
Techniques, Methods
& Applications in
Futures Studies
Juana Maness

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Chapter- 1

Future Techniques

In the multi-disciplinary field of futurology, futurologists use a diverse range of forecasting methods, including:

Anticipatory thinking protocols

Delphi method

The Delphi method is a very popular technique used in Futures Studies. It was developed by Gordon and Helmer in 1953 at RAND. It can be defined as a method for structuring a group communication process, so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.

It uses the iterative, independent questioning of a panel of experts to assess the timing, probability, significance and implications of factors, trends and events in the relation to the problem being considered. Panelists are not brought together but individually questioned in rounds. After the initial round, the panelists are given lists of anonymous answers from other panelists which they can use to refine their own views.

Studies employing Delphi method tend to be difficult to perform. The application of the Delphi method requires a great deal of attention to the selection of participating experts and the questionnaires have to be scrupulously prepared and tested in advance. The initial preparation and follow-up rounds of questioning of the panelists tends to be time consuming.

Delphi's primary strength is its ability to explore, tranquilly and objectively, issues that require judgement. Unlike panel sessions, the iterative Delphi method allows the forecasting and assessment to be done without the effect of strong personalities or reputations influencing other panelists and also overcomes the difficulty of getting all experts together in a single time and place.

Causal layered analysis (CLA)

This method, developed by Sohail Inayatullah, is one of the newest developments in the Futures Studies. Causal layered analysis focuses on "opening up" the present and past to create alternative futures rather than on developing a picture of particular future.

It is concerned with the vertical dimension of futures studies, with the layers of analysis. CLA is based on the assumption that the way in which a problem is formulated changes the policy solutions and the actors in charge of initiating transformations.

The key principle of the method is using and integrating different ways of knowing.

There are a number of benefits arising from the application of this method. Causal layered analysis increases the range and richness of scenarios; leads to inclusion of different ways of knowing among participants in workshops; appeals to wider range of individuals through incorporation of non-textual and artistic elements; extends the discussion beyond the obvious to the deeper and marginal; and leads to the policy actions that can be educated by alternative layers of analysis.

Environmental scanning

Environmental scanning is usually used at the start of a futures project. It aims at broad exploration of all major trends, issues, advancements, events and ideas across a wide range of activities. Information is collected from many different sources, such as newspapers, magazines, Internet, television, conferences, reports, and also science-fiction books. Various tools and methodologies are used by large corporations to systematically scope their external environment. An example is the widely used FUTURE structure developed by Futurist Patrick Dixon described in his book Futurewise - F ast, U rban, T ribal, U niversal, R adical, E thical. Attention needs to be given to potential Wild Cards - low probability but potentially high impact events.

Scanning is used to build up a comprehensive picture of factors that could impact strategy.

Four types of indicators can be examined in the process of environmental scanning:

1. Lone signals (individual factors that might indicate change)
2. Landmark events (in various areas of life)
3. Forecasts of experts
4. Statistical descriptions (to portray development of elements of the study).

Morphological analysis

Morphological analysis is a technique developed by Fritz Zwicky (1966, 1969) for exploring all the possible solutions to a multi-dimensional, non-quantified problem complex.

As a problem structuring and problem solving technique, morphological analysis was designed for multi-dimensional, non-quantifiable problems where causal modeling and simulation do not function well or at all. Zwicky developed this approach to address seemingly non-reducible complexity. Using the technique of cross consistency assessment (CCA), the system however does allow for reduction, not by reducing the number of variables involved, but by reducing the number of possible solutions through the elimination of the illogical solution combinations in a grid box.

MA has also been employed for the identification of new product opportunities. The technique involves mapping options in order to attain an overall perspective of possible solutions. It comprises the two main activities: a systematic analysis of a current and future structure of the area including the gaps in that structure, stimulation for creation of new alternative, which could fill the gaps and meet any needs.

Scenario planning

Scenarios are one of the most popular and persuasive methods used in the Futures Studies. Government planners, corporate strategists and military analysts use them in order to aid decision-making. The term scenario was introduced into planning and decision-making by Herman Kahn in connection with military and strategic studies done by RAND in the 1950s.

It can be defined as a rich and detailed portrait of a plausible future world, one sufficiently vivid that a planner can clearly see and comprehend the problems, challenges and opportunities that such an environment would present.

A scenario is not a specific forecast of the future, but a plausible description of what might happen. Scenarios are like stories built around carefully constructed plots based on trends and events. They assist in selection of strategies, identification of possible futures, making people aware of uncertainties and opening up their imagination and initiating learning processes.

One of the key strengths of the scenario process is its influence on the way of thinking of its participants. A mindset, in which the focus is placed on one possible future, is altered towards the balanced thinking about a number of possible alternative futures.

Although it is a very rewarding method it is also very demanding. The difficulties in its use can arise from a lack of clear focus, purpose or directions. As a result too many scenario stories can be created and/or their content may not be directly related to the strategic question.

Future history

A **future history** is a postulated history of the future.Some science fiction authors construct as a common background for fiction. The author may include a timeline of events for this history. A related field is alternate history, which assumes that the events at a critical point in past history turned out differently and then draws a fictional future timeline from that event.

Monitoring

It is a process that aims at evaluation of events, as they occur or just after. It involves activities like scanning, detecting, projecting, assessing, responding and tracking. Monitoring is one of the fundamental activities performed by Futures Studies.

Content analysis

This technique is used for the systematic and objective study of the particular aspects of various 'messages'. Such 'messages' can be found in books, journals, newspapers, private letters, publications of political parties, reports, surveys, interviews, television, Internet and so on. This method, in order to be reliable and valid, needs to be performed with high competency.

Backcasting (eco-history)

It is a technique that often is pointed out as an opposite to forecasting. It involves identification of a particular scenario and tracing its origins and lines of development back to the present.

Back-view mirror analysis

It builds upon the assumption that any future oriented group process has to manage peoples' difficulties in thinking into the future. These difficulties can arise from the fears as well as from the lack of experience in futures thinking.

Back-view mirror analysis allows dealing with the fears related to the future by creating a new perspective that looks to the past instead of starting the process in the present. The method is used to perform qualitative analysis of the past using both quantitative and qualitative data.

Cross-impact analysis

The method was developed by Theodore Gordon and Olaf Helmer in 1966 in an attempt to answer a question whether perceptions of how future events may interact with each other can be used in forecasting.

As it is well known, most events and trends are interdependent in some ways. Cross-impact analysis provides an analytical approach to the probabilities of an element in a forecast set, and it helps to assess probabilities in view of judgements about potential interactions between those elements.

The technique can be used by individuals and groups at an elementary qualitative level as well as it can be employed to perform more complicated and intensive quantitative analysis. One of its strengths is that it forces the attention towards "chains of causality: x affects y; y affects z". On the other side it can be very fatiguing and monotonous.

Futures workshops

Future workshops were developed by Robert Jungk in order to allow anybody to become involved in creating their preferred future rather than being subjected to decisions made by experts. Future workshops are very strongly action oriented. They aim, first to imagine the desired future, and then to plan it and implement it.

Future workshops have four distinctive phases:

1. In the first preparatory phase the issue that will be considered is identified and the structure and details of sessions are arranged.
2. The operative phase involves clarification of the issue considered and articulation of negative experiences in the present situation.
3. In the fantasy stage participants verbalise their desires, dreams, fantasies and views about the future in a free idea generation session. The participants are asked to forget all the limitations and obstacles of the present reality.
4. The last step involves: analysis of the feasibility of ideas and solutions generated in the fantasy phase; recognition of limits and barriers for implementation and discovering how they can be overcome.

A similar method is found in Future Search.

Failure mode and effects analysis

Failure mode and effects analysis (FMEA) is a safety analysis method first developed for systems engineering which examines potential failures in products or processes. It may be used to evaluate risk management priorities for mitigating known threat-vulnerabilities.

FMEA helps select remedial actions that reduce **cumulative impacts** of life cycle consequences (risks) from a systems failure (fault).

Measured Action

Measured Action is an action that improves Production Capability by a measured amount, (e.g. if X hours of overtime then Y additional files transmitted). Measured actions enhance FMEA by perfectly matching calculated risks with calculated contingencies to ensure a specific outcome.

Futures biographies

This method, also called futures imagining, aims to create individual imaginaries, to gather peoples' views on the future and to examine them in the study of collective future. Peoples' expectations and opinions are considered as an important indication of possible goals and to possible directions that can influence peoples' actions and in result steer the future.

Futures wheel

The method is a form of structured brainstorming that aims at identifying and packaging secondary and tertiary consequences of trends and events. A trend or event is placed in the middle of a piece of paper and then small spokes are drawn wheel-like from the centre. Primary impacts and consequences are written in circles of the first ring.

Then secondary consequences of each primary impact are derived forming the second ring. This ripple effect continues until there is a clear picture of implications that the event or trend can have. Futures wheel is a very simple but powerful technique for drawing out people's opinions and ideas. However, it is sensitive to underlying assumptions.

Relevance tree

It is an analytical technique that subdivides a large subject into increasingly smaller subtopics. The relevance tree has a form of a hierarchical structure that begins with a high level of abstraction and moves down with greater degree of detail in the following levels of the tree. It is a powerful technique that helps to ensure that a given problem or issue is broken into comprehensive detail and that important connections among the elements considered are presented in both current and potential situations.

Simulation and modelling

Simulation and modelling are computer-based tools developed to represent reality. They are widely used to analyse behaviours and to understand processes. Models allow demonstration of past changes as well as the examination of various transformations and their impact on each other and other considered factors.

They can help to understand the connections between factors and events and to examine their dynamics. Simulation is a process that represents a structure and change of a system. In simulation some aspects of reality are duplicated or reproduced, usually within the model. The main purpose of simulation is to discern what would really happen in the real world if certain conditions, imitated by the model, developed.

Although modelling and simulation became even more popular with the development of computing technology, application of these techniques have certain limits. Models represent a simplification of a system that is being examined; therefore the results need to be carefully considered.

As the complexity of real systems increases models need to be more and more complex to represent the reality most accurately. In result, they may become increasingly difficult to understand and to be operated. Their complex nature can cause problems with using and managing results.

As models constitute a simpler version of reality, certain factors can be omitted, and in consequence can lead to mistakes. Such mistakes are not easy to be found and corrected.

Social network analysis

Social network analysis (also sometimes called *network theory*) has emerged as a key technique in modern sociology, anthropology, Social Psychology and organizational studies, as well as a popular topic of speculation and study.

Research in a number of academic fields have demonstrated that social networks operate on many levels, from families up to the level of nations, and play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

Systems engineering

An interdisciplinary approach to engineering systems that is inherently complex, since the behavior of and interaction among system components is not always well defined.

Defining and characterizing such systems and subsystems, and the interactions among them, is the primary aim of systems engineering. On *very* large programs, a systems architect may be designated to serve as an interface between the user/sponsor and systems engineer.

RADM Grace Hopper, USNR was quoted as saying "Life was simple before World War II. After that, we had systems."

Visioning

Visioning is a popular method in the studies of desirable futures and the one that gives emphasis to values. It is extensively used in urban planning. The visioning process is based on the assumption that images of the future lead peoples' present behaviours, guide choices and influence decisions. Images of the future can be positive or negative and cause different responses according to the perceptions.

Vision is usually seen as a positive, desirable image of the future and can be defined as a compelling, inspiring statement of the preferred future that the authors and those who subscribe to the vision want to create.

There are a number of issues that need to be addressed while using the visioning method. Vision comprises peoples' values, wishes, fears and desires. In order to make the visioning process work it is necessary to ensure that it is not making an idealistic wish-list; that vision is an image of the future shared by a whole community; and that the vision is translatable into reality.

Trend analysis

Trend analysis is one of the most often used methods in forecasting. It aims to observe and register the past performance of a certain factor and project it into the future. It involves analysis of two groups of trends: quantitative, mainly based on statistical data, and qualitative, these are at large concerned with social, institutional, organisational and political patterns.

In the quantitative trend analysis data is plotted along a time axis, so that a simple curve can be established. Short term forecasting seems quite simple; it becomes more complex when the trend is extrapolated further into the future, as the number of dynamic forces that can change direction of the trend increases. This form of simple trend extrapolation helps to direct attention towards the forces, which can change the projected pattern.

A more elaborated curve that uses times series analysis can often reveal surprising historical and current data patterns. The qualitative trend analysis is one of the most demanding and creative methods in Futures Studies.

As trends never speak for themselves, the identification and description of patterns is partly empirical and partly creative activity. The most challenging part of qualitative trends analysis is identification of a tendency early, as recognition of a mature trend is "relatively useless" in influencing anyone's behaviour.

Adaptive role-playing

Although similar to decision theory, game theory studies decisions that are made in an environment where various players interact. In other words, game theory studies choice of optimal behavior when costs and benefits of each option are not fixed, but depend upon the choices of other individuals.

ALL-WinWin collaborative efforts require group decision support systems (GDSS) that enable the knowledge management community of practice to assure sustainable mutually-beneficial results.

Chapter- 2

Delphi Method

The **Delphi method** is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts.

In the standard version, the experts answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process the range of the answers will decrease and the group will converge towards the "correct" answer. Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, stability of results) and the mean or median scores of the final rounds determine the results.

Other versions, such as the Policy Delphi, have been designed for normative and explorative use, particularly in the area of social policy and public health. In Europe, more recent web-based experiments have used the Delphi method as a communication technique for interactive decision-making and e-democracy.

Delphi is based on the principle that forecasts (or decisions) from a structured group of individuals are more accurate than those from unstructured groups. This has been indicated with the term "collective intelligence". The technique can also be adapted for use in face-to-face meetings, and is then called mini-Delphi or Estimate-Talk-Estimate (ETE). Delphi has been widely used for business forecasting and has certain advantages over another structured forecasting approach, prediction markets.

History

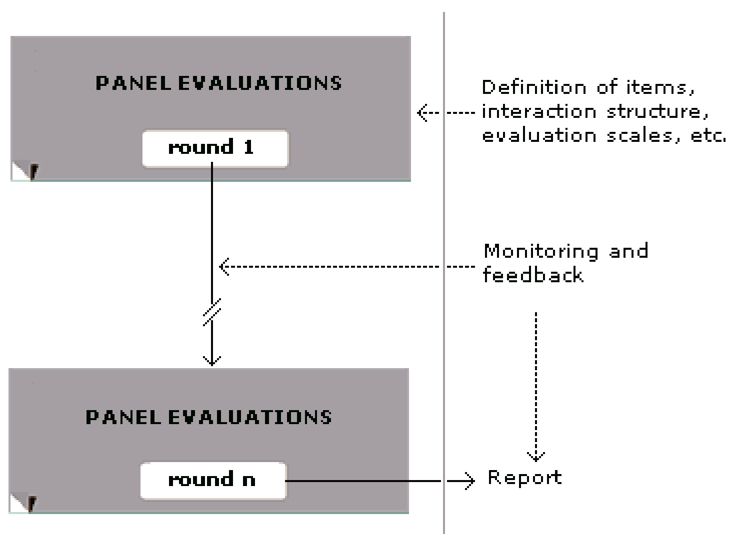
The name "Delphi" derives from the Oracle of Delphi. The authors of the method were not happy with this name, because it implies "something oracular, something smacking a little of the occult". The Delphi method is based on the assumption that group judgments are more valid than individual judgments.

The Delphi method was developed at the beginning of the Cold War to forecast the impact of technology on warfare. In 1944, General Henry H. Arnold ordered the creation of the report for the U.S. Army Air Corps on the future technological capabilities that might be used by the military.

Different approaches were tried, but the shortcomings of traditional forecasting methods, such as theoretical approach, quantitative models or trend extrapolation, in areas where precise scientific laws have not been established yet, quickly became apparent. To combat these shortcomings, the Delphi method was developed by Project RAND during the 1950-1960s (1959) by Olaf Helmer, Norman Dalkey, and Nicholas Rescher. It has been used ever since, together with various modifications and reformulations, such as the Imen-Delphi procedure.

Experts were asked to give their opinion on the probability, frequency and intensity of possible enemy attacks. Other experts could anonymously give feedback. This process was repeated several times until a consensus emerged.

Key characteristics



The Delphi Method communication structure

The following key characteristics of the Delphi method help the participants to focus on the issues at hand and separate Delphi from other methodologies:

Structuring of information flow

The initial contributions from the experts are collected in the form of answers to questionnaires and their comments to these answers. The panel director controls the interactions among the participants by processing the information and filtering out irrelevant content. This avoids the negative effects of face-to-face panel discussions and solves the usual problems of group dynamics.

Regular feedback

Participants comment on their own forecasts, the responses of others and on the progress of the panel as a whole. At any moment they can revise their earlier statements. While in regular group meetings participants tend to stick to previously stated opinions and often conform too much to group leader, the Delphi method prevents it.

Anonymity of the participants

Usually all participants maintain anonymity. Their identity is not revealed even after the completion of the final report. This stops them from dominating others in the process using their authority or personality, frees them to some extent from their personal biases, minimizes the "bandwagon effect" or "halo effect", allows them to freely express their opinions, encourages open critique and admitting errors by revising earlier judgments.

Role of the facilitator

The person coordinating the Delphi method can be known as a *facilitator*, and facilitates the responses of their *panel of experts*, who are selected for a reason, usually that they hold knowledge on an opinion or view. The facilitator sends out questionnaires, surveys etc. and if the panel of experts accept, they follow instructions and present their views. Responses are collected and analyzed, then common and conflicting viewpoints are identified. If consensus is not reached, the process continues through thesis and antithesis, to gradually work towards synthesis, and building consensus.

Use in forecasting

First applications of the Delphi method were in the field of science and technology forecasting. The objective of the method was to combine expert opinions on likelihood and expected development time, of the particular technology, in a single indicator. One of the first such reports, prepared in 1964 by Gordon and Helmer, assessed the direction of long-term trends in science and technology development, covering such topics as scientific breakthroughs, population control, automation, space progress, war prevention and weapon systems. Other forecasts of technology were dealing with vehicle-highway systems, industrial robots, intelligent internet, broadband connections, and technology in education.

Later the Delphi method was applied in other areas, especially those related to public policy issues, such as economic trends, health and education. It was also applied successfully and with high accuracy in business forecasting. For example, in one case reported by Basu and Schroeder (1977), the Delphi method predicted the sales of a new product during the first two years with inaccuracy of 3–4% compared with actual sales.

Quantitative methods produced errors of 10–15%, and traditional unstructured forecast methods had errors of about 20%.

The Delphi method has also been used as a tool to implement multi-stakeholder approaches for participative policy-making in developing countries. The governments of Latin America and the Caribbean have successfully used the Delphi method as an open-ended public-private sector approach to identify the most urgent challenges for their regional ICT-for-development eLAC Action Plans. As a result, governments have widely acknowledged the value of collective intelligence from civil society, academic and private sector participants of the Delphi, especially in a field of rapid change, such as technology policies. In this sense, the Delphi method can contribute to a general appreciation of participative policy-making.

Acceptance

Overall the track record of the Delphi method is mixed. There have been many cases when the method produced poor results. Still, some authors attribute this to poor application of the method and not to the weaknesses of the method itself. It must also be realized that in areas such as science and technology forecasting the degree of uncertainty is so great that exact and always correct predictions are impossible, so a high degree of error is to be expected.

Another particular weakness of the Delphi method is that future developments are not always predicted correctly by consensus of experts. Firstly, the issue of ignorance is important. If panelists are misinformed about a topic, the use of Delphi may only add confidence to their ignorance. Secondly, sometimes unconventional thinking of amateur outsiders may be superior to expert thinking.

One of the initial problems of the method was its inability to make complex forecasts with multiple factors. Potential future outcomes were usually considered as if they had no effect on each other. Later on, several extensions to the Delphi method were developed to address this problem, such as cross impact analysis, that takes into consideration the possibility that the occurrence of one event may change probabilities of other events covered in the survey. Still the Delphi method can be used most successfully in forecasting single scalar indicators.

Despite these shortcomings, today the Delphi method is a widely accepted forecasting tool and has been used successfully for thousands of studies in areas varying from technology forecasting to drug abuse.

