    if (result_pointer→centroid_head ≠ NULL)
        first_result_row++;
    if (first_result_row ≠ 0) {
        if ((facts_head ≠ NULL) ∧ (first_result_row > 1) ∧
            ¬Is_Zero_Subdistance(result_pointer→specified_direction)) {
            first_result_row--;

```

```

if ( $\neg$ all_three_equal(result_pointer→specified_direction,
                        result_pointer→ideal_point_direction,
                        result_pointer→centroid_direction)) {
    if ((first_result_row > 1)  $\wedge$ 
         $\neg$ Is_Zero_Subdistance(result_pointer→ideal_point_direction))
        first_result_row--;
    if ((first_result_row > 1)  $\wedge$ 
         $\neg$ Is_Zero_Subdistance(result_pointer→centroid_direction))
        first_result_row--;
    }
}
first_result_row = (first_result_row + 1) / 2;

count = 1;
fprintf(stream, "\\hline");

/* for every case with this result ... */

for (case_pointer = result_pointer→case_head; case_pointer  $\neq$  NULL;
      case_pointer = case_pointer→next) {
    fprintf(stream, "\\n");
    Indent(stream, 3);
    fprintf(stream, "$C_{%u}$&", case_pointer→number);

    /* write the attribute values for this case */

    for (matrix_pointer = case_pointer→matrix_head; matrix_pointer  $\neq$  NULL;
          matrix_pointer = matrix_pointer→case_next)
        fprintf(stream, "%s&",
                matrix_pointer→attribute_value  $\equiv$  YES ? Yes_Symbol :
                matrix_pointer→attribute_value  $\equiv$  NO ? No_Symbol :
                Unknown_Symbol);

    if (court_head  $\neq$  NULL)

        /* write the rank of the case's court */

        if ((case_pointer→court_string  $\neq$  NULL)  $\wedge$ 
            (case_pointer→court_rank  $\neq$  0))
            fprintf(stream, "%u&", case_pointer→court_rank);
        else
            fprintf(stream, "\\footnotesize?&");

    if (facts_head  $\neq$  NULL)
        write_metrics(stream, case_pointer→metrics,
                      $\neg$ area_pointer→infinite_weight, area_pointer→correlation_coefficients);

    write_result(stream, count++, first_result_row, facts_head  $\neq$  NULL,
                 result_pointer);
    fprintf(stream, "\\");
}

```

```

/* write a line (an appropriate number of columns wide) under the cases for this
result */

if ((result_pointer→case_head ≠ NULL) ∧
    ((result_pointer→ideal_point_head ≠ NULL) ∨
     (result_pointer→centroid_head ≠ NULL)))
  fprintf(stream, "\\cline{2-%u}", facts_head ≡ NULL ?
          court_head ≡ NULL ?
          area_pointer→number_of_attributes + 1 :
          area_pointer→number_of_attributes + 2 :
          court_head ≡ NULL ?
          area_pointer→infinite_weight ?
          area_pointer→correlation_coefficients ?
          area_pointer→number_of_attributes + 7 :
          area_pointer→number_of_attributes + 5 :
          area_pointer→correlation_coefficients ?
          area_pointer→number_of_attributes + 8 :
          area_pointer→number_of_attributes + 6 :
          area_pointer→infinite_weight ?
          area_pointer→correlation_coefficients ?
          area_pointer→number_of_attributes + 8 :
          area_pointer→number_of_attributes + 6 :
          area_pointer→correlation_coefficients ?
          area_pointer→number_of_attributes + 9 :
          area_pointer→number_of_attributes + 7);

if (result_pointer→ideal_point_head ≠ NULL) {
  /* this result has an ideal point, so write its details */

  fprintf(stream, "\\n");
  Indent(stream, 3);
  fprintf(stream, "$I_{\\mbox{\\scriptsize}s_s}}$$",
          Identifier_Font, result_pointer→identifier);

  /* write the attribute values for this ideal point */

  for (vector_pointer = result_pointer→ideal_point_head;
       vector_pointer ≠ NULL; vector_pointer = vector_pointer→next)
    fprintf(stream, "%s&", (vector_pointer→attribute_value ≡ YES ?
                           Yes_Symbol : (vector_pointer→attribute_value ≡ NO ?
                                           No_Symbol : Unknown_Symbol)));

  if (court_head ≠ NULL)
    fprintf(stream, "&");

  if (facts_head ≠ NULL)
    write_metrics(stream, result_pointer→ideal_point_metrics,
                 →area_pointer→infinite_weight, area_pointer→correlation_coefficients);

  write_result(stream, count++, first_result_row, facts_head ≠ NULL,
              result_pointer);
  fprintf(stream, "\\");
}

```

```

if (result_pointer→centroid_head ≠ NULL) {

    /* this result has a centroid, so write its details */

    fprintf(stream, "\n");
    Indent(stream, 3);
    fprintf(stream, "$\mu_{\mbox{\scriptsize s}s}}\$\&",
            Identifier_Font, result_pointer→identifier);

    /* write the attribute values for this centroid */

    for (centroid_pointer = result_pointer→centroid_head;
        centroid_pointer ≠ NULL; centroid_pointer = centroid_pointer→next)
        fprintf(stream, "%s&",
                centroid_pointer→unknown ? Unknown_Symbol :
                Nearest_Attribute_Value(centroid_pointer→value) ≡ YES ?
                Yes_Symbol : No_Symbol);

    if (court_head ≠ NULL)
        fprintf(stream, "&");

    if (facts_head ≠ NULL)
        write_metrics(stream, result_pointer→centroid_metrics,
            ¬area_pointer→infinite_weight, area_pointer→correlation_coefficients);

    write_result(stream, count++, first_result_row, facts_head ≠ NULL,
        result_pointer);
    fprintf(stream, "\\\");
}
fprintf(stream, "\\hline");
}
}
fprintf(stream, "\n");
Indent(stream, 2);
fprintf(stream, "\\end{tabular}\n");
Indent(stream, 1);
fprintf(stream, "\\end{small}\n\n");
}

```

static void

```

write_opening_and_closing(
    file dump_stream,
    area *area_pointer,
    boolean verbose)

```

```

/* Writes the opening and closing strings for the area pointed to by area_pointer. Writes each
string in full only if verbose is TRUE. */

```

```

{
  if (area_pointer→opening ≠ NULL) {
    fprintf(dump_stream, "%s{Opening}\n\n", Subheading);
    Indent(dump_stream, 1);
    fprintf(dump_stream, "\\begin{list}{}{\\leftmargin=0mm}\\item[]\n");
    if (verbose)
      Write(dump_stream, area_pointer→opening, Empty_String, 2, Hang);
    else
      Write(dump_stream, "[Opening.]", Empty_String, 2, Hang);
    Indent(dump_stream, 1);
    fprintf(dump_stream, "\\end{list}\n\n");
  }
  if (area_pointer→closing ≠ NULL) {
    fprintf(dump_stream, "%s{Closing}\n\n", Subheading);
    Indent(dump_stream, 1);
    fprintf(dump_stream, "\\begin{list}{}{\\leftmargin=0mm}\\item[]\n");
    if (verbose)
      Write(dump_stream, area_pointer→closing, Empty_String, 2, Hang);
    else
      Write(dump_stream, "[Closing.]", Empty_String, 2, Hang);
    Indent(dump_stream, 1);
    fprintf(dump_stream, "\\end{list}\n\n");
  }
}

static void
write_result_list(
  file dump_stream,
  result *result_pointer)

/* Writes details of each result in the list of results pointed to by result_pointer. */

{
  fprintf(dump_stream, "%s{Results}\n\n", Subheading);
  Indent(dump_stream, 1);

  fprintf(dump_stream, "\\begin{description}\n\n");

  /* while there are still results ... */

  while (result_pointer ≠ NULL) {
    Indent(dump_stream, 2);
    fprintf(dump_stream, "\\item[\\rm{s}s:]\n",
      Identifier_Font, result_pointer→identifier);
    Write(dump_stream, result_pointer→string, ".\n", 3, No_Hang);
    result_pointer = result_pointer→next;
  }
  Indent(dump_stream, 1);
  fprintf(dump_stream, "\\end{description}\n\n");
}

```



```

static void
write_attribute_list(
    file dump_stream,
    attribute *attribute_pointer)

/* Writes details of each attribute in the list of attributes pointed to by attribute_pointer. */
{
    direction_list_element *direction_list_pointer;
    identifier_list_element *identifier_list_pointer;

    fprintf(dump_stream, "%s{Attributes}\n\n", Subheading);
    Indent(dump_stream, 1);

    fprintf(dump_stream, "\\begin{description}\n\n");

    /* while there are still attributes ... */
    while (attribute_pointer != NULL) {

        Indent(dump_stream, 2);
        fprintf(dump_stream, "\\item[\\rm$A_{%u}$:]\\n", attribute_pointer->number);

        if (attribute_pointer->external_attribute) {

            /* the attribute is external, so indicate the area to which it is linked using a ⇔
            symbol */

            Indent(dump_stream, 3);
            fprintf(dump_stream, "%s_{%s}_{%s}_area\\n", External_Area_Symbol,
                Identifier_Font, attribute_pointer->details.external.area_identifier);

        } else

            /* the attribute is local, so write the attribute's question */

            Write(dump_stream, attribute_pointer->details.local.question, "?", 3, No_Hang);

        fprintf(dump_stream, "\\n");

        Indent(dump_stream, 3);
        fprintf(dump_stream, "\\begin{description}\n\n");

        if (attribute_pointer->yes != NULL) {

            /* the attribute has a YES string, so write it */

            Indent(dump_stream, 4);
            fprintf(dump_stream, "\\item[\\sc_yes:]\\n");
            Write(dump_stream, attribute_pointer->yes, ".\\n", 5, No_Hang);
        }
    }
}

```

```

if (attribute_pointer→external_attribute) {

    /* the attribute is external, so indicate the association of results from the ex-
       ternal area with YES values of this attribute using a ⇐ symbol (list the result
       identifiers, separated by a ∨ symbol) */

    identifier_list_pointer = attribute_pointer→details.external.yes_identifier_head;
    while (identifier_list_pointer ≠ NULL) {
        if (identifier_list_pointer ≡
            attribute_pointer→details.external.yes_identifier_head) {

            /* this is the first identifier to write */

            Indent(dump_stream, 5);
            fprintf(dump_stream, "%s_{"%s_"}", External_Result_Symbol,
                Identifier_Font, identifier_list_pointer→identifier);
        } else {
            fprintf(dump_stream, "~%s\n", Disjunction_Symbol);
            Indent(dump_stream, 5);
            fprintf(dump_stream, "{"%s_"}", Identifier_Font,
                identifier_list_pointer→identifier);
        }
        identifier_list_pointer = identifier_list_pointer→next;
    }
    if (attribute_pointer→details.external.yes_identifier_head ≠ NULL)
        fprintf(dump_stream, "\n\n");
}

/* indicate the specified direction for YES values of this attribute using a ⇒ symbol
   (list the result identifiers, separated by a ∨ symbol) */

direction_list_pointer = attribute_pointer→yes_direction_head;
while (direction_list_pointer ≠ NULL) {
    if (direction_list_pointer ≡ attribute_pointer→yes_direction_head) {

        /* this is the first identifier to write */

        Indent(dump_stream, 5);
        fprintf(dump_stream, "%s_{"%s_"}", Specified_Direction_Symbol,
            Identifier_Font, direction_list_pointer→result→identifier);
    } else {
        fprintf(dump_stream, "~%s\n", Disjunction_Symbol);
        Indent(dump_stream, 5);
        fprintf(dump_stream, "{"%s_"}", Identifier_Font,
            direction_list_pointer→result→identifier);
    }
    direction_list_pointer = direction_list_pointer→next;
}
if (attribute_pointer→yes_direction_head ≠ NULL)
    fprintf(dump_stream, "\n\n");
}

```

```

if (attribute_pointer→no ≠ NULL) {
    /* the attribute has a NO string, so write it */
    Indent(dump_stream, 4);
    fprintf(dump_stream, "\\item[\\sc_no:]\n");
    Write(dump_stream, attribute_pointer→no, ".\n", 5, No_Hang);
    if (attribute_pointer→external_attribute) {
        /* the attribute is external, so indicate the association of results from the external area with NO values of this attribute using a ⇐ symbol (list the result identifiers, separated by a ∨ symbol) */
        identifier_list_pointer = attribute_pointer→details.external.no_identifier_head;
        while (identifier_list_pointer ≠ NULL) {
            if (identifier_list_pointer ≡
                attribute_pointer→details.external.no_identifier_head) {
                /* this is the first identifier to write */
                Indent(dump_stream, 5);
                fprintf(dump_stream, "%s_{"s_"}", External_Result_Symbol,
                    Identifier_Font, identifier_list_pointer→identifier);
            } else {
                fprintf(dump_stream, "~s\n", Disjunction_Symbol);
                Indent(dump_stream, 5);
                fprintf(dump_stream, "{s_"}", Identifier_Font,
                    identifier_list_pointer→identifier);
            }
            identifier_list_pointer = identifier_list_pointer→next;
        }
        if (attribute_pointer→details.external.no_identifier_head ≠ NULL)
            fprintf(dump_stream, "\n\n");
    }

    /* indicate the specified direction for NO values of this attribute using a ⇒ symbol
    (list the result identifiers, separated by a ∨ symbol) */
    direction_list_pointer = attribute_pointer→no_direction_head;
    while (direction_list_pointer ≠ NULL) {
        if (direction_list_pointer ≡ attribute_pointer→no_direction_head) {
            /* this is the first identifier to write */
            Indent(dump_stream, 5);
            fprintf(dump_stream, "%s_{"s_"}", Specified_Direction_Symbol,
                Identifier_Font, direction_list_pointer→result→identifier);
        } else {
            fprintf(dump_stream, "~s\n", Disjunction_Symbol);
            Indent(dump_stream, 5);
            fprintf(dump_stream, "{s_"}", Identifier_Font,
                direction_list_pointer→result→identifier);
        }
        direction_list_pointer = direction_list_pointer→next;
    }
    if (attribute_pointer→no_direction_head ≠ NULL)
        fprintf(dump_stream, "\n\n");
}

```

```

if (attribute_pointer→unknown ≠ NULL) {
    /* the attribute has an UNKNOWN string, so write it */
    Indent(dump_stream, 4);
    fprintf(dump_stream, "\\item[\\sc_unknow:n:]\\n");
    Write(dump_stream, attribute_pointer→unknown, ".\\n", 5, No_Hang);
    if (attribute_pointer→external_attribute) {
        /* the attribute is external, so indicate the association of results from the ex-
           ternal area with UNKNOWN values of this attribute using a ⇐ symbol (list
           the result identifiers, separated by a ∨ symbol) */
        identifier_list_pointer =
            attribute_pointer→details.external.unknown_identifier_head;
        while (identifier_list_pointer ≠ NULL) {
            if (identifier_list_pointer ≡
                attribute_pointer→details.external.unknown_identifier_head) {
                /* this is the first identifier to write */
                Indent(dump_stream, 5);
                fprintf(dump_stream, "%s_{{s_}}s", External_Result_Symbol,
                    Identifier_Font, identifier_list_pointer→identifier);
            } else {
                fprintf(dump_stream, "~%s\\n", Disjunction_Symbol);
                Indent(dump_stream, 5);
                fprintf(dump_stream, "{{s_}}s", Identifier_Font,
                    identifier_list_pointer→identifier);
            }
            identifier_list_pointer = identifier_list_pointer→next;
        }
        if (attribute_pointer→details.external.unknown_identifier_head ≠ NULL)
            fprintf(dump_stream, "\\n\\n");
    }

    /* indicate the specified direction for UNKNOWN values of this attribute using
       a ⇒ symbol (list the result identifiers, separated by a ∨ symbol) */
    direction_list_pointer = attribute_pointer→unknown_direction_head;
    while (direction_list_pointer ≠ NULL) {
        if (direction_list_pointer ≡ attribute_pointer→unknown_direction_head) {
            /* this is the first identifier to write */
            Indent(dump_stream, 5);
            fprintf(dump_stream, "%s_{{s_}}s", Specified_Direction_Symbol,
                Identifier_Font, direction_list_pointer→result→identifier);
        } else {
            fprintf(dump_stream, "~%s\\n", Disjunction_Symbol);
            Indent(dump_stream, 5);
            fprintf(dump_stream, "{{s_}}s", Identifier_Font,
                direction_list_pointer→result→identifier);
        }
        direction_list_pointer = direction_list_pointer→next;
    }
}

```

```

        if (attribute_pointer->unknown_direction_head ≠ NULL)
            fprintf(dump_stream, "\n\n");
    }
    Indent(dump_stream, 3);
    fprintf(dump_stream, "\\end{description}\n\n");

    if (¬attribute_pointer->external_attribute ∧
        (attribute_pointer->details.local.help ≠ NULL))

        /* the attribute has a help string, so write it */

        Write(dump_stream, attribute_pointer->details.local.help, "\n", 3, No_Hang);

    attribute_pointer = attribute_pointer->next;
}
Indent(dump_stream, 1);
fprintf(dump_stream, "\\end{description}\n\n");
}

```

extern void

```

Write_Year_and_Court(
    file stream,
    kase *case_pointer,
    cardinal level)

```

/* Describes the case pointed to by *case_pointer* as “a *year* decision of *court*”. */

```

{
    cardinal hundreds = case_pointer->year / 100;

    Indent(stream, level);
    if ((hundreds ≡ 8) ∨ (hundreds ≡ 11) ∨ (hundreds ≡ 18))
        fprintf(stream, "an");
    else
        fprintf(stream, "a");
    fprintf(stream, "□%u□decision", case_pointer->year);

    if (case_pointer->court_string ≠ NULL) {
        fprintf(stream, "□of\n");
        Indent(stream, level);
        fprintf(stream, "□□%s", case_pointer->court_string);
    }
}
}

```

static void

```

write_case_list(
    file dump_stream,
    file log_stream,
    area *area_pointer,
    boolean verbose)

```

/* Writes details of each case in the area pointed to by *area_pointer*. Summarizes each case in full only if *verbose* is *TRUE*. */

```

{
  result *result_pointer = area_pointer→result_head;
  kase *case_pointer;
  attribute *attribute_pointer;
  matrix_element *matrix_pointer;
  vector_element *vector_pointer;
  string attribute_string;
  char message[Max_Error_Message_Length];

  /* while there are still results ... */

  while (result_pointer ≠ NULL) {

    if ((result_pointer→case_head ≠ NULL) ∨
        (result_pointer→ideal_point_head ≠ NULL)) {

      /* this result has a case or an ideal point */

      fprintf(dump_stream, "%s{Cases_in_which_s}\n\n", Subheading,
              result_pointer→string);
      Indent(dump_stream, 1);
      fprintf(dump_stream, "\\begin{description}\n\n", result_pointer→string);

      /* for every case with this result ... */

      for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
           case_pointer = case_pointer→next) {

        Indent(dump_stream, 2);
        fprintf(dump_stream,
                "\\item[\\rm$C_{%u}$:]\\frenchspacing\n", case_pointer→number);
        Indent(dump_stream, 3);
        fprintf(dump_stream,
                "{\\it_s\\}/\\nonfrenchspacing\n", case_pointer→name);
        Indent(dump_stream, 3);
        fprintf(dump_stream, "%s\n", case_pointer→citation);

        if (case_pointer→short_name ≠ case_pointer→name) {
          Indent(dump_stream, 3);
          fprintf(dump_stream, "( ‘\\frenchspacing\n");
          Indent(dump_stream, 3);
          fprintf(dump_stream, "{\\it_s\\}/\\nonfrenchspacing’)\n",
                  case_pointer→short_name);
        }
        fprintf(dump_stream, "\n");

        attribute_pointer = area_pointer→attribute_head;
        matrix_pointer = case_pointer→matrix_head;
        Indent(dump_stream, 3);
        fprintf(dump_stream, "\\begin{description}\n\n");

```

```

/* while there are still attributes ... */
while (attribute_pointer ≠ NULL) {
    /* write the strings corresponding to each attribute value for the case */
    attribute_string = matrix_pointer→attribute_value ≡ YES ?
        attribute_pointer→yes : matrix_pointer→attribute_value ≡ NO ?
        attribute_pointer→no : attribute_pointer→unknown;
    Indent(dump_stream, 4);
    fprintf(dump_stream, "\\item[\\rm$A_{%u}$:]\\n",
        attribute_pointer→number);

    if (attribute_string ≡ NULL) {
        sprintf(message,
            "A%u in C%u in %s area has a value
            for which there is no string",
            attribute_pointer→number, case_pointer→number,
            area_pointer→identifier);
        warning(log_stream, message);
        Indent(dump_stream, 5);
        fprintf(dump_stream, "%s\\n", Null_String);
    } else
        Write(dump_stream, attribute_string, ".", 5, No_Hang);
    fprintf(dump_stream, "\\n");

    matrix_pointer = matrix_pointer→case_next;
    attribute_pointer = attribute_pointer→next;
}

/* summarize the case */
Indent(dump_stream, 3);
fprintf(dump_stream, "\\end{description}\\n\\n");
if (case_pointer→summary ≠ NULL) {
    Indent(dump_stream, 3);
    fprintf(dump_stream, "In\\frenchspacing\\n");
    Indent(dump_stream, 3);
    fprintf(dump_stream, "{\\it%s}\\nonfrenchspacing,%%\\n",
        case_pointer→name);
    Indent(dump_stream, 3);
    fprintf(dump_stream, "\\footnote{%s.}\\n", case_pointer→citation);
    if (verbose) {
        Write_Year_and_Court(dump_stream, case_pointer, 3);
        fprintf(dump_stream, ",\\n");
        if (case_pointer→summary ≠ NULL)
            Write(dump_stream, case_pointer→summary, Empty_String, 3, Hang);
    } else
        Write(dump_stream, "[summary] .\\n", Empty_String, 3, Hang);
    fprintf(dump_stream, "\\n");
}
}
}

```

```

if (result_pointer→ideal_point_head ≠ NULL) {
    /* this result has an ideal point, so write its details */
    Indent(dump_stream, 2);
    fprintf(dump_stream, "\\item[ $I_{\scriptsize s}$ ]}{\n",
        Identifier_Font, result_pointer→identifier);
    Indent(dump_stream, 3);
    fprintf(dump_stream, "(the_ideal_case_in_which\n");
    Indent(dump_stream, 3);
    fprintf(dump_stream, "%s):\n\n", result_pointer→string);

    attribute_pointer = area_pointer→attribute_head;
    vector_pointer = result_pointer→ideal_point_head;
    Indent(dump_stream, 3);
    fprintf(dump_stream, "\\begin{description}\n\n");

    /* while there are still attributes ... */
    while (attribute_pointer ≠ NULL) {
        /* write the strings corresponding to each attribute value for the ideal
           point */
        attribute_string = vector_pointer→attribute_value ≡ YES ?
            attribute_pointer→yes : vector_pointer→attribute_value ≡ NO ?
            attribute_pointer→no : attribute_pointer→unknown;
        Indent(dump_stream, 4);
        fprintf(dump_stream, "\\item[ $A_{u}$ ]:\n",
            attribute_pointer→number);
        if (attribute_string ≡ NULL) {
            sprintf(message,
                "Au in ideal point s in s area has a value,
                "for which there is no string",
                attribute_pointer→number, result_pointer→identifier,
                area_pointer→identifier);
            warning(log_stream, message);
            Indent(dump_stream, 5);
            fprintf(dump_stream, "%s\n", Null_String);
        } else
            Write(dump_stream, attribute_string, " . ", 5, No_Hang);
        fprintf(dump_stream, "\n");

        vector_pointer = vector_pointer→next;
        attribute_pointer = attribute_pointer→next;
    }
    Indent(dump_stream, 3);
    fprintf(dump_stream, "\\end{description}\n\n");
}
Indent(dump_stream, 1);
fprintf(dump_stream, "\\end{description}\n\n");
}
result_pointer = result_pointer→next;
}

```


extern void

```

Dump_Specification(
    file dump_stream,
    file log_stream,
    case_law_specification case_law,
    boolean inputable_latex,
    boolean verbose)

/* Writes to dump_stream a formatted version of the specification case_law. Writes LATEX
code that can be included in another LATEX document (i.e. not stand-alone code), if
inputable_latex is TRUE. Summarizes cases in full, and writes opening and closing strings
in full, if verbose is TRUE. */