Use in policy-making

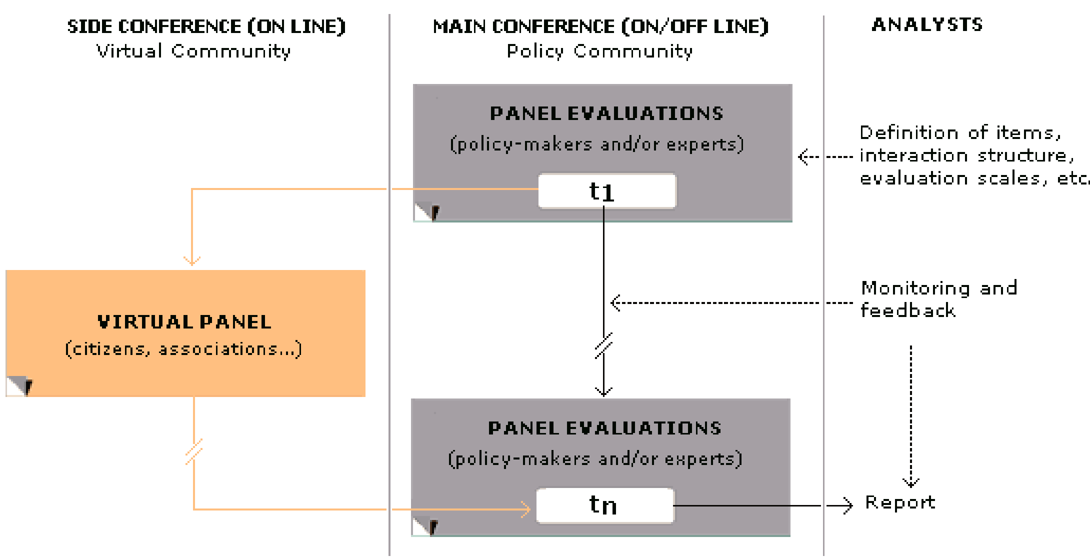
From the 1970's, the use of the Delphi technique in public policy-making introduces a number of methodological innovations. In particular:

- the need to examine several types of items (not only *forecasting* items but, typically, *issue* items, *goal* items, and *option* items) leads to introducing different evaluation scales which are not used in the standard Delphi. These often include *desirability*, *feasibility* (technical and political) and *probability*, which the analysts can use to outline different scenarios: the *desired* scenario (from desirability), the *potential* scenario (from feasibility) and the *expected* scenario (from probability);
- the complexity of the issues posed in public policy-making leads to give more importance to the arguments supporting the evaluations of the panelists; so these are often invited to list arguments for and against each option item, and sometimes they are given the possibility to suggest new items to be submitted to the panel;
- for the same reason, the scaling methods, which are used to measure panel evaluations, often include more sophisticated approaches such as multi-dimensional scaling.

Further innovations come from the use of computer-based (and later web-based) Delphi conferences. According to Turoff and Hiltz, in computer-based Delphis:

- the iteration structure used in the paper Delphis, which is divided into three or more discrete rounds, can be replaced by a process of continuous (roundless) interaction, enabling panelists to change their evaluations at any time;
- the statistical group response can be updated in real-time, and shown whenever a panelist provides a new evaluation.

According to Bolognini, web-based Delphis offer two further possibilities, relevant in the context of interactive policy-making and e-democracy. These are:



A web-based communication structure (Hyperdelphi)

- the involvement of a large number of participants,
- the use of two or more panels representing different groups (such as policy-makers, experts, citizens), which the administrator can give tasks reflecting their diverse roles and expertise, and make them to interact within ad hoc communication structures. For example, the *policy community* members (policy-makers and experts) may interact as part of the *main conference* panel, while they receive inputs from a *virtual community* (citizens, associations etc.) involved in a *side conference*. These web-based variable communication structures, which he calls *Hyperdelphi* (HD), are designed to make Delphi conferences "more fluid and adapted to the hypertextual and interactive nature of digital communication".

Delphi applications not aiming at consensus

Traditionally the Delphi method has aimed at a consensus of the most probable future by iteration. The Policy Delphi, launched by Murray Turoff, is instead a decision support method aiming at structuring and discussing the diverse views of the preferred future. The Argument Delphi, developed by Osmo Kuusi, focuses on ongoing discussion and finding relevant arguments rather than focusing on the output. The Disaggregative Policy Delphi, developed by Petri Tapio, uses cluster analysis as a systematic tool to construct various scenarios of the future in the latest Delphi round. The respondent's view on the probable and the preferable future are dealt with as separate cases.

Delphi vs. prediction markets

As can be seen from the Methodology Tree of Forecasting, Delphi has characteristics similar to prediction markets as both are structured approaches that aggregate diverse opinions from groups. Yet, there are differences that may be decisive for their relative applicability for different problems.

Some advantages of prediction markets derive from the possibility to provide incentives for participation.

1. They can motivate people to participate over a long period of time and to reveal their true beliefs.
2. They aggregate information automatically and instantly incorporate new information in the forecast.
3. Participants do not have to be selected and recruited manually by a facilitator. They themselves decide whether to participate if they think their private information is not yet incorporated in the forecast.

Delphi seems to have these advantages over prediction markets:

1. Potentially quicker forecasts if experts are readily available.

Online Delphi forecasting systems

A number of Delphi forecasts are conducted using web sites that allow the process to be conducted in Real-time Delphi. For instance, the TechCast Project uses a panel of 100 experts worldwide to forecast breakthroughs in all fields of science and technology. Further examples are several studies conducted by the Center for Futures Studies and Knowledge Management that use an online-based Delphi method.

Prediction Market

Prediction markets (also known as **predictive markets**, **information markets**, **decision markets**, **idea futures**, **event derivatives**, or **virtual markets**) are speculative markets created for the purpose of making predictions. Assets are created whose final cash value is tied to a particular event (e.g., will the next US president be a Republican) or parameter (e.g., total sales next quarter). The current market prices can then be interpreted as predictions of the probability of the event or the expected value of the parameter. Prediction markets are thus structured as betting exchanges, without any risk for the bookmaker.

People who buy low and sell high are rewarded for improving the market prediction, while those who buy high and sell low are punished for degrading the market prediction. Evidence so far suggests that prediction markets are at least as accurate as other institutions predicting the same events with a similar pool of participants.

Many prediction markets are open to the public. Betfair is the world's biggest prediction exchange, with a turnover exceeding 50m weekly. In October 2010 betfair announced to go public with valuations ranging up to £1.5 billion GBP.Intrade is a for-profit company with a large variety of contracts not including sports. The Iowa Electronic Markets is an academic market examining elections where positions are limited to $500. TradeSports are prediction markets for sporting events. The simExchange, Hollywood Stock Exchange, Fantasy Trader, NewsFutures, the Popular Science Predictions Exchange, Hubdub, Tahministan, The Industry Standard's technology industry prediction market, and the Foresight Exchange Prediction Market are virtual prediction markets where purchases are made with virtual money. Bet2Give is a charity prediction market where real money is traded but ultimately all winnings are donated to the charity of the winner's choice.

History

One of the oldest and most famous is the University of Iowa's Iowa Electronic Market. The Hollywood Stock Exchange, a virtual market game established in 1996 and now a division of Cantor Fitzgerald, LP, in which players buy and sell prediction shares of movies, actors, directors, and film-related options, correctly predicted 32 of 2006's 39 big-category Oscar nominees and 7 out of 8 top category winners. HedgeStreet, designated in 2004 as a market and regulated by the Commodity Futures Trading Commission, enables Internet traders to speculate on economic events.

Prediction markets actually have a long and colorful lineage. Betting on elections was common in the U.S. until at least the 1940s, with formal markets existing on Wall Street in the months leading up to the race. Newspapers reported market conditions to give a sense of the closeness of the contest in this period prior to widespread polling. The markets involved thousands of participants, had millions of dollars in volume in current terms, and had remarkable predictive accuracy.

Around 1990 at Project Xanadu, Robin Hanson used the first known corporate prediction market. Employees used it in order to bet on, for example, the cold fusion controversy.

In July 2003, the U.S. Department of Defense publicized a Policy Analysis Market and on their website speculated that additional topics for markets might include terrorist attacks. A critical backlash quickly denounced the program as a "terrorism futures market" and the Pentagon hastily canceled the program.

Prediction markets are championed in James Surowiecki's 2004 book *The Wisdom of Crowds*, Cass Sunstein's 2006 *Infotopia*, and *How to Measure Anything: Finding the Value of Intangibles in Business* by Douglas Hubbard.

The research literature is collected together in the peer reviewed *The Journal of Prediction Markets*, edited by Leighton Vaughan Williams and published by the University of Buckingham Press. The journal was first published in 2007, and is available online and in print.

In John Brunner's 1975 science fiction story *The Shockwave Rider* there is a description of a prediction market that he called the Delphi Pool.

In October 2007 companies from the United States, Ireland, Austria, Germany, and Denmark formed the Prediction Market Industry Association, tasked with promoting awareness, education, and validation for prediction markets.

Accuracy

Some academic research has focused on potential flaws with the prediction market concept. In particular, Dr. Charles F. Manski of Northwestern University published “Interpreting the Predictions of Prediction Markets”, which attempts to show mathematically that under a wide range of assumptions the "predictions" of such markets do not closely correspond to the actual probability beliefs of the market participants unless the market probability is near either 0 or 1. Manski suggests that directly asking a group of participants to estimate probabilities may lead to better results.

However, Steven Gjerstad (Purdue) in his paper "Risk Aversion, Beliefs, and Prediction Market Equilibrium," has shown that prediction market prices are very close to the mean belief of market participants if the agents are risk averse and the distribution of beliefs is spread out (as with a normal distribution, for example). Justin Wolfers (Wharton) and Eric Zitzewitz (Dartmouth) have obtained similar results, and also include some analysis of prediction market data, in their paper "Interpreting Prediction Market Prices as Probabilities." In practice, the prices of binary prediction markets have proven to be closely related to actual frequencies of events in the real world.

Douglas Hubbard has also conducted a sample of over 400 retired claims which showed that the probability of an event is close to its market price but, more importantly, significantly closer than the average single subjective estimate. However, he also shows that this benefit is partly offset if individuals first undergo calibrated probability assessment training so that they are good at assessing odds subjectively. The key benefit of the market, Hubbard claims, is that it mostly adjusts for uncalibrated estimates and, at the same time, incentivizes market participants to seek further information.

A common belief among economists and the financial community in general is that prediction markets based on play money cannot possibly generate credible predictions. However, the data collected so far disagrees. Analyzed data from the Hollywood Stock Exchange and the Foresight Exchange concluded that market prices predicted actual outcomes and/or outcome frequencies in the real world. Comparing an entire season's worth of NFL predictions from NewsFutures' play-money exchange to those of Tradesports, an equivalent real-money exchange based in Ireland, both exchanges performed equally well. In this case, using real money did not lead to better predictions.

Hollywood Stock Exchange creator Max Keiser suggests that not only are these markets no more predictive than their established counterparts such as the New York Stock Exchange and the London Stock Exchange, but that reducing the unpredictability of markets would mean reducing risk and, therefore, reducing the amount of speculative capital needed to keep markets open and liquid.

Sources of inaccuracy

Prediction markets suffer from the same types of inaccuracy as other kinds of market, i.e. liquidity or other factors not intended to be measured are taken into account as risk factors by the market participants, distorting the market probabilities. Prediction markets may also be subject to speculative bubbles. For example, in the year 2000 IEM presidential futures markets, a flood of new traders in the final week of the election caused the market to gyrate wildly, making its "predictions" useless.

There can also be direct attempts to manipulate such markets. In the Tradesports 2004 presidential markets there was an apparent manipulation effort. An anonymous trader sold short so many Bush 2004 presidential futures contracts that the price was driven to zero, implying a zero percent chance that Bush would win. The only rational purpose of such a trade would be an attempt to manipulate the market in a strategy called a "bear raid". If this was a deliberate manipulation effort it failed, however, as the price of the contract rebounded rapidly to its previous level. As more press attention is paid to prediction markets, it is likely that more groups will be motivated to manipulate them. However, in practice, such attempts at manipulation have always proven to be very short lived. In their paper entitled "Information Aggregation and Manipulation in an Experimental Market" (2005), Hanson, Oprea and Porter (George Mason U), show how attempts at market manipulation in fact end up increasing the accuracy of the market because they provide that much more profit incentive to bet against the manipulator.

Using real-money prediction market contracts as a form of insurance can also affected the price of the contract. For example, if the election of a leader is perceived as negatively impacting the economy, traders may buy shares of that leader being elected, as a form of insurance.

Other issues

Legality

Because online gambling is outlawed in the United States through federal laws and many state laws as well, most prediction markets that target U.S. users operate with "play money" rather than "real money": they are free to play (no purchase necessary) and usually offer prizes to the best traders as incentives to participate. Notable exceptions are Intrade/TradeSports, which escapes U.S. legal restrictions by operating from Dublin, Ireland, where gambling is legal and regulated, and the Iowa Electronic Markets, which operates from the University of Iowa under the cover of a no-action letter from the Commodity Futures Trading Commission and allows bets up to $500.

Controversial incentives

Some kinds of prediction markets may create controversial incentives. For example, a market predicting the death of a world leader might be quite useful for those whose activities are strongly related to this leader's policies, but it also might turn into an assassination market.

Use by corporations

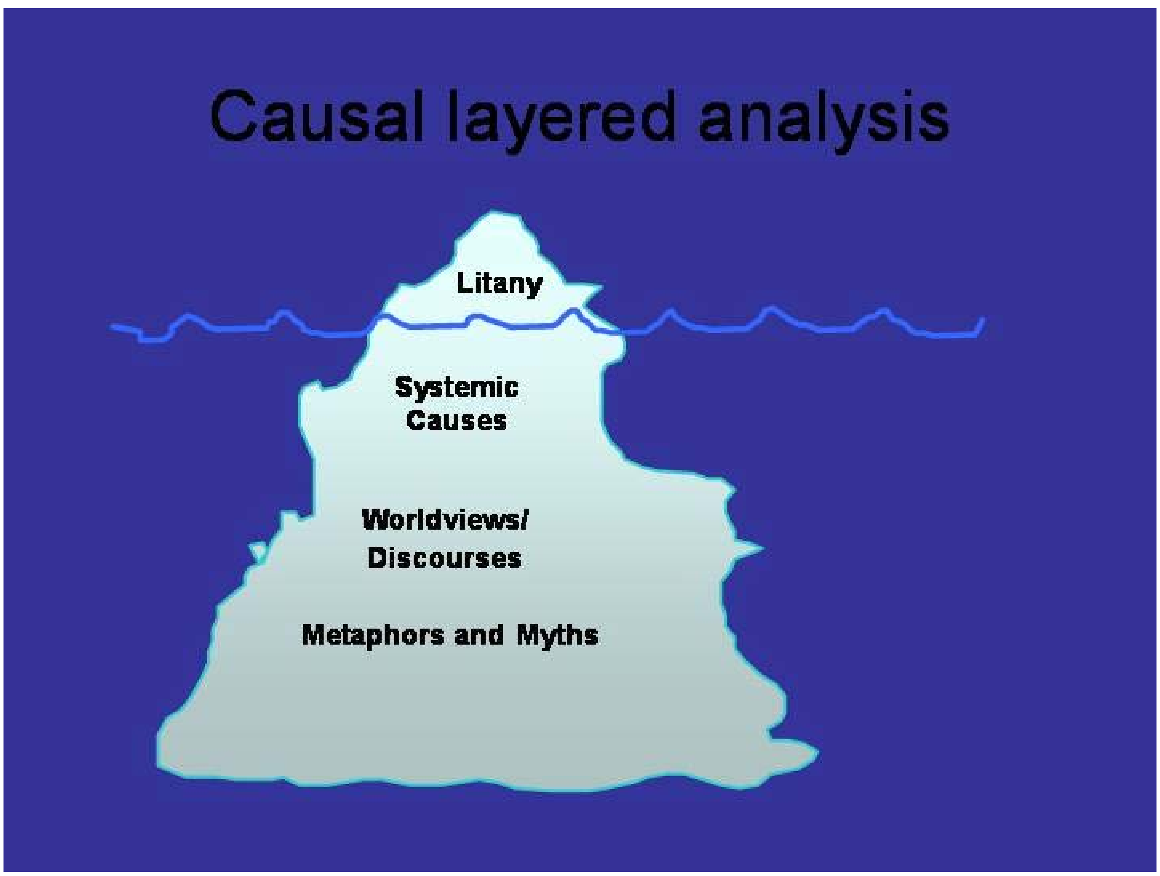
- The simExchange introduced a perpetual contract that it calls "stocks" to predict the global, lifetime sales of video game consoles and software titles. These stocks do not expire like most contracts on prediction markets because the founder, Brian Shiau, argued that video game sales can continue for years. The premise for these stocks is that Shiau believes the video game industry suffers from a "lack of comprehensive sales data" and he compares the information problem of a game's sales to the information problem of evaluating a company's market value. Hanson warns that such a system may not work if a connection is not enforced. Keith Gamble has described the simExchange as a Keynesian beauty contest and that financial markets have certain remedies such as company buy-outs that cannot happen on the simExchange. Gamble concludes that such a prediction market can work but will be confined to play money.

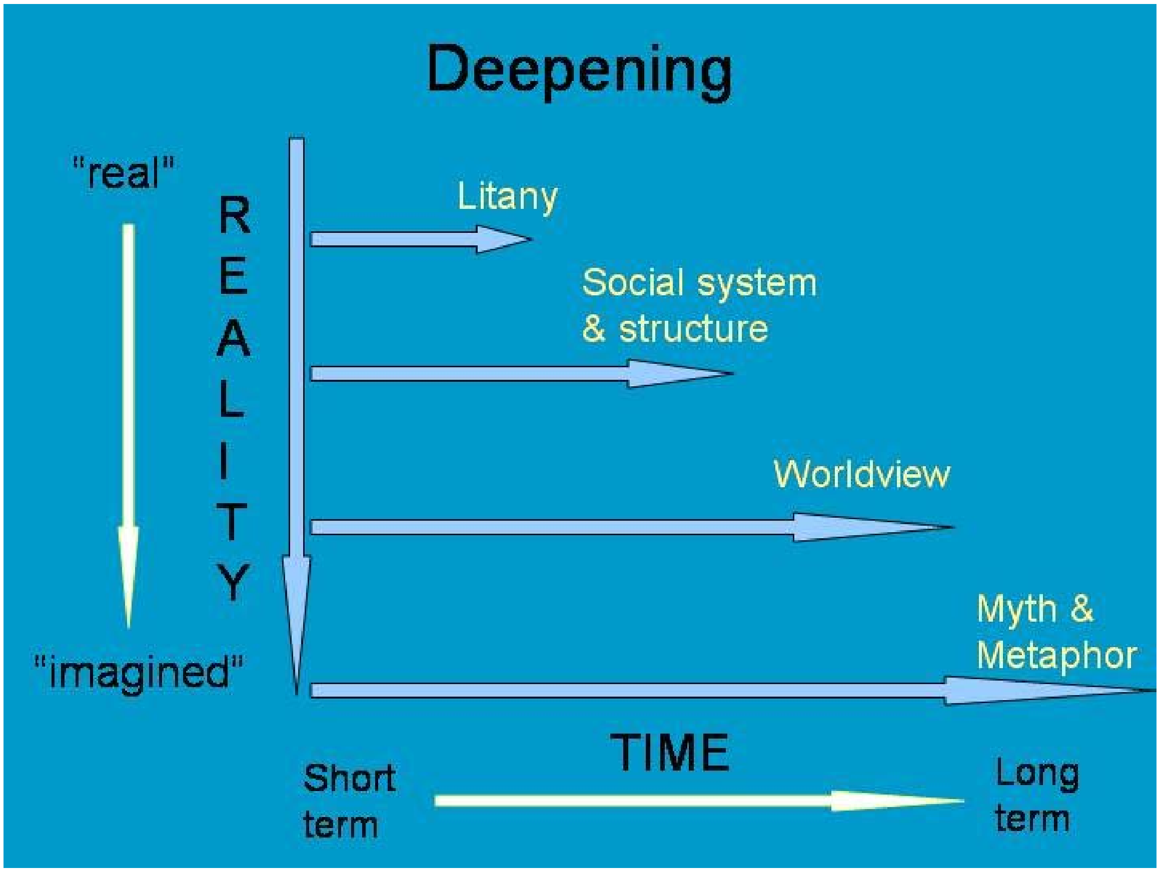
- Best Buy, Motorola, Qualcomm, Edmunds.com, and Misys Banking Systems are listed as Consensus Point clients.
- Hewlett-Packard pioneered applications in sales forecasting and now uses prediction markets in several business units. Mentioned in academic publications from HP Labs. Also mentioned in Newsweek. It is working towards a commercial launch of the implementation as a product, BRAIN (Behaviorally Robust Aggregation of Information Networks).
- Corning, Renault, Eli Lilly, Pfizer, Siemens, Masterfoods, Arcelor Mittal and other global companies are listed as NewsFutures customers.
- Intel mentioned in Harvard Business Review (April 2004) in relation to managing manufacturing capacity.
- Microsoft is piloting prediction markets internally.
- France Telecom's Project Destiny has been in use since mid-2004 with demonstrated success.
- Google has confirmed that it uses a predictive market internally in its official blog.
- The Wall Street Journal reported that General Electric uses prediction market software from Consensus Point to generate new business ideas.
- BusinessWeek lists MGM and Lionsgate Studios as two HSX clients.
- HSX built and operated a televised virtual stock market, the Interactive Music Exchange for Fuse Networks Fuse TV to be used as the basis of their daily live television broadcast, IMX, which ran from January, 2003 through July, 2004. The television audience traded virtual stocks of artists/videos/songs, and predicted which would make it to the top of the Billboard music charts. The first of its kind, Fuse Network and HSX won an AFI Enhanced TV (American Film Institute) Award for innoviation in television interactivity.
- Starwood embraced the use of prediction markets for developing and selecting marketing campaigns. Marketing department started out with some initial ideas and allowed employees to add new ideas or make changes to existing ones. Then subsequently incentives based prediction markets were leveraged to select the best of the lot.
- A new startup named "Recorded Future" being backed by Google and CIA is creating ripples in this domain.