{
    area *area_pointer;

    fprintf(dump_stream, "%_Dump_file\n\n");
    Write_LaTeX_Header(dump_stream, inputable_latex);

    if (case_law.court_head ≠ NULL)
        write_hierarchy_table(dump_stream, case_law.court_head);

    /* for every area ... */

    for (area_pointer = case_law.area_head; area_pointer ≠ NULL;
         area_pointer = area_pointer→next) {

        fprintf(dump_stream, "%s{%s_area}\n\n", Heading,
                area_pointer→identifier);
        Write_Matrix(dump_stream, area_pointer, NULL, case_law.court_head, FALSE, 0);
        write_opening_and_closing(dump_stream, area_pointer, verbose);
        write_result_list(dump_stream, area_pointer→result_head);
        write_attribute_list(dump_stream, area_pointer→attribute_head);
        write_case_list(dump_stream, log_stream, area_pointer, verbose);
    }
    Write_LaTeX_Trailer(dump_stream, inputable_latex);
}

```


7

The CHECKER module

checker.h

```
/* This is the header file for the CHECKER module. It is also included by the CASES module. */
/* external function */

extern void
Check_for_Attribute_Dependence(
    file probabilities_stream,
    file log_stream,
    case_law_specification case_law,
    boolean inputable_latex);
```

checker.c

```
/* This is the implementation file for the CHECKER module. */

#include <stdio.h>
#include <stdlib.h>
#include "shyster.h"
#include "cases.h"
#include "checker.h"

static void
error_exit(
    file stream,
    const string message)
{
    Write_Error_Message_And_Exit(stream, "Checker", message);
}
```

```

static void
warning(
    file stream,
    const string message)
{
    Write_Warning_Message(stream, "Checker", message, Top_Level);
}

static floating_point
factorial(
    cardinal number)

/* Returns number! */
{
    if (number  $\equiv$  0)
        return 1.0;
    else
        return (floating_point) number  $\times$  factorial(number - 1);
}

static boolean
calculate_probabilities(
    attribute *attribute_pointer_X,
    attribute *attribute_pointer_Y,
    boolean *equivalence_function,
    boolean *inverse_function,
    floating_point *probability_that_or_fewer,
    floating_point *probability_that_or_more)

/* Calculates the probabilities for the two attributes pointed to by
attribute_pointer_X and attribute_pointer_Y, and sets *probability_that_or_fewer
and *probability_that_or_more appropriately. Sets *equivalence_function to
TRUE, if there is an equivalence function mapping attribute X to attribute Y.
Sets *inverse_function to TRUE, if there is an inverse function mapping
attribute X to attribute Y. Returns FALSE, if there are no known pairs. */
{
    matrix_element *matrix_pointer_X,
    *matrix_pointer_Y;
    cardinal yes_count_X = 0,
    yes_count_Y = 0,
    yes_yes_count = 0,
    total_count = 0,
    count;
    floating_point multiplier,
    probability;

    /* assume that there is both an equivalence function and an inverse function */

    *equivalence_function = TRUE;
    *inverse_function = TRUE;

    matrix_pointer_Y = attribute_pointer_Y  $\rightarrow$  matrix_head;

```

```

/* for every attribute value for attribute X ... */
for (matrix_pointer_X = attribute_pointer_X→matrix_head; matrix_pointer_X ≠ NULL;
     matrix_pointer_X = matrix_pointer_X→attribute_next)
  if (matrix_pointer_Y ≠ NULL) {
    if ((matrix_pointer_X→attribute_value ≠ UNKNOWN) ∧
        (matrix_pointer_Y→attribute_value ≠ UNKNOWN)) {
      /* both attribute values for this case are known, so count the YESs */
      if (matrix_pointer_X→attribute_value ≡ YES) {
        yes_count_X++;
        if (matrix_pointer_Y→attribute_value ≡ YES)
          yes_yes_count++;
      }
      if (matrix_pointer_Y→attribute_value ≡ YES)
        yes_count_Y++;
      total_count++;

      if (matrix_pointer_X→attribute_value ≡ matrix_pointer_Y→attribute_value)
        /* the attribute values are the same */
        *inverse_function = FALSE;
      else
        /* the attribute values are the different */
        *equivalence_function = FALSE;
    }
    /* move to the next attribute value for attribute Y */
    matrix_pointer_Y = matrix_pointer_Y→attribute_next;
  }
if (total_count ≡ 0)
  /* there are no known pairs */
  return FALSE;

```

```
else {
```

```
  /* calculate the probability  $P(n)$  of there being exactly  $n$  YES/YES pairs:
```

$$P(n) = \frac{\binom{y}{n} \binom{N-y}{x-n}}{\binom{N}{x}}$$

```

  where  $n$  is yes_yes_count (the number of YES/YES pairs),  $N$  is total_count (the number
  of known pairs),  $x$  is yes_count_X (the number of YESs in attribute X), and  $y$  is
  yes_count_Y (the number of YESs in attribute Y) */

```

```
if (yes_count_X + yes_count_Y > total_count) {
```

```
  /* the first non-zero probability is  $P(x + y - N) = \frac{x! y!}{N! (x+y-N)!}$  */
```

```

  count = yes_count_X + yes_count_Y - total_count;
  probability = (factorial(yes_count_X) × factorial(yes_count_Y)) /
    (factorial(total_count) ×
     factorial(yes_count_X + yes_count_Y - total_count));

```

```

} else {
    /* the first non-zero probability is  $P(0) = \frac{(N-x)!(N-y)!}{N!(N-x-y)!}$  */
    count = 0;
    probability = (factorial(total_count - yes_count_X) ×
                  factorial(total_count - yes_count_Y)) /
                  (factorial(total_count) ×
                  factorial(total_count - yes_count_X - yes_count_Y));
}
*probability_that_or_fewer = probability;

/* successively multiply the probability by  $\frac{P(i+1)}{P(i)} = \frac{(i-x)(i-y)}{(i+1)(N-x-y+i+1)}$  */
while (count < yes_yes_count) {
    multiplier = (floating_point)((count - yes_count_X) × (count - yes_count_Y)) /
                 (floating_point)((count + 1) ×
                 (total_count - yes_count_X - yes_count_Y + count + 1));
    probability ×= multiplier;

    /* the probability of  $i$  YES/YES pairs or fewer is  $P(n \leq i) = \sum_{n=0}^i P(n)$  */
    *probability_that_or_fewer += probability;
    count++;
}

/* the probability of  $i$  YES/YES pairs or greater is  $P(n \geq i) = 1 - \sum_{n=0}^{i-1} P(n)$  */
*probability_that_or_more = 1.0 - (*probability_that_or_fewer - probability);
return TRUE;
}
}

static void
write_probabilities_matrix(
    file probabilities_stream,
    file log_stream,
    area *area_pointer)

/* Calculates the probabilities for the area pointed to by area_pointer, and writes a matrix of
probabilities. */

{
    attribute *attribute_pointer_X,
    *attribute_pointer_Y;
    probability_element *probability_pointer;
    boolean equivalence_function,
    inverse_function;
    cardinal count;
    char message[Max_Error_Message_Length];

    if (probabilities_stream ≠ NULL) {
        fprintf(probabilities_stream, "%s{%s_area}\n\n",
            Heading, area_pointer→identifier);
    }
}

```

```

if (area_pointer→number_of_attributes < 2)
    return;

Indent(probabilities_stream, 1);
fprintf(probabilities_stream, "\\begin{small}\n");
Indent(probabilities_stream, 2);
fprintf(probabilities_stream, "\\def\\arraystretch{0}\n");
Indent(probabilities_stream, 2);
fprintf(probabilities_stream,
        "\\begin{tabular}{*%u}{|c|@{}p{\\doublerulesep}@{}|c|}"
        "\\cline{1-%u}\n",
        area_pointer→number_of_attributes - 1,
        area_pointer→number_of_attributes - 1);
Indent(probabilities_stream, 3);

/* write the column headings */

for (count = 2; count ≤ area_pointer→number_of_attributes; count++)
    fprintf(probabilities_stream, "\\smash{\\raisebox{%s}{$A_{%u}$}}&",
            Raise_Height, count);

fprintf(probabilities_stream,
        "\\multicolumn{2}{c}{\\raisebox{\\ht\\strutbox}{\\strut}}"
        "\\cline{1-%u}\n", area_pointer→number_of_attributes - 1);
Indent(probabilities_stream, 3);
fprintf(probabilities_stream,
        "\\multicolumn{%u}{c}{\\rule{0mm}{\\doublerulesep}}\\\\"
        "\\cline{1-%u}\\cline{%u-%u}\n",
        area_pointer→number_of_attributes + 1,
        area_pointer→number_of_attributes - 1,
        area_pointer→number_of_attributes + 1,
        area_pointer→number_of_attributes + 1);
}

/* for every attribute X ... */

for (attribute_pointer_X = area_pointer→attribute_head;
      (attribute_pointer_X ≠ NULL) ∧ (attribute_pointer_X→next ≠ NULL);
      attribute_pointer_X = attribute_pointer_X→next) {

if (probabilities_stream ≠ NULL) {
    Indent(probabilities_stream, 3);
    if (attribute_pointer_X→number > 1)
        fprintf(probabilities_stream, "\\multicolumn{%u}{c|}{}&",
                attribute_pointer_X→number - 1);
}
}

```

```

/* for every attribute Y (i.e. every attribute after attribute X) ... */
for (attribute_pointer_Y = attribute_pointer_X→next; attribute_pointer_Y ≠ NULL;
      attribute_pointer_Y = attribute_pointer_Y→next) {

  if (attribute_pointer_X→probability_head ≡ NULL) {

    /* allocate memory for this pair of probabilities (the first in the list) */

    if ((attribute_pointer_X→probability_head =
          (probability_element *) malloc(sizeof(probability_element))) ≡
          NULL)
      error_exit(log_stream,
                  "malloc_failed_during_probability_matrix_building");
    probability_pointer = attribute_pointer_X→probability_head;
  } else {

    /* go to the end of the list of probabilities */

    for (probability_pointer = attribute_pointer_X→probability_head;
          probability_pointer→next ≠ NULL;
          probability_pointer = probability_pointer→next);

    /* allocate memory for this pair of probabilities */

    if ((probability_pointer→next =
          (probability_element *) malloc(sizeof(probability_element))) ≡
          NULL)
      error_exit(log_stream,
                  "malloc_failed_during_probability_matrix_building");
    probability_pointer = probability_pointer→next;
  }

  /* calculate the probabilities for attributes X and Y */

  probability_pointer→unknown = ¬calculate_probabilities(attribute_pointer_X,
                                                         attribute_pointer_Y, &equivalence_function, &inverse_function,
                                                         &probability_pointer→probability_that_or_fewer,
                                                         &probability_pointer→probability_that_or_more);

  if (probability_pointer→unknown) {

    /* there are no known pairs */

    if (probabilities_stream ≠ NULL)
      fprintf(probabilities_stream, "\\footnotesize?&");
  } else {

    probability_pointer→functional_dependence =
      equivalence_function ∨ inverse_function;
  }

```



```

if (probabilities_stream ≠ NULL) {
    /* write the first probability for this cell in the matrix (the probability of
       the actual number of YES/YES pairs or fewer) */

    Write_Floating_Point(probabilities_stream,
        probability_pointer→probability_that_or_fewer,
        probability_pointer→functional_dependence ?
        Functional_Dependence_Symbol :
        probability_pointer→probability_that_or_fewer ≤ Threshold ?
        Stochastic_Dependence_Symbol : Empty_String);
    fprintf(probabilities_stream, "&");
}

/* issue warnings if necessary */

if (equivalence_function) {
    sprintf(message,
        "functional_dependence_(equivalence)_□"
        "between_□A%u□and_□A%u□in_□s□area",
        attribute_pointer_X→number, attribute_pointer_Y→number,
        area_pointer→identifier);
    warning(log_stream, message);
} else if (inverse_function) {
    sprintf(message,
        "functional_dependence_(inverse)_□"
        "between_□A%u□and_□A%u□in_□s□area",
        attribute_pointer_X→number, attribute_pointer_Y→number,
        area_pointer→identifier);
    warning(log_stream, message);
} else if (probability_pointer→probability_that_or_fewer ≤ Threshold ∨
    probability_pointer→probability_that_or_more ≤ Threshold) {
    sprintf(message,
        "evidence_of_stochastic_dependence_□"
        "between_□A%u□and_□A%u□in_□s□area",
        attribute_pointer_X→number, attribute_pointer_Y→number,
        area_pointer→identifier);
    warning(log_stream, message);
}
}
probability_pointer→next = NULL;
}
if (probabilities_stream ≠ NULL) {
    fprintf(probabilities_stream, "&\\ \\ \\ \\ \\n");
    Indent(probabilities_stream, 3);
    if (attribute_pointer_X→number > 1)
        fprintf(probabilities_stream, "\\ \\ multicolumn{%u}{c|}{}&",
            attribute_pointer_X→number - 1);
}

```

```

/* for every pair of probabilities for attribute X ... */
for (probability_pointer = attribute_pointer_X→probability_head;
     probability_pointer ≠ NULL; probability_pointer = probability_pointer→next)
  if (probabilities_stream ≠ NULL)

    /* write the second probability for this cell in the matrix (the probability of the
       actual number of YES/YES pairs or more) */

    if (probability_pointer→unknown)
      fprintf(probabilities_stream, "\\footnotesize?&");
    else {
      Write_Floating_Point(probabilities_stream,
                           probability_pointer→probability_that_or_more,
                           ¬probability_pointer→functional_dependence ∧
                           probability_pointer→probability_that_or_more ≤ Threshold ?
                           Stochastic_Dependence_Symbol : Empty_String);
      fprintf(probabilities_stream, "&");
    }
  if (probabilities_stream ≠ NULL)
    fprintf(probabilities_stream, "&\\smash{\\raisebox{%s}{\$A_{%u}\$}}\\\\\\\"
           \"\\cline{%u-%u}\\cline{%u-%u}\\n\", Raise_Height,
           attribute_pointer_X→number, attribute_pointer_X→number,
           area_pointer→number_of_attributes - 1,
           area_pointer→number_of_attributes + 1,
           area_pointer→number_of_attributes + 1);
}
if (probabilities_stream ≠ NULL) {
  Indent(probabilities_stream, 2);
  fprintf(probabilities_stream, "\\end{tabular}\\n");
  Indent(probabilities_stream, 1);
  fprintf(probabilities_stream, "\\end{small}\\n\\n");
}
}

extern void
Check_for_Attribute_Dependence(
  file probabilities_stream,
  file log_stream,
  case_law_specification case_law,
  boolean inputable_latex)

/* Checks for evidence of dependence between the attributes in each area in the specification
   case_law. Calculates the probabilities, and writes a matrix of probabilities for each area to
   probabilities_stream (if it is not NULL). Writes LATEX code that can be included in another
   LATEX document (i.e. not stand-alone code), if inputable_latex is TRUE. */

{
  area *area_pointer;

  if (probabilities_stream ≠ NULL) {
    fprintf(probabilities_stream, "%u_Probabilities_file\\n\\n");
    Write_LaTeX_Header(probabilities_stream, inputable_latex);
  }
}

```

```
/* for every area ... */  
for (area_pointer = case_law.area_head; area_pointer ≠ NULL;  
      area_pointer = area_pointer→next)  
    write_probabilities_matrix(probabilities_stream, log_stream, area_pointer);  
if (probabilities_stream ≠ NULL)  
    Write_LaTeX_Trailer(probabilities_stream, inputable_latex);  
}
```


8

The SCALES module

scales.h

```
/* This is the header file for the SCALES module. It is also included by the CASES, ADJUSTER  
and ODOMETER modules. */
```

```
/* external functions */
```

```
extern void
```

```
Zero_Weight(  
    weight_type *weight_pointer);
```

```
extern void
```

```
Write_Weights_Table(  
    file weights_stream,  
    area *area_pointer);
```

```
extern void
```

```
Weight_Attributes(  
    file weights_stream,  
    file log_stream,  
    case_law_specification case_law,  
    boolean inputable_latex);
```

scales.c

```
/* This is the implementation file for the SCALES module. */
```

```
#include <stdio.h>  
#include <stdlib.h>  
#include "shyster.h"  
#include "cases.h"  
#include "scales.h"
```

static void

```

error_exit(
    file stream,
    const string message)
{
    Write_Error_Message_And_Exit(stream, "Scales", message);
}

```

static void

```

warning(
    file stream,
    const string message)
{
    Write_Warning_Message(stream, "Scales", message, Top_Level);
}

```

extern void

```

Zero_Weight(
    weight_type *weight_pointer)

/* Sets the weight pointed to by weight_pointer to zero. */
{
    weight_pointer→infinite = FALSE;
    weight_pointer→finite = 0.0;
}

```

static boolean

```

calculate_mean_and_centroids(
    file log_stream,
    result *result_head,
    attribute *attribute_pointer)

/* Calculates the mean (and, for each result, centroid element) for the attribute pointed to by
attribute_pointer. Returns TRUE, iff the attribute has known values. */
{
    result *result_pointer;
    kase *case_pointer;
    matrix_element *matrix_pointer;
    centroid_element *centroid_pointer;
    floating_point sum,
    temp;
    cardinal count,
    total_count = 0;

    attribute_pointer→mean = 0.0;
    matrix_pointer = attribute_pointer→matrix_head;

    /* for every result ... */
    for (result_pointer = result_head; result_pointer ≠ NULL;
        result_pointer = result_pointer→next) {
        sum = 0.0;
        count = 0;

```

```

/* sum the attribute values for this attribute for each case with this result */
for (case_pointer = result_pointer->case_head;
     (case_pointer != NULL) ^ (matrix_pointer != NULL);
     case_pointer = case_pointer->next) {
    if (Attribute_Value(matrix_pointer->attribute_value, &temp)) {
        sum += temp;
        count++;
    }
    matrix_pointer = matrix_pointer->attribute_next;
}

if (result_pointer->centroid_head == NULL) {
    /* allocate memory for this centroid element (the first in the list) */
    if ((result_pointer->centroid_head =
         (centroid_element *) malloc(sizeof(centroid_element))) == NULL)
        error_exit(log_stream, "malloc_failed_during_centroid_building");
    centroid_pointer = result_pointer->centroid_head;
} else {
    /* go to the end of the centroid */
    for (centroid_pointer = result_pointer->centroid_head;
         centroid_pointer->next != NULL;
         centroid_pointer = centroid_pointer->next);

    /* allocate memory for this centroid element */
    if ((centroid_pointer->next =
         (centroid_element *) malloc(sizeof(centroid_element))) == NULL)
        error_exit(log_stream, "malloc_failed_during_centroid_building");
    centroid_pointer = centroid_pointer->next;
}

if (!(centroid_pointer->unknown == count == 0))
    centroid_pointer->value = sum / (floating_point) count;
centroid_pointer->next = NULL;

attribute_pointer->mean += sum;
total_count += count;
}
if (total_count == 0)
    /* the attribute has no known values */
    return FALSE;
else {
    attribute_pointer->mean = attribute_pointer->mean / (floating_point) total_count;
    return TRUE;
}
}

```

static void

```

calculate_weights(
    file log_stream,
    area *area_pointer)

/* Calculates the weight of each attribute in the area pointed to by area_pointer. (The weight is
the inverse of the variance of the attribute values. The variance  $\sigma^2$  of the numerical values
of an attribute  $i$  across  $n$  cases is  $\frac{1}{n} \sum_{j=1}^n (A_{ij} - \bar{A}_i)^2$ , where  $A_{ij}$  is the value of the  $i$ th
attribute for the  $j$ th case, and  $\bar{A}_i$  is the mean of all attribute values for the  $i$ th attribute.
Because known attribute values are assigned numerical values of 0 or 1,  $\sigma^2$  simplifies to
 $\bar{A}_i - \bar{A}_i^2$ .) */

{
    attribute *attribute_pointer;
    cardinal count;
    floating_point variance;
    char message[Max_Error_Message_Length];

    count = 1;

    /* for every attribute ... */

    for (attribute_pointer = area_pointer->attribute_head; attribute_pointer != NULL;
        attribute_pointer = attribute_pointer->next) {

        variance = 0.0;
        Zero_Weight(&attribute_pointer->weight);

        if (!calculate_mean_and_centroids(log_stream, area_pointer->result_head,
            attribute_pointer)) {

            /* the attribute has no known values */

            sprintf(message, "A%u in %s area has no weight", count,
                attribute_pointer->identifier);
            warning(log_stream, message);

        } else {

            /* the attribute has known values, so determine its weight */

            variance = attribute_pointer->mean -
                (attribute_pointer->mean * attribute_pointer->mean);

            if (attribute_pointer->weight.infinite = Is_Zero(variance)) {
                sprintf(message,
                    "A%u in %s area has infinite weight", count,
                    attribute_pointer->identifier);
                warning(log_stream, message);
                attribute_pointer->infinite_weight = TRUE;
            } else
                attribute_pointer->weight.finite = 1 / variance;
        }
        count++;
    }
}

```



```

static void
calculate_result_weights(
    file log_stream,
    area *area_pointer)

/* Calculates the result weight for each attribute in the area pointed to by area_pointer. (The
result weight is the inverse of the variance of the attribute values for that result.) */

{
    attribute *attribute_pointer;
    result *result_pointer;
    centroid_element *centroid_pointer;
    cardinal count;
    floating_point variance;
    weight_list_element *weights_pointer;
    boolean zero_result_weight = FALSE;
    char message[Max_Error_Message_Length];

    /* for every attribute ... */

    for (attribute_pointer = area_pointer->attribute_head; attribute_pointer ≠ NULL;
        attribute_pointer = attribute_pointer->next)

        /* for every result ... */

        for (result_pointer = area_pointer->result_head; result_pointer ≠ NULL;
            result_pointer = result_pointer->next) {

            /* find, in the centroid for this result, the mean for this attribute */

            centroid_pointer = result_pointer->centroid_head;
            for (count = 1; count < attribute_pointer->number; count++)
                centroid_pointer = centroid_pointer->next;

            if (attribute_pointer->weights_head ≡ NULL) {

                /* allocate memory for this result weight (the first in the list) */

                if ((attribute_pointer->weights_head =
                    (weight_list_element *) malloc(sizeof(weight_list_element))) ≡
                    NULL)
                    error_exit(log_stream, "malloc_failed_during_weights_building");
                weights_pointer = attribute_pointer->weights_head;

            } else {

                /* allocate memory for this result weight */

                if ((weights_pointer->next =
                    (weight_list_element *) malloc(sizeof(weight_list_element))) ≡
                    NULL)
                    error_exit(log_stream, "malloc_failed_during_weights_building");
                weights_pointer = weights_pointer->next;
            }

            Zero_Weight(&weights_pointer->weight);

```

```

if (centroid_pointer→unknown ∧
      (attribute_pointer→weight.infinite ∨
       ¬Is_Zero(attribute_pointer→weight.finite)))

    /* the result weight is zero, but the weight for the whole attribute is not zero,
       so ensure a warning is issued later (if the weight for the whole attribute is
       zero, a warning has already been issued) */

    zero_result_weight = TRUE;

else if (attribute_pointer→weight.infinite)

    /* this attribute has infinite weight, so make this result weight infinite too */

    weights_pointer→weight.infinite = TRUE;

else {

    /* the attribute has known values, so determine the result weight */

    variance = centroid_pointer→value −
               (centroid_pointer→value × centroid_pointer→value);

    if (¬(weights_pointer→weight.infinite = Is_Zero(variance)))
        weights_pointer→weight.finite = 1 / variance;
    }
    weights_pointer→next = NULL;
}

if (zero_result_weight) {
    sprintf(message,
            "one_or_more_attributes_in_%s_area_has_a_zero_result_weight",
            area_pointer→identifier);
    warning(log_stream, message);
}
}

```

extern void

```

Write_Weights_Table(
    file weights_stream,
    area *area_pointer)

```

/* Writes a table of weights for the area pointed to by *area_pointer*. */

```

{
    result *result_pointer;
    attribute *attribute_pointer;
    centroid_element *centroid_pointer;
    cardinal centroid_count;
    weight_list_element *weights_pointer;

```

```

Indent(weights_stream, 1);
fprintf(weights_stream, "\\begin{small}\n");
Indent(weights_stream, 2);
fprintf(weights_stream,
        "\\begin{tabular}{|c|*%u{c@{\hspace{%s}}c@{\hspace{%s}}r|}}"
        "\\hline\n", area_pointer→number_of_results + 1,
        Column_Separation, Column_Separation);
Indent(weights_stream, 3);
fprintf(weights_stream, "&");

/* write the column headings */

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
    fprintf(weights_stream, "\\multicolumn{3}{c|}{%s_}%s&",
            Identifier_Font, result_pointer→identifier);
fprintf(weights_stream, "&&\\\\\n");
Indent(weights_stream, 3);
fprintf(weights_stream, "\\smash{\\raisebox{%s}{\\it_Attr.}}&",
        Raise_Height);
for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
    fprintf(weights_stream,
            "$\\mu$&$\\sigma^2$&\\multicolumn{1}{c|}{%w$}&");
fprintf(weights_stream,
        "\\smash{\\raisebox{%s}{\\mu$}}&"
        "\\smash{\\raisebox{%s}{\\sigma^2$}}&"
        "\\multicolumn{1}{c|}{\\smash{\\raisebox{%s}{%w$}}}"
        "\\\\\\hline\\hline", Raise_Height, Raise_Height, Raise_Height);

/* for every attribute ... */

for (attribute_pointer = area_pointer→attribute_head; attribute_pointer ≠ NULL;
     attribute_pointer = attribute_pointer→next) {

    weights_pointer = attribute_pointer→weights_head;
    fprintf(weights_stream, "\\n");
    Indent(weights_stream, 3);
    fprintf(weights_stream, "$A_{%u}$&", attribute_pointer→number);

    /* for every result ... */

    for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
         result_pointer = result_pointer→next) {

        /* find, in the centroid for this result, the mean for this attribute */

        centroid_pointer = result_pointer→centroid_head;
        for (centroid_count = 1; centroid_count < attribute_pointer→number;
             centroid_count++)
            centroid_pointer = centroid_pointer→next;
    }
}

```

```

/* write the mean  $\mu$  and the variance  $\sigma^2$  for this result and attribute */

if (centroid_pointer→unknown)
    fprintf(weights_stream, "\\footnotesize?&\\footnotesize?&");
else {
    Write_Floating_Point(weights_stream, centroid_pointer→value, Empty_String);
    fprintf(weights_stream, "&");
    Write_Floating_Point(weights_stream, centroid_pointer→value -
        (centroid_pointer→value × centroid_pointer→value), Empty_String);
    fprintf(weights_stream, "&");
}

/* write the result weight for this attribute */

if (weights_pointer→weight.infinite)
    fprintf(weights_stream, "\\multicolumn{1}{c|}{\\infty$}");
else if (Is_Zero(weights_pointer→weight.finite))
    fprintf(weights_stream, "\\multicolumn{1}{c|}{--}");
else
    Write_Floating_Point(weights_stream, weights_pointer→weight.finite,
        Empty_String);
    fprintf(weights_stream, "&");

    weights_pointer = weights_pointer→next;
}

/* write the mean  $\mu$  and the variance  $\sigma^2$  for this attribute */

Write_Floating_Point(weights_stream, attribute_pointer→mean, Empty_String);
fprintf(weights_stream, "&");
Write_Floating_Point(weights_stream, attribute_pointer→mean -
    (attribute_pointer→mean × attribute_pointer→mean), Empty_String);
fprintf(weights_stream, "&");

/* write the weight  $w$  for this attribute */

if (attribute_pointer→weight.infinite)
    fprintf(weights_stream, "\\multicolumn{1}{c|}{\\infty$}");
else if (Is_Zero(attribute_pointer→weight.finite))
    fprintf(weights_stream, "\\multicolumn{1}{c|}{--}");
else
    Write_Floating_Point(weights_stream, attribute_pointer→weight.finite,
        Empty_String);
    fprintf(weights_stream, "\\");
}
fprintf(weights_stream, "\\hline\n");
Indent(weights_stream, 2);
fprintf(weights_stream, "\\end{tabular}\n");
Indent(weights_stream, 1);
fprintf(weights_stream, "\\end{small}\n\n");
}

```

extern void

```

Weight_Attributes(
    file weights_stream,
    file log_stream,
    case_law_specification case_law,
    boolean inputable_latex)

/* Calculates the weights for each area in the specification case_law, and writes a table of
weights for each area to weights_stream (if it is not NULL). Writes LATEX code that can
be included in another LATEX document (i.e. not stand-alone code), if inputable_latex is
TRUE. */

{
    area *area_pointer;

    if (weights_stream ≠ NULL) {
        fprintf(weights_stream, "%_Weights_file\n\n");
        Write_LaTeX_Header(weights_stream, inputable_latex);
    }

    /* for every area ... */

    for (area_pointer = case_law.area_head; area_pointer ≠ NULL;
         area_pointer = area_pointer→next) {

        if (weights_stream ≠ NULL)
            fprintf(weights_stream, "%s{s_s_area}\n\n", Heading,
                    area_pointer→identifier);

        area_pointer→infinite_weight = FALSE;
        calculate_weights(log_stream, area_pointer);
        calculate_result_weights(log_stream, area_pointer);

        if (weights_stream ≠ NULL)
            Write_Weights_Table(weights_stream, area_pointer);
    }

    if (weights_stream ≠ NULL)
        Write_LaTeX_Trailer(weights_stream, inputable_latex);
}

```


9

The ADJUSTER module

adjuster.h

```
/* This is the header file for the ADJUSTER module. It is also included by the CASES
   module. */

/* external function */

extern void
Adjust_Attributes(
    file log_stream,
    area *area_pointer,
    string weights_filename,
    cardinal level,
    boolean inputable_latex);
```

adjuster.c

```
/* This is the implementation file for the ADJUSTER module. */

#include <stdio.h>
#include <stdlib.h>
#include "shyster.h"
#include "cases.h"
#include "adjuster.h"
#include "scales.h"
#include "consultant.h"

static void
error_exit(
    file stream,
    const string message)
{
    Write_Error_Message_And_Exit(stream, "Adjuster", message);
}
```

static void

```

write_weight(
    file stream,
    weight_type weight)

/* Writes the value of weight in words. */

{
    if (weight.infinite) {
        fprintf(stream, "infinite_weight");
    } else if (Is_Zero(weight.finite))
        fprintf(stream, "no_weight");
    else {
        fprintf(stream, "a_weight_of");
        Write_Floating_Point(stream, weight.finite, Empty_String);
    }
}

```

static void

```

adjust_weight(
    file log_stream,
    area *area_pointer,
    cardinal attribute_number,
    cardinal level,
    boolean *adjustment_made)

/* Allows the legal expert to set the weight of attribute attribute_number in the area pointed
to by area_pointer. Sets *adjustment_made to TRUE, if an adjustment is made. */

{
    cardinal count = 1;
    attribute *attribute_pointer;
    char dummy;
    int option;
    weight_type old_weight;
    floating_point new_weight;

    /* find attribute attribute_number */

    for (attribute_pointer = area_pointer->attribute_head;
         (count++ < attribute_number) ^ (attribute_pointer != NULL);
         attribute_pointer = attribute_pointer->next);

    /* tell the legal expert about the attribute's current weight */

    fprintf(stdout, "A%u_has", attribute_number);
    write_weight(stdout, attribute_pointer->weight);
    fprintf(stdout, ".\n");

    /* make a copy of the weight */

    old_weight.infinite = attribute_pointer->weight.infinite;
    old_weight = attribute_pointer->weight;

    option = Get_Option("Infinite,Zero,orOther", "IZO");

```



```

/* adjust the attribute's weight as requested */
switch (option) {
    case 'I':
        attribute_pointer->weight.infinite = TRUE;
        break;
    case 'Z':
        Zero_Weight(&attribute_pointer->weight);
        break;
    case 'O':
        fprintf(stdout, "New_weight_for_A%u:\n", attribute_number);
        if (fscanf(stdin, "%f%c", &new_weight, &dummy) == EOF)
            error_exit(log_stream, "fscanf_input_failed_for_floating_point");
        attribute_pointer->weight.infinite = FALSE;
        attribute_pointer->weight.finite = new_weight;
        break;
    case Quit_Character:
        return;
}
*adjustment_made = TRUE;

/* report on the adjustment */

Indent(log_stream, level);
fprintf(log_stream, "A%u, which had\n", attribute_number);
write_weight(log_stream, old_weight);
fprintf(log_stream, ", now has\n");
write_weight(log_stream, attribute_pointer->weight);
fprintf(log_stream, ".\n");
}

static void
adjust_result_weight(
    file log_stream,
    area *area_pointer,
    cardinal attribute_number,
    cardinal level,
    boolean *adjustment_made)

/* Allows the legal expert to set any of the result weights for attribute attribute_number in
the area pointed to by area_pointer. Sets *adjustment_made to TRUE, if an adjustment is
made. */

{
    cardinal count = 1,
        result_number;
    attribute *attribute_pointer;
    char dummy;
    int option;
    weight_type old_weight;
    floating_point new_weight;
    weight_list_element *weights_pointer;
    result *result_pointer;

```

```

/* find attribute attribute_number */

for (attribute_pointer = area_pointer→attribute_head;
     (count++ < attribute_number) ∧ (attribute_pointer ≠ NULL);
     attribute_pointer = attribute_pointer→next);

/* tell the legal expert about the attribute's current result weights */

fprintf(stdout, "%u has the following result weights:", attribute_number);
weights_pointer = attribute_pointer→weights_head;
result_pointer = area_pointer→result_head;
for (count = 1; count ≤ area_pointer→number_of_results;
     count++) {
  if (count ≠ 1)
    fprintf(stdout, ";");
  fprintf(stdout, "\n");
  Indent(stdout, 1);
  fprintf(stdout, "%u: %s result has", count, result_pointer→identifier);
  write_weight(stdout, weights_pointer→weight);
  weights_pointer = weights_pointer→next;
  result_pointer = result_pointer→next;
}
fprintf(stdout, ".\n");

/* prompt the legal expert for a result number */

do {
  fprintf(stdout, "Result number (1-%u):",
          area_pointer→number_of_results);
  if (fscanf(stdin, "%u%c", &result_number, &dummy) ≡ EOF)
    error_exit(log_stream, "fscanf input failed for cardinal");
} while (result_number > area_pointer→number_of_results);

if (result_number ≠ 0) {

  /* find the result weight */

  weights_pointer = attribute_pointer→weights_head;
  result_pointer = area_pointer→result_head;
  for (count = 1; count < result_number; count++) {
    weights_pointer = weights_pointer→next;
    result_pointer = result_pointer→next;
  }

  /* make a copy of the result weight */

  old_weight.infinite = weights_pointer→weight.infinite;
  old_weight = weights_pointer→weight;

  option = Get_Option("Infinite, Zero, or Other", "IZO");
}

```

```

/* adjust the result weight as requested */
switch (option) {
  case 'I':
    weights_pointer->weight.infinite = TRUE;
    break;
  case 'Z':
    Zero_Weight(&weights_pointer->weight);
    break;
  case 'O':
    fprintf(stdout, "New weight for A%u for s result: ",
            attribute_number, result_pointer->identifier);
    if (fscanf(stdin, "%f%c", &new_weight, &dummy) == EOF)
      error_exit(log_stream, "fscanf input failed for floating point");
    weights_pointer->weight.infinite = FALSE;
    weights_pointer->weight.finite = new_weight;
    break;
  case Quit_Character:
    return;
}
*adjustment_made = TRUE;

/* report on the adjustment */
Indent(log_stream, level);
fprintf(log_stream, "A%u, which had ", attribute_number);
write_weight(log_stream, old_weight);
fprintf(log_stream, " for s result, now has ", result_pointer->identifier);
write_weight(log_stream, weights_pointer->weight);
fprintf(log_stream, " for that result.\n");
}
}

extern void
Adjust_Attributes(
  file log_stream,
  area *area_pointer,
  string weights_filename,
  cardinal level,
  boolean inputable_latex)

/* Allows the legal expert to set any of the weights (including result weights) in the area
pointed to by area_pointer. Prompts the expert by writing to stdout; reads the expert's
response from stdin. Writes a table of weights to the adjusted weights file weights_filename
(if it is not NULL). Writes LATEX code that can be included in another LATEX document
(i.e. not stand-alone code), if inputable_latex is TRUE. */

{
  file weights_stream = NULL;
  char dummy;
  static char filename[Max_Filename_Length];
  char message[Max_Error_Message_Length];
  cardinal attribute_number;
  int option;
  boolean adjustment_made = FALSE;

```

```

Indent(log_stream, level);
fprintf(log_stream, "Entering_Adjuster_module.\n\n");
fprintf(stdout, "Adjust_weights_in_%s_area...\n", area_pointer→identifier);
do {
    /* prompt the legal expert for an attribute number */
    do {
        fprintf(stdout, "Attribute_number_(1-%u):_",
            area_pointer→number_of_attributes);
        if (fscanf(stdin, "%u%c", &attribute_number, &dummy) == EOF)
            error_exit(log_stream, "fscanf_input_failed_for_cardinal");
    } while (attribute_number > area_pointer→number_of_attributes);
    if (attribute_number != 0) {
        option = Get_Option("Weight_or_Result_weight", "WR");
        /* adjust the attribute's weight, or one of its result weights, as requested */
        switch (option) {
            case 'W':
                adjust_weight(log_stream, area_pointer, attribute_number,
                    level + 1, &adjustment_made);
                break;
            case 'R':
                adjust_result_weight(log_stream, area_pointer, attribute_number,
                    level + 1, &adjustment_made);
                break;
            case Quit_Character:
                attribute_number = 0;
                break;
        }
    }
} while (attribute_number != 0);
if (adjustment_made) {
    fprintf(log_stream, "\n");
    if (weights_filename != NULL) {
        /* a weights filename was specified, so open the adjusted weights file */
        sprintf(filename, "%s-%s%s", weights_filename, area_pointer→identifier,
            LaTeX_File_Extension);
        if ((weights_stream = fopen(filename, "w")) == NULL) {
            sprintf(message, "can't_open_adjusted_weights_file\"%s\"", filename);
            error_exit(log_stream, message);
        }
        Indent(log_stream, level + 1);
        fprintf(log_stream, "Writing_adjusted_weights_to\"%s\".\n\n", filename);
    }
}

```

```

if (weights_stream ≠ NULL) {
    /* write the table of adjusted weights */
    fprintf(weights_stream, "%_Adjusted_weights_file\n\n");
    Write_LaTeX_Header(weights_stream, inputable_latex);
    fprintf(weights_stream, "%s{%s_area}\n\n", Heading, area_pointer→identifier);
    Write_Weights_Table(weights_stream, area_pointer);
    Write_LaTeX_Trailer(weights_stream, inputable_latex);
}
if (weights_filename ≠ NULL)
    /* a weights filename was specified, so close the adjusted weights file */
    if (fclose(weights_stream) ≡ EOF) {
        sprintf(message, "can't_close_adjusted_weights_file\"%s\"", filename);
        error_exit(log_stream, message);
    }
} else {
    Indent(log_stream, level + 1);
    fprintf(log_stream, "No_adjustments_made.\n\n");
}
Indent(log_stream, level);
fprintf(log_stream, "Leaving_Adjuster_module.\n\n");
}

```


10

The CONSULTANT module

consultant.h

```
/* This is the header file for the CONSULTANT module. It is also included by the CASES and  
ADJUSTER modules. */
```

```
/* external functions */
```

```
extern int
```

```
Get_Option(  
    string question,  
    string options);
```

```
extern vector_element *
```

```
Get_Facts(  
    file log_stream,  
    case_law_specification case_law,  
    area *area_pointer,  
    boolean adjust,  
    boolean echo,  
    boolean inputable_latex,  
    boolean verbose,  
    cardinal hypothetical_reports,  
    cardinal hypothetical_changes,  
    cardinal level,  
    string distances_filename,  
    string weights_filename,  
    string report_filename);
```

consultant.c

```

/* This is the implementation file for the CONSULTANT module. */

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "shyster.h"
#include "cases.h"
#include "consultant.h"

static void
error_exit(
    file stream,
    const string message)
{
    Write_Error_Message_And_Exit(stream, "Consultant", message);
}

extern int
Get_Option(
    string question,
    string options)

/* Asks the user the question, and reads the user's response until a valid option—one of
the characters in the options string, or Q (quit)—is chosen. Treats lower-case alphabetic
characters entered by the user as if they were upper-case. Treats the end of the file as a Q.
Returns the chosen character. */

{
    int ch,
        temp_ch;
    cardinal count;

    fprintf(stdout, "%s□(%sQ)?□", question, options);

    for (;;) {
        if ((ch =getc(stdin)) ≡ EOF)
            return Quit_Character;

        /* convert ch to upper-case if necessary */
        if ((ch ≥ Little_A_Character) ∧ (ch ≤ Little_Z_Character))
            ch = Big_A_Character + ch - Little_A_Character;

        if (ch ≡ Quit_Character) {
            /* skip over the rest of the line of input */
            for (temp_ch =getc(stdin);
                (temp_ch ≠ Carriage_Return_Character) ∧ (temp_ch ≠ EOF);
                temp_ch =getc(stdin));

            return Quit_Character;
        }
    }
}

```



```

if (ch ≠ Carriage_Return_Character) {
    /* skip over the rest of the line of input */

    for (temp_ch = getc(stdin);
        (temp_ch ≠ Carriage_Return_Character) ∧ (temp_ch ≠ EOF);
        temp_ch = getc(stdin));

        if (temp_ch ≡ EOF)
            return Quit_Character;
    }
if (strchr(options, ch) ≠ NULL)

    /* the user has entered a valid option */

    return ch;

    /* the user has entered an invalid option */

    fprintf(stdout, "Please enter '%c'", options[0]);
    for (count = 1; options[count] ≠ Null_Character; count += sizeof(char))
        fprintf(stdout, ", '%c'", options[count]);
    fprintf(stdout, "\nor '%c' .\n%s?", Quit_Character, question);
}
}

```

static boolean

get_local_fact(

file log_stream,
 *attribute *attribute_pointer,*
 *vector_element *vector_pointer,*
 boolean echo,
 cardinal level)

/* Interrogates the user as to the value, in the instant case, of the local attribute pointed to by *attribute_pointer*. Puts the attribute value in the vector element pointed to by *vector_pointer*. Returns *FALSE*, if the user chooses to quit. */

```

{
    char options[Max_Attribute_Options + 1],
        option;
    cardinal count = 0;

    /* determine which values are valid for this attribute */

    if (attribute_pointer→yes ≠ NULL) {
        options[count] = Yes_Character;
        count += sizeof(char);
    }
    if (attribute_pointer→no ≠ NULL) {
        options[count] = No_Character;
        count += sizeof(char);
    }
}

```

```

if (attribute_pointer→unknown ≠ NULL) {
    options[count] = Unknown_Character;
    count += sizeof(char);
}
if (attribute_pointer→details.local.help ≠ NULL) {
    options[count] = Help_Character;
    count += sizeof(char);
}
options[count] = Null_Character;
count += sizeof(char);

/* prompt the user for one of the valid attribute values */

do {
    if ((option = Get_Option(attribute_pointer→details.local.question, options)) ≡
        Quit_Character) {
        Indent(log_stream, level);
        fprintf(log_stream, "Quitting_□consultation.\n\n");
        return FALSE;
    }
    if (option ≡ Help_Character)
        fprintf(stdout, "%s\n", attribute_pointer→details.local.help);
} while (option ≡ Help_Character);

/* set this attribute's value to that chosen */

switch (option) {
    case Yes_Character:
        vector_pointer→attribute_value = YES;
        if (echo)
            fprintf(stdout, "Yes: □%s.\n", attribute_pointer→yes);
        break;
    case No_Character:
        vector_pointer→attribute_value = NO;
        if (echo)
            fprintf(stdout, "No: □%s.\n", attribute_pointer→no);
        break;
    case Unknown_Character:
        vector_pointer→attribute_value = UNKNOWN;
        if (echo)
            fprintf(stdout, "Unknown: □%s.\n", attribute_pointer→unknown);
        break;
}
return TRUE;
}

```

```

static boolean
get_external_fact(
    file log_stream,
    case_law_specification case_law,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    cardinal level,
    string distances_filename,
    string weights_filename,
    string report_filename,
    attribute *attribute_pointer,
    cardinal attribute_number,
    vector_element *vector_pointer)

/* Resolves the value, in the instant case, of the external attribute pointed to by attribute_pointer (attribute attribute_number) by reference to the relevant area. Puts the attribute value in the vector element pointed to by vector_pointer. Returns FALSE, if the user chooses to quit. */

{
    string nearest_result_identifier;
    boolean found = FALSE;
    identifier_list_element *identifier_list_pointer;
    char message[Max_Error_Message_Length];

    Indent(log_stream, level);
    fprintf(log_stream, "%u is external.\n\n", attribute_number);

    /* determine the identifier of the "likely result" of the instant case in the relevant area
       (attribute_pointer→details.external.area_identifier) */
    nearest_result_identifier = Case_Law(log_stream, case_law,
        attribute_pointer→details.external.area_identifier, adjust, echo,
        inputable_latex, verbose, hypothetical_reports, hypothetical_changes,
        level + 1, distances_filename, weights_filename, report_filename);

    if (nearest_result_identifier ≡ NULL)

        /* quit */
        return FALSE;

    /* search for the result identifier in the list of external result identifiers for YES for this
       attribute */
    identifier_list_pointer = attribute_pointer→details.external.yes_identifier_head;
    vector_pointer→attribute_value = YES;
    while ((identifier_list_pointer ≠ NULL) ∧ ¬found) {
        found = ¬strcmp(identifier_list_pointer→identifier, nearest_result_identifier);
        if (¬found)
            identifier_list_pointer = identifier_list_pointer→next;
    }
}

```

```

if ( $\neg$ found) {

    /* search for the result identifier in the list of external result identifiers for NO for this
       attribute */

    identifier_list_pointer = attribute_pointer→details.external.no_identifier_head;
    vector_pointer→attribute_value = NO;
    while ((identifier_list_pointer  $\neq$  NULL)  $\wedge$   $\neg$ found) {
        found =  $\neg$ strcmp(identifier_list_pointer→identifier, nearest_result_identifier);
        if ( $\neg$ found)
            identifier_list_pointer = identifier_list_pointer→next;
    }
    if ( $\neg$ found) {

        /* search for the result identifier in the list of external result identifiers for UNKNOWN
           for this attribute */

        identifier_list_pointer = attribute_pointer→details.external.unknown_identifier_head;
        vector_pointer→attribute_value = UNKNOWN;
        while ((identifier_list_pointer  $\neq$  NULL)  $\wedge$   $\neg$ found) {
            found =  $\neg$ strcmp(identifier_list_pointer→identifier, nearest_result_identifier);
            if ( $\neg$ found)
                identifier_list_pointer = identifier_list_pointer→next;
        }
        if ( $\neg$ found) {
            sprintf(message, "Unexpected_external_result_identifier\%"s\\"",
                    nearest_result_identifier);
            error_exit(log_stream, message);
        }
    }
}

/* write details of the attribute value to the log file */

Indent(log_stream, level);
fprintf(log_stream, "Value_of_A%u_is", attribute_number);
switch (vector_pointer→attribute_value) {
    case YES:
        fprintf(log_stream, "YES");
        break;
    case NO:
        fprintf(log_stream, "NO");
        break;
    case UNKNOWN:
        fprintf(log_stream, "UNKNOWN");
        break;
}
fprintf(log_stream, ".\n\n");

return TRUE;
}

```

```

static vector_element *
get_fact(
    file log_stream,
    case_law_specification case_law,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    cardinal level,
    string distances_filename,
    string weights_filename,
    string report_filename,
    attribute *attribute_pointer,
    cardinal attribute_number)

/* Determines the value, in the instant case, of the attribute pointed to by attribute_pointer
   (attribute attribute_number). Interrogates the user, if the attribute is local; resolves the
   value by reference to the relevant area, if the attribute is external. Returns a pointer to a
   single vector element containing the attribute value; or NULL, if the user chooses to quit. */
{
    vector_element *vector_pointer;

    /* allocate memory for this vector element */
    if ((vector_pointer = (vector_element *) malloc(sizeof(vector_element))) == NULL)
        error_exit(log_stream, "malloc failed during fact vector handling");

    if (attribute_pointer->external_attribute) {
        /* the attribute is external */

        if (!get_external_fact(log_stream, case_law, adjust, echo, inputable_latex, verbose,
                               hypothetical_reports, hypothetical_changes, level,
                               distances_filename, weights_filename, report_filename,
                               attribute_pointer, attribute_number, vector_pointer)) {