Chapter- 3

Causal Layered Analysis and Morphological Analysis (problem-solving)

Causal Layered Analysis





Causal layered analysis (CLA) is one of several futures techniques used as a means to inquire into the causes of social phenomena and to generate a set of forecasts as to the future course of the phenomena.

As a theory, CLA seeks to integrate empiricist, interpretive, critical and action learning modes of knowing (loosely, science, social science, philosophy and mythology). As a method, its utility is not in predicting the future but in creating transformative spaces for the creation of alternative futures. It is also likely to be of use in developing more effective — deeper, inclusive, longer term — policy.

Causal layered analysis consists of four levels: the litany, social causes, discourse/world-view and myth/metaphor.

1. The first level is the litany – the official unquestioned view of reality.
2. The second level is the social causation level, the systemic perspective. The data of the litany is explained and questioned at this level.
3. The third level is the worldview/discourse. Deeper, unconsciously held ideological, worldview and discursive assumptions are unpacked at this level. The way in which different stakeholders construct the litany and system are also explored.
4. The fourth level is the myth-metaphor, the unconscious emotive dimensions of the issue. The challenge is to conduct research that moves up and down these layers

> of analysis and thus is inclusive of different ways of knowing. Doing so allows for the creation of authentic alternative futures and integrated transformation. CLA begins and ends by questioning the future.

Advantages

CLA has these advantages:

(1) Expands the range and richness of scenarios (the CLA categories can be used in the incasting phase); (2) When used in a workshop setting, it leads to the inclusion of different ways of knowing among participants; (3) It appeals to and can be used by a wider range of individuals as it incorporates non-textual and poetic/artistic expression in the futures process; (4) CLA layers participant's positions (conflicting and harmonious ones); (5) It moves the debate/discussion beyond the superficial and obvious to the deeper and marginal; (6) It allows for a range of transformative actions; (7) CLA leads to policy actions that can be informed by alternative layers of analysis; and (7) CLA reinstates the vertical in social analysis, that is, from postmodern relativism to global ethics.

Embedded in the emerging discourse of futures studies, causal layered analysis (CLA) draws largely from poststructuralism, macrohistory, and postcolonial multicultural theory. It seeks to move beyond the superficiality of conventional social science research and forecasting methods insofar as these methods are often unable to unpack discourses — worldviews and ideologies — not to mention archetypes, myths, and metaphors.

Causal layered analysis is concerned less with predicting a particular future and more with opening up the present and past to create alternative futures. It focuses less on the horizontal spatiality of futures and more on the vertical dimension of futures studies, of layers of analysis. Causal layered analysis opens up space for the articulation of constitutive discourses, which can then be shaped as scenarios. In essence, CLA is a search for integration in methodology, seeking to combine differing research traditions.

These traditions are in flux: in the social sciences generally and futures studies specifically. Futures studies has decisively moved from ontological concerns about the nature of the predicability of the universe to epistemological concerns about the knowledge interests in varied truth claims about the future.

This has led futures studies from being focused on empirical/prediction modes to interpretation and ethnography (the meanings we give to data). And the field's conceptual evolution has not stopped there. More recently, futures methodologies have been influenced by the poststructural thrust, with concerns for not what is being forecasted but what is missing from particular forecasts and images of the future. This is the layered approach to reality.

At the same time, the limits of instrumental rationality and strategic consciousness have become accepted, largely because of critiques of rationality by scholars associated with the environmental movement, the feminist movement, and spiritual movements — the new post-normal sciences — among others. Moreover, while globalisation has not suddenly developed a soft heart, the agenda now includes how we know the world and how these knowings are complicit in the disasters around us.

Within the CLA framework, the move to post-structuralism, is not at the expense of data–orientation or meaning–oriented research and activism. Indeed, data is seen in the context of meanings, within the context of epistemes (or knowledge parameters that structure meanings; for example, class, gender, the interstate system), and myths and metaphors that organise the deep beliefs, the traumas and transcendence that over time define identity — what it means to mean and to be.

CLA does not argue for excluding the top level of the iceberg for bottom–of–the–sea analysis; rather, all levels are required and needed for fulfilling — valid and transformative — research. Moreover, in this loop of data–meaning–episteme–myth, reconstruction is not lost. Action is embedded in epistemology.

With the CLA framework, the politics of epistemology is considered part of the research process. Politics is acknowledged and self-interest disclosed. Of course, not all self-interest can be disclosed since individuals operate from epistemes that are often outside of our knowing efforts. Indeed, epistemes shapes what we can and cannot know. While eclectic and layered approaches hope to capture some of the unknowns, by definition, the unknown remains mysterious. Acknowledging the unknown is central to futures research. This does not mean that the future cannot be precisely predicted, but rather that the unknown creeps into any research, as does the subjective. Moreover, the unknown is expressed in different ways and different ways of knowing are required to have access to it. Freeing methodology from politics is a never–ending task; however, within the CLA framework this is accomplished not by controlling for these variables but by layering them.

Morphological analysis (problem-solving)

Morphological analysis or **General Morphological Analysis** is a method developed by Fritz Zwicky (1967, 1969) for exploring all the possible solutions to a multi-dimensional, non-quantified problem complex.

As a problem-structuring and problem-solving technique, morphological analysis was designed for multi-dimensional, non-quantifiable problems where causal modeling and simulation do not function well or at all. Zwicky developed this approach to address seemingly non-reducible complexity. Using the technique of cross consistency assessment (CCA) (Ritchey, 1998), the system however does allow for reduction, not by reducing the number of variables involved, but by reducing the number of possible solutions through the elimination of the illogical solution combinations in a grid box. A detailed introduction to morphological modeling is given in Ritchey (2002, 2006).

Overview

Morphology comes from the classical Greek concept *morphé*, meaning shape or form. Morphological Analysis (MA) concerns the arrangement of objects and how they conform to create a whole or Gestalt. The objects in question can be a physical system (e.g. anatomy), a social system (e.g. an organisation) or a logical system (e.g. word forms or a system of ideas).

General morphology was developed by Fritz Zwicky, the Swiss astrophysicist based at the California Institute of Technology. Zwicky applied MA inter alia to astronomical studies and the development of jet and rocket propulsion systems.

Illustration of the need for Morphological Analysis

Consider a complex real world problem, like those of marketing or making policies for a nation, where there are many governing factors, and most of them cannot be expressed as numerical time series data, as one would like to have for building mathematical models. The conventional approach here would be to break the system down into parts, isolate the vital parts (dropping the trivial components) for their contributions to the output and solve the simplified system for creating desired models or scenarios. The disadvantage of this approach is that real world scenarios do not behave rationally and more often than not a simplified model will break down when the contribution of trivial components becomes significant. Also significantly, the behaviour of many components will be governed by states of, and relations with other components, perhaps minor.

Morphological Analysis on the other hand, does not drop any of the components of the system itself, but works backwards from the output towards the system internals. Again, the interactions and relations get to play their parts in MP and their effects are accounted for in the analysis.

Problem Solving

Problem solving is a mental process and is part of the larger problem process that includes problem finding and problem shaping. Considered the most complex of all intellectual functions, problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills. Problem solving occurs when an organism or an artificial intelligence system needs to move from a given state to a desired goal state.

Overview

The nature of human problem solving methods has been studied by psychologists over the past hundred years. There are several methods of studying problem solving, including; introspection, behaviorism, simulation, computer modeling and experiment.

Beginning with the early experimental work of the Gestaltists in Germany (e.g. Duncker, 1935) and continuing through the 1960s and early 1970s, research on problem solving typically conducted relatively simple, laboratory tasks (e.g. Duncker's "X-ray" problem; Ewert & Lambert's 1932 "disk" problem, later known as Tower of Hanoi) that appeared novel to participants (e.g. Mayer, 1992). Various reasons account for the choice of simple novel tasks: they had clearly defined optimal solutions, they were solvable within a relatively short time frame, researchers could trace participants' problem-solving steps, and so on. The researchers made the underlying assumption, of course, that simple tasks such as the Tower of Hanoi captured the main properties of "real world" problems, and that the cognitive processes underlying participants' attempts to solve simple problems were representative of the processes engaged in when solving "real world" problems. Thus researchers used simple problems for reasons of convenience, and thought generalizations to more complex problems would become possible. Perhaps the best-known and most impressive example of this line of research remains the work by Allen Newell and Herbert Simon.

Simple laboratory-based tasks can be useful in explicating the steps of logic and reasoning that underlie problem solving; however, they omit the complexity and emotional valence of "real-world" problems. In clinical psychology, researchers have focused on the role of emotions in problem solving (D'Zurilla & Goldfried, 1971; D'Zurilla & Nezu, 1982), demonstrating that poor emotional control can disrupt focus on the target task and impede problem resolution (Rath, Langenbahn, Simon, Sherr, & Diller, 2004). In this conceptualization, human problem solving consists of two related processes: problem orientation, the motivational/attitudinal/affective approach to problematic situations and problem-solving skills, the actual cognitive-behavioral steps, which, if successfully implemented, lead to effective problem resolution. Working with individuals with frontal lobe injuries, neuropsychologists have discovered that deficits in emotional control and reasoning can be remediated, improving the capacity of injured persons to resolve everyday problems successfully (Rath, Simon, Langenbahn, Sherr, & Diller, 2003).

Europe

In Europe, two main approaches have surfaced, one initiated by Donald Broadbent in the United Kingdom and the other one by Dietrich Dörner in Germany. The two approaches have in common an emphasis on relatively complex, semantically rich, computerized laboratory tasks, constructed to resemble real-life problems. The approaches differ somewhat in their theoretical goals and methodology, however. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness, and typically employs mathematically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, has an interest in the interplay of the cognitive, motivational, and social components of problem solving, and utilizes very complex computerized scenarios that contain up to 2,000 highly interconnected variables (e.g., Dörner, Kreuzig, Reither & Stäudel's 1983 LOHHAUSEN project; Ringelband, Misiak & Kluwe, 1990). Buchner (1995) describes the two traditions in detail.

To sum up, researchers' realization that problem-solving processes differ across knowledge domains and across levels of expertise (e.g. Sternberg, 1995) and that, consequently, findings obtained in the laboratory cannot necessarily generalize to problem-solving situations outside the laboratory, has during the past two decades led to an emphasis on real-world problem solving. This emphasis has been expressed quite differently in North America and Europe, however. Whereas North American research has typically concentrated on studying problem solving in separate, natural knowledge domains, much of the European research has focused on novel, complex problems, and has been performed with computerized scenarios.

USA and Canada

In North America, initiated by the work of Herbert Simon on learning by doing in semantically rich domains (e.g. Anzai & Simon, 1979; Bhaskar & Simon, 1977), researchers began to investigate problem solving separately in different natural knowledge domains – such as physics, writing, or chess playing – thus relinquishing their attempts to extract a global theory of problem solving (e.g. Sternberg & Frensch, 1991). Instead, these researchers have frequently focused on the development of problem solving within a certain domain, that is on the development of expertise (e.g. Anderson, Boyle & Reiser, 1985; Chase & Simon, 1973; Chi, Feltovich & Glaser, 1981).

Areas that have attracted rather intensive attention in North America include such diverse fields as:

- Problem Solving (Kepner & Tregoe, 1958)
- Reading (Stanovich & Cunningham, 1991)
- Writing (Bryson, Bereiter, Scardamalia & Joram, 1991)
- Calculation (Sokol & McCloskey, 1991)
- Political decision making (Voss, Wolfe, Lawrence & Engle, 1991)
- Managerial problem solving (Wagner, 1991)
- Lawyers' reasoning (Amsel, Langer & Loutzenhiser, 1991)
- Mechanical problem solving (Hegarty, 1991)
- Problem solving in electronics (Lesgold & Lajoie, 1991)
- Computer skills (Kay, 1991)
- Game playing (Frensch & Sternberg, 1991)
- Personal problem solving (Heppner & Krauskopf, 1987)
- Mathematical problem solving (Polya, 1945; Schoenfeld, 1985)
- Social problem solving (D'Zurilla & Goldfreid, 1971; D'Zurilla & Nezu, 1982)

- Problem solving for innovations and inventions: TRIZ (Altshuller, 1973, 1984, 1994)

Characteristics of difficult problems

As elucidated by Dietrich Dörner and later expanded upon by Joachim Funke, difficult problems have some typical characteristics that can be summarized as follows:

- Intransparency (lack of clarity of the situation)
    - commencement opacity
    - continuation opacity
- Polytely (multiple goals)
    - inexpressiveness
    - opposition
    - transience
- Complexity (large numbers of items, interrelations and decisions)
    - enumerability
    - connectivity (hierarchy relation, communication relation, allocation relation)
    - heterogeneity
- Dynamics (time considerations)
    - temporal constraints
    - temporal sensitivity
    - phase effects
    - dynamic unpredictability

The resolution of difficult problems requires a direct attack on each of these characteristics that are encountered.

In reform mathematics, greater emphasis is placed on problem solving relative to basic skills, where basic operations can be done with calculators. However some "problems" may actually have standard solutions taught in higher grades. For example, kindergarteners could be asked how many fingers are there on all the gloves of 3 children, which can be solved with multiplication.

Problem-solving techniques

- Abstraction: solving the problem in a model of the system before applying it to the real system
- Analogy: using a solution that solved an analogous problem
- Brainstorming: (especially among groups of people) suggesting a large number of solutions or ideas and combining and developing them until an optimum is found
- Divide and conquer: breaking down a large, complex problem into smaller, solvable problems
- Hypothesis testing: assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption

- Lateral thinking: approaching solutions indirectly and creatively
- Means-ends analysis: choosing an action at each step to move closer to the goal
- Method of focal objects: synthesizing seemingly non-matching characteristics of different objects into something new
- Morphological analysis: assessing the output and interactions of an entire system
- Reduction: transforming the problem into another problem for which solutions exist
- Research: employing existing ideas or adapting existing solutions to similar problems
- Root cause analysis: eliminating the cause of the problem
- Trial-and-error: testing possible solutions until the right one is found

"A solution, to be a solution, must share some of the problems characteristics." Richard L Kempe

Problem-solving methodologies

- Eight Disciplines Problem Solving
- 5Φ (IAPIE)
- GROW model
- *How to solve it*
- Kepner-Tregoe
- Southbeach Notation
- PDCA
- RPR Problem Diagnosis
- TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch, "theory of solving inventor's problems")

Example applications

Problem solving is of crucial importance in engineering when products or processes fail, so corrective action can be taken to prevent further failures. Perhaps of more value, problem solving can be applied to a product or process prior to an actual fail event i.e. a potential problem can be predicted, analyzed and mitigation applied so the problem never actually occurs. Techniques like Failure Mode Effects Analysis can be used to pro-actively reduce the likelihood of problems occurring. Forensic engineering is an important technique of failure analysis which involves tracing product defects and flaws. Corrective action can then be taken to prevent further failures.

Chapter- 4

Environmental Scanning

Environmental scanning is one component of the global environmental analysis. Environmental monitoring, environmental forecasting and environmental assessment complete the global environmental analysis. Environmental scanning refers to the macro environment.The global environment refers to the macro environment which comprises industries, markets, companies, clients and competitors. Consequently, there exist corresponding analyses on the micro-level. Suppliers, customers and competitors representing the micro environment of a company are analyzed within the industry analysis.

Definition

Environmental scanning can be defined as 'the study and interpretation of the political, economic, social and technological events and trends which influence a business, an industry or even a total market'. The factors which need to be considered for environmental scanning are events, trends, issues and expectations of the different interest groups. Issues are often forerunners of trend breaks. A trend break could be a value shift in society, a technological innovation that might be permanent or a paradigm change. Issues are less deep-seated and can be 'a temporary short-lived reaction to a social phenomenon'. A trend can be defined as an 'environmental phenomenon that has adopted a structural character'.

Modes of scanning

There are three modes of scanning the business environment according to Kubr:

- Systematic scanning - Information related to markets and customers, changes in legislation, regulations having a direct impact on the organization's activities, government policy etc.are collected continuously by taking relevant factors into account
- Ad-hoc scanning - Conducting special surveys and studies to deal with environmental issues from time to time

- Processed-form scanning - Using information in a processed form available from different sources inside and outside the organization

Macro environment

Environmental scanning usually refers just to the macro environment, but it can also include industry, competitor analysis, marketing research (consumer analysis), new product development (product innovations) or the company's internal environment.

Macro environmental scanning involves analysing:

Economy

- GDP per capita
- economic growth
- unemployment rate
- inflation rate
- consumer and investor confidence
- inventory levels
- currency exchange rates
- merchandise trade balance
- financial and political health of trading partners
- balance of payments
- future trends

Government

- political climate - amount of government activity
- political stability and risk
- government debt
- budget deficit or surplus
- corporate and personal tax rates
- payroll taxes
- import tariffs and quotas
- export restrictions
- restrictions on international financial flows

Legal

- minimum wage laws
- environmental protection laws
- worker safety laws
- union laws
- copyright and patent laws
- anti- monopoly laws
- Sunday closing laws

- municipal licences
- laws that favour business investment

Technology

- efficiency of infrastructure, including: roads, ports, airports, rolling stock, hospitals, education, healthcare, communication, etc.
- industrial productivity
- new manufacturing processes
- new products and services of competitors
- new products and services of supply chain partners
- any new technology that could impact the company
- cost and accessibility of electrical power

Ecology

- ecological concerns that affect the firms production processes
- ecological concerns that affect customers' buying habits
- ecological concerns that affect customers' perception of the company or product

Socio-cultural

- demographic factors such as:
    - population size and distribution
    - age distribution
    - education levels
    - income levels
    - ethnic origins
    - religious affiliations
- attitudes towards:
    - materialism, capitalism, free enterprise
    - individualism, role of family, role of government, collectivism
    - role of church and religion
    - consumerism
    - environmentalism
    - importance of work, pride of accomplishment
- cultural structures including:
    - diet and nutrition
    - housing conditions

Potential suppliers

- Labour supply
    - quantity of labour available
    - quality of labour available
    - stability of labour supply

    - wage expectations
    - employee turn-over rate
    - strikes and labour relations
    - educational facilities
- Material suppliers
    - quality, quantity, price, and stability of material inputs
    - delivery delays
    - proximity of bulky or heavy material inputs
    - level of competition among suppliers
- Service providers
    - quantity, quality, price, and stability of service facilitators
    - special requirements

Stakeholders

- Lobbyists
- Shareholders
- Employees
- Partners
- Employees

Scanning these macro environmental variables for threats and opportunities requires that each issue be rated on two dimensions. It must be rated on its potential impact on the company, and rated on its likeliness of occurrence. Multiplying the potential impact parameter by the likeliness of occurrence parameter gives a good indication of its importance to the firm.

Competitor Analysis

Competitor analysis in marketing and strategic management is an assessment of the strengths and weaknesses of current and potential competitors. This analysis provides both an offensive and defensive strategic context through which to identify opportunities and threats. Competitor profiling coalesces all of the relevant sources of competitor analysis into one framework in the support of efficient and effective strategy formulation, implementation, monitoring and adjustment.