            /* quit */
            free(vector_pointer);
            return NULL;
        }
    } else {
        /* the attribute is local */

        if (!get_local_fact(log_stream, attribute_pointer, vector_pointer, echo, level)) {
            /* quit */
            free(vector_pointer);
            return NULL;
        }
    }
    vector_pointer->next = NULL;
    return vector_pointer;
}

```

```

extern vector_element *
Get_Facts(
    file log_stream,
    case_law_specification case_law,
    area *area_pointer,
    boolean adjust,
    boolean echo,
    boolean inputable_latex,
    boolean verbose,
    cardinal hypothetical_reports,
    cardinal hypothetical_changes,
    cardinal level,
    string distances_filename,
    string weights_filename,
    string report_filename)

/* Interrogates the user as to the values of local attributes, in the instant case, in the area
   pointed to by area_pointer. Resolves the value of external attributes by reference to the
   relevant area, recursively invoking Case_Law(). Prompts the user by writing to stdout;
   reads the user's response from stdin. Returns a pointer to a fact vector containing the facts
   of the instant case; or NULL, if the user chooses to quit. */

{
    attribute *attribute_pointer;
    vector_element *facts_head = NULL,
        *vector_pointer = NULL;
    cardinal count = 1;

    /* for every attribute ... */
    for (attribute_pointer = area_pointer→attribute_head; attribute_pointer ≠ NULL;
        attribute_pointer = attribute_pointer→next)
        if (facts_head ≡ NULL) {
            /* this is the first attribute */
            if ((facts_head = get_fact(log_stream, case_law, adjust, echo, inputable_latex,
                verbose, hypothetical_reports, hypothetical_changes, level,
                distances_filename, weights_filename, report_filename,
                attribute_pointer, 1)) ≡ NULL)

                /* quit */

            return NULL;

            vector_pointer = facts_head;

```

```
    } else {
        /* this is not the first attribute */
        count++;
        if ((vector_pointer→next =
            get_fact(log_stream, case_law, adjust, echo, inputable_latex,
                    verbose, hypothetical_reports, hypothetical_changes, level,
                    distances_filename, weights_filename, report_filename,
                    attribute_pointer, count)) ≡ NULL)

            /* quit */

            return NULL;

        vector_pointer = vector_pointer→next;
    }
    return facts_head;
}
```


11

The ODOMETER module

odometer.h

```
/* This is the header file for the ODOMETER module. It is also included by the CASES, DUMPER
and REPORTER modules. */
/* external functions */
extern relative_distance_type
Relative_Distance(
    distance_type x,
    distance_type y);
extern void
Calculate_Distances(
    file distances_stream,
    file log_stream,
    area *area_pointer,
    case_law_specification case_law,
    vector_element *facts_head,
    boolean hypothetical,
    cardinal number,
    cardinal level);
```

odometer.c

```
/* This is the implementation file for the ODOMETER module. */
#include <stdio.h>
#include <math.h>
#include "shyster.h"
#include "cases.h"
#include "odometer.h"
#include "dumper.h"
#include "scales.h"
```

static void

```
error_exit(  
    file stream,  
    const string message)  
{  
    Write_Error_Message_And_Exit(stream, "Odometer", message);  
}
```

static void

```
warning(  
    file stream,  
    const string message,  
    cardinal level)  
{  
    Write_Warning_Message(stream, "Odometer", message, level);  
}
```

static void

```
zero_subdistance(  
    distance_subtype *subdistance_pointer)  
  
/* Sets the subdistance pointed to by subdistance_pointer to zero. */  
{  
    subdistance_pointer->infinite = 0;  
    subdistance_pointer->finite = 0.0;  
}
```

static void

```
zero_distance(  
    distance_type *distance_pointer)  
  
/* Sets the distance pointed to by distance_pointer to zero. */  
{  
    zero_subdistance(&distance_pointer->known);  
    zero_subdistance(&distance_pointer->unknown);  
}
```

```

static void
zero_correlation(
    correlation_type *correlation_pointer)

/* Sets the correlation coefficient pointed to by correlation_pointer to zero. */
{
    correlation_pointer→meaningless = FALSE;
    correlation_pointer→unweighted = 0.0;
    correlation_pointer→weighted = 0.0;
}

static void
zero_metrics(
    metrics_type *metrics_pointer)

/* Sets the metrics pointed to by metrics_pointer to zero. */
{
    zero_distance(&metrics_pointer→distance);
    metrics_pointer→number_of_known_differences = 0;
    metrics_pointer→number_of_known_pairs = 0;
    metrics_pointer→weighted_association_coefficient = 0.0;
    zero_correlation(&metrics_pointer→correlation_coefficient);
}

static relative_distance_type
relative_subdistance(
    distance_subtype x,
    distance_subtype y)

/* Returns NEARER, if the subdistance x is less than the subdistance y; returns FURTHER,
if x is greater than y; returns EQUIDISTANT, otherwise. */
{
    if ((x.infinite ≡ y.infinite) ∧ Is_Equal(x.finite, y.finite, Distance_Precision))
        return EQUIDISTANT;
    else if ((x.infinite < y.infinite) ∨
            ((x.infinite ≡ y.infinite) ∧ Is_Less(x.finite, y.finite, Distance_Precision)))
        return NEARER;
    else
        return FURTHER;
}

```

extern *relative_distance_type*

Relative_Distance(
 distance_type *x*,
 distance_type *y*)

/* Returns *NEARER*, if the distance *x* is less than the distance *y*; returns *FURTHER*, if *x* is greater than *y*; returns *EQUIDISTANT*, otherwise. */

```
{
  if ((x.known.infinite + x.unknown.infinite ≡
        y.known.infinite + y.unknown.infinite) ∧
       Is_Equal(x.known.finite + x.unknown.finite,
                 y.known.finite + y.unknown.finite, Distance_Precision))
    return EQUIDISTANT;
  else if ((x.known.infinite + x.unknown.infinite <
            y.known.infinite + y.unknown.infinite) ∨
           ((x.known.infinite + x.unknown.infinite ≡
            y.known.infinite + y.unknown.infinite) ∧
            Is_Less(x.known.finite + x.unknown.finite,
                    y.known.finite + y.unknown.finite, Distance_Precision)))
    return NEARER;
  else
    return FURTHER;
}
```

static void

add_weight(
 file *log_stream*,
 attribute_value_type *x*,
 attribute_value_type *y*,
 weight_type *weight*,
 metrics_type **metrics_pointer*,
 cardinal *level*)

/* Adds *weight* to the known distance in the metrics pointed to by *metrics_pointer*, if the attribute values *x* and *y* are known and different. Adds *weight* to the unknown distance in the metrics pointed to by *metrics_pointer*, if either of the attribute values *x* or *y* is UNKNOWN. */

```
{
  if (¬weight.infinite ∧ Is_Zero(weight.finite) ∧ ((x ≠ UNKNOWN) ∨ (y ≠ UNKNOWN)))
    warning(log_stream, "known_attribute_value_for_weightless_attribute", level);
  else if ((x ≡ UNKNOWN) ∨ (y ≡ UNKNOWN))
    if (weight.infinite)
      metrics_pointer→distance.unknown.infinite++;
    else
      metrics_pointer→distance.unknown.finite += weight.finite;
}
```

```

else {
    if (x ≠ y) {
        if (weight.infinite)
            metrics_pointer→distance.known.infinite++;
        else
            metrics_pointer→distance.known.finite += weight.finite;
    }
}
}

```

static void

sum_pair(

```

    attribute_value_type x,
    attribute_value_type y,
    weight_type weight,
    metrics_type *sum_pointer_X,
    correlation_type *sum_pointer_Y)

```

/ Adds the attribute values (weighted and unweighted) of both x and y to various of the metrics of sum_pointer_X and sum_pointer_Y, if both x and y are known. (These metrics are used here as temporary storage; the final sums are later used to calculate association and correlation coefficients.) */*

```

{
    floating_point temp;

    if ((x ≠ UNKNOWN) ∧ (y ≠ UNKNOWN)) {

        sum_pointer_X→number_of_known_pairs++;
        if (x ≠ y)
            sum_pointer_X→number_of_known_differences++;

        sum_pointer_X→weighted_association_coefficient += weight.finite;

        if (weight.infinite)

            /* one of the attributes is infinitely weighted, so use a "pseudo-infinite" weight for
               the calculation of weighted correlation coefficients */

            weight.finite = Very_Heavy_Indeed;

        (void) Attribute_Value(x, &temp);
        sum_pointer_X→correlation_coefficient.unweighted += temp;
        sum_pointer_X→correlation_coefficient.weighted += temp × weight.finite;

        (void) Attribute_Value(y, &temp);
        sum_pointer_Y→unweighted += temp;
        sum_pointer_Y→weighted += temp × weight.finite;
    }
}

```

static void

```
correlate_pair(
    attribute_value_type x,
    attribute_value_type y,
    floating_point mean_X,
    floating_point mean_Y,
    floating_point *numerator,
    floating_point *left_denominator,
    floating_point *right_denominator,
    weight_type weight)
```

/* Updates **numerator*, **left_denominator* and **right_denominator* appropriately, if both *x* and *y* are known: **left_denominator* is incremented by the square of the weighted value of *x* less *mean_X*; **right_denominator* is incremented by the square of the weighted value of *y* less *mean_Y*; **numerator* is incremented by the product of the weighted value of *x* less *mean_X* and the weighted value of *y* less *mean_Y*. These variables are later used in the calculation of the weighted correlation coefficient *r'* which is defined as

$$r' = \frac{\sum_{i=1}^n (A_{ij} \times w_i - \bar{A}'_j) (A_{ik} \times w_i - \bar{A}'_k)}{\sqrt{\sum_{i=1}^n (A_{ij} \times w_i - \bar{A}'_j)^2 \sum_{i=1}^n (A_{ik} \times w_i - \bar{A}'_k)^2}}$$

where A_{ij} is the value of the i th attribute for the j th case, w_i is the weight of the i th attribute, and \bar{A}'_j is the weighted mean of all attribute values for the j th case. (**numerator*, **left_denominator* and **right_denominator* are so-named because they form the numerator, and the left and right side of the (square of the) denominator, in the above formula.) */

```
{
    floating_point temp_X,
    temp_Y;

    if ((x ≠ UNKNOWN) ∧ (y ≠ UNKNOWN)) {
        if (weight.infinite)

            /* one of the attributes is infinitely weighted, so use a “pseudo-infinite” weight for
            the calculation of weighted correlation coefficients */

            weight.finite = Very_Heavy_Indeed;

        (void) Attribute_Value(x, &temp_X);
        (void) Attribute_Value(y, &temp_Y);

        *numerator += (temp_X × weight.finite - mean_X) ×
            (temp_Y × weight.finite - mean_Y);
        *left_denominator += (temp_X × weight.finite - mean_X) ×
            (temp_X × weight.finite - mean_X);
        *right_denominator += (temp_Y × weight.finite - mean_Y) ×
            (temp_Y × weight.finite - mean_Y);
    }
}
```

static void

calculate_case_means(

matrix_element **matrix_pointer*,
 vector_element **vector_pointer*,
 attribute **attribute_pointer*,
 metrics_type **metrics_pointer*,
 correlation_type **correlation_pointer*)

/* Calculates the mean attribute values for a leading case and the instant case (their attribute values are pointed to by *matrix_pointer* and *vector_pointer*, respectively) and stores them as the correlation coefficients in **metrics_pointer* and **correlation_pointer*, respectively. (These correlation coefficients are used here as temporary storage; their values are later used to calculate the actual correlation coefficients.) **attribute_pointer* is the head of the list of attributes for this area. */

```
{
  while (matrix_pointer ≠ NULL) {
    sum_pair(matrix_pointer→attribute_value, vector_pointer→attribute_value,
            attribute_pointer→weight, metrics_pointer, correlation_pointer);
    matrix_pointer = matrix_pointer→case_next;
    vector_pointer = vector_pointer→next;
    attribute_pointer = attribute_pointer→next;
  }
  if (metrics_pointer→number_of_known_pairs ≠ 0) {
    metrics_pointer→correlation_coefficient.unweighted /=
      metrics_pointer→number_of_known_pairs;
    metrics_pointer→correlation_coefficient.weighted /=
      metrics_pointer→number_of_known_pairs;
    correlation_pointer→unweighted /=
      metrics_pointer→number_of_known_pairs;
    correlation_pointer→weighted /=
      metrics_pointer→number_of_known_pairs;
  }
}
```

static void

calculate_case_metrics(

file *log_stream*,
 matrix_element **matrix_pointer*,
 vector_element **vector_pointer*,
 attribute **attribute_pointer*,
 metrics_type **metrics_pointer*,
 boolean **correlation_coefficients*,
 cardinal *level*)

/* Calculates the metrics for a leading case and the instant case (their attribute values are pointed to by *matrix_pointer* and *vector_pointer*, respectively) and stores them in **metrics_pointer*. **attribute_pointer* is the head of the list of attributes for this area. **correlation_coefficients* is set to *TRUE*, if the correlation coefficients are meaningful (i.e. neither of the two cases has all attribute values equal). */

```

{
    correlation_type vector_means,
        numerator,
        left_denominator,
        right_denominator;
    weight_type unit_weight = { FALSE, 1.0 };

    zero_correlation(&vector_means);
    zero_correlation(&numerator);
    zero_correlation(&left_denominator);
    zero_correlation(&right_denominator);

    calculate_case_means(matrix_pointer, vector_pointer, attribute_pointer,
        metrics_pointer, &vector_means);
    while (attribute_pointer ≠ NULL) {
        add_weight(log_stream, matrix_pointer→attribute_value,
            vector_pointer→attribute_value,
            attribute_pointer→weight, metrics_pointer, level);

        correlate_pair(matrix_pointer→attribute_value, vector_pointer→attribute_value,
            metrics_pointer→correlation_coefficient.unweighted, vector_means.unweighted,
            &numerator.unweighted, &left_denominator.unweighted,
            &right_denominator.unweighted, unit_weight);

        correlate_pair(matrix_pointer→attribute_value, vector_pointer→attribute_value,
            metrics_pointer→correlation_coefficient.weighted, vector_means.weighted,
            &numerator.weighted, &left_denominator.weighted,
            &right_denominator.weighted, attribute_pointer→weight);

        matrix_pointer = matrix_pointer→case_next;
        vector_pointer = vector_pointer→next;
        attribute_pointer = attribute_pointer→next;
    }
    metrics_pointer→weighted_association_coefficient =
        metrics_pointer→distance.known.finite /
        metrics_pointer→weighted_association_coefficient;
    if (Is_Zero(left_denominator.unweighted × right_denominator.unweighted))
        /* either this case or the instant case has all attribute values equal: the correlation
        coefficients are meaningless */
        metrics_pointer→correlation_coefficient.meaningless = TRUE;
    else {
        metrics_pointer→correlation_coefficient.unweighted = numerator.unweighted /
            (floating_point) sqrt((double)
                (left_denominator.unweighted × right_denominator.unweighted));
        metrics_pointer→correlation_coefficient.weighted = numerator.weighted /
            (floating_point) sqrt((double)
                (left_denominator.weighted × right_denominator.weighted));
        *correlation_coefficients = TRUE;
    }
}

```


static void

```
calculate_ideal_point_means(
    vector_element *vector_pointer_X,
    vector_element *vector_pointer_Y,
    attribute *attribute_pointer,
    metrics_type *metrics_pointer,
    correlation_type *correlation_pointer)
```

/* Calculates the mean attribute values for an ideal point and the instant case (their attribute values are pointed to by *vector_pointer_X* and *vector_pointer_Y*, respectively) and stores them as the correlation coefficients in **metrics_pointer* and **correlation_pointer*, respectively. (These correlation coefficients are used here as temporary storage; their values are later used to calculate the actual correlation coefficients.) **attribute_pointer* is the head of the list of attributes for this area. */

```
{
    while (vector_pointer_X ≠ NULL) {
        sum_pair(vector_pointer_X→attribute_value, vector_pointer_Y→attribute_value,
            attribute_pointer→weight, metrics_pointer, correlation_pointer);
        vector_pointer_X = vector_pointer_X→next;
        vector_pointer_Y = vector_pointer_Y→next;
        attribute_pointer = attribute_pointer→next;
    }
    if (metrics_pointer→number_of_known_pairs ≠ 0) {
        metrics_pointer→correlation_coefficient.unweighted /=
            metrics_pointer→number_of_known_pairs;
        metrics_pointer→correlation_coefficient.weighted /=
            metrics_pointer→number_of_known_pairs;
        correlation_pointer→unweighted /=
            metrics_pointer→number_of_known_pairs;
        correlation_pointer→weighted /=
            metrics_pointer→number_of_known_pairs;
    }
}
```

static void

```
calculate_ideal_point_metrics(
    file log_stream,
    vector_element *vector_pointer_X,
    vector_element *vector_pointer_Y,
    attribute *attribute_pointer,
    metrics_type *metrics_pointer,
    boolean *correlation_coefficients,
    cardinal level)
```

/* Calculates the metrics for an ideal point and the instant case (their attribute values are pointed to by *vector_pointer_X* and *vector_pointer_Y*, respectively) and stores them in **metrics_pointer*. **attribute_pointer* is the head of the list of attributes for this area. **correlation_coefficients* is set to *TRUE*, if the correlation coefficients are meaningful (i.e. neither the ideal point nor the instant case has all attribute values equal). */

```

{
    correlation_type vector_means,
        numerator,
        left_denominator,
        right_denominator;
    weight_type unit_weight = { FALSE, 1.0 };

    zero_correlation(&vector_means);
    zero_correlation(&numerator);
    zero_correlation(&left_denominator);
    zero_correlation(&right_denominator);

    calculate_ideal_point_means(vector_pointer_X, vector_pointer_Y, attribute_pointer,
        metrics_pointer, &vector_means);

    while (attribute_pointer ≠ NULL) {
        add_weight(log_stream, vector_pointer_X→attribute_value,
            vector_pointer_Y→attribute_value,
            attribute_pointer→weight, metrics_pointer, level);

        correlate_pair(vector_pointer_X→attribute_value, vector_pointer_Y→attribute_value,
            metrics_pointer→correlation_coefficient.unweighted, vector_means.unweighted,
            &numerator.unweighted, &left_denominator.unweighted,
            &right_denominator.unweighted, unit_weight);

        correlate_pair(vector_pointer_X→attribute_value, vector_pointer_Y→attribute_value,
            metrics_pointer→correlation_coefficient.weighted, vector_means.weighted,
            &numerator.weighted, &left_denominator.weighted,
            &right_denominator.weighted, attribute_pointer→weight);

        vector_pointer_X = vector_pointer_X→next;
        vector_pointer_Y = vector_pointer_Y→next;
        attribute_pointer = attribute_pointer→next;
    }
    metrics_pointer→weighted_association_coefficient =
        metrics_pointer→distance.known.finite /
        metrics_pointer→weighted_association_coefficient;

    if (Is_Zero(left_denominator.unweighted × right_denominator.unweighted))

        /* either this ideal point or the instant case has all attribute values equal: the correla-
            tion coefficients are meaningless */

        metrics_pointer→correlation_coefficient.meaningless = TRUE;
    else {
        metrics_pointer→correlation_coefficient.unweighted = numerator.unweighted /
            (floating_point) sqrt((double)
                (left_denominator.unweighted × right_denominator.unweighted));
        metrics_pointer→correlation_coefficient.weighted = numerator.weighted /
            (floating_point) sqrt((double)
                (left_denominator.weighted × right_denominator.weighted));
        *correlation_coefficients = TRUE;
    }
}

```

```

static void
calculate_centroid_means(
    centroid_element *centroid_pointer,
    vector_element *vector_pointer,
    attribute *attribute_pointer,
    metrics_type *metrics_pointer,
    correlation_type *correlation_pointer)
/* Calculates the mean attribute values for a centroid and the instant case (their attribute
values are pointed to by centroid_pointer and vector_pointer, respectively) and stores them as
the correlation coefficients in *metrics_pointer and *correlation_pointer, respectively. (These
correlation coefficients are used here as temporary storage; their values are later used to
calculate the actual correlation coefficients.) *attribute_pointer is the head of the list of
attributes for this area. */
{
    floating_point temp;
    weight_type weight;
    while (centroid_pointer ≠ NULL) {
        if ((¬centroid_pointer→unknown) ∧ (vector_pointer→attribute_value ≠ UNKNOWN)) {
            metrics_pointer→number_of_known_pairs++;
            if (Nearest_Attribute_Value(centroid_pointer→value) ≠
                vector_pointer→attribute_value)
                metrics_pointer→number_of_known_differences++;
            weight = attribute_pointer→weight;
            metrics_pointer→weighted_association_coefficient += weight.finite;
            /* use the actual centroid value, not the nearest attribute value (as is done for
            leading cases and ideal points) */
            metrics_pointer→correlation_coefficient.unweighted += centroid_pointer→value;
            metrics_pointer→correlation_coefficient.weighted +=
                centroid_pointer→value × weight.finite;
            (void) Attribute_Value(vector_pointer→attribute_value, &temp);
            correlation_pointer→unweighted += temp;
            correlation_pointer→weighted += temp × weight.finite;
        }
        centroid_pointer = centroid_pointer→next;
        vector_pointer = vector_pointer→next;
        attribute_pointer = attribute_pointer→next;
    }
    if (metrics_pointer→number_of_known_pairs ≠ 0) {
        metrics_pointer→correlation_coefficient.unweighted /=
            metrics_pointer→number_of_known_pairs;
        metrics_pointer→correlation_coefficient.weighted /=
            metrics_pointer→number_of_known_pairs;
        correlation_pointer→unweighted /=
            metrics_pointer→number_of_known_pairs;
        correlation_pointer→weighted /=
            metrics_pointer→number_of_known_pairs;
    }
}

```

static void

```

calculate_centroid_metrics(
    file log_stream,
    centroid_element *centroid_pointer,
    vector_element *vector_pointer,
    attribute *attribute_pointer,
    metrics_type *metrics_pointer,
    boolean *correlation_coefficients,
    cardinal level)

/* Calculates the metrics for a centroid and the instant case (their attribute values are pointed
to by centroid_pointer and vector_pointer, respectively) and stores them in *metrics_pointer.
*attribute_pointer is the head of the list of attributes for this area. *correlation_coefficients
is set to TRUE, if the correlation coefficients are meaningful (i.e. neither the centroid nor
the instant case has all attribute values equal). */

{
    correlation_type vector_means,
        numerator,
        left_denominator,
        right_denominator;
    floating_point temp,
        weight;

    zero_correlation(&vector_means);
    zero_correlation(&numerator);
    zero_correlation(&left_denominator);
    zero_correlation(&right_denominator);

    calculate_centroid_means(centroid_pointer, vector_pointer, attribute_pointer,
        metrics_pointer, &vector_means);

    while (attribute_pointer ≠ NULL) {
        if (centroid_pointer→unknown)
            add_weight(log_stream, UNKNOWN, vector_pointer→attribute_value,
                attribute_pointer→weight, metrics_pointer, level);
        else {
            add_weight(log_stream, Nearest_Attribute_Value(centroid_pointer→value),
                vector_pointer→attribute_value, attribute_pointer→weight,
                metrics_pointer, level);

            if (vector_pointer→attribute_value ≠ UNKNOWN) {
                if (attribute_pointer→weight.infinite)

                    /* one of the attributes is infinitely weighted, so use a “pseudo-infinite”
                    weight for the calculation of weighted correlation coefficients */

                    weight = Very_Heavy_Indeed;
                else
                    weight = attribute_pointer→weight.finite;

                (void) Attribute_Value(vector_pointer→attribute_value, &temp);
            }
        }
    }
}

```