Given that competitor analysis is an essential component of corporate strategy, it is argued that most firms do not conduct this type of analysis systematically enough. Instead, many enterprises operate on what is called “informal impressions, conjectures, and intuition gained through the tidbits of information about competitors every manager continually receives.” As a result, traditional environmental scanning places many firms at risk of dangerous competitive blindspots due to a lack of robust competitor analysis.

Competitor array

One common and useful technique is constructing a *competitor array*. The steps include:

- Define your industry - scope and nature of the industry
- Determine who your competitors are
- Determine who your customers are and what benefits they expect
- Determine what the key success factors are in your industry
- Rank the key success factors by giving each one a weighting - The sum of all the weightings must add up to one.
- Rate each competitor on each of the key success factors
- Multiply each cell in the matrix by the factor weighting.

This can best be displayed on a two dimensional matrix - competitors along the top and key success factors down the side. An example of a competitor array follows:

Key Industry Success Factors	**Weighting**	**Competitor #1 rating**	**Competitor #1 weighted**	**Competitor #2 rating**	**Competitor #2 weighted**
1 - Extensive distribution	.4	6	2.4	3	1.2
2 - Customer focus	.3	4	1.2	5	1.5
3 - Economies of scale	.2	3	.6	3	.6
4 - Product innovation	.1	7	.7	4	.4
Totals	**1.0**	**20**	**4.9**	**15**	**3.7**

In this example competitor #1 is rated higher than competitor #2 on product innovation ability (7 out of 10, compared to 4 out of 10) and distribution networks (6 out of 10), but competitor #2 is rated higher on customer focus (5 out of 10). Overall, competitor #1 is rated slightly higher than competitor #2 (20 out of 40 compared to 15 out of 40). When the success factors are weighted according to their importance, competitor #1 gets a far better rating (4.9 compared to 3.7).

Two additional columns can be added. In one column you can rate your own company on each of the key success factors (try to be objective and honest). In another column you can list benchmarks. They are the ideal standards of comparisons on each of the factors. They reflect the workings of a company using all the industry's best practices.

Competitor profiling

The strategic rationale of competitor profiling is powerfully simple. Superior knowledge of rivals offers a legitimate source of competitive advantage. The raw material of competitive advantage consists of offering superior customer value in the firm's chosen market. The definitive characteristic of customer value is the adjective, superior. Customer value is defined relative to rival offerings making competitor knowledge an intrinsic component of corporate strategy. Profiling facilitates this strategic objective in three important ways. First, profiling can reveal strategic weaknesses in rivals that the firm may exploit. Second, the proactive stance of competitor profiling will allow the firm to anticipate the strategic response of their rivals to the firm's planned strategies, the strategies of other competing firms, and changes in the environment. Third, this proactive knowledge will give the firms strategic agility. Offensive strategy can be implemented more quickly in order to exploit opportunities and capitalize on strengths. Similarly, defensive strategy can be employed more deftly in order to counter the threat of rival firms from exploiting the firm's own weaknesses.

Clearly, those firms practicing systematic and advanced competitor profiling have a significant advantage. As such, a comprehensive profiling capability is rapidly becoming a core competence required for successful competition. An appropriate analogy is to consider this advantage as akin to having a good idea of the next move that your opponent in a chess match will make. By staying one move ahead, checkmate is one step closer. Indeed, as in chess, a good offense is the best defense in the game of business as well.

A common technique is to create detailed profiles on each of your major competitors. These profiles give an in-depth description of the competitor's background, finances, products, markets, facilities, personnel, and strategies. This involves:

- Background
    - location of offices, plants, and online presences
    - history - key personalities, dates, events, and trends
    - ownership, corporate governance, and organizational structure
- Financials
    - P-E ratios, dividend policy, and profitability
    - various financial ratios, liquidity, and cash flow
    - Profit growth profile; method of growth (organic or acquisitive)
- Products.
    - products offered, depth and breadth of product line, and product portfolio balance
    - new products developed, new product success rate, and R&D strengths
    - brands, strength of brand portfolio, brand loyalty and brand awareness
    - patents and licenses
    - quality control conformance
    - reverse engineering
- Marketing
    - segments served, market shares, customer base, growth rate, and customer loyalty
    - promotional mix, promotional budgets, advertising themes, ad agency used, sales force success rate, online promotional strategy
    - distribution channels used (direct & indirect), exclusivity agreements, alliances, and geographical coverage
    - pricing, discounts, and allowances
- Facilities
    - plant capacity, capacity utilization rate, age of plant, plant efficiency, capital investment

    - location, shipping logistics, and product mix by plant
- Personnel
    - number of employees, key employees, and skill sets
    - strength of management, and management style
    - compensation, benefits, and employee morale & retention rates
- Corporate and marketing strategies
    - objectives, mission statement, growth plans, acquisitions, and divestitures
    - marketing strategies

Media scanning

Scanning competitor's ads can reveal much about what that competitor believes about marketing and their target market. Changes in a competitor's advertising message can reveal new product offerings, new production processes, a new branding strategy, a new positioning strategy, a new segmentation strategy, line extensions and contractions, problems with previous positions, insights from recent marketing or product research, a new strategic direction, a new source of sustainable competitive advantage, or value migrations within the industry. It might also indicate a new pricing strategy such as penetration, price discrimination, price skimming, product bundling, joint product pricing, discounts, or loss leaders. It may also indicate a new promotion strategy such as push, pull, balanced, short term sales generation, long term image creation, informational, comparative, affective, reminder, new creative objectives, new unique selling proposition, new creative concepts, appeals, tone, and themes, or a new advertising agency. It might also indicate a new distribution strategy, new distribution partners, more extensive distribution, more intensive distribution, a change in geographical focus, or exclusive distribution. Little of this intelligence is definitive: additional information is needed before conclusions should be drawn.

A competitor's media strategy reveals budget allocation, segmentation and targeting strategy, and selectivity and focus. From a tactical perspective, it can also be used to help a manager implement his own media plan. By knowing the competitor's media buy, media selection, frequency, reach, continuity, schedules, and flights, the manager can arrange his own media plan so that they do not coincide.

Other sources of corporate intelligence include trade shows, patent filings, mutual customers, annual reports, and trade associations.

Some firms hire competitor intelligence professionals to obtain this information. The Society of Competitive Intelligence Professionals maintains a listing of individuals who provide these services.

New competitors

In addition to analyzing current competitors, it is necessary to estimate future competitive threats. The most common sources of new competitors are ==

- Companies competing in a related product/market
- Companies using related technologies
- Companies already targeting your prime market segment but with unrelated products
- Companies from other geographical areas and with similar products
- New start-up companies organized by former employees and/or managers of existing companies

The entrance of new competitors is likely when:

- There are high profit margins in the industry
- There is unmet demand (insufficient supply) in the industry
- There are no major barriers to entry
- There is future growth potential
- Competitive rivalry is not intense
- Gaining a competitive advantage over existing firms is feasible

New Product Development

New product development (NPD) is the term used to describe the complete process of bringing a new product or service to market. There are two parallel paths involved in the NPD process: one involves the idea generation, product design and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

The process

1. **Idea Generation** is often called the "fuzzy front end" of the NPD process
    - Ideas for new products can be obtained from basic research using a SWOT analysis (Strengths, Weaknesses, Opportunities & Threats), Market and consumer trends, company's R&D department, competitors, focus groups, employees, salespeople, corporate spies, trade shows, or Ethnographic discovery methods (searching for user patterns and habits) may also be used to get an insight into new product lines or product features.
    - Idea Generation or Brainstorming of new product, service, or store concepts - idea generation techniques can begin when you have done your OPPORTUNITY ANALYSIS to support your ideas in the **Idea Screening Phase** (shown in the next development step).
2. **Idea Screening**
    - The object is to eliminate unsound concepts prior to devoting resources to them.
    - The screeners should ask several questions:
        - Will the customer in the target market benefit from the product?

        - What is the size and growth forecasts of the market segment/target market?
        - What is the current or expected competitive pressure for the product idea?
        - What are the industry sales and market trends the product idea is based on?
        - Is it technically feasible to manufacture the product?
        - Will the product be profitable when manufactured and delivered to the customer at the target price?

3. **Concept Development and Testing**
    - Develop the marketing and engineering details
        - Investigate intellectual property issues and search patent data bases
        - Who is the target market and who is the decision maker in the purchasing process?
        - What product features must the product incorporate?
        - What benefits will the product provide?
        - How will consumers react to the product?
        - How will the product be produced most cost effectively?
        - Prove feasibility through virtual computer aided rendering, and rapid prototyping
        - What will it cost to produce it?
    - Testing the Concept by asking a sample of prospective customers what they think of the idea. Usually via Choice Modelling.
4. **Business Analysis**
    - Estimate likely selling price based upon competition and customer feedback
    - Estimate sales volume based upon size of market and such tools as the Fourt-Woodlock equation
    - Estimate profitability and break-even point
5. **Beta Testing and Market Testing**
    - Produce a physical prototype or mock-up
    - Test the product (and its packaging) in typical usage situations
    - Conduct focus group customer interviews or introduce at trade show
    - Make adjustments where necessary
    - Produce an initial run of the product and sell it in a test market area to determine customer acceptance
6. **Technical Implementation**
    - New program initiation
    - Finalize Quality management system
    - Resource estimation
    - Requirement publication
    - Publish technical communications such as data sheets
    - Engineering operations planning
    - Department scheduling
    - Supplier collaboration
    - Logistics plan

- Resource plan publication
- Program review and monitoring
- Contingencies - what-if planning

7. **Commercialization** (often considered post-NPD)
    - Launch the product
    - Produce and place advertisements and other promotions
    - Fill the distribution pipeline with product
    - Critical path analysis is most useful at this stage
8. **New Product Pricing**
    - Impact of new product on the entire product portfolio
    - Value Analysis (internal & external)
    - Competition and alternative competitive technologies
    - Differing value segments (price, value, and need)
    - Product Costs (fixed & variable)
    - Forecast of unit volumes, revenue, and profit

These steps may be iterated as needed. Some steps may be eliminated. To reduce the time that the NPD process takes, many companies are completing several steps at the same time (referred to as **concurrent engineering** or **time to market**). Most industry leaders see new product development as a *proactive* process where resources are allocated to identify market changes and seize upon new product opportunities before they occur (in contrast to a *reactive strategy* in which nothing is done until problems occur or the competitor introduces an innovation). Many industry leaders see new product development as an ongoing process (referred to as *continuous development*) in which the entire organization is always looking for opportunities.

For the more innovative products indicated on the diagram above, great amounts of uncertainty and change may exist, which makes it difficult or impossible to plan the complete project before starting it. In this case, a more flexible approach may be advisable.

Because the NPD process typically requires both engineering and marketing expertise, cross-functional teams are a common way of organizing projects. The team is responsible for all aspects of the project, from initial idea generation to final commercialization, and they usually report to senior management (often to a vice president or Program Manager). In those industries where products are technically complex, development research is typically expensive, and product life cycles are relatively short, strategic alliances among several organizations helps to spread the costs, provide access to a wider skill set, and speeds the overall process.

Also, notice that because engineering and marketing expertise are usually both critical to the process, choosing an appropriate blend of the two is important.

People respond to new products in different ways. The adoption of a new technology can be analyzed using a variety of diffusion theories such as the Diffusion of innovations theory.

A new product pricing process is important to reduce risk and increase confidence in the pricing and marketing decisions to be made. Bernstein and Macias describe an integrated process that breaks down the complex task of new product pricing into manageable elements.

Fuzzy Front End

The Fuzzy Front End is the messy "getting started" period of new product development processes. It is in the front end where the organization formulates a concept of the product to be developed and decides whether or not to invest resources in the further development of an idea. It is the phase between first consideration of an opportunity and when it is judged ready to enter the structured development process (Kim and Wilemon, 2002; Koen et al., 2001). It includes all activities from the search for new opportunities through the formation of a germ of an idea to the development of a precise concept. The Fuzzy Front End ends when an organization approves and begins formal development of the concept.

Although the Fuzzy Front End may not be an expensive part of product development, it can consume 50% of development time and it is where major commitments are typically made involving time, money, and the product's nature, thus setting the course for the entire project and final end product. Consequently, this phase should be considered as an essential part of development rather than something that happens "before development," and its cycle time should be included in the total development cycle time.

Koen et al. (2001, pp. 47–51) distinguish five different front-end elements (not necessarily in a particular order):

1. Opportunity Identification
2. Opportunity Analysis
3. Idea Genesis
4. Idea Selection
5. Concept and Technology Development

The first element is the opportunity identification. In this element, large or incremental business and technological chances are identified in a more or less structured way. Using the guidelines established here, resources will eventually be allocated to new projects.... which then lead to a structured NPPD (New Product & Process Development)strategy. The second element is the opportunity analysis. It is done to translate the identified opportunities into implications for the business and technology specific context of the company. Here extensive efforts may be made to align ideas to target customer groups and do market studies and/or technical trials and research. The third element is the idea genesis, which is described as evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside inputs, e.g. a supplier offering a new material/technology, or from a customer with an unusual request. The fourth element is the idea selection. Its purpose is to choose whether to pursue an idea by analyzing its potential business value. The fifth element is the concept and technology development. During this part of the front-end, the business case is developed based on estimates of the total available market, customer needs, investment requirements, competition analysis and project uncertainty. Some organizations consider this to be the first stage of the NPPD process (i.e., Stage 0).

The Fuzzy Front End is also described in literature as "Front End of Innovation", "Phase 0", "Stage 0" or "Pre-Project-Activities".

A universally acceptable definition for Fuzzy Front End or a dominant framework has not been developed so far. In a glossary of PDMA, it is mentioned that the Fuzzy Front End generally consists of three tasks: strategic planning, concept generation, and, especially, pre-technical evaluation. These activities are often chaotic, unpredictible, and unstructured. In comparison, the subsequent new product development process is typically structured, predictable, and formal. The term *Fuzzy Front End* was first popularized by Smith and Reinertsen (1991) R.G.Cooper (1988) describes the early stages of NPPD as a four step process in which ideas are generated (I),subjected to a preliminary technical and market assessment(II) and merged to coherent product concepts(III) which are finally judged for their fit with existing product strategies and portfolios (IV). In a more recent paper, Cooper and Edgett (2008) affirm that vital predevelopment activities include:

1. Preliminary market assessment.
2. Technical assessment.
3. Source-of-supply-assessment:suppliers and partners or alliances.
4. Market research : market size and segmentation analysis,VoC (voice of customer) research.
5. Product concept testing
6. Value-to-the customer assessment
7. Product definition
8. Business and financial analysis.

These activities yield vital information to make a Go/No-Go to Development decision.

In the in-depth study by Khurana and Rosenthal front-end activities include:

- product strategy formulation and communication,
- opportunity identification and assessment,
- idea generation,
- product definition,
- project planning, and
- executive reviews.

Economical analysis, benchmarking of competitive products,and modeling and proto-typing are also important activities during the front-end activities.

The outcomes of FFE are the

- mission statement
- customer needs
- details of the selected concept
- product definition and specifications
- economic analysis of the product
- the development schedule
- project staffing and the budget, and a
- business plan aligned with corporate strategy.

In a paper by Husig, Kohn and Huskela (2005) was proposed a conceptual model of Front-End Process which includes early Phases of Innovation Process. This model is structured in three phases and three gates:

- Phase 1: Environmental screening or opportunity identification stage in which external changes will be analysed and translated into potential business opportunities.
- Phase 2: Preliminary definition of an idea or concept.
- Phase 3: Detailed product, project or concept definition, and Business planning.

The gates are:

- Opportunity screening;
- Idea evaluation;
- Go/No-Go for development.

The final gate leads to a dedicated new product development project. Many professionals and academics consider that the general features of Fuzzy Front End (fuzziness, ambiguity and uncertainty) make difficult to see the FFE as a structured process, but rather as a set of interdependent activities (e.g.Kim and Wilemon, 2002). However, Husig et al., 2005 argue that front-end not need to be fuzzy, but can be handled in a structured manner. Peter Koen argue that in the FFE for incremental, platform and radical projects, three separate strategies and processes are typically involved. The traditional Stage Gate (TM) process was designed for incremental product development, namely for a single product. The FFE for developing a new platform must start out with a strategic vision of where the company wants to develop products and this will lead to a family of products. Projects for breakthrough products start out with a similar strategic vision, but are associated with technologies which require new discoveries. It is worth mentioning what are incremental, platform and breakthrough products. *Incremental products* are considered to be cost reductions, improvements to existing product lines, additions to existing platforms and repositioning of existing products introduced in markets. *Breakthrough products* are new to the company or new to the world and offer a 5-10 times or greater improvement in performance combined with a 30-50% or greater reduction in costs. *Platform products* establish a basic architecture for a next generation product or process and are substantially larger in scope and resources than incremental projects.

Chapter- 5

Scenario Planning

Scenarios are one of the most popular and persuasive methods used in the Futures Studies. Government planners, corporate strategists and military analysts use them in order to aid decision-making. The term scenario was introduced into planning and decision-making by Herman Kahn in connection with military and strategic studies done by RAND in the 1950s.

It can be defined as a rich and detailed portrait of a plausible future world, one sufficiently vivid that a planner can clearly see and comprehend the problems, challenges and opportunities that such an environment would present.

A scenario is not a specific forecast of the future, but a plausible description of what might happen. Scenarios are like stories built around carefully constructed plots based on trends and events. They assist in selection of strategies, identification of possible futures, making people aware of uncertainties and opening up their imagination and initiating learning processes.

One of the key strengths of the scenario process is its influence on the way of thinking of its participants. A mindset, in which the focus is placed on one possible future, is altered towards the balanced thinking about a number of possible alternative futures.

Although it is a very rewarding method it is also very demanding. The difficulties in its use can arise from a lack of clear focus, purpose or directions. As a result too many scenario stories can be created and/or their content may not be directly related to the strategic question.

Scenario planning, also called scenario thinking or scenario analysis, is a strategic planning method that some organizations use to make flexible long-term plans. It is in large part an adaptation and generalization of classic methods used by military intelligence.

The original method was that a group of analysts would generate simulation games for policy makers. The games combine known facts about the future, such as demographics, geography, military, political, industrial information, and mineral reserves, with plausible alternative social, technical, economic, environmental, educational, political and aesthetic (STEEEPA) trends which are key driving forces.

In business applications, the emphasis on gaming the behavior of opponents was reduced (shifting more toward a game against nature). At Royal Dutch/Shell for example, scenario planning was viewed as changing mindsets about the exogenous part of the world, prior to formulating specific strategies.

Scenario planning may involve aspects of Systems thinking, specifically the recognition that many factors may combine in complex ways to create sometime surprising futures (due to non-linear feedback loops). The method also allows the inclusion of factors that are difficult to formalize, such as novel insights about the future, deep shifts in values, unprecedented regulations or inventions. Systems thinking used in conjunction with scenario planning leads to plausible scenario story lines because the causal relationship between factors can be demonstrated. In these cases when scenario planning is integrated with a systems thinking approach to scenario development, it is sometimes referred to as structural dynamics.

Crafting scenarios

These combinations and permutations of fact and related social changes are called "scenarios." The scenarios usually include plausible, but unexpectedly important situations and problems that exist in some small form in the present day. Any particular scenario is unlikely. However, future studies analysts select scenario features so they are both possible and uncomfortable. Scenario planning helps policy-makers to anticipate hidden weaknesses and inflexibilities in organizations and methods.

When disclosed years in advance, these weaknesses can be avoided or their impacts reduced more effectively than if similar real-life problems were considered under duress of an emergency. For example, a company may discover that it needs to change contractual terms to protect against a new class of risks, or collect cash reserves to purchase anticipated technologies or equipment. Flexible business continuity plans with "PREsponse protocols" help cope with similar operational problems and deliver measurable future value-added.

Zero-sum game scenarios

Strategic military intelligence organizations also construct scenarios. The methods and organizations are almost identical, except that scenario planning is applied to a wider variety of problems than merely military and political problems.

As in military intelligence, the chief challenge of scenario planning is to find out the real needs of policy-makers, when policy-makers may not themselves know what they need to know, or may not know how to describe the information that they really want.

Good analysts design wargames so that policy makers have great flexibility and freedom to adapt their simulated organizations. Then these simulated organizations are "stressed" by the scenarios as a game plays out. Usually, particular groups of facts become more clearly important. These insights enable intelligence organizations to refine and repackage real information more precisely to better-serve the policy-makers' real-life needs. Usually the games' simulated time runs hundreds of times faster than real life, so policy-makers experience several years of policy decisions, and their simulated effects, in less than a day.