```

/* use the actual centroid value, not the nearest attribute value (as is done for
   leading cases and ideal points) */

numerator.unweighted += (centroid_pointer->value -
    metrics_pointer->correlation_coefficient.unweighted) ×
    (temp - vector_means.unweighted);
left_denominator.unweighted += (centroid_pointer->value -
    metrics_pointer->correlation_coefficient.unweighted) ×
    (centroid_pointer->value -
    metrics_pointer->correlation_coefficient.unweighted);
right_denominator.unweighted += (temp - vector_means.unweighted) ×
    (temp - vector_means.unweighted);

numerator.weighted += (centroid_pointer->value × weight -
    metrics_pointer->correlation_coefficient.weighted) ×
    (temp × weight - vector_means.weighted);
left_denominator.weighted += (centroid_pointer->value × weight -
    metrics_pointer->correlation_coefficient.weighted) ×
    (centroid_pointer->value × weight -
    metrics_pointer->correlation_coefficient.weighted);
right_denominator.weighted += (temp × weight - vector_means.weighted) ×
    (temp × weight - vector_means.weighted);
    }
}
centroid_pointer = centroid_pointer->next;
vector_pointer = vector_pointer->next;
attribute_pointer = attribute_pointer->next;
}
metrics_pointer->weighted_association_coefficient =
    metrics_pointer->distance.known.finite /
    metrics_pointer->weighted_association_coefficient;

if (Is_Zero(left_denominator.unweighted × right_denominator.unweighted))

    /* either this centroid or the instant case has all attribute values equal: the correlation
       coefficients are meaningless */

    metrics_pointer->correlation_coefficient.meaningless = TRUE;
else {
    metrics_pointer->correlation_coefficient.unweighted = numerator.unweighted /
        (floating_point) sqrt((double)
            (left_denominator.unweighted × right_denominator.unweighted));
    metrics_pointer->correlation_coefficient.weighted = numerator.weighted /
        (floating_point) sqrt((double)
            (left_denominator.weighted × right_denominator.weighted));
    *correlation_coefficients = TRUE;
}
}

static weight_list_element *
result_weight(
    weight_list_element *weights_pointer,
    result *result_pointer,
    result *target_result_pointer)

```

```

/* Returns the result weight (from the list of result weights pointed to by weights_pointer)
which corresponds to the result pointed to by target_result_pointer. (*result_pointer is the
head of the list of results for this area.) */

{
  while (result_pointer ≠ target_result_pointer) {
    weights_pointer = weights_pointer→next;
    result_pointer = result_pointer→next;
  }
  return weights_pointer;
}

static void
calculate_specified_directions(
  attribute *attribute_pointer,
  vector_element *vector_pointer,
  result *result_head)

/* For every attribute, if the attribute value in the instant case is directed towards a result,
adds the weight of the attribute to the specified direction for that result. *attribute_pointer
is the head of the list of attributes for this area. The attribute values of the instant case
are pointed to by vector_pointer. */

{
  direction_list_element *direction_pointer;
  weight_list_element *weights_pointer;

  while (attribute_pointer ≠ NULL) {
    switch (vector_pointer→attribute_value) {
      case YES:
        direction_pointer = attribute_pointer→yes_direction_head;
        break;
      case NO:
        direction_pointer = attribute_pointer→no_direction_head;
        break;
      case UNKNOWN:
        direction_pointer = attribute_pointer→unknown_direction_head;
        break;
    }
    while (direction_pointer ≠ NULL) {
      weights_pointer = result_weight(attribute_pointer→weights_head,
        result_head, direction_pointer→result);

      if (weights_pointer→weight.infinite)
        direction_pointer→result→specified_direction.infinite++;

      else
        direction_pointer→result→specified_direction.finite +=
          weights_pointer→weight.finite;

      direction_pointer = direction_pointer→next;
    }
    vector_pointer = vector_pointer→next;
    attribute_pointer = attribute_pointer→next;
  }
}

```

static void

```
calculate_other_directions(
    area *area_pointer,
    vector_element *vector_pointer)
```

/* For every attribute, if only one ideal point has an attribute value matching that of the instant case, adds the weight of the attribute to the ideal point direction for that ideal point's result. Similarly, for every attribute, if only one centroid has an attribute value matching that of the instant case, adds the weight of the attribute to the centroid direction for that centroid's result. The attribute values of the instant case are pointed to by *vector_pointer*.

UNKNOWN values are ignored when counting matches. This differs from the calculation of specified directions (in *calculate_specified_directions()*) because an UNKNOWN value in an ideal point could mean "don't know," while in a centroid it just indicates an absence of values; by contrast, an UNKNOWN specified direction means "an UNKNOWN value for this attribute suggests this result." */

```
{
    result *result_pointer,
    *ideal_point_matching_result,
    *centroid_matching_result;
    attribute *attribute_pointer = area_pointer->attribute_head;
    vector_element *ideal_point_pointer;
    centroid_element *centroid_pointer;
    cardinal count,
    ideal_point_matches_count,
    centroid_matches_count;
    weight_list_element *weights_pointer;

    while (vector_pointer != NULL) {

        if (vector_pointer->attribute_value != UNKNOWN) {

            /* count the number of ideal points and centroids with the same value for this
               attribute as has the instant case */

            ideal_point_matches_count = 0;
            centroid_matches_count = 0;
            result_pointer = area_pointer->result_head;
            while (result_pointer != NULL) {
                ideal_point_pointer = result_pointer->ideal_point_head;
                centroid_pointer = result_pointer->centroid_head;
                for (count = 1; count < attribute_pointer->number; count++) {
                    if (ideal_point_pointer != NULL)
                        ideal_point_pointer = ideal_point_pointer->next;
                    if (centroid_pointer != NULL)
                        centroid_pointer = centroid_pointer->next;
                }
            }
        }
    }
}
```

```

if ((ideal_point_pointer ≠ NULL) ∧
      (ideal_point_pointer→attribute_value ≡
       vector_pointer→attribute_value)) {
    ideal_point_matches_count++;
    ideal_point_matching_result = result_pointer;
}
if ((centroid_pointer ≠ NULL) ∧
      ((centroid_pointer→unknown ∧
        (vector_pointer→attribute_value ≡ UNKNOWN)) ∨
       (Nearest_Attribute_Value(centroid_pointer→value) ≡
        vector_pointer→attribute_value))) {
    centroid_matches_count++;
    centroid_matching_result = result_pointer;
}
result_pointer = result_pointer→next;
}

if (ideal_point_matches_count ≡ 1) {

    /* add the weight of the attribute to the ideal point direction for the matching
       ideal point's result */

    weights_pointer = result_weight(attribute_pointer→weights_head,
                                     area_pointer→result_head, ideal_point_matching_result);

    if (weights_pointer→weight.infinite)
        ideal_point_matching_result→ideal_point_direction.infinite++;
    else
        ideal_point_matching_result→ideal_point_direction.finite +=
            weights_pointer→weight.finite;
}

if (centroid_matches_count ≡ 1) {

    /* add the weight of the attribute to the centroid direction for the matching
       centroid's result */

    weights_pointer = result_weight(attribute_pointer→weights_head,
                                     area_pointer→result_head, centroid_matching_result);

    if (weights_pointer→weight.infinite)
        centroid_matching_result→centroid_direction.infinite++;
    else
        centroid_matching_result→centroid_direction.finite +=
            weights_pointer→weight.finite;
}
}
attribute_pointer = attribute_pointer→next;
vector_pointer = vector_pointer→next;
}
}

```


static void

find_nearest_and_strongest(*area *area_pointer*)

/ Finds the nearest result, nearest ideal point, nearest centroid, and strongest directions (specified, ideal point, and centroid) in the area pointed to by area_pointer, and adjusts various pointers in *area_pointer to point to them. */*

```
{
    result *result_pointer,
        *equidistant_pointer,
        *nearest_result = NULL;
    relative_distance_type relative_distance;
    kase *nearest_neighbour;

    area_pointer→nearest_result = NULL;
    area_pointer→nearest_ideal_point = NULL;
    area_pointer→nearest_centroid = NULL;
    area_pointer→strongest_specified_direction = NULL;
    area_pointer→strongest_ideal_point_direction = NULL;
    area_pointer→strongest_centroid_direction = NULL;

    /* for every result ... */

    for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
        result_pointer = result_pointer→next) {

        result_pointer→equidistant_next = NULL;

        if (result_pointer→nearest_known_compared_with_unknown ≡ FURTHER)
            nearest_neighbour = result_pointer→nearest_unknown_case;
        else
            nearest_neighbour = result_pointer→nearest_known_case;

        if (nearest_neighbour ≠ NULL)

            /* this result has a nearest neighbour (i.e. it has at least one case) */

            if (nearest_result ≡ NULL)

                /* no nearest result has been found yet, so this result is the nearest so far */

                nearest_result = result_pointer;

            else {

                /* a nearest result has previously been found, so compare the nearest neighbour
                for this result with the nearest neighbour for that nearest result */

                if (nearest_result→nearest_known_compared_with_unknown ≡ FURTHER)
                    relative_distance = Relative_Distance(nearest_neighbour→metrics.distance,
                        nearest_result→nearest_unknown_case→metrics.distance);
                else
                    relative_distance = Relative_Distance(nearest_neighbour→metrics.distance,
                        nearest_result→nearest_known_case→metrics.distance);
            }
        }
    }
}
```

```

if (relative_distance  $\equiv$  EQUIDISTANT) {
    /* the two cases are equidistant from the instant case, so add this result to
       the end of the list of equidistant results */

    for (equidistant_pointer = nearest_result;
         equidistant_pointer→equidistant_next  $\neq$  NULL;
         equidistant_pointer = equidistant_pointer→equidistant_next);
    equidistant_pointer→equidistant_next = result_pointer;

} else if (relative_distance  $\equiv$  NEARER)

    /* the nearest neighbour for this result is nearer to the instant case than the
       previous nearest neighbour, so this result becomes the nearest result */

    nearest_result = result_pointer;
}

/* check whether this result has the nearest ideal point */

result_pointer→equidistant_ideal_point_next = NULL;
if (result_pointer→ideal_point_head  $\neq$  NULL) {
    if (area_pointer→nearest_ideal_point  $\equiv$  NULL)
        area_pointer→nearest_ideal_point = result_pointer;
    else if ((relative_distance =
               Relative_Distance(result_pointer→ideal_point_metrics.distance,
                                   area_pointer→nearest_ideal_point→
                                   ideal_point_metrics.distance))  $\equiv$  EQUIDISTANT) {
        for (equidistant_pointer = area_pointer→nearest_ideal_point;
             equidistant_pointer→equidistant_ideal_point_next  $\neq$  NULL;
             equidistant_pointer = equidistant_pointer→equidistant_ideal_point_next);
        equidistant_pointer→equidistant_ideal_point_next = result_pointer;
    } else if (relative_distance  $\equiv$  NEARER)
        area_pointer→nearest_ideal_point = result_pointer;
}

/* check whether this result has the nearest centroid */

result_pointer→equidistant_centroid_next = NULL;
if (result_pointer→centroid_head  $\neq$  NULL) {
    if (area_pointer→nearest_centroid  $\equiv$  NULL)
        area_pointer→nearest_centroid = result_pointer;
    else if ((relative_distance =
               Relative_Distance(result_pointer→centroid_metrics.distance,
                                   area_pointer→nearest_centroid→
                                   centroid_metrics.distance))  $\equiv$  EQUIDISTANT) {
        for (equidistant_pointer = area_pointer→nearest_centroid;
             equidistant_pointer→equidistant_centroid_next  $\neq$  NULL;
             equidistant_pointer = equidistant_pointer→equidistant_centroid_next);
        equidistant_pointer→equidistant_centroid_next = result_pointer;
    } else if (relative_distance  $\equiv$  NEARER)
        area_pointer→nearest_centroid = result_pointer;
}

```

```

/* check whether this result has the strongest specified direction */
result_pointer→equidistant_specified_direction_next = NULL;
if (area_pointer→strongest_specified_direction ≡ NULL)
    area_pointer→strongest_specified_direction = result_pointer;
else if ((relative_distance = relative_subdistance(result_pointer→specified_direction,
    area_pointer→strongest_specified_direction→
    specified_direction)) ≡ EQUIDISTANT) {
    for (equidistant_pointer = area_pointer→strongest_specified_direction;
        equidistant_pointer→equidistant_specified_direction_next ≠ NULL;
        equidistant_pointer =
            equidistant_pointer→equidistant_specified_direction_next);
        equidistant_pointer→equidistant_specified_direction_next = result_pointer;
    } else if (relative_distance ≡ FURTHER)
        area_pointer→strongest_specified_direction = result_pointer;

/* check whether this result has the strongest ideal point direction */
result_pointer→equidistant_ideal_point_direction_next = NULL;
if (area_pointer→strongest_ideal_point_direction ≡ NULL)
    area_pointer→strongest_ideal_point_direction = result_pointer;
else if ((relative_distance = relative_subdistance(result_pointer→ideal_point_direction,
    area_pointer→strongest_ideal_point_direction→
    ideal_point_direction)) ≡ EQUIDISTANT) {
    for (equidistant_pointer = area_pointer→strongest_ideal_point_direction;
        equidistant_pointer→equidistant_ideal_point_direction_next ≠ NULL;
        equidistant_pointer =
            equidistant_pointer→equidistant_ideal_point_direction_next);
        equidistant_pointer→equidistant_ideal_point_direction_next = result_pointer;
    } else if (relative_distance ≡ FURTHER)
        area_pointer→strongest_ideal_point_direction = result_pointer;

/* check whether this result has the strongest centroid direction */
result_pointer→equidistant_centroid_direction_next = NULL;
if (area_pointer→strongest_centroid_direction ≡ NULL)
    area_pointer→strongest_centroid_direction = result_pointer;
else if ((relative_distance = relative_subdistance(result_pointer→centroid_direction,
    area_pointer→strongest_centroid_direction→
    centroid_direction)) ≡ EQUIDISTANT) {
    for (equidistant_pointer = area_pointer→strongest_centroid_direction;
        equidistant_pointer→equidistant_centroid_direction_next ≠ NULL;
        equidistant_pointer =
            equidistant_pointer→equidistant_centroid_direction_next);
        equidistant_pointer→equidistant_centroid_direction_next = result_pointer;
    } else if (relative_distance ≡ FURTHER)
        area_pointer→strongest_centroid_direction = result_pointer;
}
area_pointer→nearest_result = nearest_result;

```



```

    highest_ranking_result = result_pointer;
    highest_ranking_court = nearest_neighbour→court_rank;
    one_highest_ranking_court = TRUE;

    /* this must also be the most recent case for this rank so far */
    most_recent_result = result_pointer;
    most_recent_year = nearest_neighbour→year;
    one_most_recent_year = TRUE;
} else if (nearest_neighbour→court_rank ≡ highest_ranking_court) {
    /* there are two or more equidistant cases with courts of this rank */
    one_highest_ranking_court = FALSE;
    if (nearest_neighbour→year > most_recent_year) {
        /* this is the most recent case for this rank so far */
        most_recent_result = result_pointer;
        most_recent_year = nearest_neighbour→year;
        one_most_recent_year = TRUE;
    } else if (nearest_neighbour→year ≡ most_recent_year)
        /* this case is exactly as old as the most recent case yet found for this
           rank */
        one_most_recent_year = FALSE;
    }
} else {
    /* this case has no court, or a court with no rank */
    if ((most_recent_year ≡ 0) ∨
        (nearest_neighbour→year > most_recent_year)) {
        /* this is the first case for any result, or this case is more recent than the most
           recent yet found */
        most_recent_result = result_pointer;
        most_recent_year = nearest_neighbour→year;
        one_most_recent_year = TRUE;
    } else if (nearest_neighbour→year ≡ most_recent_year)
        /* this decision is exactly as old as the most recent decision yet found */
        one_most_recent_year = FALSE;
    }
}
if (one_highest_ranking_court) {
    /* there was only one highest ranking court, so choose that case's result */
    area_pointer→nearest_result = highest_ranking_result;
    warning(log_stream,
            "equidistant_results; nearest_result_chosen"
            "on the basis of rank", level);
return;
}

```

```

if (one_most_recent_year) {
    /* there was only one case decided as recently as this, so choose that case's result */
    area_pointer→nearest_result = most_recent_result;
    warning(log_stream,
            "equidistant_results; nearest_result_chosen"
            "on the basis of recentness", level);
    return;
}
error_exit(log_stream, "can't choose between equidistant results");
}

```

extern void

```

Calculate_Distances(
    file distances_stream,
    file log_stream,
    area *area_pointer,
    case_law_specification case_law,
    vector_element *facts_head,
    boolean hypothetical,
    cardinal number,
    cardinal level)

/* Calculates the distances between the instant case and every leading case, ideal point
and centroid in the area pointed to by area_pointer, and writes a table of distances to
distances_stream (if it is not NULL). If number is not zero then the instant case is actually
a hypothetical (if hypothetical is TRUE) or an instantiation, and number is its number. */

{
    result *result_pointer;
    kase *case_pointer,
    *equidistant_pointer;
    relative_distance_type relative_distance;

    /* for every result ... */

    for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
         result_pointer = result_pointer→next) {

        /* initialize result details */

        result_pointer→nearest_known_case = NULL;
        result_pointer→nearest_unknown_case = NULL;
        zero_metrics(&result_pointer→ideal_point_metrics);
        zero_metrics(&result_pointer→centroid_metrics);
        zero_subdistance(&result_pointer→specified_direction);
        zero_subdistance(&result_pointer→ideal_point_direction);
        zero_subdistance(&result_pointer→centroid_direction);
    }
}

```

```

/* for every case with this result ... */
for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
     case_pointer = case_pointer→next) {

    /* initialize case details */

    zero_metrics(&case_pointer→metrics);
    case_pointer→equidistant_known_next = NULL;
    case_pointer→equidistant_unknown_next = NULL;

    calculate_case_metrics(log_stream, case_pointer→matrix_head,
                          facts_head, area_pointer→attribute_head, &case_pointer→metrics,
                          &area_pointer→correlation_coefficients, level);

    if (¬Is_Zero_Subdistance(case_pointer→metrics.distance.unknown)) {

        /* the case has unknown distance, so check to see whether it is the nearest
           unknown neighbour */

        if (result_pointer→nearest_unknown_case ≡ NULL)
            result_pointer→nearest_unknown_case = case_pointer;
        else if ((relative_distance = Relative_Distance(case_pointer→metrics.distance,
                                                       result_pointer→nearest_unknown_case→
                                                       metrics.distance)) ≡ EQUIDISTANT) {
            for (equidistant_pointer = result_pointer→nearest_unknown_case;
                 equidistant_pointer→equidistant_unknown_next ≠ NULL;
                 equidistant_pointer
                 = equidistant_pointer→equidistant_unknown_next);
            equidistant_pointer→equidistant_unknown_next = case_pointer;
        } else if (relative_distance ≡ NEARER)
            result_pointer→nearest_unknown_case = case_pointer;

    } else {

        /* the case has no unknown distance, so check to see whether it is the nearest
           known neighbour */

        if (result_pointer→nearest_known_case ≡ NULL)
            result_pointer→nearest_known_case = case_pointer;
        else if ((relative_distance = Relative_Distance(case_pointer→metrics.distance,
                                                       result_pointer→nearest_known_case→
                                                       metrics.distance)) ≡ EQUIDISTANT) {
            for (equidistant_pointer = result_pointer→nearest_known_case;
                 equidistant_pointer→equidistant_known_next ≠ NULL;
                 equidistant_pointer = equidistant_pointer→equidistant_known_next);
            equidistant_pointer→equidistant_known_next = case_pointer;
        } else if (relative_distance ≡ NEARER)
            result_pointer→nearest_known_case = case_pointer;

    }
}
}

```

```

/* note which of the nearest known neighbour and the nearest unknown neighbour is
the nearest neighbour */
if ((result_pointer→nearest_known_case ≡ NULL) ∧
      (result_pointer→nearest_unknown_case ≡ NULL))
    result_pointer→nearest_known_compared_with_unknown = EQUIDISTANT;
else if (result_pointer→nearest_known_case ≡ NULL)
    result_pointer→nearest_known_compared_with_unknown = FURTHER;
else if (result_pointer→nearest_unknown_case ≡ NULL)
    result_pointer→nearest_known_compared_with_unknown = NEARER;
else
    result_pointer→nearest_known_compared_with_unknown =
        Relative_Distance(result_pointer→nearest_known_case→metrics.distance,
                          result_pointer→nearest_unknown_case→metrics.distance);
if (result_pointer→ideal_point_head ≠ NULL) {
    calculate_ideal_point_metrics(log_stream, result_pointer→ideal_point_head,
                                  facts_head, area_pointer→attribute_head,
                                  &result_pointer→ideal_point_metrics,
                                  &area_pointer→correlation_coefficients, level);
}
calculate_centroid_metrics(log_stream, result_pointer→centroid_head,
                            facts_head, area_pointer→attribute_head, &result_pointer→centroid_metrics,
                            &area_pointer→correlation_coefficients, level);
}
calculate_specified_directions(area_pointer→attribute_head, facts_head,
                                area_pointer→result_head);
calculate_other_directions(area_pointer, facts_head);
find_nearest_and_strongest(area_pointer);
if (area_pointer→nearest_result→equidistant_next ≠ NULL)
    /* there are two or more equidistant results, so choose one of them */
    resolve_equidistant_results(log_stream, area_pointer, level);
if (distances_stream ≠ NULL) {
    if (number ≡ 0)
        /* the instant case is the uninstantiated and unhypothesized instant case */
        fprintf(distances_stream, "%s{%-s□area}\n\n"
                "%s{Instant□case}\n\n", Heading, area_pointer→identifier, Subheading);
    else if (hypothetical)
        /* the instant case is hypothetical number */
        fprintf(distances_stream, "%s{Hypothetical□%u}\n\n", Subheading, number);
    else
        /* the instant case is instantiation number */
        fprintf(distances_stream, "%s{Instantiation□%u}\n\n", Subheading, number);
    Write_Matrix(distances_stream, area_pointer, facts_head,
                  case_law.court_head, hypothetical, number);
}
}

```


12

The REPORTER module

reporter.h

```
/* This is the header file for the REPORTER module. It is also included by the CASES
   module. */

/* external function */

extern void
Write_Report(
    file report_stream,
    file log_stream,
    area *area_pointer,
    vector_element *facts_head,
    vector_element *original_facts,
    boolean verbose,
    boolean hypothetical,
    boolean same_result,
    cardinal number,
    cardinal level);
```

reporter.c

```
/* This is the implementation file for the REPORTER module. */

#include <stdio.h>
#include "shyster.h"
#include "cases.h"
#include "reporter.h"
#include "dumper.h"
#include "odometer.h"
```

static void

```

warning(
    file stream,
    const string message,
    cardinal level)
{
    Write_Warning_Message(stream, "Reporter", message, level);
}

```

static void

```

list_facts(
    file report_stream,
    vector_element *vector_pointer,
    attribute *attribute_pointer,
    cardinal count)

/* Lists the facts pointed to by vector_pointer by writing the appropriate string (YES, NO, or
UNKNOWN) for each attribute. *attribute_pointer is the head of the list of attributes for this
area. count is the number of attributes. */

{
    /* while there are still facts to list ... */
    while ((attribute_pointer ≠ NULL) ∧ (count ≠ 0)) {
        if (count ≡ 1)
            Write(report_stream, vector_pointer→attribute_value ≡ YES ?
                attribute_pointer→yes : vector_pointer→attribute_value ≡ NO ?
                attribute_pointer→no : attribute_pointer→unknown, ".", 1, Hang);
        else if (count ≡ 2)
            Write(report_stream, vector_pointer→attribute_value ≡ YES ?
                attribute_pointer→yes : vector_pointer→attribute_value ≡ NO ?
                attribute_pointer→no : attribute_pointer→unknown, "; and", 1, Hang);
        else
            Write(report_stream, vector_pointer→attribute_value ≡ YES ?
                attribute_pointer→yes : vector_pointer→attribute_value ≡ NO ?
                attribute_pointer→no : attribute_pointer→unknown, ";", 1, Hang);

        vector_pointer = vector_pointer→next;
        attribute_pointer = attribute_pointer→next;
        count--;
    }
}

```

static void

```

list_equidistant_cases_known_first(
    file report_stream,
    kase *known_case_pointer,
    kase *unknown_case_pointer,
    boolean short_names,
    boolean and)

/* Lists the case pointed to by known_case_pointer (and any known equidistant cases), then
the case pointed to by unknown_case_pointer (and any unknown equidistant cases). Writes
short case names, if short_names is TRUE. Writes “and” between the last two cases in the
list, if and is TRUE; writes “or”, otherwise. */

```

```

{
/* while there are still known cases to list ... */
while (known_case_pointer ≠ NULL) {
    /* write the case name with appropriate trailing characters */
    fprintf(report_stream, "{\\it_□%s", short_names ?
        known_case_pointer→short_name : known_case_pointer→name);
    if ((known_case_pointer→equidistant_known_next ≡ NULL) ∧
        (unknown_case_pointer ≡ NULL))