This chief value of scenario planning is that it allows policy-makers to make and learn from mistakes without risking career-limiting failures in real life. Further, policymakers can make these mistakes in a safe, unthreatening, game-like environment, while responding to a wide variety of concretely-presented situations based on facts. This is an opportunity to "rehearse the future," an opportunity that does not present itself in day-to-day operations where every action and decision counts.

How military scenario planning or scenario thinking is done

1. *Decide on the key question to be answered by the analysis.* By doing this, it is possible to assess whether scenario planning is preferred over the other methods. If the question is based on small changes or a very small number of elements, other more formalized methods may be more useful.
2. *Set the time and scope of the analysis.* Take into consideration how quickly changes have happened in the past, and try to assess to what degree it is possible to predict common trends in demographics, product life cycles. A usual timeframe can be five to 10 years.
3. *Identify major stakeholders.* Decide who will be affected and have an interest in the possible outcomes. Identify their current interests, whether and why these interests have changed over time in the past.
4. *Map basic trends and driving forces.* This includes industry, economic, political, technological, legal, and societal trends. Assess to what degree these trends will affect your research question. Describe each trend, how and why it will affect the organisation. In this step of the process, brainstorming is commonly used, where all trends that can be thought of are presented before they are assessed, to capture possible group thinking and tunnel vision.
5. *Find key uncertainties.* Map the driving forces on two axes, assessing each force on an uncertain/(relatively) predictable and important/unimportant scale. All driving forces that are considered unimportant are discarded. Important driving forces that are relatively predictable (ex. demographics) can be included in any scenario, so the scenarios should not be based on these. This leaves you with a number of important and unpredictable driving forces. At this point, it is also useful to assess whether any linkages between driving forces exist, and rule out any "impossible" scenarios (ex. full employment and zero inflation).
6. *Check for the possibility to group the linked forces* and if possible, reduce the forces to the *two* most important. (To allow the scenarios to be presented in a neat xy-diagram)
7. *Identify the extremes* of the possible outcomes of the two driving forces and check the dimensions for consistency and plausibility. Three key points should be assessed:
    1. Time frame: are the trends compatible within the time frame in question?

2. Internal consistency: do the forces describe uncertainties that can construct probable scenarios.
3. Vs the stakeholders: are any stakeholders currently in disequilibrium compared to their preferred situation, and will this evolve the scenario? Is it possible to create probable scenarios when considering the stakeholders? This is most important when creating macro-scenarios where governments, large organisations et al. will try to influence the outcome.

8. *Define the scenarios,* plotting them on a grid if possible. Usually, two to four scenarios are constructed. The current situation does not need to be in the middle of the diagram (inflation may already be low), and possible scenarios may keep one (or more) of the forces relatively constant, especially if using three or more driving forces. One approach can be to create all positive elements into one scenario and all negative elements (relative to the current situation) in another scenario, then refining these. In the end, try to avoid pure best-case and worst-case scenarios.
9. *Write out the scenarios.* Narrate what has happened and what the reasons can be for the proposed situation. Try to include good reasons why the changes have occurred as this helps the further analysis. Finally, give each scenario a descriptive (and catchy) name to ease later reference.
10. *Assess the scenarios.* Are they relevant for the goal? Are they internally consistent? Are they archetypical? Do they represent relatively stable outcome situations?
11. *Identify research needs.* Based on the scenarios, assess where more information is needed. Where needed, obtain more information on the motivations of stakeholders, possible innovations that may occur in the industry and so on.
12. *Develop quantitative methods.* If possible, develop models to help quantify consequences of the various scenarios, such as growth rate, cash flow etc. This step does of course require a significant amount of work compared to the others, and may be left out in back-of-the-envelope-analyses.
13. *Converge towards decision scenarios.* Retrace the steps above in an iterative process until you reach scenarios which address the fundamental issues facing the organization. Try to assess upsides and downsides of the possible scenarios.

Scenario planning in military applications

Scenario planning is also extremely popular with military planners. Most states' department of war maintains a continuously-updated series of strategic plans to cope with well-known military or strategic problems. These plans are almost always based on scenarios, and often the plans and scenarios are kept up-to-date by war games, sometimes played out with real troops. This process was first carried out (arguably the method was invented by) the Prussian general staff of the mid-19th century.

Development of scenario analysis in business organizations

In the past, strategic plans have often considered only the "official future," which was usually a straight-line graph of current trends carried into the future. Often the trend lines were generated by the accounting department, and lacked discussions of demographics, or qualitative differences in social conditions.

These simplistic guesses are surprisingly good most of the time, but fail to consider qualitative social changes that can affect a business or government. Scenarios focus on the joint effect of many factors. Scenario planning helps us understand how the various strands of a complex tapestry move if one or more threads are pulled. When you just list possible causes, as for instance in fault tree analysis, you may tend to discount any one factor in isolation. But when you explore the factors together, you realize that certain combinations could magnify each other's impact or likelihood. For instance, an increased trade deficit may trigger an economic recession, which in turn creates unemployment and reduces domestic production. Paul J. H. Schoemaker offers a strong managerial case for the use of scenario planning in business and had wide impact.

Scenarios planning starts by dividing our knowledge into two broad domains: (1) things we believe we know something about and (2) elements we consider uncertain or unknowable. The first component – trends – casts the past forward, recognizing that our world possesses considerable momentum and continuity. For example, we can safely make assumptions about demographic shifts and, perhaps, substitution effects for certain new technologies. The second component – true uncertainties – involve indeterminables such as future interest rates, outcomes of political elections, rates of innovation, fads and fashions in markets, and so on. The art of scenario planning lies in blending the known and the unknown into a limited number of internally consistent views of the future that span a very wide range of possibilities.

Numerous organizations have applied scenario planning to a broad range of issues, from relatively simple, tactical decisions to the complex process of strategic planning and vision building. The power of scenario planning for business was originally established by Royal Dutch/Shell, which has used scenarios since the early 1970s as part of a process for generating and evaluating its strategic options. Shell has been consistently better in its oil forecasts than other major oil companies, and saw the overcapacity in the tanker business and Europe's petrochemicals earlier than its competitors. But ironically, the approach may have had more impact outside Shell than within, as many others firms and consultancies started to benefit as well from scenario planning. Scenario planning is as much art as science, and prone to a variety of traps (both in process and content) as enumerated by Paul J. H. Schoemaker.

History of use by academic and commercial organizations

Most authors attribute the introduction of scenario planning to Herman Kahn through his work for the US Military in the 1950s at the RAND corporation where he developed a technique of describing the future in stories as if written by people in the future. He adopted the term "scenarios" to describe these stories. In 1961 he founded the Hudson Institute where he expanded his scenario work to social forecasting and public policy. One of his most controversial uses of scenarios was to suggest that a nuclear war could be won. Though Kahn is often cited as the father of scenario planning, at the same time

Kahn was developing his methods at RAND, Gaston Berger was developing similar methods at the Centre d'Etudes Prospectives which he founded in France. His method, which he named 'La Prospective', was to develop normative scenarios of the future which were to be used as a guide in formulating public policy. During the mid 1960s various authors from the French and American institutions began to publish scenario planning concepts such as 'La Prospective' by Berger in 1964 and 'The Next Thirty-Three Years' by Kahn and Wiener in 1967. By the 1970s scenario planning was in full swing with a number of institutions now established to provide support to business including the Hudson Foundation, the Stanford Research Institute, and the SEMA Metra Consulting Group in France. Several large companies also began to embrace scenario planning including Dutch Royal Shell and General Electric.

Possibly as a result of these very sophisticated approaches, and of the difficult techniques they employed (which usually demanded the resources of a central planning staff), scenarios earned a reputation for difficulty (and cost) in use. Even so, the theoretical importance of the use of alternative scenarios, to help address the uncertainty implicit in long-range forecasts, was dramatically underlined by the widespread confusion which followed the Oil Shock of 1973. As a result many of the larger organizations started to use the technique in one form or another. By 1983 Diffenbach reported that 'alternate scenarios' were the third most popular technique for long-range forecasting - used by 68% of the large organizations he surveyed.

Practical development of scenario forecasting, to guide strategy rather than for the more limited academic uses which had previously been the case, was started by Pierre Wack in 1971 at the Royal Dutch Shell group of companies - and it, too, was given impetus by the Oil Shock two years later. Shell has, since that time, led the commercial world in the use of scenarios - and in the development of more practical techniques to support these. Indeed, as - in common with most forms of long-range forecasting - the use of scenarios has (during the depressed trading conditions of the last decade) reduced to only a handful of private-sector organisations, Shell remains almost alone amongst them in keeping the technique at the forefront of forecasting.

There has only been anecdotal evidence offered in support of the value of scenarios, even as aids to forecasting; and most of this has come from one company - Shell. In addition, with so few organisations making consistent use of them - and with the timescales involved reaching into decades - it is unlikely that any definitive supporting evidenced will be forthcoming in the foreseeable future. For the same reasons, though, a lack of such proof applies to almost all long-range planning techniques. In the absence of proof, but taking account of Shell's well documented experiences of using it over several decades (where, in the 1990s, its then CEO ascribed its success to its use of such scenarios), can be significant benefit to be obtained from extending the horizons of managers' long-range forecasting in the way that the use of scenarios uniquely does.

Critique of Shell's use of scenario planning

In the 1970s, many energy companies were surprised by both environmentalism and the OPEC cartel, and thereby lost billions of dollars of revenue by mis-investment. The dramatic financial effects of these changes led at least one organization, Royal Dutch Shell, to implement scenario planning. The analysts of this company publicly estimated that this planning process made their company the largest in the world. However other observers of Shell's use of scenario planning have suggested that few if any significant long term business advantages accrued to Shell from the use of scenario methodology. Whilst the intellectual robustness of Shell's long term scenarios was seldom in doubt their actual practical use was seen as being minimal by many senior Shell executives. A Shell insider has commented "The scenario team were bright and their work was of a very high intellectual level. However neither the high level "Group scenarios" nor the country level scenarios produced with operating companies really made much difference when key decisions were being taken".

The use of scenarios was audited by Arie de Geus's team in the early 1980s and they found that the decision making processes following the scenarios were the primary cause of the lack of strategic implementation, rather than the scenarios themselves. Many practitioners today spend as much time on the decision making process as on creating the scenarios themselves.

General Limitations of Scenario Planning

Although scenario planning has gained much adherence in industry, its subjective and heuristic nature leaves many academics uncomfortable. How do we know if we have the right scenarios? And how do we go from scenarios to decisions? These concerns are legitimate and scenario planning would gain in academic standing if more research were conducted on its comparative performance and underlying theoretical premises. A collection of chapters by noted scenario planners failed to contain a single reference to an academic source! In general, there are few academically validated analyses of scenario planning. The technique was born from practice and its appeal is based more on anecdotal than scientific evidence. Furthermore, significant misconceptions remain about its intent and claims. Above all, scenario planning is a tool for collective learning, reframing perceptions and preserving uncertainty when the latter is pervasive. Too many decision makers want to bet on one future scenario, falling prey to the seductive temptation of trying to predict the future rather than to entertain multiple futures. Another trap is to take the scenarios too literally as though they were static beacons that map out a fixed future. In actuality, their aim is to bound the future but in a flexible way that permits learning and adjustment as the future unfolds.

One criticism of the two-by-two technique commonly used is that the resulting matrix results in four somewhat arbitrary scenario themes. If other key uncertainties had been selected, it might be argued, very different scenarios could emerge. How true this is depends on whether the matrix is viewed as just a starting point to be superseded by the ensuing blueprint or is considered as the grand architecture that nests everything else. In either case, however, the issue should not be which are the "right" scenarios but rather whether they delineate the range of possible future appropriately. Any tool that tries to simplify a complex picture will introduce distortions, whether it is a geographic map or a set of scenarios. Seldom will complexity decompose naturally into simple states. But it might. Consider, for example, the behavior of water (the molecule H_2O) which, depending on temperature and pressure, naturally exists in just one of three states: gas, liquid or ice. The art of scenarios is to look for such natural states or points of bifurcation in the behavior of a complex system.

Apart from some inherent subjectivity in scenario design, the technique can suffer from various process and content traps. These traps mostly relate to how the process is conducted in organizations (such as team composition, role of facilitators, etc.) as well as the substantive focus of the scenarios (long vs. short term, global vs. regional, incremental vs. paradigm shifting, etc.). One might think of these as merely challenges of implementation, but since the process component is integral to the scenario experience, they can also be viewed as weaknesses of the methodology itself. Limited safeguards exist against political derailing, agenda control, myopia and limited imagination when conducting scenario planning exercises within real organizations. But, to varying extents, all forecasting techniques will suffer from such organizational limitations. The benchmark to use is not perfection, especially when faced with high uncertainty and complexity, or even strict adherence to such normative precepts as procedural invariance and logical consistency, but whether the technique performs better than its rivals. And to answer this question fairly, performance must be carefully specified. It should clearly include some measures of accuracy as well as a cost-benefit analysis that considers the tradeoff between effort and accuracy. In addition, legitimation criteria may be important to consider as well as the ability to refine and improve the approach as more experience is gained.

A third limitation of scenario planning in organizational settings is its weak integration into other planning and forecasting techniques. Most companies have plenty of trouble dealing with just one future, let alone multiple ones. Typically, budgeting and planning systems are predicated on single views of the future, with adjustments made as necessary through variance analysis, contingency planning, rolling budgets, and periodic renegotiations. The weaknesses of these traditional approaches were very evident after the tragic attack of September 11, 2001 when many companies became paralyzed and quite a few just threw away the plan and budget. Their strategies were not future-proof and they lacked organized mechanisms to adjust to external turmoil. In cases of crisis, leadership becomes important but so does some degree of preparedness. Once the scenarios are finished, the real works starts of how to craft flexible strategies and appropriate monitoring systems. Managers need a simple but comprehensive compass to navigate uncertainty from beginning to end. Scenario planning is just one component of a more complete management system. The point is that scenario thinking needs to be integrated with the existing planning and budgeting system, as awkward as this fit may be. The reality is that most organizations do not handle uncertainty well and that researchers have not provided adequate answers about how to plan under conditions of high uncertainty and complexity.

Use of scenario planning by managers

The basic concepts of the process are relatively simple. In terms of the overall approach to forecasting, they can be divided into three main groups of activities (which are, generally speaking, common to all long range forecasting processes):

1. Environmental analysis
2. Scenario planning
3. Corporate strategy

The first of these groups quite simply comprises the normal environmental analysis. This is almost exactly the same as that which should be undertaken as the first stage of any serious long-range planning. However, the quality of this analysis is especially important in the context of scenario planning.

The central part represents the specific techniques - covered here - which differentiate the scenario forecasting process from the others in long-range planning.

The final group represents all the subsequent processes which go towards producing the corporate strategy and plans. Again, the requirements are slightly different but in general they follow all the rules of sound long-range planning.

Process

The part of the overall process which is radically different from most other forms of long-range planning is the central section, the actual production of the scenarios. Even this, though, is relatively simple, at its most basic level. As derived from the approach most commonly used by Shell, it follows six steps:

1. Decide drivers for change/assumptions
2. Bring drivers together into a viable framework
3. Produce 7-9 initial mini-scenarios
4. Reduce to 2-3 scenarios
5. Draft the scenarios
6. Identify the issues arising

Step 1 - decide assumptions/drivers for change

The first stage is to examine the results of environmental analysis to determine which are the most important factors that will decide the nature of the future environment within which the organisation operates. These factors are sometimes called 'variables' (because they will vary over the time being investigated, though the terminology may confuse scientists who use it in a more rigorous manner). Users tend to prefer the term 'drivers' (for change), since this terminology is not laden with quasi-scientific connotations and reinforces the participant's commitment to search for those forces which will act to change the future. Whatever the nomenclature, the main requirement is that these will be informed assumptions.

This is partly a process of analysis, needed to recognise what these 'forces' might be. However, it is likely that some work on this element will already have taken place during the preceding environmental analysis. By the time the formal scenario planning stage has been reached, the participants may have already decided - probably in their sub-conscious rather than formally - what the main forces are.

In the ideal approach, the first stage should be to carefully decide the overall assumptions on which the scenarios will be based. Only then, as a second stage, should the various drivers be specifically defined. Participants, though, seem to have problems in separating these stages.

Perhaps the most difficult aspect though, is freeing the participants from the pre-conceptions they take into the process with them. In particular, most participants will want to look at the medium term, five to ten years ahead rather than the required longer-term, ten or more years ahead. However, a time horizon of anything less than ten years often leads participants to extrapolate from present trends, rather than consider the alternatives which might face them. When, however, they are asked to consider timescales in excess of ten years they almost all seem to accept the logic of the scenario planning process, and no longer fall back on that of extrapolation. There is a similar problem with expanding participants horizons to include the whole external environment.

Brainstorming

In any case, the brainstorming which should then take place, to ensure that the list is complete, may unearth more variables - and, in particular, the combination of factors may suggest yet others.

A very simple technique which is especially useful at this - brainstorming - stage, and in general for handling scenario planning debates is derived from use in Shell where this type of approach is often used. An especially easy approach, it only requires a conference room with a bare wall and copious supplies of 3M Post-It Notes.

The six to ten people ideally taking part in such face-to-face debates should be in a conference room environment which is isolated from outside interruptions. The only special requirement is that the conference room has at least one clear wall on which Post-It notes will stick. At the start of the meeting itself, any topics which have already been identified during the environmental analysis stage are written (preferably with a thick magic marker, so they can be read from a distance) on separate Post-It Notes. These Post-It Notes are then, at least in theory, randomly placed on the wall. In practice, even at this early stage the participants will want to cluster them in groups which seem to make sense. The only requirement (which is why Post-It Notes are ideal for this approach) is that there is no bar to taking them off again and moving them to a new cluster.

A similar technique - using 5" by 3" index cards - has also been described (as the 'Snowball Technique'), by Backoff and Nutt, for grouping and evaluating ideas in general.

As in any form of brainstorming, the initial ideas almost invariably stimulate others. Indeed, everyone should be encouraged to add their own Post-It Notes to those on the wall. However it differs from the 'rigorous' form described in 'creative thinking' texts, in that it is much slower paced and the ideas are discussed immediately. In practice, as many ideas may be removed, as not being relevant, as are added. Even so, it follows many of the same rules as normal brainstorming and typically lasts the same length of time - say, an hour or so only.

It is important that all the participants feel they 'own' the wall - and are encouraged to move the notes around themselves. The result is a very powerful form of creative decision-making for groups, which is applicable to a wide range of situations (but is especially powerful in the context of scenario planning). It also offers a very good introduction for those who are coming to the scenario process for the first time. Since the workings are largely self-evident, participants very quickly come to understand exactly what is involved.

Important and uncertain

This step is, though, also one of selection - since only the most important factors will justify a place in the scenarios. The 80:20 Rule here means that, at the end of the process, management's attention must be focused on a limited number of most important issues. Experience has proved that offering a wider range of topics merely allows them to select those few which interest them, and not necessarily those which are most important to the organisation.

In addition, as scenarios are a technique for presenting alternative futures, the factors to be included must be genuinely 'variable'. They should be subject to significant alternative outcomes. Factors whose outcome is predictable, but important, should be spelled out in the introduction to the scenarios (since they cannot be ignored). The Important Uncertainties Matrix, as reported by Kees van der Heijden of Shell, is a useful check at this stage.

At this point it is also worth pointing out that a great virtue of scenarios is that they can accommodate the input from any other form of forecasting. They may use figures, diagrams or words in any combination. No other form of forecasting offers this flexibility.

Step 2 - bring drivers together into a viable framework

The next step is to link these drivers together to provide a meaningful framework. This may be obvious, where some of the factors are clearly related to each other in one way or another. For instance, a technological factor may lead to market changes, but may be constrained by legislative factors. On the other hand, some of the 'links' (or at least the 'groupings') may need to be artificial at this stage. At a later stage more meaningful links may be found, or the factors may then be rejected from the scenarios. In the most theoretical approaches to the subject, probabilities are attached to the event strings. This is difficult to achieve, however, and generally adds little - except complexity - to the outcomes.