        /* this is the last case to list */
        fprintf(report_stream, "\\}/");

    else if (((known_case_pointer→equidistant_known_next ≠ NULL) ∧
        (known_case_pointer→equidistant_known_next→
            equidistant_known_next ≡ NULL) ∧
        (unknown_case_pointer ≡ NULL)) ∨
        ((known_case_pointer→equidistant_known_next ≡ NULL) ∧
        (unknown_case_pointer ≠ NULL) ∧
        (unknown_case_pointer→equidistant_unknown_next ≡ NULL)))

        /* this is the penultimate case to list */
        fprintf(report_stream, "\\}/_□%s\\n", and ? "and" : "or");

    else
        fprintf(report_stream, "},\\n");

    known_case_pointer = known_case_pointer→equidistant_known_next;
}

/* while there are still unknown cases to list ... */
while (unknown_case_pointer ≠ NULL) {
    /* write the case name with appropriate trailing characters */
    fprintf(report_stream, "{\\it_□%s", short_names ?
        unknown_case_pointer→short_name : unknown_case_pointer→name);
    if (unknown_case_pointer→equidistant_unknown_next ≡ NULL)

        /* this is the last case to list */
        fprintf(report_stream, "\\}/");

    else if (unknown_case_pointer→equidistant_unknown_next→
        equidistant_unknown_next ≡ NULL)

        /* this is the penultimate case to list */
        fprintf(report_stream, "\\}/_□%s\\n", and ? "and" : "or");

    else
        fprintf(report_stream, "},\\n");

    unknown_case_pointer = unknown_case_pointer→equidistant_unknown_next;
}
}

```

static void

```
list_equidistant_cases_unknown_first(
    file report_stream,
    kase *known_case_pointer,
    kase *unknown_case_pointer,
    boolean short_names,
    boolean and)
```

/* Lists the case pointed to by *unknown_case_pointer* (and any unknown equidistant cases), then the case pointed to by *known_case_pointer* (and any known equidistant cases). Writes short case names, if *short_names* is *TRUE*. Writes “and” between the last two cases in the list, if *and* is *TRUE*; writes “or”, otherwise. */

```
{
    /* while there are still unknown cases to list ... */
    while (unknown_case_pointer ≠ NULL) {
        /* write the case name with appropriate trailing characters */
        fprintf(report_stream, "{\\it_□%s", short_names ?
            unknown_case_pointer→short_name : unknown_case_pointer→name);
        if ((unknown_case_pointer→equidistant_unknown_next ≡ NULL) ∧
            (known_case_pointer ≡ NULL))
            /* this is the last case to list */
            fprintf(report_stream, "\\}");
        else if (((unknown_case_pointer→equidistant_unknown_next ≠ NULL) ∧
            (unknown_case_pointer→equidistant_unknown_next→
                equidistant_unknown_next ≡ NULL) ∧
            (known_case_pointer ≡ NULL)) ∨
            ((unknown_case_pointer→equidistant_unknown_next ≡ NULL) ∧
            (known_case_pointer ≠ NULL) ∧
            (known_case_pointer→equidistant_known_next ≡ NULL)))
            /* this is the penultimate case to list */
            fprintf(report_stream, "\\}□%s\\n", and ? "and" : "or");
        else
            fprintf(report_stream, "}, \\n");
        unknown_case_pointer = unknown_case_pointer→equidistant_unknown_next;
    }
    /* while there are still known cases to list ... */
    while (known_case_pointer ≠ NULL) {
        /* write the case name with appropriate trailing characters */
        fprintf(report_stream, "{\\it_□%s", short_names ?
            known_case_pointer→short_name : known_case_pointer→name);
        if (known_case_pointer→equidistant_known_next ≡ NULL)
            /* this is the last case to list */
            fprintf(report_stream, "\\}");
```

```

    else if (known_case_pointer→equidistant_known_next→equidistant_known_next ≡ NULL)
        /* this is the penultimate case to list */
        fprintf(report_stream, "\\}\_□%s\n", and ? "and" : "or");
    else
        fprintf(report_stream, "},\n");
    known_case_pointer = known_case_pointer→equidistant_known_next;
}
}

```

static void

```
list_equidistant_cases(
```

```

    file report_stream,
    kase *known_case_pointer,
    kase *unknown_case_pointer,
    boolean unknown_first,
    boolean short_names,
    boolean and)

```

```

/* Lists the case pointed to by known_case_pointer (and any known equidistant cases) and the
case pointed to by unknown_case_pointer (and any unknown equidistant cases). Lists the
unknown cases first, if unknown_first is TRUE. Writes short case names, if short_names is
TRUE. Writes "and" between the last two cases in the list, if and is TRUE; writes "or",
otherwise. */

```

```

{
    if (unknown_first)
        list_equidistant_cases_unknown_first(report_stream, known_case_pointer,
        unknown_case_pointer, short_names, and);
    else
        list_equidistant_cases_known_first(report_stream, known_case_pointer,
        unknown_case_pointer, short_names, and);
}

```

static void

```
state_opinion(
```

```

    file report_stream,
    result *result_pointer,
    kase *known_case_pointer,
    kase *unknown_case_pointer,
    boolean unknown_first)

```

```

/* States its opinion: that, following the cases pointed to by known_case_pointer and
unknown_case_pointer, the result will be that which is pointed to by result_pointer. Lists
the unknown cases first, if unknown_first is TRUE. */

```

```

{
    fprintf(report_stream, "---following\_□\\frenchspacing\n");
    list_equidistant_cases(report_stream, known_case_pointer, unknown_case_pointer,
        unknown_first, FALSE, TRUE);
    fprintf(report_stream, "\\nonfrenchspacing---%%\n"
        "%s.\n\n", result_pointer→string);
}

```

static void

```
state_counter_opinion(
```

```
    file report_stream,
    result *result_pointer,
    kase *known_case_pointer,
    kase *unknown_case_pointer,
    boolean unknown_first)
```

```
/* States a counter opinion: that, if the cases pointed to by known_case_pointer and
unknown_case_pointer are followed, the result will be that which is pointed to by
result_pointer. Lists the unknown cases first, if unknown_first is TRUE. */
```

```
{
    boolean plural = FALSE;

    fprintf(report_stream, "%sIf\\frenchspacing\n", Skip);

    list_equidistant_cases(report_stream, known_case_pointer, unknown_case_pointer,
        unknown_first, FALSE, FALSE);

    if (known_case_pointer ≠ NULL) {
        if (unknown_case_pointer ≠ NULL)
            plural = TRUE;
        else if (known_case_pointer→equidistant_known_next ≠ NULL)
            plural = TRUE;
    } else if (unknown_case_pointer ≠ NULL)
        if (unknown_case_pointer→equidistant_unknown_next ≠ NULL)
            plural = TRUE;

    fprintf(report_stream, "\\nonfrenchspacing\n"
        "%sfollowed then%s.\n\n",
        plural ? "are" : "is", result_pointer→string);
}
```

static cardinal

```
number_of_similarities(
```

```
    matrix_element *matrix_pointer,
    vector_element *vector_pointer)
```

```
/* Returns the number of similarities in attribute value pairs between a leading case and the
instant case (their attribute values are pointed to by matrix_pointer and vector_pointer,
respectively), where both cases have known attribute values. */
```

```
{
    cardinal count = 0;

    /* while there are still attribute values to compare ... */
    while (matrix_pointer ≠ NULL) {
        if ((matrix_pointer→attribute_value ≠ UNKNOWN) ∧
            (matrix_pointer→attribute_value ≡ vector_pointer→attribute_value))
            /* the corresponding attribute values are identical and known */
            count++;
    }
}
```

```

        matrix_pointer = matrix_pointer→case_next;
        vector_pointer = vector_pointer→next;
    }
    return count;
}

static void
list_similarities(
    file report_stream,
    matrix_element *matrix_pointer,
    vector_element *vector_pointer,
    attribute *attribute_pointer,
    cardinal count)

/* Lists the similarities between a leading case and the instant case (their attribute values are
pointed to by matrix_pointer and vector_pointer, respectively), where both cases have known
attribute values, by writing the appropriate string (YES or NO) for the similar attributes.
*attribute_pointer is the head of the list of attributes for this area. count is the number of
similarities. */

{
    /* while there are still attribute values to compare, and not all of the similarities have been
listed ... */

    while ((attribute_pointer ≠ NULL) ∧ (count ≠ 0)) {

        if ((matrix_pointer→attribute_value ≠ UNKNOWN) ∧
            (matrix_pointer→attribute_value ≡ vector_pointer→attribute_value)) {

            /* the corresponding attribute values are identical and known, so write the relevant
string with appropriate trailing characters */

            if (count ≡ 1)
                Write(report_stream, matrix_pointer→attribute_value ≡ YES ?
                    attribute_pointer→yes : attribute_pointer→no, ".\n", 1, Hang);
            else if (count ≡ 2)
                Write(report_stream, matrix_pointer→attribute_value ≡ YES ?
                    attribute_pointer→yes : attribute_pointer→no, ";\nand", 1, Hang);
            else
                Write(report_stream, matrix_pointer→attribute_value ≡ YES ?
                    attribute_pointer→yes : attribute_pointer→no, ";\n", 1, Hang);

            count--;
        }
        matrix_pointer = matrix_pointer→case_next;
        vector_pointer = vector_pointer→next;
        attribute_pointer = attribute_pointer→next;
    }
}

```

```

static cardinal
number_of_known_differences(
    matrix_element *matrix_pointer,
    vector_element *vector_pointer)

/* Returns the number of differences in attribute value pairs between a leading case and the
instant case (their attribute values are pointed to by matrix_pointer and vector_pointer,
respectively), where the leading case has a known attribute value. */

{
    cardinal count = 0;

    /* while there are still attribute values to compare ... */
    while (matrix_pointer ≠ NULL) {
        if ((matrix_pointer→attribute_value ≠ UNKNOWN) ∧
            (matrix_pointer→attribute_value ≠ vector_pointer→attribute_value))
            /* the corresponding attribute values are different, and the leading case's value is
            known, so increment the count */
            count++;

        matrix_pointer = matrix_pointer→case_next;
        vector_pointer = vector_pointer→next;
    }
    return count;
}

```

```

static void
list_known_differences(
    file_report_stream,
    matrix_element *matrix_pointer,
    vector_element *vector_pointer,
    attribute *attribute_pointer,
    cardinal count)

/* Lists the differences between a leading case and the instant case (their attribute values are
pointed to by matrix_pointer and vector_pointer, respectively), where the leading case has
a known attribute value, by writing the appropriate string (YES or NO) for the different
attributes. *attribute_pointer is the head of the list of attributes for this area. count is the
number of differences. */

{
    /* while there are still attribute values to compare, and not all of the differences have been
    listed ... */
    while ((attribute_pointer ≠ NULL) ∧ (count ≠ 0)) {
        if ((matrix_pointer→attribute_value ≠ UNKNOWN) ∧
            (matrix_pointer→attribute_value ≠ vector_pointer→attribute_value)) {
            /* the corresponding attribute values are different, and the leading case's value is
            known, so write the relevant string with appropriate trailing characters */
            if (count ≡ 1)
                Write(report_stream, matrix_pointer→attribute_value ≡ YES ?
                    attribute_pointer→yes : attribute_pointer→no, " .", 1, Hang);
        }
    }
}

```



```

    else if (count == 2)
        Write(report_stream, matrix_pointer->attribute_value == YES ?
            attribute_pointer->yes : attribute_pointer->no, " ; and", 1, Hang);
    else
        Write(report_stream, matrix_pointer->attribute_value == YES ?
            attribute_pointer->yes : attribute_pointer->no, " ;", 1, Hang);
    count--;
}
matrix_pointer = matrix_pointer->case_next;
vector_pointer = vector_pointer->next;
attribute_pointer = attribute_pointer->next;
}
}

static cardinal
number_of_unknowns(
    matrix_element *matrix_pointer)

/* Returns the number of UNKNOWNs in the leading case whose attribute values are pointed
to by matrix_pointer. */

{
    cardinal count = 0;

    /* while there are still attribute values to check ... */
    while (matrix_pointer != NULL) {
        if (matrix_pointer->attribute_value == UNKNOWN)
            count++;
        matrix_pointer = matrix_pointer->case_next;
    }
    return count;
}

static void
list_unknowns(
    file report_stream,
    matrix_element *matrix_pointer,
    attribute *attribute_pointer,
    cardinal count)

/* Lists the UNKNOWN string for each unknown attribute in the leading case whose attribute
values are pointed to by matrix_pointer. *attribute_pointer is the head of the list of attributes
for this area. count is the number of UNKNOWNs. */

{
    /* while there are still attribute values to compare, and not all of the UNKNOWNs have
been listed ... */
    while ((attribute_pointer != NULL) ^ (count != 0)) {
        if (matrix_pointer->attribute_value == UNKNOWN) {
            if (count == 1)
                Write(report_stream, attribute_pointer->unknown, ". ", 1, Hang);

```

```

    else if (count == 2)
        Write(report_stream, attribute_pointer→unknown, " ;_and", 1, Hang);
    else
        Write(report_stream, attribute_pointer→unknown, " ;", 1, Hang);
    count--;
}
matrix_pointer = matrix_pointer→case_next;
attribute_pointer = attribute_pointer→next;
}
}

static cardinal
number_of_differences(
    vector_element *vector_pointer_X,
    vector_element *vector_pointer_Y)
/* Returns the number of differences in attribute value pairs between two fact vectors. */
{
    cardinal count = 0;
    /* while there are still attribute values to compare ... */
    while (vector_pointer_X ≠ NULL) {
        if (vector_pointer_X→attribute_value ≠ vector_pointer_Y→attribute_value)
            count++;
        vector_pointer_X = vector_pointer_X→next;
        vector_pointer_Y = vector_pointer_Y→next;
    }
    return count;
}

static void
list_new_differences(
    file report_stream,
    vector_element *vector_pointer,
    vector_element *original_vector_pointer,
    attribute *attribute_pointer,
    cardinal count)
/* Lists the differences between an instantiation or hypothetical and the uninstantiated
and unhypothesized instant case (their attribute values are pointed to by vector_pointer
and original_vector_pointer, respectively), by writing the appropriate string (YES, NO or
UNKNOWN) for the different attributes. *attribute_pointer is the head of the list of attrib-
utes for this area. count is the number of differences. */
{
    /* while there are still attribute values to compare, and not all of the differences have been
    listed ... */
    while ((attribute_pointer ≠ NULL) ∧ (count ≠ 0)) {
        if (vector_pointer→attribute_value ≠ original_vector_pointer→attribute_value) {
            /* the corresponding attribute values are different, so write the relevant string with
            appropriate trailing characters */

```

```

    if (count == 1)
        Write(report_stream, vector_pointer->attribute_value == YES ?
              attribute_pointer->yes : vector_pointer->attribute_value == NO ?
              attribute_pointer->no : attribute_pointer->unknown, ". ", 1, Hang);
    else if (count == 2)
        Write(report_stream, vector_pointer->attribute_value == YES ?
              attribute_pointer->yes : vector_pointer->attribute_value == NO ?
              attribute_pointer->no : attribute_pointer->unknown, "; and", 1, Hang);
    else
        Write(report_stream, vector_pointer->attribute_value == YES ?
              attribute_pointer->yes : vector_pointer->attribute_value == NO ?
              attribute_pointer->no : attribute_pointer->unknown, "; ", 1, Hang);
    count--;
}
vector_pointer = vector_pointer->next;
original_vector_pointer = original_vector_pointer->next;
attribute_pointer = attribute_pointer->next;
}
}
}

```

static void

```
summarize_case(
```

```

    file report_stream,
    kase *case_pointer,
    boolean written_linking_paragraph,
    boolean verbose)

```

/* Writes the name of the case pointed to by *case_pointer* with its citation in a footnote. Summarizes the case, if *verbose* is *TRUE*. If *written_linking_paragraph* is *TRUE*, a brief paragraph was just written linking the previous case with this case (the two cases are equidistant). */

```

{
    if (!case_pointer->summarized) {
        /* the case has not been summarized yet */

        if (written_linking_paragraph)

            /* the case's citation has already been footnoted in the linking paragraph */

            fprintf(report_stream, "In \\frenchspacing\n"
                  "{\\it_\\s}\\nonfrenchspacing, \\n",
                  case_pointer->short_name);

        else {

            fprintf(report_stream, "In \\frenchspacing\n"
                  "{\\it_\\s}\\nonfrenchspacing, %%\n"
                  "\\footnote{\\s.}\\n",
                  case_pointer->name, case_pointer->citation);
            Write_Year_and_Court(report_stream, case_pointer, 1);
            fprintf(report_stream, ", \\n");
        }
    }
}

```

```

    if (verbose) {
        if (case_pointer→summary ≠ NULL) {
            Write(report_stream, case_pointer→summary, "\n", 1, Hang);
            case_pointer→summarized = TRUE;
        } else
            fprintf(report_stream, "\n");
    } else
        Write(report_stream, "[summary] .\n", Empty_String, 1, Hang);

} else

    /* the case has already been summarized */

    fprintf(report_stream, "Details_of_\frenchspacing\n"
        "{\it\s\}/_\nonfrenchspacing\n"
        "are_summarized_above.\n",
        case_pointer→short_name);
}

static void
list_similarities_and_differences(
    file report_stream,
    kase *case_pointer,
    attribute *attribute_head,
    vector_element *facts_head,
    string instant_case_type,
    boolean neighbour,
    boolean written_linking_paragraph,
    boolean unknown_list_to_follow,
    boolean verbose)

/* Cites the case pointed to by case_pointer, and lists the similarities between that case
and the instant case (whose attribute values are pointed to by facts_head). Summar-
izes the case, if verbose is TRUE. instant_case_type is either "instant", "instantiated" or
"hypothetical". If neighbour is TRUE, this case is a nearest neighbour; otherwise, it is a
nearest other. If written_linking_paragraph is TRUE, a brief paragraph was just written link-
ing the previous case with this case (the two cases are equidistant). If unknown_list_to_follow
is TRUE, an invocation of list_unknowns() will immediately follow this invocation of
list_similarities_and_differences(). */

{
    cardinal count;

    if (¬written_linking_paragraph)

        /* a linking paragraph has not just been written */

        fprintf(report_stream, "%s_", Skip);

```

```

if (case_pointer→summary ≠ NULL)
    /* this case has a summary, so write the case name (with its citation in a footnote) and
       the summary */
    summarize_case(report_stream, case_pointer, written_linking_paragraph, verbose);
if (Is_Zero_Subdistance(case_pointer→metrics.distance.known))
    /* there is no known distance between this case and the instant case */
    if (Is_Zero_Subdistance(case_pointer→metrics.distance.unknown)) {
        /* there is no unknown distance between this case and the instant case */
        fprintf(report_stream,
            "The %s case is on all fours with \frenchspacing\n",
            instant_case_type);
        if (case_pointer→summary ≠ NULL)
            fprintf(report_stream,
                "{\it %s}\null\nonfrenchspacing.\n",
                case_pointer→short_name);
        else
            /* the case has no summary, so its citation has not yet been footnoted */
            fprintf(report_stream,
                "{\it %s}\null\nonfrenchspacing.%%\n"
                "\footnote{%s.}\n",
                case_pointer→name, case_pointer→citation);
    } else {
        /* there is some unknown distance between this case and the instant case */
        fprintf(report_stream, "The %s case {\it may\}/be
            "on all fours with \frenchspacing\n", instant_case_type);
        if (case_pointer→summary ≠ NULL)
            fprintf(report_stream, "{\it %s\}/\nonfrenchspacing",
                case_pointer→short_name);
        else
            /* the case has no summary, so its citation has not yet been footnoted */
            fprintf(report_stream, "{\it %s\}/\nonfrenchspacing%\n"
                "\footnote{%s.}",
                case_pointer→name, case_pointer→citation);
        if (unknown_list_to_follow)
            /* a list of unknown differences follows immediately */
            fprintf(report_stream, "---but\n");
        else
            /* a statement that this case would have been followed (instead of the nearest
               neighbour) follows—and a list of unknown differences follows that */
            fprintf(report_stream, "\and");
    }

```

```

} else {
    /* there is some known and/or unknown distance between this case and the instant
       case */
    count = number_of_similarities(case_pointer→matrix_head, facts_head);
    if (count ≠ 0) {
        fprintf(report_stream, "There_");
        if (neighbour)
            /* characterize the similarities as “extremely significant” (one), “very signific-
               ant” (two), or just “significant” (three or more) */
            switch (count) {
                case 1:
                    fprintf(report_stream,
                        "is_one_extremely_significant_similarity\n");
                    break;
                case 2:
                    fprintf(report_stream,
                        "are_two_very_significant_similarities\n");
                    break;
                default:
                    fprintf(report_stream,
                        "are_several_significant_similarities\n");
                    break;
            }
        else
            switch (count) {
                case 1:
                    fprintf(report_stream,
                        "is_one_similarity\n");
                    break;
                case 2:
                    fprintf(report_stream,
                        "are_two_similarities\n");
                    break;
                default:
                    fprintf(report_stream,
                        "are_several_similarities\n");
                    break;
            }
        fprintf(report_stream, "between_the_s_case_and_\\frenchspacing\n",
            instant_case_type);
        if (case_pointer→summary ≠ NULL)
            fprintf(report_stream, "{\\it_s}\\}\\null\\nonfrenchspacing:\n",
                case_pointer→short_name);
        else
            /* the case has no summary, so its citation has not yet been footnoted */
            fprintf(report_stream, "{\\it_s}\\}\\null\\nonfrenchspacing:%\n"
                "\\footnote{s.}\n",
                case_pointer→name, case_pointer→citation);
    }
}

```

```

/* list the similarities between this case and the instant case */
list_similarities(report_stream, case_pointer→matrix_head, facts_head,
                 attribute_head, count);
}
count = number_of_known_differences(case_pointer→matrix_head, facts_head);
if (neighbour)
    fprintf(report_stream,
           "However, the %s case is not on all fours"
           "with\\frenchspacing\n"
           "{\\it%s}\\null\\nonfrenchspacing.\n",
           instant_case_type, case_pointer→short_name);
else {
    if (count ≠ 0) {
        /* characterize the differences as “extremely significant” (one), “very significant” (two), or just “significant” (three or more) */
        fprintf(report_stream, "However, there");
        switch (count) {
            case 1:
                fprintf(report_stream,
                       "is one extremely significant difference\n");
                break;
            case 2:
                fprintf(report_stream,
                       "are two very significant differences\n");
                break;
            default:
                fprintf(report_stream,
                       "are several significant differences\n");
                break;
        }
        fprintf(report_stream, "between the %s case and\\frenchspacing\n",
                instant_case_type);
        fprintf(report_stream,
                "{\\it%s}\\null\\nonfrenchspacing.\n",
                case_pointer→short_name);
    }
}
fprintf(report_stream, "In that case\n");

/* list the differences between this case and the instant case */
list_known_differences(report_stream, case_pointer→matrix_head, facts_head,
                     attribute_head, count);
}
}

```

static boolean

```
has_less_known_distance(
    kase *case_pointer_X,
    kase *case_pointer_Y)
```

/* Returns *TRUE*, iff the case pointed to by *case_pointer_X* has less known distance than does that pointed to by *case_pointer_Y*. */

```
{
    return ((case_pointer_X ≠ NULL) ∧ (case_pointer_Y ≠ NULL) ∧
           ((case_pointer_X→metrics.distance.known.infinite <
             case_pointer_Y→metrics.distance.known.infinite) ∨
            ((case_pointer_X→metrics.distance.known.infinite ≡
              case_pointer_Y→metrics.distance.known.infinite) ∧
             Is_Less(case_pointer_X→metrics.distance.known.finite,
                    case_pointer_Y→metrics.distance.known.finite,
                    Distance_Precision))));
}
```

static void

```
state_confidence(
    file report_stream,
    string short_name)
```

/* States its confidence that the case called *short_name* should still be followed. */

```
{
    fprintf(report_stream, "Nevertheless, I believe that \\frenchspacing\\n"
           "\\it,%s\\/}\\nonfrenchspacing\\n"
           "should be followed. \\n\\n", short_name);
}
```

static boolean

```
write_number_as_word(
    file report_stream,
    cardinal number)
```

/* Writes *number*: as a word, if *number* ≤ 10; as a number, otherwise. Returns *TRUE*, iff *number* ≠ 1: i.e. if the noun to follow should be plural. */