This is probably the most (conceptually) difficult step. It is where managers' 'intuition' - their ability to make sense of complex patterns of 'soft' data which more rigorous analysis would be unable to handle - plays an important role. There are, however, a range of techniques which can help; and again the Post-It-Notes approach is especially useful:

Thus, the participants try to arrange the drivers, which have emerged from the first stage, into groups which seem to make sense to them. Initially there may be many small groups. The intention should, therefore, be to gradually merge these (often having to reform them from new combinations of drivers to make these bigger groups work). The aim of this stage is eventually to make 6 - 8 larger groupings; 'mini-scenarios'. Here the Post-It Notes may be moved dozens of times over the length - perhaps several hours or more - of each meeting. While this process is taking place the participants will probably want to add new topics - so more Post-It Notes are added to the wall. In the opposite direction, the unimportant ones are removed (possibly to be grouped, again as an 'audit trail' on another wall). More important, the 'certain' topics are also removed from the main area of debate - in this case they must be grouped in clearly labelled area of the main wall.

As the clusters - the 'mini-scenarios' - emerge, the associated notes may be stuck to each other rather than individually to the wall; which makes it easier to move the clusters around (and is a considerable help during the final, demanding stage to reducing the scenarios to two or three).

The great benefit of using Post-It Notes is that there is no bar to participants changing their minds. If they want to rearrange the groups - or simply to go back (iterate) to an earlier stage - then they strip them off and put them in their new position.

Step 3 - produce initial mini-scenarios

The outcome of the previous step is usually between seven and nine logical groupings of drivers. This is usually easy to achieve. The 'natural' reason for this may be that it represents some form of limit as to what participants can visualise.

Having placed the factors in these groups, the next action is to work out, very approximately at this stage, what is the connection between them. What does each group of factors represent?

Step 4 - reduce to two or three scenarios

The main action, at this next stage, is to reduce the seven to nine mini-scenarios / groupings detected at the previous stage to two or three larger scenarios. The challenge in practice seems to come down to finding just two or three 'containers' into which all the topics can be sensibly fitted. This usually requires a considerable amount of debate - but in the process it typically generates as much light as it does heat. Indeed, the demanding process of developing these basic scenario frameworks often, by itself, produces fundamental insights into what are the really important (perhaps life and death) issues affecting the organisation. During this extended debate - and even before it is summarised in the final reports - the participants come to understand, by their own involvement in the debate, what the most important drivers for change may be, and (perhaps even more important) what their peers think they are. Based on this intimate understanding, they are well prepared to cope with such changes - reacting almost instinctively - when they actually do happen; even without recourse to the formal reports which are eventually produced!

There is no theoretical reason for reducing to just two or three scenarios, only a practical one. It has been found that the managers who will be asked to use the final scenarios can only cope effectively with a maximum of three versions! Shell started, more than three decades ago, by building half a dozen or more scenarios - but found that the outcome was that their managers selected just one of these to concentrate on. As a result the planners reduced the number to three, which managers could handle easily but could no longer so easily justify the selection of only one! This is the number now recommended most frequently in most of the literature.

Complementary scenarios

As used by Shell, and as favoured by a number of the academics, two scenarios should be complementary; the reason being that this helps avoid managers 'choosing' just one, 'preferred', scenario - and lapsing once more into single-track forecasting (negating the benefits of using 'alternative' scenarios to allow for alternative, uncertain futures). This is, however, a potentially difficult concept to grasp, where managers are used to looking for opposites; a good and a bad scenario, say, or an optimistic one versus a pessimistic one - and indeed this is the approach (for small businesses) advocated by Foster. In the Shell approach, the two scenarios are required to be equally likely, and between them to cover all the 'event strings'/drivers. Ideally they should not be obvious opposites, which might once again bias their acceptance by users, so the choice of 'neutral' titles is important. For example, Shell's two scenarios at the beginning of the 1990s were titled 'Sustainable World' and 'Global Mercantilism'[xv]. In practice, we found that this requirement, much to our surprise, posed few problems for the great majority, 85%, of those in the survey; who easily produced 'balanced' scenarios. The remaining 15% mainly fell into the expected trap of 'good versus bad'. We have found that our own relatively complex (OBS) scenarios can also be made complementary to each other; without any great effort needed from the teams involved; and the resulting two scenarios are both developed further by all involved, without unnecessary focusing on one or the other.

Testing

Having grouped the factors into these two scenarios, the next step is to test them, again, for viability. Do they make sense to the participants? This may be in terms of logical analysis, but it may also be in terms of intuitive 'gut-feel'. Once more, intuition often may offer a useful - if academically less respectable - vehicle for reacting to the complex and ill-defined issues typically involved. If the scenarios do not intuitively 'hang together', why not? The usual problem is that one or more of the assumptions turns out to be unrealistic in terms of how the participants see their world. If this is the case then you need to return to the first step - the whole scenario planning process is above all an iterative one (returning to its beginnings a number of times until the final outcome makes the best sense).

Step 5 - write the scenarios

The scenarios are then 'written up' in the most suitable form. The flexibility of this step often confuses participants, for they are used to forecasting processes which have a fixed format. The rule, though, is that you should produce the scenarios in the form most suitable for use by the managers who are going to base their strategy on them. Less obviously, the managers who are going to implement this strategy should also be taken into account. They will also be exposed to the scenarios, and will need to believe in these. This is essentially a 'marketing' decision, since it will be very necessary to 'sell' the final results to the users. On the other hand, a not inconsiderable consideration may be to use the form the author also finds most comfortable. If the form is alien to him or her the chances are that the resulting scenarios will carry little conviction when it comes to the 'sale'.

Most scenarios will, perhaps, be written in word form (almost as a series of alternative essays about the future); especially where they will almost inevitably be qualitative which is hardly surprising where managers, and their audience, will probably use this in their day to day communications. Some, though use an expanded series of lists and some enliven their reports by adding some fictional 'character' to the material - perhaps taking literally the idea that they are stories about the future - though they are still clearly intended to be factual. On the other hand, they may include numeric data and/or diagrams - as those of Shell do (and in the process gain by the acid test of more measurable 'predictions').

Step 6 - identify issues arising

The final stage of the process is to examine these scenarios to determine what are the most critical outcomes; the 'branching points' relating to the 'issues' which will have the greatest impact (potentially generating 'crises') on the future of the organisation. The subsequent strategy will have to address these - since the normal approach to strategy deriving from scenarios is one which aims to minimise risk by being 'robust' (that is it will safely cope with all the alternative outcomes of these 'life and death' issues) rather than aiming for performance (profit) maximisation by gambling on one outcome.

Use of scenarios

It is important to note that scenarios may be used in a number of ways:

a) Containers for the drivers/event strings

Most basically, they are a logical device, an artificial framework, for presenting the individual factors/topics (or coherent groups of these) so that these are made easily available for managers' use - as useful ideas about future developments in their own right - without reference to the rest of the scenario. It should be stressed that no factors should be dropped, or even given lower priority, as a result of producing the scenarios. In this context, which scenario contains which topic (driver), or issue about the future, is irrelevant.

b) Tests for consistency

At every stage it is necessary to iterate, to check that the contents are viable and make any necessary changes to ensure that they are; here the main test is to see if the scenarios seem to be internally consistent - if they are not then the writer must loop back to earlier stages to correct the problem. Though it has been mentioned previously, it is important to stress once again that scenario building is ideally an iterative process. It usually does not just happen in one meeting - though even one attempt is better than none - but takes place over a number of meetings as the participants gradually refine their ideas.

c) Positive perspectives

Perhaps the main benefit deriving from scenarios, however, comes from the alternative 'flavours' of the future their different perspectives offer. It is a common experience, when the scenarios finally emerge, for the participants to be startled by the insight they offer - as to what the general shape of the future might be - at this stage it no longer is a theoretical exercise but becomes a genuine framework (or rather set of alternative frameworks) for dealing with that.

Scenario planning compared to other techniques

Scenario planning differs from contingency planning, sensitivity analysis and computer simulations.

Contingency planning is a "What if" tool, that only takes into account one uncertainty. However, scenario planning considers combinations of uncertainties in each scenario. Planners also try to select especially plausible but uncomfortable combinations of social developments.

Sensitivity analysis analyzes changes in one variable only, which is useful for simple changes, while scenario planning tries to expose policy makers to significant interactions of major variables.

While scenario planning can benefit from computer simulations, scenario planning is less formalized, and can be used to make plans for qualitative patterns that show up in a wide variety of simulated events.

During the past 5 years, computer supported Morphological Analysis has been employed as aid in scenario development by the Swedish Defence Research Agency in Stockholm. This method makes it possible to create a multi-variable morphological field which can be treated as an inference model – thus integrating scenario planning techniques with contingency analysis and sensitivity analysis.

Combination of Delphi and scenarios

Scenario planning concerns planning based on the systematic examination of the future by picturing plausible and consistent images thereof. Delphi, in turn, attempts to develop systematically expert opinion consensus concerning future developments and events. It is a judgmental forecasting procedure in form of an anonymous, written, multi-stage survey process, where feedback of group opinion is provided after each round.

Numerous researchers have stressed that both approaches are best suited to be combined. Kinkel et al. (2006) recently reported on their experiences with both Delphi-scenarios and scenario-Delphis. The authors found that, due to their process similarity, the two methodologies can be easily combined. Generally speaking, the output of the different phases of the Delphi method can be used as input for the scenario method and vice versa. A combination makes a realization of the benefits of both tools possible. In practice, usually one of the two tools is considered the dominant methodology and the other one is integrated at some stage. In fact, the authors found that in either case the combination of the methodologies adds significant value to futures projects.

The variant that is most often found in practice is the integration of the Delphi method into the scenario process (e.g. Rikkonen, 2005; von der Gracht, 2007; Transportation & Logistics 2030 – How will supply chains evolve in an energy constrained and low-carbon world; Transportation & Logistics 2030 – Transport infrastructure – Engine or hand brakes for global supply chains?; Future of Logistics – Global Scenarios 2025). Authors refer to this type as Delphi-scenario (writing), expert-based scenarios, or Delphi panel derived scenarios. Von der Gracht (2010) is a scientifically valid example of this method. Since scenario planning is "information hungry", Delphi research can deliver valuable input for the process. There are various types of information output of Delphi that can be used as input for scenario planning. Researchers can, for example, identify relevant events or developments and, based on expert opinion, assign probabilities to them. Moreover, expert comments and arguments provide deeper insights into relationships of factors that can, in turn, be integrated into scenarios afterwards. Also, Delphi helps to identify extreme opinions and dissent among the experts. Such controversial topics are particularly suited for extreme scenarios or wildcards.

In his doctoral thesis, Rikkonen (2005) has thoroughly examined the utilization of Delphi techniques in scenario planning and, concretely, in construction of scenarios. The author comes to the conclusion that the Delphi technique has instrumental value in providing different alternative futures and the argumentation of scenarios. It is therefore recommended to use Delphi in order to make the scenarios more profound and to create confidence in scenario planning. Further benefits lie in the simplification of the scenario writing process and the deep understanding of the interrelations between the forecast items and social factors.

Chapter- 6

Futures Workshops

Future workshops were developed by Robert Jungk in order to allow anybody to become involved in creating their preferred future rather than being subjected to decisions made by experts. Future workshops are very strongly action oriented. They aim, first to imagine the desired future, and then to plan it and implement it.

Future workshops have four distinctive phases:

1. In the first preparatory phase the issue that will be considered is identified and the structure and details of sessions are arranged.
2. The operative phase involves clarification of the issue considered and articulation of negative experiences in the present situation.
3. In the fantasy stage participants verbalise their desires, dreams, fantasies and views about the future in a free idea generation session. The participants are asked to forget all the limitations and obstacles of the present reality.
4. The last step involves: analysis of the feasibility of ideas and solutions generated in the fantasy phase; recognition of limits and barriers for implementation and discovering how they can be overcome.

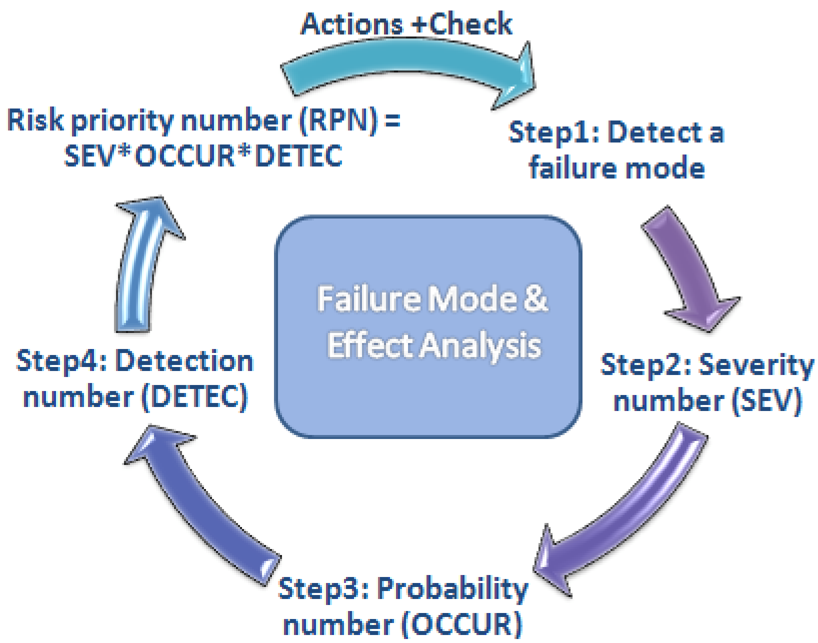
Failure mode and effects analysis

Failure mode and effects analysis (FMEA) is a safety analysis method first developed for systems engineering which examines potential failures in products or processes. It may be used to evaluate risk management priorities for mitigating known threat-vulnerabilities.

FMEA helps select remedial actions that reduce **cumulative impacts** of life cycle consequences (risks) from a systems failure (fault).

A failure modes and effects analysis (FMEA), is a procedure in product development and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. *Failure modes* are any errors or defects in a process, design, or item, especially those that affect the customer, and can be potential or actual. *Effects analysis* refers to studying the consequences of those failures.

Basic terms



FMEA cycle

Failure

"The LOSS of an intended function of a device under stated conditions."

Failure mode

"The manner by which a failure is observed; it generally describes the way the failure occurs."

Failure effect

Immediate consequences of a failure on operation, function or functionality, or status of some item

Indenture levels

An identifier for item complexity. Complexity increases as levels are closer to one.

Local effect

The Failure effect as it applies to the item under analysis.

Next higher level effect

The Failure effect as it applies at the next higher indenture level.

End effect

The failure effect at the highest indenture level or total system.

Failure cause

Defects in design, process, quality, or part application, which are the underlying cause of the failure or which initiate a process which leads to failure.

Severity

"The consequences of a failure mode. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, or system damage that could ultimately occur."

History

Learning from each failure is both costly and time consuming, and FMEA is a more systematic method of studying failure. As such, it is considered better to first conduct some thought experiments.

FMEA was formally introduced in the late 1940s for military usage by the US Armed Forces. Later it was used for aerospace/rocket development to avoid errors in small sample sizes of costly rocket technology. An example of this is the Apollo Space program. It was also used as application for HACCP for the Apollo Space Program, and later the food industry in general. The primary push came during the 1960s, while developing the means to put a man on the moon and return him safely to earth. In the late 1970s the Ford Motor Company introduced FMEA to the automotive industry for safety and regulatory consideration after the Pinto affair. They applied the same approach to processes (PFMEA) to consider potential process induced failures prior to launching production.

Although initially developed by the military, FMEA methodology is now extensively used in a variety of industries including semiconductor processing, food service, plastics, software, and healthcare. It is integrated into the Automotive Industry Action Group's (AIAG) Advanced Product Quality Planning (APQP) process to provide risk mitigation, in both product and process development phases. Each potential cause must be considered for its effect on the product or process and, based on the risk, actions are determined and risks revisited after actions are complete. Toyota has taken this one step further with its Design Review Based on Failure Mode (DRBFM) approach. The method is now supported by the American Society for Quality which provides detailed guides on applying the method.

Implementation

In FMEA, failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. An FMEA also documents current knowledge and actions about the risks of failures for use in continuous improvement. FMEA is used during the design stage with an aim to avoid future failures (sometimes called DFMEA in that case). Later it is used for process control, before and during ongoing operation of the process. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service.

The outcome of an FMEA development is actions to prevent or reduce the severity or likelihood of failures, starting with the highest-priority ones. It may be used to evaluate risk management priorities for mitigating known threat vulnerabilities. FMEA helps select remedial actions that reduce cumulative impacts of life-cycle consequences (risks) from a systems failure (fault).

It is used in many formal quality systems such as QS-9000 or ISO/TS 16949.

Using FMEA when designing

FMEA can provide an analytical approach, when dealing with potential failure modes and their associated causes. When considering possible failures in a design – like safety, cost, performance, quality and reliability – an engineer can get a lot of information about how to alter the development/manufacturing process, in order to avoid these failures. FMEA provides an easy tool to determine which risk has the greatest concern, and therefore an action is needed to prevent a problem before it arises. The development of these specifications will ensure the product will meet the defined requirements.

The pre-work

The process for conducting an FMEA is straightforward. It is developed in three main phases, in which appropriate actions need to be defined. But before starting with an FMEA, it is important to complete some pre-work to confirm that robustness and past history are included in the analysis.

A robustness analysis can be obtained from interface matrices, boundary diagrams, and parameter diagrams. A lot of failures are due to noise factors and shared interfaces with other parts and/or systems, because engineers tend to focus on what they control directly.

To start it is necessary to describe the system and its function. A good understanding simplifies further analysis. This way an engineer can see which uses of the system are desirable and which are not. It is important to consider both intentional and unintentional uses. Unintentional uses are a form of hostile environment.

Then, a block diagram of the system needs to be created. This diagram gives an overview of the major components or process steps and how they are related. These are called logical relations around which the FMEA can be developed. It is useful to create a coding system to identify the different system elements. The block diagram should always be included with the FMEA.

Before starting the actual FMEA, a worksheet needs to be created, which contains the important information about the system, such as the revision date or the names of the components. On this worksheet all the items or functions of the subject should be listed in a logical manner, based on the block diagram.

Example FMEA Worksheet

Function	Failure mode	Effects	S (severity rating)	Cause(s)	O (occurrence rating)	Current controls	D (detection rating)	CRIT (critical characteristic	RPN (risk priority number)	Recommended actions	Responsibility and target completion date
Fill tub	High level sensor never trips	Liquid spills on customer floor	8	level sensor failed level sensor disconnected	2	Fill timeout based on time to fill to low level sensor	5	N	80	Perform cost analysis of adding additional sensor halfway between low and high level sensors	Jane Doe 10-Oct-2010

Step 1: Severity

Determine all failure modes based on the functional requirements and their effects. Examples of failure modes are: Electrical short-circuiting, corrosion or deformation. A failure mode in one component can lead to a failure mode in another component, therefore each failure mode should be listed in technical terms and for function. Hereafter the ultimate effect of each failure mode needs to be considered. A failure effect is defined as the result of a failure mode on the function of the system as perceived by the user. In this way it is convenient to write these effects down in terms of what the user might see or experience. Examples of failure effects are: degraded performance, noise or even injury to a user. Each effect is given a *severity number (S)* from 1 (no danger) to 10 (critical). These numbers help an engineer to prioritize the failure modes and their effects. If the severity of an effect has a number 9 or 10, actions are considered to change the design by eliminating the failure mode, if possible, or protecting the user from the effect. A severity rating of 9 or 10 is generally reserved for those effects which would cause injury to a user or otherwise result in litigation.

Step 2: Occurrence

In this step it is necessary to look at the cause of a failure mode and how many times it occurs. This can be done by looking at similar products or processes and the failure modes that have been documented for them. A failure cause is looked upon as a design weakness. All the potential causes for a failure mode should be identified and documented. Again this should be in technical terms. Examples of causes are: erroneous algorithms, excessive voltage or improper operating conditions. A failure mode is given an *occurrence ranking (O)*, again 1–10. Actions need to be determined if the occurrence is high (meaning > 4 for non-safety failure modes and > 1 when the severity-number from step 1 is 9 or 10). This step is called the detailed development section of the FMEA process. Occurrence also can be defined as %. If a non-safety issue happened less than 1%, we can give 1 to it. It is based on your product and customer specification

Step 3: Detection

When appropriate actions are determined, it is necessary to test their efficiency. In addition, design verification is needed. The proper inspection methods need to be chosen. First, an engineer should look at the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer. Hereafter one should identify testing, analysis, monitoring and other techniques that can be or have been used on similar systems to detect failures. From these controls an engineer can learn how likely it is for a failure to be identified or detected. Each combination from the previous 2 steps receives a *detection number (D)*. This ranks the ability of planned tests and inspections to remove defects or detect failure modes in time. The assigned detection number measures the risk that the failure will *escape detection*. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low.

After these three basic steps, risk priority numbers (RPN) are calculated

Risk priority numbers

RPN do not play an important part in the choice of an action against failure modes. They are more threshold values in the evaluation of these actions.

After ranking the severity, occurrence and detectability the RPN can be easily calculated by multiplying these three numbers: $RPN = S \times O \times D$

This has to be done for the entire process and/or design. Once this is done it is easy to determine the areas of greatest concern. The failure modes that have the highest RPN should be given the highest priority for corrective action. This means it is not always the failure modes with the highest severity numbers that should be treated first. There could be less severe failures, but which occur more often and are less detectable.

After these values are allocated, recommended actions with targets, responsibility and dates of implementation are noted. These actions can include specific inspection, testing or quality procedures, redesign (such as selection of new components), adding more redundancy and limiting environmental stresses or operating range. Once the actions have been implemented in the design/process, the new RPN should be checked, to confirm the improvements. These tests are often put in graphs, for easy visualization. Whenever a design or a process changes, an FMEA should be updated.

A few logical but important thoughts come in mind:

- Try to eliminate the failure mode (some failures are more preventable than others)
- Minimize the severity of the failure

- Reduce the occurrence of the failure mode
- Improve the detection

Timing of FMEA

The FMEA should be updated whenever:

- At the beginning of a cycle (new product/process)
- Changes are made to the operating conditions
- A change is made in the design
- New regulations are instituted
- Customer feedback indicates a problem

Uses of FMEA

- Development of system requirements that minimize the likelihood of failures.
- Development of methods to design and test systems to ensure that the failures have been eliminated.
- Evaluation of the requirements of the customer to ensure that those do not give rise to potential failures.
- Identification of certain design characteristics that contribute to failures, and minimize or eliminate those effects.
- Tracking and managing potential risks in the design. This helps avoid the same failures in future projects.
- Ensuring that any failure that could occur will not injure the customer or seriously impact a system.
- To produce world class quality products

Advantages

- Improve the quality, reliability and safety of a product/process
- Improve company image and competitiveness
- Increase user satisfaction
- Reduce system development timing and cost
- Collect information to reduce future failures, capture engineering knowledge
- Reduce the potential for warranty concerns
- Early identification and elimination of potential failure modes
- Emphasize problem prevention
- Minimize late changes and associated cost
- Catalyst for teamwork and idea exchange between functions
- Reduce the possibility of same kind of failure in future

Limitations

Since FMEA is effectively dependent on the members of the committee which examines product failures, it is limited by their experience of previous failures. If a failure mode cannot be identified, then external help is needed from consultants who are aware of the many different types of product failure. FMEA is thus part of a larger system of quality control, where documentation is vital to implementation. General texts and detailed publications are available in forensic engineering and failure analysis. It is a general requirement of many specific national and international standards that FMEA is used in evaluating product integrity. If used as a top-down tool, FMEA may only identify major failure modes in a system. Fault tree analysis (FTA) is better suited for "top-down" analysis. When used as a "bottom-up" tool FMEA can augment or complement FTA and identify many more causes and failure modes resulting in top-level symptoms. It is not able to discover complex failure modes involving multiple failures within a subsystem, or to report expected failure intervals of particular failure modes up to the upper level subsystem or system.

Additionally, the multiplication of the severity, occurrence and detection rankings may result in rank reversals, where a less serious failure mode receives a higher RPN than a more serious failure mode. The reason for this is that the rankings are ordinal scale numbers, and multiplication is not defined for ordinal numbers. The ordinal rankings only say that one ranking is better or worse than another, but not by how much. For instance, a ranking of "2" may not be twice as bad as a ranking of "1," or an "8" may not be twice as bad as a "4," but multiplication treats them as though they are.

Software

Most FMEAs are created as a spreadsheet. Specialized FMEA software packages exist that offer some advantages over spreadsheets.

Types of FMEA

- Process: analysis of manufacturing and assembly processes
- Design: analysis of products prior to production
- Concept: analysis of systems or subsystems in the early design concept stages
- Equipment: analysis of machinery and equipment design before purchase
- Service: analysis of service industry processes before they are released to impact the customer
- System: analysis of the global system functions
- Software: analysis of the software functions

Measured Action

Measured Action is an action that improves Production Capability by a measured amount, (e.g. if X hours of overtime then Y additional files transmitted). Measured actions enhance FMEA by perfectly matching calculated risks with calculated contingencies to ensure a specific outcome.

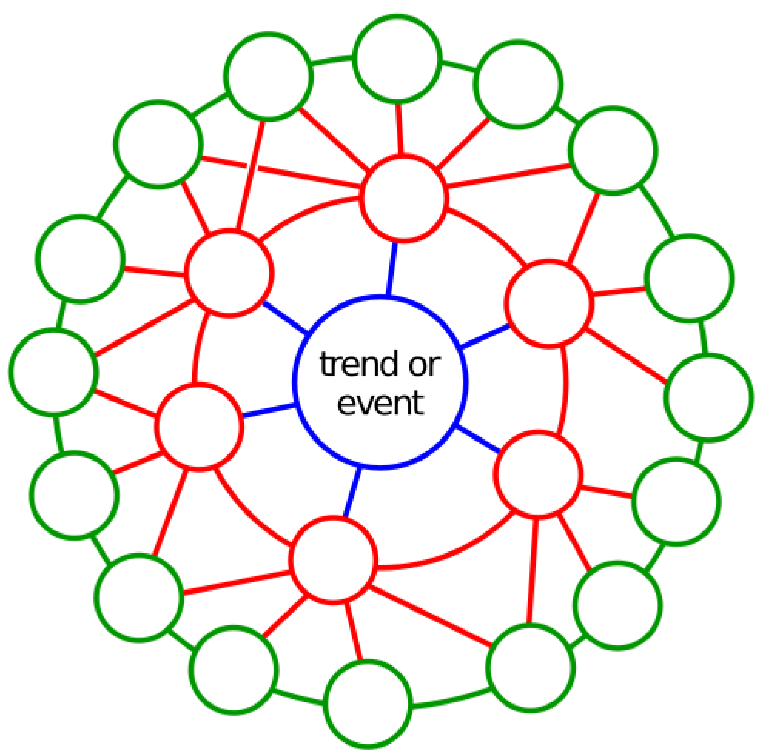
Futures biographies

This method, also called futures imagining, aims to create individual imaginaries, to gather peoples' views on the future and to examine them in the study of collective future. Peoples' expectations and opinions are considered as an important indication of possible goals and to possible directions that can influence peoples' actions and in result steer the future.

Futures wheel

The method is a form of structured brainstorming that aims at identifying and packaging secondary and tertiary consequences of trends and events. A trend or event is placed in the middle of a piece of paper and then small spokes are drawn wheel-like from the centre. Primary impacts and consequences are written in circles of the first ring.

Then secondary consequences of each primary impact are derived forming the second ring. This ripple effect continues until there is a clear picture of implications that the event or trend can have. Futures wheel is a very simple but powerful technique for drawing out people's opinions and ideas. However, it is sensitive to underlying assumptions.



A futures wheel as described by Jerome C. Glenn

The Futures wheel is an instrument for graphical visualisation of direct and indirect future consequences of a particular change or development. It was invented by Jerome C. Glenn in 1971, when he was a student at the Antioch Graduate School of Education (now Antioch University New England).

The Futures Wheel is a way of organizing thinking and questioning about the future – a kind of structured brainstorming. (Jerome C. Glenn (1994) The Futures Wheel)

Description

To start a Futures wheel the central term describing the change to evaluate is positioned in the center of the page (or drawing area). Then, events or consequences following directly from that development are positioned around it. Next, the (indirect) consequences of the direct consequences are positioned around the first level consequences. The terms may be connected as nodes in a tree (or even a web). The levels will often be marked by concentric circles.

Usage

The Futures wheel is usually used to organize thoughts about a future development or trend. With it, possible impacts can be collected and put down in a structured way. The use of interconnecting lines makes it possible to visualize interrelationships of the causes and resulting changes. Thus, Futures wheels can assist in developing multi-concepts about possible future development by offering a futures-conscious perspective and aiding in group brainstorming.

Relevance tree

It is an analytical technique that subdivides a large subject into increasingly smaller subtopics. The relevance tree has a form of a hierarchical structure that begins with a high level of abstraction and moves down with greater degree of detail in the following levels of the tree. It is a powerful technique that helps to ensure that a given problem or issue is broken into comprehensive detail and that important connections among the elements considered are presented in both current and potential situations.

Chapter- 7

Technology Forecasting

Is forecasting the future characteristics of useful technological machines, procedures or techniques.

Important aspects

Primarily, a technological forecast deals with the characteristics of technology, such as levels of technical performance, like speed of a military aircraft, the power in watts of a particular future engine, the accuracy or precision of a measuring instrument, the number of transistors in a chip in the year 2015, etc. The forecast does not have to state how these characteristics will be achieved.

Secondly, technological forecasting usually deals with only useful machines, procedures or techniques. This is to exclude from the domain of technological forecasting those commodities, services or techniques intended for luxury or amusement.

Rational and explicit methods

The whole purpose of the recitation of alternatives, is to show that there really is no alternative to forecasting. If a decisionmaker has several alternatives open to him, he will choose among them on the basis of which provides him with the most desirable outcome. Thus his decision is inevitably based on a forecast. His only choice is whether the forecast is obtained by rational and explicit methods, or by intuitive means.

The virtues of the use of rational methods are as follows:

1. They can be taught and learned,
2. They can be described and explained,
3. They provide a procedure followable by anyone who has absorbed the necessary training, and in some cases,
4. These methods are even guaranteed to produce the same forecast regardless of who uses them.

The virtue of the use of explicit methods is that they can be reviewed by others, and can be checked for consistency. Furthermore, the forecast can be reviewed at any subsequent time. Technology forecasting is not imagination.

Methods of technology forecasting

Commonly adopted methods of technology forecasting include the Delphi method, forecast by analogy, growth curves and extrapolation. Normative methods of technology forecasting — like the relevance trees, morphological models, and mission flow diagrams — are also commonly used.

THE DELPHI METHOD: The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts. In the standard version, the experts answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process the range of the answers will decrease and the group will converge towards the "correct" answer. Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, stability of results) and the mean or median scores of the final rounds determine the results.

Combining forecasts

Studies of past forecasts have shown that one of the most frequent reasons why a forecast goes wrong is that the forecaster ignores related fields.

A given technical approach may fail to achieve the level of capability forecast for it, because it is superseded by another technical approach which the forecaster ignored.

Another problem is that of inconsistency between forecasts. Because of these problems, it is often necessary to combine forecasts of different technologies. Therefore rather than to try to select the one method which is most appropriate, it may be better to try to combine the forecasts obtained by different methods.

If this is done, the strengths of one method may help compensate for the weaknesses of another.

Reasons for combining forecasts

The primary reason for combining forecasts of the same technology is to attempt to offset the weaknesses of one forecasting method with the strengths of another. In addition, the use of more than one forecasting method often gives the forecaster more insight into the processes at work which are responsible for the growth of the technology being forecast.

Trend curve and growth curves

A frequently used combination is that of growth curves and a trend curve for some technology. Here we see a succession of growth curves, each describing the level of functional capability achieved by a specific technical approach.

An overall trend curve is also shown, fitted to those items of historical data which represent the currently superior approach.

The use of growth curves and a trend curve in combination allows the forecaster to draw some conclusions about the future growth of a technology which might not be possible, were either method used alone.

With growth curves alone, the forecaster could not say anything about the time at which a given technical approach is likely to be supplanted by a successor approach.

With the trend curve alone, the forecaster could not say anything about the ability of a specific technical approach to meet the projected trend, or about the need to look for a successor approach. Thus the need for combining forecasts.

Identification of consistent deviations

Another frequently used combination of forecasts is that of the trend curve and one or more analogies.

We customarily consider the scatter of data points about a trend curve to be due to random influences which we can neither control nor even measure. However, consistent deviations may represent something other than just random influences.

Where such consistent deviations are identified, we may have an opportunity to apply an analogy. Typical events which bring about deviations from a trend are wars and depressions. Thus the purpose of combining analogies with a trend forecast is to predict deviations from the trend deviations which are associated with or caused by external events or influences.

As with other uses of analogy, it is important to determine the extent to which the analogy between the event used as the basis for the forecast, and the historical model event, satisfies the criteria for a valid analogy.

Forecasts of different technologies

Combining forecasts of different technologies may be even more important than combining the forecasts of the same technology.

One reason for this is the fact that technologies may interact or be interrelated in some fashion. Another reason for this is that of consistency in an overall picture or scenario.

One of the simplest examples of interacting trends is the projection to absurdity, i.e. simply projecting the given data indefinitely without getting any specific result. For instance, if one simply projects recent rates of growth of world population, one arrives at some fantastic conclusions about the density of population in a particular place by various dates in the next millennium.

Some other trends which can confidently be expected to not continue indefinitely are:

1. Annual production of scientific papers.
2. Number of automobiles per capita.
3. Kilowatt hours of electricity generated annually.

Another instance of interacting trends was in the case of the number of scientists in the U.S. growing faster than the overall population. Since 1940s through the 1960s, science as an activity in the United States grew exponentially. The number of dollars spent on R&D was growing faster than the GNP (in the 1960s).

If projected indefinitely, these two curves would give the result that eventually every person in the U.S. would be working as a scientist and the entire GNP would be devoted to R&D alone, which are however absurd conclusions. Thus it is clear that the scientific discipline of technology forecasting is not mere trend extrapolation but also involves combining forecasts.

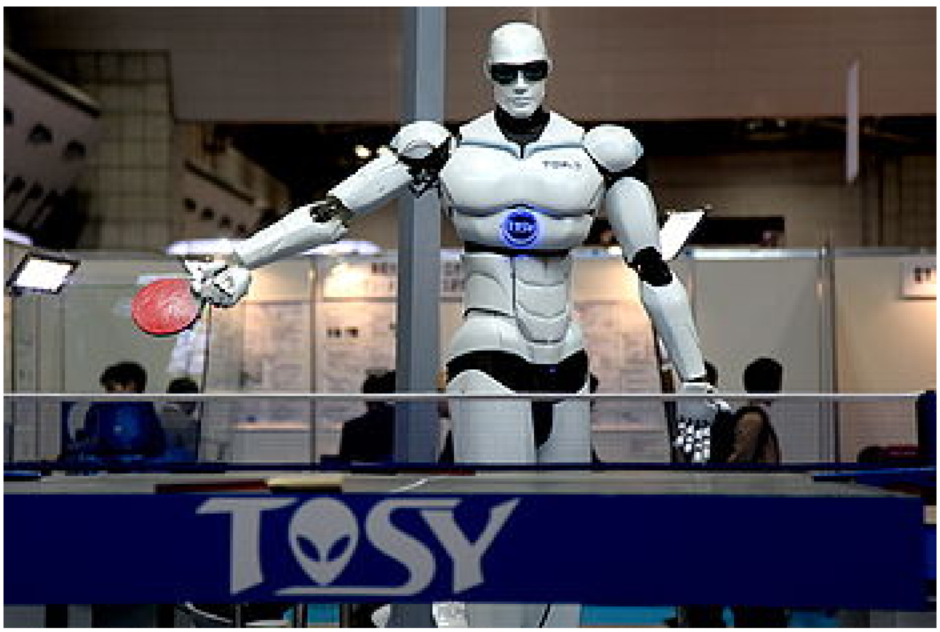
Uses in manufacturing

Almost all modern manufacturing firms utilize the services of a technological forecaster. Nevertheless, there are a number of alternatives to the rational and explicit forecasting of technology, such as 'no forecast', 'anything can happen' (i.e. relying on pure chance), 'window-blind forecasting', 'genius forecasting' and boasting of a 'glorious past' (i.e. adopting the same old techniques).

Thus technological forecasting is not mere astrology or palmistry, but a scientific and well defined procedure adopted by a technological forecaster or a consultancy for the forecasting of a particular technology. Even though technological forecasting is a scientific discipline, some experts are of the view that "the only certainty of a particular forecast is that it is wrong to some degree."

Chapter- 8

Artificial Intelligence



TOPIO, a humanoid robot, played table tennis at Tokyo International Robot Exhibition (IREX) 2009.

Artificial intelligence (**AI**) is the intelligence of machines and the branch of computer science that aims to create it. AI textbooks define the field as "the study and design of intelligent agents" where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success. John McCarthy, who coined the term in 1956, defines it as "the science and engineering of making intelligent machines."

The field was founded on the claim that a central property of humans, intelligence—the sapience of *Homo sapiens*—can be so precisely described that it can be simulated by a machine. This raises philosophical issues about the nature of the mind and the ethics of creating artificial beings, issues which have been addressed by myth, fiction and philosophy since antiquity. Artificial intelligence has been the subject of optimism, but has also suffered setbacks and, today, has become an essential part of the technology industry, providing the heavy lifting for many of the most difficult problems in computer science.

AI research is highly technical and specialized, and deeply divided into subfields that often fail to communicate with each other. Subfields have grown up around particular institutions, the work of individual researchers, the solution of specific problems, longstanding differences of opinion about how AI should be done and the application of widely differing tools. The central problems of AI include such traits as reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects. General intelligence (or "strong AI") is still among the field's long term goals.

History

Thinking machines and artificial beings appear in Greek myths, such as Talos of Crete, the bronze robot of Hephaestus, and Pygmalion's Galatea. Human likenesses believed to have intelligence were built in every major civilization: animated cult images were worshipped in Egypt and Greece and humanoid automatons were built by Yan Shi, Hero of Alexandria and Al-Jazari. It was also widely believed that artificial beings had been created by Jābir ibn Hayyān, Judah Loew and Paracelsus. By the 19th and 20th centuries, artificial beings had become a common feature in fiction, as in Mary Shelley's *Frankenstein* or Karel Čapek's *R.U.R. (Rossum's Universal Robots)*. Pamela McCorduck argues that all of these are examples of an ancient urge, as she describes it, "to forge the gods". Stories of these creatures and their fates discuss many of the same hopes, fears and ethical concerns that are presented by artificial intelligence.

Mechanical or "formal" reasoning has been developed by philosophers and mathematicians since antiquity. The study of logic led directly to the invention of the programmable digital electronic computer, based on the work of mathematician Alan Turing and others. Turing's theory of computation suggested that a machine, by shuffling symbols as simple as "0" and "1", could simulate any conceivable act of mathematical deduction. This, along with concurrent discoveries in neurology, information theory and cybernetics, inspired a small group of researchers to begin to seriously consider the possibility of building an electronic brain.

The field of AI research was founded at a conference on the campus of Dartmouth College in the summer of 1956. The attendees, including John McCarthy, Marvin Minsky, Allen Newell and Herbert Simon, became the leaders of AI research for many decades. They and their students wrote programs that were, to most people, simply astonishing: computers were solving word problems in algebra, proving logical theorems and speaking English. By the middle of the 1960s, research in the U.S. was heavily funded by the Department of Defense and laboratories had been established around the world. AI's founders were profoundly optimistic about the future of the new field: Herbert Simon predicted that "machines will be capable, within twenty years, of doing any work a man can do" and Marvin Minsky agreed, writing that "within a generation ... the problem of creating 'artificial intelligence' will substantially be solved".

They had failed to recognize the difficulty of some of the problems they faced. In 1974, in response to the criticism of Sir James Lighthill and ongoing pressure from the US Congress to fund more productive projects, both the U.S. and British governments cut off all undirected exploratory research in AI. The next few years, when funding for projects was hard to find, would later be called the "AI winter".

In the early 1980s, AI research was revived by the commercial success of expert systems, a form of AI program that simulated the knowledge and analytical skills of one or more human experts. By 1985 the market for AI had reached over a billion dollars. At the same time, Japan's fifth generation computer project inspired the U.S and British governments to restore funding for academic research in the field. However, beginning with the collapse of the Lisp Machine market in 1987, AI once again fell into disrepute, and a second, longer lasting AI winter began.

In the 1990s and early 21st century, AI achieved its greatest successes, albeit somewhat behind the scenes. Artificial intelligence is used for logistics, data mining, medical diagnosis and many other areas throughout the technology industry. The success was due to several factors: the increasing computational power of computers, a greater emphasis on solving specific subproblems, the creation of new ties between AI and other fields working on similar problems, and a new commitment by researchers to solid mathematical methods and rigorous scientific standards.

The artificial intelligence quiz show contestant "Watson", appearing on *Jeopardy!* in 2011.