```
{
    switch (number) {
        case 1:
            fprintf(report_stream, "one");
            break;
        case 2:
            fprintf(report_stream, "two");
            break;
    }
```



```

    case 3:
        fprintf(report_stream, "three");
        break;
    case 4:
        fprintf(report_stream, "four");
        break;
    case 5:
        fprintf(report_stream, "five");
        break;
    case 6:
        fprintf(report_stream, "six");
        break;
    case 7:
        fprintf(report_stream, "seven");
        break;
    case 8:
        fprintf(report_stream, "eight");
        break;
    case 9:
        fprintf(report_stream, "nine");
        break;
    case 10:
        fprintf(report_stream, "ten");
        break;
    default:
        fprintf(report_stream, "%u", number);
        break;
}
return (number ≠ 1);
}

```

static void

state_intransigence(

file report_stream,

kase *nearest_neighbour,

kase *nearest_other)

/* Restates its opinion that the case pointed to by *nearest_neighbour* should be followed, and compares the relative importance of the courts that decided that case and the case pointed to by *nearest_other*. */

```

{
    if ((nearest_neighbour→court_string ≡ NULL) ∨ (nearest_other→court_string ≡ NULL))

        /* the nearest neighbour or the nearest other has no court, so make no comment about
           each case's relative importance */

        fprintf(report_stream, "\nConsequently,");
}

```

```

else if (nearest_neighbour→court_rank < nearest_other→court_rank)

/* the nearest neighbour was decided by a more important court than was the nearest
   other */

fprintf(report_stream, "Note%s_that_\frenchspacing\n"
        "{\it\s\}\_\nonfrenchspacing\n"
        "is_only_a_decision_of\n"
        "%s\n"
        "and_not_as_good_authority_as_a_case_decided_by\n"
        "%s%\n"
        "---like_\frenchspacing\n"
        "{\it\s}\_\nonfrenchspacing.\n\n"
        "Consequently, ",
        Is_Zero_Subdistance(nearest_other→metrics.distance.known) ^
        Is_Zero_Subdistance(nearest_other→metrics.distance.unknown) ?
        ",_however,": "_also",
        nearest_other→short_name, nearest_other→court_string,
        nearest_neighbour→court_string, nearest_neighbour→short_name);

else if (nearest_neighbour→court_rank > nearest_other→court_rank)

/* the nearest other was decided by a more important court than was the nearest
   neighbour */

fprintf(report_stream, "\nDespite_the_fact_that_\frenchspacing\n"
        "{\it\s\}\_\nonfrenchspacing\n"
        "is_a_decision_of\n"
        "%s\n"
        "(and_better_authority_than_a_case_decided_by\n"
        "%s%\n"
        "---like_\frenchspacing\n"
        "{\it\s\}\_\nonfrenchspacing),\n",
        nearest_other→short_name, nearest_other→court_string,
        nearest_neighbour→court_string, nearest_neighbour→short_name);

else if (nearest_neighbour→court_string ≡ nearest_other→court_string)

/* the nearest neighbour and the nearest other were decided by the same court */

fprintf(report_stream, "\nDespite_the_fact_that_\frenchspacing\n"
        "{\it\s\}\_\nonfrenchspacing\n"
        "and_\frenchspacing\n"
        "{\it\s\}\_\nonfrenchspacing\n"
        "are_both_decisions_of\n"
        "%s,\n", nearest_other→short_name,
        nearest_neighbour→short_name, nearest_other→court_string);

```

```

else
    /* the nearest neighbour and the nearest other were decided by different courts of the
       same rank */

    fprintf(report_stream, "\nDespite the fact that \frenchspacing\n"
           "{\it\s}\}\nonfrenchspacing\n"
           "is a decision of\n"
           "%s\n"
           "(and as good authority as a case decided by\n"
           "%s%\n"
           "---like \frenchspacing\n"
           "{\it\s}\}\nonfrenchspacing), \n",
           nearest_other→short_name, nearest_other→court_string,
           nearest_neighbour→court_string, nearest_neighbour→short_name);

    fprintf(report_stream, "there is nothing in \frenchspacing\n"
           "{\it\s}\}\nonfrenchspacing\n"
           "to warrant any change in my conclusion. \n\n",
           nearest_other→short_name);
}

static boolean
write_linking_paragraph(
    file report_stream,
    kase *previous_case_pointer,
    kase *next_case_pointer)

/* Writes a brief paragraph linking the previous case with the next case (the two cases are
   equidistant), if there is a next case. Puts the two cases into context (i.e. explains which
   is more important and why). Returns TRUE, if a paragraph is written, which means that
   the next paragraph should not include year and court information—information included
   in this linking paragraph. */

{
    if ((next_case_pointer ≠ NULL) ∧
        (previous_case_pointer→court_string ≠ NULL) ∧
        (next_case_pointer→court_string ≠ NULL)) {

        /* the previous case and the next case are equidistant and both have a court string, so
           write a linking paragraph */

        fprintf(report_stream, "%s In %u, \n", Skip, next_case_pointer→year);

        if (previous_case_pointer→court_string ≡ next_case_pointer→court_string) {

            /* the previous case and the next case were decided by the same court */

            if (previous_case_pointer→year ≡ next_case_pointer→year)

                /* the previous case and the next case were decided in the same year */

                fprintf(report_stream, "the same year in which \frenchspacing\n"
                       "{\it\s}\}\nonfrenchspacing\n"
                       "was decided, \n",
                       previous_case_pointer→short_name);
        }
    }
}

```

```

fprintf(report_stream, "%s\n"
        "also_decided_\frenchspacing\n"
        "{\it_s}\null\nonfrenchspacing.%%\n"
        "\footnote{s.}\n",
        next_case_pointer→court_string, next_case_pointer→name,
        next_case_pointer→citation);

if (previous_case_pointer→year ≠ next_case_pointer→year) {

    /* the previous case and the next case were decided in a different year; the
       previous case must be more recent than the next case (otherwise the next
       case would be earlier in the list than the previous case) */

    fprintf(report_stream, "(Note, however, that_\frenchspacing\n"
            "{\it_s}\}\nonfrenchspacing\n"
            "is_", previous_case_pointer→short_name);

    if (write_number_as_word(report_stream,
                            previous_case_pointer→year - next_case_pointer→year))
        fprintf(report_stream, "_years");
    else
        fprintf(report_stream, "_year");

    fprintf(report_stream, "_more_recent_than_\frenchspacing\n"
            "{\it_s}\}\nonfrenchspacing.)\n",
            next_case_pointer→short_name);
}
} else if (previous_case_pointer→court_rank ≡ next_case_pointer→court_rank) {

    /* the previous case and the next case were decided by different courts of the same
       rank */

    if (previous_case_pointer→year ≡ next_case_pointer→year)

        /* the previous case and the next case were decided in the same year */

        fprintf(report_stream, "the_same_year_in_which_\frenchspacing\n"
                "{\it_s}\}\nonfrenchspacing\n"
                "was_decided_by\n"
                "%s_",
                previous_case_pointer→short_name,
                previous_case_pointer→court_string);

    fprintf(report_stream, "\frenchspacing\n"
            "{\it_s}\}\nonfrenchspacing%%\n"
            "\footnote{s.}\n"
            "was_decided_by\n"
            "%s.\n"
            "(A_case_decided_by\n"
            "%s\n"
            "is_as_good_authority_as_a_case_decided_by\n"
            "%s", next_case_pointer→name, next_case_pointer→citation,
            next_case_pointer→court_string, next_case_pointer→court_string,
            previous_case_pointer→court_string);

```

```

if (previous_case_pointer→year ≡ next_case_pointer→year)
    /* the previous case and the next case were decided in the same year */
    fprintf(report_stream, ".)\n");
else {
    /* the previous case and the next case were decided in a different year; the
       previous case must be more recent than the next case (otherwise the next
       case would be earlier in the list than the previous case) */
    fprintf(report_stream, "%%\n"
            "----like_\frenchspacing\n"
            "{\it\s}\nonfrenchspacing;\n"
            "note, however, that_\frenchspacing\n"
            "{\it\s}\nonfrenchspacing\n"
            "is",
            previous_case_pointer→short_name,
            previous_case_pointer→short_name);

    if (write_number_as_word(report_stream,
        previous_case_pointer→year - next_case_pointer→year))
        fprintf(report_stream, "_years");
    else
        fprintf(report_stream, "_year");

    fprintf(report_stream, "_more_recent_than_\frenchspacing\n"
            "{\it\s}\nonfrenchspacing.)\n",
            next_case_pointer→short_name);
}
} else {
    /* the previous case and the next case were decided by different courts of different
       ranks; the previous case must be more important than the next case, otherwise
       the next case would be earlier in the list than the previous case) */
    if (previous_case_pointer→year ≡ next_case_pointer→year)
        /* the previous case and the next case were decided in the same year */
        fprintf(report_stream, "the_same_year_in_which_\frenchspacing\n"
                "{\it\s}\nonfrenchspacing\n"
                "was_decided_by\n"
                "%s,",
                previous_case_pointer→short_name,
                previous_case_pointer→court_string);

    fprintf(report_stream, "\frenchspacing\n"
            "{\it\s}\nonfrenchspacing%\n"
            "\footnote{s.}\n"
            "was_decided_by\n"
            "%s.\n"
            "(A_case_decided_by\n"
            "%s\n"
            "is_not_as_good_authority_as_a_case_decided_by\n"
            "%s", next_case_pointer→name, next_case_pointer→citation,
            next_case_pointer→court_string, next_case_pointer→court_string,
            previous_case_pointer→court_string);
}

```

```

if (previous_case_pointer→year ≡ next_case_pointer→year)
    /* the previous case and the next case were decided in the same year */
    fprintf(report_stream, ".)\n");
else
    fprintf(report_stream, "%%\n"
           "---like_\frenchspacing\n"
           "{\it_s}\}\nonfrenchspacing;\n",
           previous_case_pointer→short_name);
if (previous_case_pointer→year > next_case_pointer→year) {
    /* the previous case is more recent than the next case */
    fprintf(report_stream, "furthermore_\frenchspacing\n"
           "{\it_s}\}\nonfrenchspacing\n"
           "is_", next_case_pointer→short_name);
    if (write_number_as_word(report_stream,
                             previous_case_pointer→year - next_case_pointer→year))
        fprintf(report_stream, "_years");
    else
        fprintf(report_stream, "_year");
    fprintf(report_stream, "_older_than_\frenchspacing\n"
           "{\it_s}\}\nonfrenchspacing.)\n",
           previous_case_pointer→short_name);
} else if (previous_case_pointer→year < next_case_pointer→year) {
    /* the next case is more recent than the previous case */
    fprintf(report_stream, "though_\frenchspacing\n"
           "{\it_s}\}\nonfrenchspacing\n"
           "is_", next_case_pointer→short_name);
    if (write_number_as_word(report_stream,
                             next_case_pointer→year - previous_case_pointer→year))
        fprintf(report_stream, "_years");
    else
        fprintf(report_stream, "_year");
    fprintf(report_stream, "_more_recent_than_\frenchspacing\n"
           "{\it_s}\}\nonfrenchspacing.)\n",
           previous_case_pointer→short_name);
}
}
fprintf(report_stream, "\n");
return TRUE;
} else
    /* no linking paragraph has been written */
    return FALSE;
}

```



```

    fprintf(report_stream, "\\nonfrenchspacing)\n"
           "except_that\n");
    list_unknowns(report_stream, case_pointer→matrix_head,
                 area_pointer→attribute_head, number_of_unknowns(case_pointer→matrix_head));
    if (¬neighbour)
        state_intransigence(report_stream, nearest_neighbour, case_pointer);
    written_linking_paragraph = write_linking_paragraph(report_stream, case_pointer,
                                                       case_pointer→equidistant_unknown_next);
}
}

```

static void

```

handle_nearest_known(
    file report_stream,
    result *result_pointer,
    result *nearest_result_pointer,
    kase *nearest_neighbour,
    area *area_pointer,
    vector_element *facts_head,
    string instant_case_type,
    boolean verbose)
/* Argues that the result should be same as that of the nearest known neighbour. Uses the
   nearest unknown neighbour too, if (but for its unknown distance) it would be the nearest
   neighbour. */
{
    kase *case_pointer;
    boolean written_linking_paragraph = FALSE;
    if (has_less_known_distance(result_pointer→nearest_unknown_case,
                               result_pointer→nearest_known_case))
        /* if not for its unknown distance, the nearest unknown neighbour would be the nearest
           neighbour, so base the argument on the nearest known and the nearest unknown
           neighbours */
        state_opinion(report_stream, result_pointer,
                     result_pointer→nearest_known_case,
                     result_pointer→nearest_unknown_case, FALSE);
    else
        /* base the argument only on the nearest known neighbours */
        state_opinion(report_stream, result_pointer,
                     result_pointer→nearest_known_case, NULL, FALSE);
    /* for each nearest known neighbour ... */
    for (case_pointer = result_pointer→nearest_known_case; case_pointer ≠ NULL;
         case_pointer = case_pointer→equidistant_known_next) {
        list_similarities_and_differences(report_stream, case_pointer,
                                         area_pointer→attribute_head, facts_head, instant_case_type, TRUE,
                                         written_linking_paragraph, FALSE, verbose);
        fprintf(report_stream, "\n");
    }
}

```



```

if ( $\neg$ Is_Zero_Distance(case_pointer→metrics.distance))
    /* the instant case is not on all fours with the case */
    state_confidence(report_stream, case_pointer→short_name);
    written_linking_paragraph = write_linking_paragraph(report_stream, case_pointer,
        case_pointer→equidistant_known_next);
}
if (has_less_known_distance(result_pointer→nearest_unknown_case,
    result_pointer→nearest_known_case)) {
    /* if not for its unknown distance, the nearest unknown neighbour would be the nearest
    neighbour */
    handle_near_unknown(report_stream, result_pointer, nearest_result_pointer,
        nearest_neighbour, TRUE, area_pointer,
        facts_head, instant_case_type, TRUE, verbose);
    fprintf(report_stream, "\n");
}
}

```

static void

```

handle_nearest_unknown(
    file report_stream,
    result *result_pointer,
    area *area_pointer,
    vector_element *facts_head,
    string instant_case_type,
    boolean verbose)
/* Argues that the result should be same as that in the nearest unknown neighbour. Uses the
nearest known neighbour too. */
{
    kase *case_pointer;
    boolean written_linking_paragraph = FALSE;
    cardinal count;

    /* base the argument on the nearest unknown and the nearest known neighbours */
    state_opinion(report_stream, result_pointer,
        result_pointer→nearest_known_case,
        result_pointer→nearest_unknown_case, TRUE);

    /* for every nearest unknown neighbour ... */
    for (case_pointer = result_pointer→nearest_unknown_case; case_pointer ≠ NULL;
        case_pointer = case_pointer→equidistant_unknown_next) {
        list_similarities_and_differences(report_stream, case_pointer,
            area_pointer→attribute_head, facts_head, instant_case_type, TRUE,
            written_linking_paragraph, TRUE, verbose);
        count = number_of_unknowns(case_pointer→matrix_head);
    }
}

```

```

if (count ≠ 0) {
    fprintf(report_stream, "Furthermore, □\n");

    list_unknowns(report_stream, case_pointer→matrix_head,
                  area_pointer→attribute_head, count);
}
fprintf(report_stream, "\n");

state_confidence(report_stream, case_pointer→short_name);

written_linking_paragraph = write_linking_paragraph(report_stream, case_pointer,
                                                    case_pointer→equidistant_unknown_next);
}

/* for every nearest known neighbour ... */

written_linking_paragraph = FALSE;

for (case_pointer = result_pointer→nearest_known_case; case_pointer ≠ NULL;
      case_pointer = case_pointer→equidistant_known_next) {

    list_similarities_and_differences(report_stream, case_pointer,
                                      area_pointer→attribute_head, facts_head, instant_case_type, TRUE,
                                      written_linking_paragraph, FALSE, verbose);

    fprintf(report_stream, "\n");

    if (¬Is_Zero_Distance(case_pointer→metrics.distance))
        state_confidence(report_stream, case_pointer→short_name);

    written_linking_paragraph = write_linking_paragraph(report_stream, case_pointer,
                                                        case_pointer→equidistant_known_next);
}
}

static void
handle_nearest_others(
    file report_stream,
    result *result_pointer,
    result *nearest_result_pointer,
    kase *nearest_other,
    boolean nearest_other_is_known,
    area *area_pointer,
    vector_element *facts_head,
    string instant_case_type,
    boolean verbose)

/* Make a counter argument that the result should be same as that of the nearest known other.
   Uses this result's nearest unknown other too, if (but for its unknown distance) it would be
   the nearest neighbour. */

```

```

{
    case *case_pointer;
    boolean written_linking_paragraph = FALSE;
    cardinal count;

    if ((result_pointer→nearest_known_compared_with_unknown ≡ FURTHER) ∨
        has_less_known_distance(result_pointer→nearest_unknown_case,
                               nearest_other)) {

        /* the nearest unknown other is the nearest other or if not for its unknown distance,
           the nearest unknown other would be the nearest neighbour */

        state_counter_opinion(report_stream, result_pointer,
                              result_pointer→nearest_known_case,
                              result_pointer→nearest_unknown_case, TRUE);

        if (has_less_known_distance(result_pointer→nearest_unknown_case,
                                    nearest_other)) {

            /* if not for its unknown distance, the nearest unknown other would be the nearest
               neighbour */

            handle_near_unknown(report_stream, result_pointer, nearest_result_pointer,
                                nearest_other, nearest_other_is_known, area_pointer,
                                facts_head, instant_case_type, FALSE, verbose);

        } else

            /* for every nearest unknown other ... */

            for (case_pointer = result_pointer→nearest_unknown_case;
                case_pointer ≠ NULL;
                case_pointer = case_pointer→equidistant_unknown_next) {

                list_similarities_and_differences(report_stream, case_pointer,
                                                  area_pointer→attribute_head, facts_head, instant_case_type, FALSE,
                                                  written_linking_paragraph, FALSE, verbose);

                count = number_of_unknows(case_pointer→matrix_head);

                if (count ≠ 0) {

                    fprintf(report_stream, "Furthermore, □\n");

                    list_unknows(report_stream, case_pointer→matrix_head,
                                 area_pointer→attribute_head, count);

                }

                state_intransigence(report_stream, nearest_other, case_pointer);

                written_linking_paragraph = write_linking_paragraph(report_stream, case_pointer,
                                                                      case_pointer→equidistant_unknown_next);

            }

        } else

        /* the nearest known other is the nearest other, so base the counter-opinion only on
           the nearest known other */

        state_counter_opinion(report_stream, result_pointer,
                              result_pointer→nearest_known_case, NULL, FALSE);

```

```

written_linking_paragraph = FALSE;
for (case_pointer = result_pointer→nearest_known_case; case_pointer ≠ NULL;
      case_pointer = case_pointer→equidistant_known_next) {
  /* for every nearest known other ... */
  list_similarities_and_differences(report_stream, case_pointer,
    area_pointer→attribute_head, facts_head, instant_case_type, FALSE,
    written_linking_paragraph, FALSE, verbose);
  state_intransigence(report_stream, nearest_other, case_pointer);
  written_linking_paragraph = write_linking_paragraph(report_stream, case_pointer,
    case_pointer→equidistant_known_next);
}
}

static void
initialize_nearest_metrics(
  cardinal *minimum_known_differences,
  floating_point *minimum_association_coefficient,
  floating_point *minimum_weighted_association_coefficient,
  floating_point *max_correlation_coefficient,
  floating_point *max_weighted_correlation_coefficient,
  cardinal number_of_attributes)
/* Initializes the minimum and maximum metric variables. */
{
  *minimum_known_differences = number_of_attributes;
  *minimum_association_coefficient = 1.0;
  *minimum_weighted_association_coefficient = 1.0;
  *max_correlation_coefficient = -1.0;
  *max_weighted_correlation_coefficient = -1.0;
}

static void
find_nearest_metrics(
  metrics_type metrics,
  cardinal *minimum_known_differences,
  floating_point *minimum_association_coefficient,
  floating_point *minimum_weighted_association_coefficient,
  floating_point *max_correlation_coefficient,
  floating_point *max_weighted_correlation_coefficient,
  boolean weighted_association_coefficient)
/* Checks metrics against the various minimum and maximum values found so far, and changes
each minimum/maximum if the relevant metric is less/more. */
{
  if (metrics.number_of_known_differences < *minimum_known_differences)
    *minimum_known_differences = metrics.number_of_known_differences;
  if (metrics.number_of_known_pairs ≡ 0) {
    *minimum_known_differences = 0;
    *minimum_association_coefficient = 0.0;
    *minimum_weighted_association_coefficient = 0.0;
  }
}

```

```

} else {
    if (Is_Less((floating_point) metrics.number_of_known_differences /
                metrics.number_of_known_pairs,
                *minimum_association_coefficient, Precision))
        *minimum_association_coefficient =
            (floating_point) metrics.number_of_known_differences /
            metrics.number_of_known_pairs;

    if (weighted_association_coefficient)
        if (Is_Less(metrics.weighted_association_coefficient,
                    *minimum_weighted_association_coefficient, Precision))
            *minimum_weighted_association_coefficient =
                metrics.weighted_association_coefficient;

    if (!metrics.correlation_coefficient.meaningless) {
        if (Is_Less(*max_correlation_coefficient,
                    metrics.correlation_coefficient.unweighted, Precision))
            *max_correlation_coefficient =
                metrics.correlation_coefficient.unweighted;

        if (Is_Less(*max_weighted_correlation_coefficient,
                    metrics.correlation_coefficient.weighted, Precision))
            *max_weighted_correlation_coefficient =
                metrics.correlation_coefficient.weighted;
    }
}

static boolean
matches_nearest_neighbour(
    kase *case_pointer,
    kase **nearest_known_neighbour_pointer,
    kase **nearest_unknown_neighbour_pointer)

/* Returns TRUE (and adjusts the appropriate pointer so as to point to the next equidistant
case), if case_pointer points to a nearest neighbour (known or unknown). */
{
    if (case_pointer == *nearest_known_neighbour_pointer) {
        *nearest_known_neighbour_pointer =
            (*nearest_known_neighbour_pointer)→equidistant_known_next;
        return TRUE;
    } else if (case_pointer == *nearest_unknown_neighbour_pointer) {
        *nearest_unknown_neighbour_pointer =
            (*nearest_unknown_neighbour_pointer)→equidistant_unknown_next;
        return TRUE;
    } else
        return FALSE;
}

```

static void

```
log_case_number_and_name(
    file log_stream,
    cardinal case_number,
    string case_name)
{
    fprintf(log_stream, "C%u%s_%s", case_number, case_number < 10 ? "_" : "", case_name);
}
```

static void

```
log_case(
    file log_stream,
    kase *case_pointer,
    result *result_pointer,
    boolean additional,
    cardinal level,
    string *subheading)
```

/* Writes, to the log file, details of the case pointed to by *case_pointer*. Writes a character before the case name: “*”, if *additional* is *TRUE* and *result_pointer* is not *NULL* (i.e. the case is suggested by an extra metric, but is not a neighbour, and has a different result to the nearest result); “+”, if *additional* is *TRUE* (i.e. the case is suggested by an extra metric, but is not a neighbour); “-”, otherwise (i.e. the case is not suggested by the metric, but is a nearest neighbour). Writes the result in parentheses after the case name, if *result_pointer* is not *NULL*. */

```
{
    if (*subheading ≠ NULL) {
        Indent(log_stream, level + 1);
        fprintf(log_stream, "%s:\n", *subheading);
        *subheading = NULL;
    }
    Indent(log_stream, level + 1);
    fprintf(log_stream, "%s", additional ? result_pointer ≠ NULL ? "*" : "+" : "-");
    log_case_number_and_name(log_stream, case_pointer→number, case_pointer→short_name);
    if (result_pointer ≠ NULL)
        fprintf(log_stream, "%s", result_pointer→identifier);
    fprintf(log_stream, "\n");
}
```

static void

```
log_case_if_necessary(
    file log_stream,
    result *result_pointer,
    result *nearest_result_pointer,
    kase *case_pointer,
    kase **nearest_known_case_pointer,
    kase **nearest_unknown_case_pointer,
    cardinal level,
    boolean neighbour,
    string *heading,
    string *subheading,
    boolean *different_result)
```

```

/* Writes, to the log file, details of those cases about which the known/unknown distance
and the extra similarity measures disagree. Sets different_result to TRUE, if an alternative
metric suggests, as a nearest neighbour, a case which is not a nearest neighbour and which
has a result different from the nearest result. */

{
  if (neighbour) {

    /* the alternative metric suggests this as a nearest neighbour */

    if ( $\neg$ matches_nearest_neighbour(case_pointer,
                                     nearest_known_case_pointer, nearest_unknown_case_pointer)) {

      /* it isn't a nearest neighbour, so log it as an additional case */

      if (*heading  $\neq$  NULL) {
        Indent(log_stream, level);
        fprintf(log_stream, "%s:\n\n", *heading);
        *heading = NULL;
      }
      if (result_pointer  $\neq$  nearest_result_pointer) {

        /* the result of this case is not the nearest result, so include the result in the
        log */

        log_case(log_stream, case_pointer, result_pointer, TRUE, level, subheading);
        if (different_result  $\neq$  NULL)
          *different_result = TRUE;

      } else

        /* the result of this case is the nearest result, so don't include it in the log */

        log_case(log_stream, case_pointer, NULL, TRUE, level, subheading);
      }
    } else if (matches_nearest_neighbour(case_pointer,
                                          nearest_known_case_pointer, nearest_unknown_case_pointer)) {

      /* the alternative metric does not suggest this case as a nearest neighbour, but it is a
      nearest neighbour, so log it as a missing case */

      if (*heading  $\neq$  NULL) {
        Indent(log_stream, level);
        fprintf(log_stream, "%s:\n\n", *heading);
        *heading = NULL;
      }

      /* the result of this case is the nearest result, so don't include it in the log */

      log_case(log_stream, case_pointer, NULL, FALSE, level, subheading);
    }
  }
}

```

static void

```

implement_safeguards(
    file log_stream,
    area *area_pointer,
    string instant_case_type,
    cardinal level)

/* Implements the safeguards based on the extra similarity measures, and issues a warning in
each of the following circumstances: the weighted association coefficients suggest that a case,
with a different result than that of the nearest neighbour, ought to be the nearest neighbour;
the weighted correlation coefficients suggest that a case, with a different result than that
of the nearest neighbour, ought to be the nearest neighbour; an ideal point suggesting a
different result is at least as near to the instant case as is the nearest neighbour; a centroid
suggesting a different result is at least as near to the instant case as is the nearest neighbour;
or the specified directions suggest a different result or results. */

{
    result *result_pointer,
        *equidistant_pointer;
    kase *case_pointer,
        *nearest_known_case_pointer,
        *nearest_unknown_case_pointer;
    cardinal minimum_known_differences;
    floating_point minimum_association_coefficient,
        minimum_weighted_association_coefficient,
        max_correlation_coefficient,
        max_weighted_correlation_coefficient;
    string heading = "Safeguards",
        subheading = NULL;
    char message[Max_Error_Message_Length];
    boolean weighted_different_result = FALSE,
        ideal_point_different_result = FALSE,
        centroid_different_result = FALSE,
        specified_direction_different_result = FALSE;

    initialize_nearest_metrics(&minimum_known_differences,
        &minimum_association_coefficient, &minimum_weighted_association_coefficient,
        &max_correlation_coefficient, &max_weighted_correlation_coefficient,
        area_pointer->number_of_attributes);

    for (result_pointer = area_pointer->result_head; result_pointer != NULL;
        result_pointer = result_pointer->next)
        for (case_pointer = result_pointer->case_head; case_pointer != NULL;
            case_pointer = case_pointer->next)
            find_nearest_metrics(case_pointer->metrics, &minimum_known_differences,
                &minimum_association_coefficient,
                &minimum_weighted_association_coefficient, &max_correlation_coefficient,
                &max_weighted_correlation_coefficient, -area_pointer->infinite_weight);

```



```

subheading = "Distance_measures";

nearest_known_case_pointer =
    area_pointer→nearest_result→nearest_known_case;
nearest_unknown_case_pointer =
    area_pointer→nearest_result→nearest_unknown_case;

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
    for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
         case_pointer = case_pointer→next)
        log_case_if_necessary(log_stream, result_pointer, area_pointer→nearest_result,
                              case_pointer, &nearest_known_case_pointer,
                              &nearest_unknown_case_pointer, level,
                              case_pointer→metrics.number_of_known_differences ≡
                              minimum_known_differences,
                              &heading, &subheading, NULL);
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");

subheading = "Association_coefficients";

nearest_known_case_pointer =
    area_pointer→nearest_result→nearest_known_case;
nearest_unknown_case_pointer =
    area_pointer→nearest_result→nearest_unknown_case;

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
    for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
         case_pointer = case_pointer→next)
        log_case_if_necessary(log_stream, result_pointer, area_pointer→nearest_result,
                              case_pointer, &nearest_known_case_pointer,
                              &nearest_unknown_case_pointer, level,
                              Is_Equal((floating_point) case_pointer→
                                       metrics.number_of_known_differences /
                                       case_pointer→metrics.number_of_known_pairs,
                                       minimum_association_coefficient, Precision),
                              &heading, &subheading, NULL);
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");

```

```

if ( $\neg$ area_pointer→infinite_weight) {
    /* none of the weights is infinite, so the values obtained for the weighted association
       coefficients are meaningful */
    subheading = "Weighted_association_coefficients";

    nearest_known_case_pointer =
        area_pointer→nearest_result→nearest_known_case;
    nearest_unknown_case_pointer =
        area_pointer→nearest_result→nearest_unknown_case;

    for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
         result_pointer = result_pointer→next)
        for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
             case_pointer = case_pointer→next)
            log_case_if_necessary(log_stream, result_pointer, area_pointer→nearest_result,
                                case_pointer, &nearest_known_case_pointer,
                                &nearest_unknown_case_pointer, level,
                                Is_Equal(case_pointer→metrics.weighted_association_coefficient,
                                        minimum_weighted_association_coefficient, Precision),
                                &heading, &subheading, &weighted_different_result);
    if (subheading ≡ NULL)
        fprintf(log_stream, "\n");
}

subheading = "Correlation_coefficients";

nearest_known_case_pointer =
    area_pointer→nearest_result→nearest_known_case;
nearest_unknown_case_pointer =
    area_pointer→nearest_result→nearest_unknown_case;

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
    for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
         case_pointer = case_pointer→next)
        if ( $\neg$ case_pointer→metrics.correlation_coefficient.meaningless)
            log_case_if_necessary(log_stream, result_pointer, area_pointer→nearest_result,
                                case_pointer, &nearest_known_case_pointer,
                                &nearest_unknown_case_pointer, level,
                                Is_Equal(max_correlation_coefficient,
                                        case_pointer→metrics.correlation_coefficient.unweighted,
                                        Precision),
                                &heading, &subheading, NULL);
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");

```

```

subheading = "Weighted_correlation_coefficients";

nearest_known_case_pointer =
    area_pointer→nearest_result→nearest_known_case;
nearest_unknown_case_pointer =
    area_pointer→nearest_result→nearest_unknown_case;

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)
    for (case_pointer = result_pointer→case_head; case_pointer ≠ NULL;
         case_pointer = case_pointer→next)
        if (¬case_pointer→metrics.correlation_coefficient.meaningless)
            log_case_if_necessary(log_stream, result_pointer, area_pointer→nearest_result,
                                 case_pointer, &nearest_known_case_pointer,
                                 &nearest_unknown_case_pointer, level,
                                 Is_Equal(max_weighted_correlation_coefficient,
                                         case_pointer→metrics.correlation_coefficient.weighted, Precision),
                                 &heading, &subheading, &weighted_different_result);
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");

subheading = "Ideal_points";

for (equidistant_pointer = area_pointer→nearest_ideal_point; equidistant_pointer ≠ NULL;
     equidistant_pointer = equidistant_pointer→equidistant_ideal_point_next)
    if (equidistant_pointer ≠ area_pointer→nearest_result) {
        if (heading ≠ NULL) {
            Indent(log_stream, level);
            fprintf(log_stream, "%s:\n\n", heading);
            heading = NULL;
        }
        if (subheading ≠ NULL) {
            Indent(log_stream, level + 1);
            fprintf(log_stream, "%s:\n", subheading);
            subheading = NULL;
        }
        Indent(log_stream, level + 2);
        fprintf(log_stream, "%s\n", equidistant_pointer→identifier);
        if (area_pointer→nearest_result→nearest_known_case ≠ NULL)
            if (Relative_Distance(equidistant_pointer→ideal_point_metrics.distance,
                                  area_pointer→nearest_result→nearest_known_case→
                                  metrics.distance) ≠ FURTHER)
                ideal_point_different_result = TRUE;
        if (area_pointer→nearest_result→nearest_unknown_case ≠ NULL)
            if (Relative_Distance(equidistant_pointer→ideal_point_metrics.distance,
                                  area_pointer→nearest_result→nearest_unknown_case→
                                  metrics.distance) ≠ FURTHER)
                ideal_point_different_result = TRUE;
    }
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");

```

```

subheading = "Centroids";

for (equidistant_pointer = area_pointer→nearest_centroid; equidistant_pointer ≠ NULL;
     equidistant_pointer = equidistant_pointer→equidistant_centroid_next)
  if (equidistant_pointer ≠ area_pointer→nearest_result) {
    if (heading ≠ NULL) {
      Indent(log_stream, level);
      fprintf(log_stream, "%s:\n\n", heading);
      heading = NULL;
    }
    if (subheading ≠ NULL) {
      Indent(log_stream, level + 1);
      fprintf(log_stream, "%s:\n", subheading);
      subheading = NULL;
    }
    Indent(log_stream, level + 2);
    fprintf(log_stream, "%s\n", equidistant_pointer→identifier);
    if (area_pointer→nearest_result→nearest_known_case ≠ NULL)
      if (Relative_Distance(equidistant_pointer→centroid_metrics.distance,
                           area_pointer→nearest_result→nearest_known_case→
                           metrics.distance) ≠ FURTHER)
        centroid_different_result = TRUE;
    if (area_pointer→nearest_result→nearest_unknown_case ≠ NULL)
      if (Relative_Distance(equidistant_pointer→centroid_metrics.distance,
                           area_pointer→nearest_result→nearest_unknown_case→
                           metrics.distance) ≠ FURTHER)
        centroid_different_result = TRUE;
  }
}
if (subheading ≡ NULL)
  fprintf(log_stream, "\n");

subheading = "Specified_directions";

for (equidistant_pointer = area_pointer→strongest_specified_direction;
     equidistant_pointer ≠ NULL;
     equidistant_pointer = equidistant_pointer→equidistant_specified_direction_next)
  if (equidistant_pointer ≠ area_pointer→nearest_result) {
    if (heading ≠ NULL) {
      Indent(log_stream, level);
      fprintf(log_stream, "%s:\n\n", heading);
      heading = NULL;
    }
    if (subheading ≠ NULL) {
      Indent(log_stream, level + 1);
      fprintf(log_stream, "%s:\n", subheading);
      subheading = NULL;
    }
    Indent(log_stream, level + 2);
    fprintf(log_stream, "%s\n", equidistant_pointer→identifier);
    specified_direction_different_result = TRUE;
  }
}
if (subheading ≡ NULL)
  fprintf(log_stream, "\n");

```

```

subheading = "Ideal_point_directions";
for (equidistant_pointer = area_pointer→strongest_ideal_point_direction;
     equidistant_pointer ≠ NULL;
     equidistant_pointer = equidistant_pointer→equidistant_ideal_point_direction_next)
if (equidistant_pointer ≠ area_pointer→nearest_result) {
    if (heading ≠ NULL) {
        Indent(log_stream, level);
        fprintf(log_stream, "%s:\n\n", heading);
        heading = NULL;
    }
    if (subheading ≠ NULL) {
        Indent(log_stream, level + 1);
        fprintf(log_stream, "%s:\n", subheading);
        subheading = NULL;
    }
    Indent(log_stream, level + 2);
    fprintf(log_stream, "%s\n", equidistant_pointer→identifier);
}
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");
subheading = "Centroid_directions";
for (equidistant_pointer = area_pointer→strongest_centroid_direction;
     equidistant_pointer ≠ NULL;
     equidistant_pointer = equidistant_pointer→equidistant_centroid_direction_next)
if (equidistant_pointer ≠ area_pointer→nearest_result) {
    if (heading ≠ NULL) {
        Indent(log_stream, level);
        fprintf(log_stream, "%s:\n\n", heading);
        heading = NULL;
    }
    if (subheading ≠ NULL) {
        Indent(log_stream, level + 1);
        fprintf(log_stream, "%s:\n", subheading);
        subheading = NULL;
    }
    Indent(log_stream, level + 2);
    fprintf(log_stream, "%s\n", equidistant_pointer→identifier);
}
if (subheading ≡ NULL)
    fprintf(log_stream, "\n");

```

```

/* issue warnings if necessary */
if (weighted_different_result)
    warning(log_stream,
            "one_or_both_of_the_weighted_safeguard_metrics_suggest_"
            "that_a_case(or_cases)_with_a_different_result_should_"
            "be_the_nearest_neighbour(or_neighbours)", level);

if (ideal_point_different_result) {
    sprintf(message,
            "one_or_more_ideal_points_with_a_different_result_are_at_"
            "least_as_near_to_the_%s_case_as_is_the_nearest_neighbour",
            instant_case_type);
    warning(log_stream, message, level);
}
if (centroid_different_result) {
    sprintf(message,
            "one_or_more_centroids_with_a_different_result_are_at_"
            "least_as_near_to_the_%s_case_as_is_the_nearest_neighbour",
            instant_case_type);
    warning(log_stream, message, level);
}
if (specified_direction_different_result)
    warning(log_stream,
            "the_specified_directions_suggest_a_different_result_or_results",
            level);
}

```

extern void*Write_Report*(

```

    file report_stream,
    file log_stream,
    area *area_pointer,
    vector_element *facts_head,
    vector_element *original_facts,
    boolean verbose,
    boolean hypothetical,
    boolean same_result,
    cardinal number,
    cardinal level)

```

*/** Writes SHYSTER's legal opinion about the facts pointed to by *facts_head* to *report_stream* (if it is not *NULL*). Cases are summarized in full, and opening and closing strings are written in full, if *verbose* is *TRUE*.

If *number* is not zero then the instant case is actually a hypothetical (if *hypothetical* is *TRUE*) or an instantiation, and *number* is its number. If the instant case is an instantiation or a hypothetical, *original_facts* points to the facts of the uninstantiated and unhypothesized instant case. If the instant case is a hypothetical and *same_result* is *TRUE*, the hypothetical has the same result as the unhypothesized instant case. **/*

```

{
    result *result_pointer;
    kase *case_pointer,
        *nearest_neighbour;
    string instant_case_type;

    if (number == 0) {

        /* the instant case is the uninstantiated and unhypothesized instant case */
        instant_case_type = "instant";

        if (report_stream != NULL) {

            fprintf(report_stream, "%s{%s_area}\n\n"
                    "%s{Instant_case}\n\n",
                    Heading, area_pointer->identifier, Subheading);

            /* write the opening string */

            if (area_pointer->opening != NULL) {
                if (verbose)
                    Write(report_stream, area_pointer->opening, "\n", Top_Level, Hang);
                else
                    Write(report_stream, "[Opening.]", "\n", Top_Level, Hang);
                fprintf(report_stream, "%s", Skip);
            }

            /* write the facts of the instant case */

            fprintf(report_stream, "In_the_instant_case,\n");
            list_facts(report_stream, facts_head, area_pointer->attribute_head,
                    area_pointer->number_of_attributes);

            fprintf(report_stream, "\n%s_In_my_opinion", Skip);
        }
    } else if (!hypothetical) {

        /* the instant case is instantiation number */
        instant_case_type = "instantiated";

        if (report_stream != NULL) {

            fprintf(report_stream, "%s{Instantiation_%u}\n\n", Subheading, number);
            fprintf(report_stream,
                    "It_may_be_that_the_following_is_true_of_the_instant_case:\n");
            list_new_differences(report_stream, facts_head, original_facts,
                    area_pointer->attribute_head,
                    number_of_differences(facts_head, original_facts));

            fprintf(report_stream, "\n%s_If_that_is_so_then_in_my_opinion", Skip);
        }
    }
}

```

```

} else {
    /* the instant case is hypothetical number */
    instant_case_type = "hypothetical";

    if (report_stream ≠ NULL) {
        fprintf(report_stream, "%s{Hypothetical_}u}\n\n", Subheading, number);
        fprintf(report_stream, "Consider_ the_ instant_ case_ changed_"
            "so_ that_ the_ following_ is_ true:\n");
        list_new_differences(report_stream, facts_head, original_facts,
            area_pointer→attribute_head,
            number_of_differences(facts_head, original_facts));

        if (same_result)
            /* this hypothetical has the same result as does the instant case */
            fprintf(report_stream,
                "\n%_s_ If_ that_ were_ so_ then_ I_ would_ be_"
                "more_ strongly_ of_ the_"
                "opinion_ that", Skip);
        else
            /* this hypothetical has a different result to that of the instant case */
            fprintf(report_stream,
                "\n%_s_ If_ that_ were_ so_ then_ my_ opinion_ would_ be_"
                "that", Skip);
    }
}
Indent(log_stream, level);
fprintf(log_stream, "Nearest_ neighbours:\n\n");
Indent(log_stream, level + 1);
fprintf(log_stream, "%s:\n", area_pointer→nearest_result→identifier);
if (area_pointer→nearest_result→nearest_known_compared_with_unknown ≠ FURTHER) {
    /* the nearest known neighbour is the nearest neighbour (although there may be an
       equidistant case with an unknown distance) */
    nearest_neighbour = area_pointer→nearest_result→nearest_known_case;

    /* for every nearest known case with this result ... */
    for (case_pointer = area_pointer→nearest_result→nearest_known_case;
        case_pointer ≠ NULL;
        case_pointer = case_pointer→equidistant_known_next) {
        /* log the case (a nearest known neighbour) */
        Indent(log_stream, level + 2);
        log_case_number_and_name(log_stream, case_pointer→number,
            case_pointer→short_name);
        if (Is_Zero_Subdistance(case_pointer→metrics.distance.known))
            fprintf(log_stream, "_ (identical)");
        fprintf(log_stream, "\n");
    }
}

```



```

if (has_less_known_distance(area_pointer→nearest_result→nearest_unknown_case,
                             area_pointer→nearest_result→nearest_known_case))

    /* if not for its unknown distance, the nearest unknown neighbour would be the
       nearest neighbour, so for every nearest unknown case with this result ... */

    for (case_pointer = area_pointer→nearest_result→nearest_unknown_case;
         case_pointer ≠ NULL;
         case_pointer = case_pointer→equidistant_unknown_next) {

        /* log the case (a nearest unknown neighbour) */

        Indent(log_stream, level + 2);
        log_case_number_and_name(log_stream, case_pointer→number,
                                case_pointer→short_name);
        fprintf(log_stream, "\n");

    } else

        /* the nearest unknown neighbours should be ignored */

        area_pointer→nearest_result→nearest_unknown_case = NULL;

        fprintf(log_stream, "\n");

    if (report_stream ≠ NULL)
        handle_nearest_known(report_stream, area_pointer→nearest_result,
                              area_pointer→nearest_result, nearest_neighbour,
                              area_pointer, facts_head, instant_case_type, verbose);

} else {

    /* the nearest unknown neighbour is the nearest neighbour */

    nearest_neighbour = area_pointer→nearest_result→nearest_unknown_case;

    /* for every nearest unknown case with this result ... */

    for (case_pointer = area_pointer→nearest_result→nearest_unknown_case;
         case_pointer ≠ NULL;
         case_pointer = case_pointer→equidistant_unknown_next) {

        /* log the case (a nearest unknown neighbour) */

        Indent(log_stream, level + 2);
        log_case_number_and_name(log_stream, case_pointer→number,
                                case_pointer→short_name);
        fprintf(log_stream, "\n");
    }
}

```

```

/* for every nearest known case with this result ... */
for (case_pointer = area_pointer→nearest_result→nearest_known_case;
     case_pointer ≠ NULL;
     case_pointer = case_pointer→equidistant_known_next) {
    /* log the case (a nearest known neighbour) */
    Indent(log_stream, level + 2);
    log_case_number_and_name(log_stream, case_pointer→number,
                             case_pointer→short_name);
    fprintf(log_stream, "\n");
}
fprintf(log_stream, "\n");
if (report_stream ≠ NULL)
    handle_nearest_unknown(report_stream, area_pointer→nearest_result,
                           area_pointer, facts_head, instant_case_type, verbose);
}

Indent(log_stream, level);
fprintf(log_stream, "Nearest_others: \n\n");

for (result_pointer = area_pointer→result_head; result_pointer ≠ NULL;
     result_pointer = result_pointer→next)

/* for every result ... */
if (result_pointer ≠ area_pointer→nearest_result) {
    /* this result is not the nearest result */
    Indent(log_stream, level + 1);
    fprintf(log_stream, "%s: \n", result_pointer→identifier);

    if ((result_pointer→nearest_known_case ≠ NULL) ∨
        (result_pointer→nearest_unknown_case ≠ NULL)) {
        /* this result has a nearest case (i.e. it has at least one case) */
        if ((result_pointer→nearest_known_compared_with_unknown ≡ FURTHER) ∨
            has_less_known_distance(result_pointer→nearest_unknown_case,
                                    nearest_neighbour))

            /* the nearest unknown other is the nearest other or, if not for its unknown
            distance, the nearest unknown other would be the nearest neighbour, so
            for every nearest unknown case with this result ... */
            for (case_pointer = result_pointer→nearest_unknown_case;
                 case_pointer ≠ NULL;
                 case_pointer = case_pointer→equidistant_unknown_next) {

                /* log the case (a nearest unknown other) */
                Indent(log_stream, level + 2);
                log_case_number_and_name(log_stream, case_pointer→number,
                                         case_pointer→short_name);
                fprintf(log_stream, "\n");
            }
        }
    }
}

```

```

    /* for every nearest known case with this result ... */
    for (case_pointer = result_pointer→nearest_known_case;
         case_pointer ≠ NULL;
         case_pointer = case_pointer→equidistant_known_next) {
        /* log the case (a nearest known other) */
        Indent(log_stream, level + 2);
        log_case_number_and_name(log_stream, case_pointer→number,
                                case_pointer→short_name);
        fprintf(log_stream, "\n");
    }
    if (report_stream ≠ NULL)
        handle_nearest_others(report_stream, result_pointer,
                              area_pointer→nearest_result, nearest_neighbour,
                              area_pointer→nearest_result→
                              nearest_known_compared_with_unknown ≠ FURTHER,
                              area_pointer, facts_head, instant_case_type, verbose);
    }
    fprintf(log_stream, "\n");
}
implement_safeguards(log_stream, area_pointer, instant_case_type, level);
/* log the nearest result */
Indent(log_stream, level - 1);
fprintf(log_stream, "Nearest_result_for");
if (number ≡ 0)
    /* this is the unhypothesized, uninstantiated instant case */
    fprintf(log_stream, "the_instant_case");
else if (¬hypothetical)
    /* this is an instantiation */
    fprintf(log_stream, "instantiation_u", number);
else
    /* this is a hypothetical */
    fprintf(log_stream, "hypothetical_u", number);
fprintf(log_stream, "_is_s.\n\n", area_pointer→nearest_result→identifier);
if ((report_stream ≠ NULL) ∧ (number ≡ 0) ∧ (area_pointer→closing ≠ NULL)) {
    /* write the closing string */
    fprintf(report_stream, "%s\n", Skip);
    if (verbose)
        Write(report_stream, area_pointer→closing, "\n", Top_Level, Hang);
    else
        Write(report_stream, "[Closing.]", "\n", Top_Level, Hang);
}
}
}

```


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Index

All of the identifiers which appear in the code listings in this report, and which are not reserved words or preprocessor commands, are listed below.

Function names are followed by a pair of parentheses. The names of SHYSTER's defined types are marked with a star.

SHYSTER's external identifiers are made up of upper- and lower-case letters; its static identifiers consist only of lower-case letters. Identifiers in all upper-case are enumerated identifiers and other constants.

Page numbers set in boldface type refer to definitions of functions or constants, or to declarations of types or variables (including structure member declarations). Page numbers set in italics refer to function declarations.

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