On 11 May 1997, Deep Blue became the first computer chess-playing system to beat a reigning world chess champion, Garry Kasparov. In 2005, a Stanford robot won the DARPA Grand Challenge by driving autonomously for 131 miles along an unrehearsed desert trail. In February 2011, in a Jeopardy! quiz show exhibition match, IBM's question answering system, Watson, defeated the two greatest Jeopardy! champions, Brad Rutter and Ken Jennings, by a significant margin.

The leading-edge definition of artificial intelligence research is changing over time. One pragmatic definition is: "AI research is that which computing scientists do not know how to do cost-effectively today." For example, in 1956 optical character recognition (OCR) was considered AI, but today, sophisticated OCR software with a context-sensitive spell checker and grammar checker software comes for free with most image scanners. No one would any longer consider already-solved computing science problems like OCR "artificial intelligence" today.

Low-cost entertaining chess-playing software is commonly available for tablet computers. DARPA no longer provides significant funding for chess-playing computing system development. The XBox 360 gaming system November 2010 Kinect 3D-body-motion interface uses algorithms that emerged from lengthy AI research, but few consumers realize the technology source.

AI applications are no longer the exclusive domain of Department of defense R&D, but are now common place consumer items and inexpensive intelligent toys.

In common usage, the term "AI" no longer seems to apply to off-the-shelf solved computing-science problems, which may have originally emerged out of years of AI research.

Problems

The general problem of simulating (or creating) intelligence has been broken down into a number of specific sub-problems. These consist of particular traits or capabilities that researchers would like an intelligent system to display. The traits described below have received the most attention.

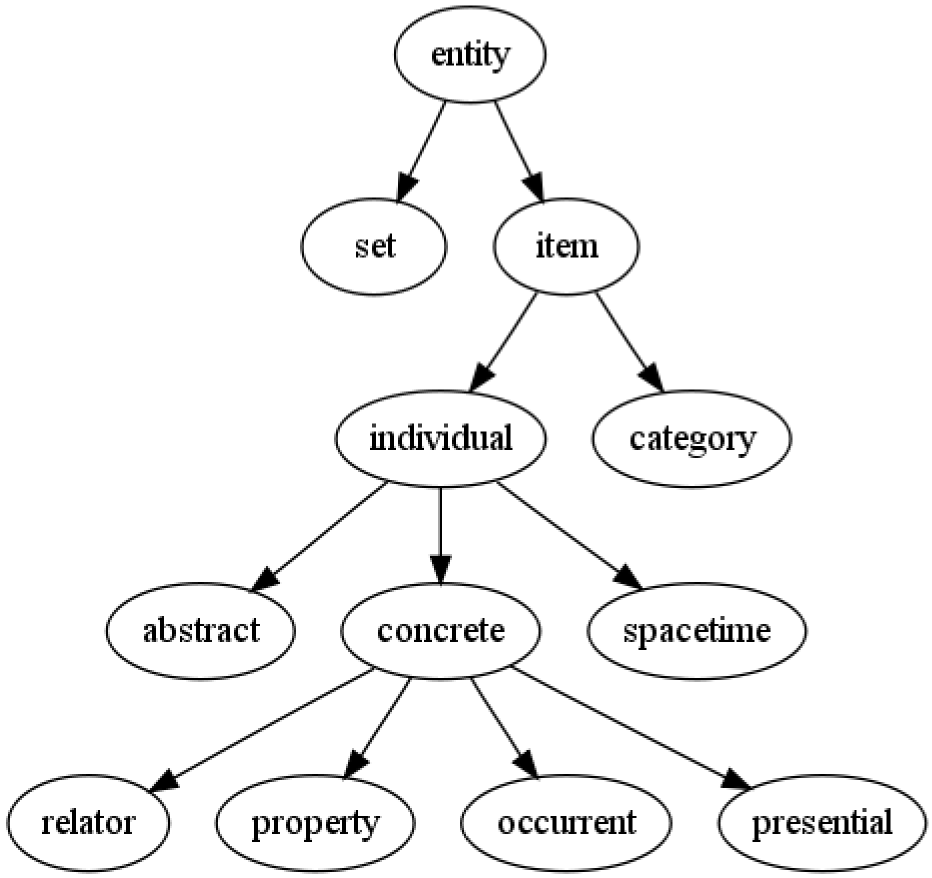
Deduction, reasoning, problem solving

Early AI researchers developed algorithms that imitated the step-by-step reasoning that humans were often assumed to use when they solve puzzles, play board games or make logical deductions. By the late 1980s and '90s, AI research had also developed highly successful methods for dealing with uncertain or incomplete information, employing concepts from probability and economics.

For difficult problems, most of these algorithms can require enormous computational resources — most experience a "combinatorial explosion": the amount of memory or computer time required becomes astronomical when the problem goes beyond a certain size. The search for more efficient problem solving algorithms is a high priority for AI research.

Human beings solve most of their problems using fast, intuitive judgments rather than the conscious, step-by-step deduction that early AI research was able to model. AI has made some progress at imitating this kind of "sub-symbolic" problem solving: embodied agent approaches emphasize the importance of sensorimotor skills to higher reasoning; neural net research attempts to simulate the structures inside human and animal brains that give rise to this skill.

Knowledge representation



An ontology represents knowledge as a set of concepts within a domain and the relationships between those concepts.

Knowledge representation and knowledge engineering are central to AI research. Many of the problems machines are expected to solve will require extensive knowledge about the world. Among the things that AI needs to represent are: objects, properties, categories and relations between objects; situations, events, states and time; causes and effects; knowledge about knowledge (what we know about what other people know); and many other, less well researched domains. A complete representation of "what exists" is an ontology (borrowing a word from traditional philosophy), of which the most general are called upper ontologies.

Among the most difficult problems in knowledge representation are:

Default reasoning and the qualification problem

Many of the things people know take the form of "working assumptions." For example, if a bird comes up in conversation, people typically picture an animal that is fist sized, sings, and flies. None of these things are true about all birds. John McCarthy identified this problem in 1969 as the qualification problem: for any commonsense rule that AI researchers care to represent, there tend to be a huge number of exceptions. Almost nothing is simply true or false in the way that abstract logic requires. AI research has explored a number of solutions to this problem.

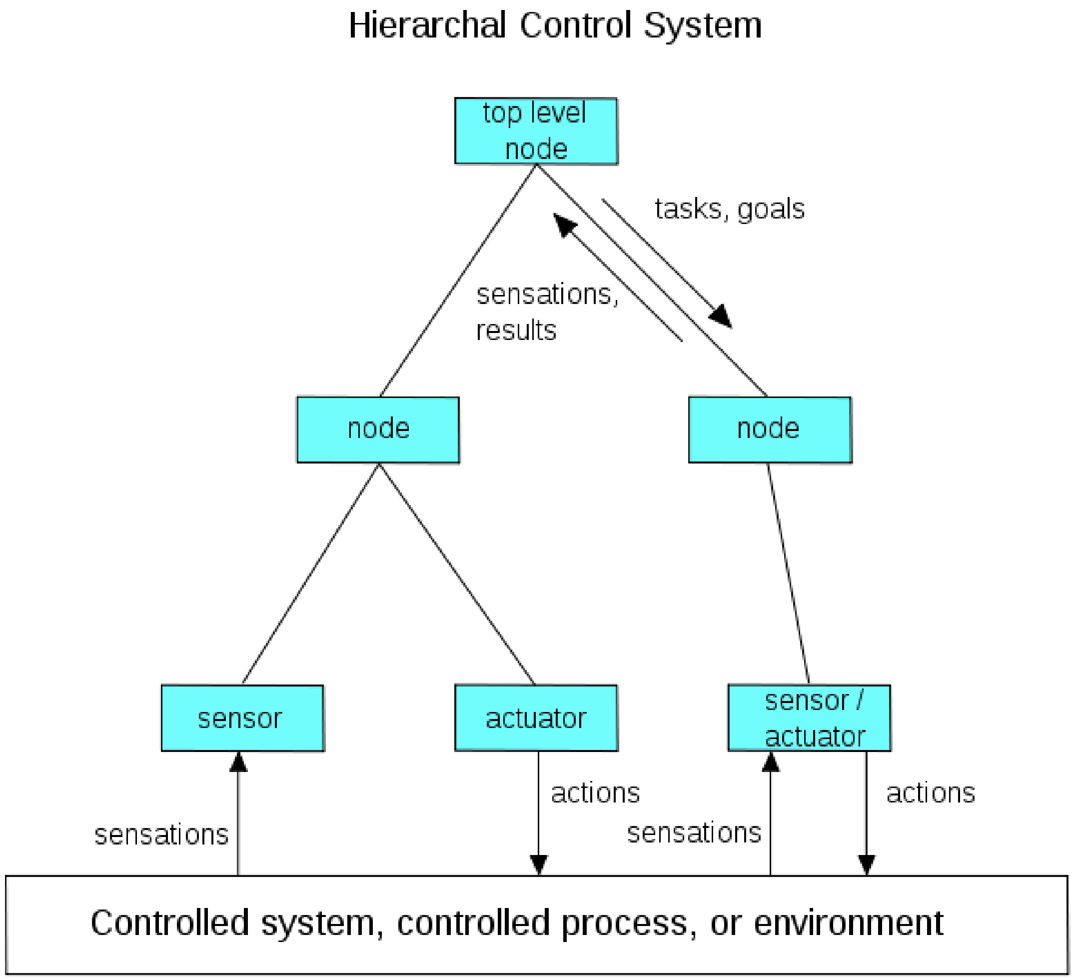
The breadth of commonsense knowledge

The number of atomic facts that the average person knows is astronomical. Research projects that attempt to build a complete knowledge base of commonsense knowledge (e.g., Cyc) require enormous amounts of laborious ontological engineering — they must be built, by hand, one complicated concept at a time. A major goal is to have the computer understand enough concepts to be able to learn by reading from sources like the internet, and thus be able to add to its own ontology.

The subsymbolic form of some commonsense knowledge

Much of what people know is not represented as "facts" or "statements" that they could express verbally. For example, a chess master will avoid a particular chess position because it "feels too exposed" or an art critic can take one look at a statue and instantly realize that it is a fake. These are intuitions or tendencies that are represented in the brain non-consciously and sub-symbolically. Knowledge like this informs, supports and provides a context for symbolic, conscious knowledge. As with the related problem of sub-symbolic reasoning, it is hoped that situated AI or computational intelligence will provide ways to represent this kind of knowledge.

Planning



A hierarchical control system is a form of control system in which a set of devices and governing software is arranged in a hierarchy.

Intelligent agents must be able to set goals and achieve them. They need a way to visualize the future (they must have a representation of the state of the world and be able to make predictions about how their actions will change it) and be able to make choices that maximize the utility (or "value") of the available choices.

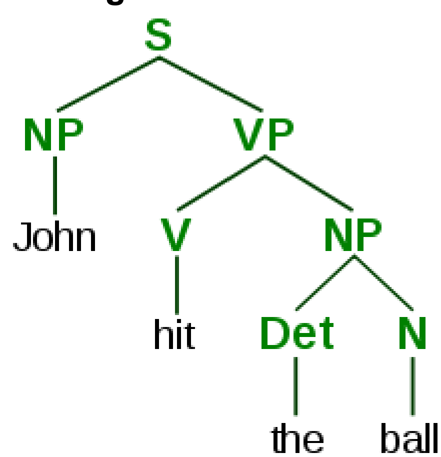
In classical planning problems, the agent can assume that it is the only thing acting on the world and it can be certain what the consequences of its actions may be. However, if this is not true, it must periodically check if the world matches its predictions and it must change its plan as this becomes necessary, requiring the agent to reason under uncertainty.

Multi-agent planning uses the cooperation and competition of many agents to achieve a given goal. Emergent behavior such as this is used by evolutionary algorithms and swarm intelligence.

Learning

Machine learning has been central to AI research from the beginning. In 1956, at the original Dartmouth AI summer conference, Ray Solomonoff wrote a report on unsupervised probabilistic machine learning: "An Inductive Inference Machine". Unsupervised learning is the ability to find patterns in a stream of input. Supervised learning includes both classification and numerical regression. Classification is used to determine what category something belongs in, after seeing a number of examples of things from several categories. Regression takes a set of numerical input/output examples and attempts to discover a continuous function that would generate the outputs from the inputs. In reinforcement learning the agent is rewarded for good responses and punished for bad ones. These can be analyzed in terms of decision theory, using concepts like utility. The mathematical analysis of machine learning algorithms and their performance is a branch of theoretical computer science known as computational learning theory.

Natural language processing



A parse tree represents the syntactic structure of a sentence according to some formal grammar.

Natural language processing gives machines the ability to read and understand the languages that humans speak. Many researchers hope that a sufficiently powerful natural language processing system would be able to acquire knowledge on its own, by reading the existing text available over the internet. Some straightforward applications of natural language processing include information retrieval (or text mining) and machine translation.

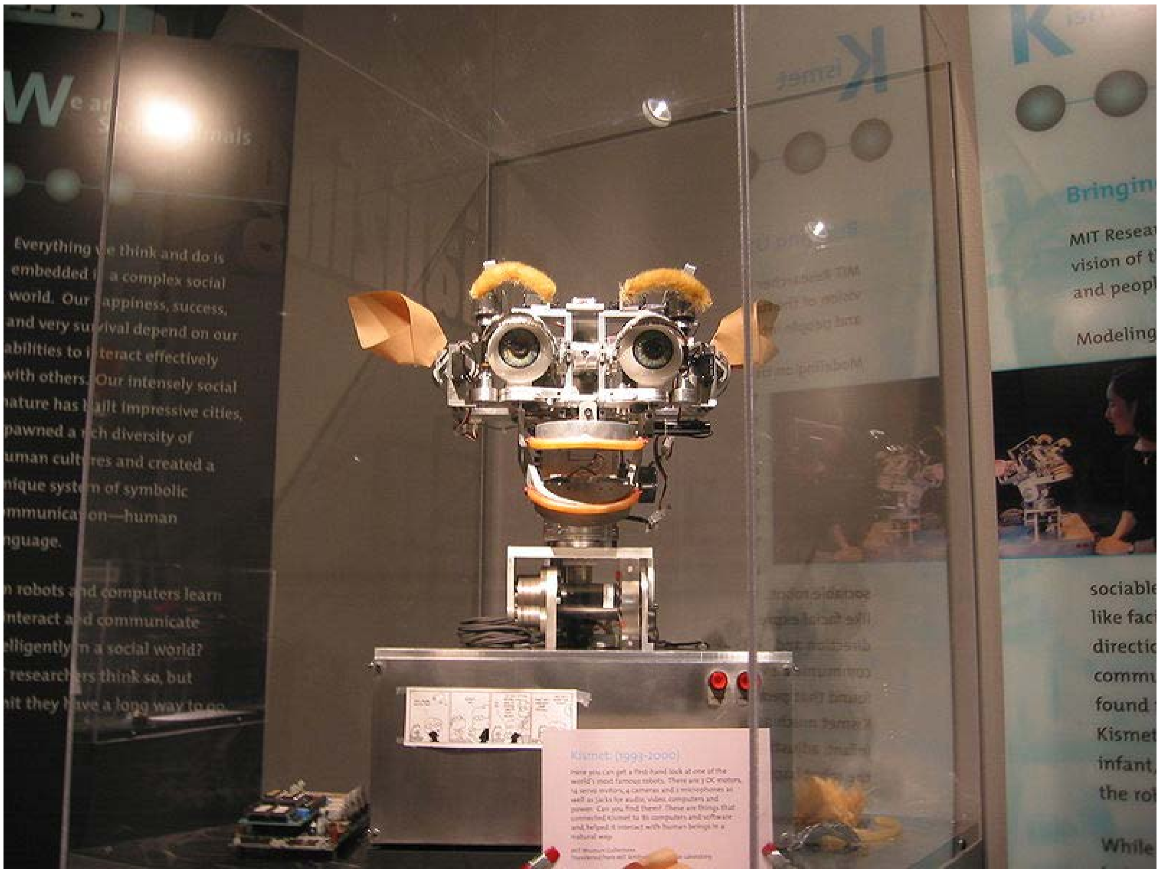
Motion and manipulation

The field of robotics is closely related to AI. Intelligence is required for robots to be able to handle such tasks as object manipulation and navigation, with sub-problems of localization (knowing where you are), mapping (learning what is around you) and motion planning (figuring out how to get there).

Perception

Machine perception is the ability to use input from sensors (such as cameras, microphones, sonar and others more exotic) to deduce aspects of the world. Computer vision is the ability to analyze visual input. A few selected subproblems are speech recognition, facial recognition and object recognition.

Social intelligence



Kismet, a robot with rudimentary social skills

Emotion and social skills play two roles for an intelligent agent. First, it must be able to predict the actions of others, by understanding their motives and emotional states. (This involves elements of game theory, decision theory, as well as the ability to model human emotions and the perceptual skills to detect emotions.) Also, for good human-computer interaction, an intelligent machine also needs to *display* emotions. At the very least it must appear polite and sensitive to the humans it interacts with. At best, it should have normal emotions itself.

Creativity

A sub-field of AI addresses creativity both theoretically (from a philosophical and psychological perspective) and practically (via specific implementations of systems that generate outputs that can be considered creative, or systems that identify and assess creativity). A related area of computational research is Artificial Intuition and Artificial Imagination.

General intelligence

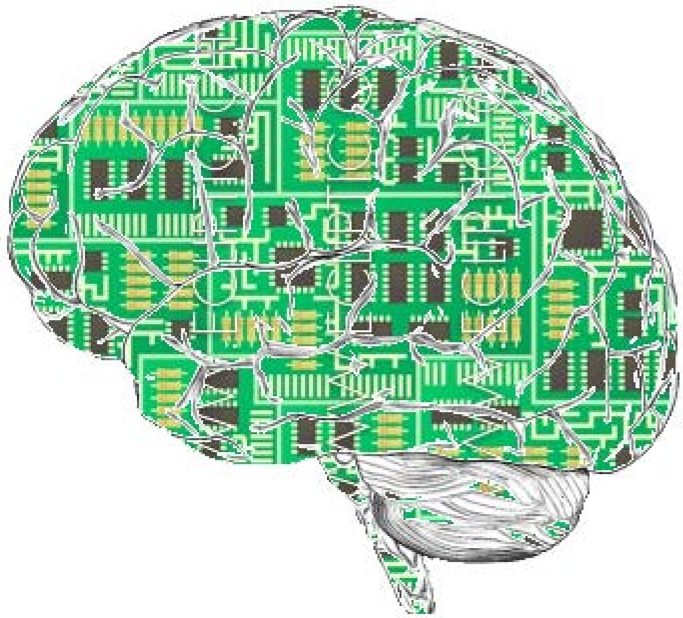
Most researchers hope that their work will eventually be incorporated into a machine with *general* intelligence (known as strong AI), combining all the skills above and exceeding human abilities at most or all of them. A few believe that anthropomorphic features like artificial consciousness or an artificial brain may be required for such a project.

Many of the problems above are considered AI-complete: to solve one problem, you must solve them all. For example, even a straightforward, specific task like machine translation requires that the machine follow the author's argument (reason), know what is being talked about (knowledge), and faithfully reproduce the author's intention (social intelligence). Machine translation, therefore, is believed to be AI-complete: it may require strong AI to be done as well as humans can do it.

Approaches

There is no established unifying theory or paradigm that guides AI research. Researchers disagree about many issues. A few of the most long standing questions that have remained unanswered are these: should artificial intelligence simulate natural intelligence by studying psychology or neurology? Or is human biology as irrelevant to AI research as bird biology is to aeronautical engineering? Can intelligent behavior be described using simple, elegant principles (such as logic or optimization)? Or does it necessarily require solving a large number of completely unrelated problems? Can intelligence be reproduced using high-level symbols, similar to words and ideas? Or does it require "sub-symbolic" processing? John Haugeland, who coined the term GOFAI, also proposed that AI should more properly be referred to as synthetic intelligence, a term which has since been adopted by some non-GOFAI researchers.

Cybernetics and brain simulation



There is currently no consensus on how closely the brain should be simulated

In the 1940s and 1950s, a number of researchers explored the connection between neurology, information theory, and cybernetics. Some of them built machines that used electronic networks to exhibit rudimentary intelligence, such as W. Grey Walter's turtles and the Johns Hopkins Beast. Many of these researchers gathered for meetings of the Teleological Society at Princeton University and the Ratio Club in England. By 1960, this approach was largely abandoned, although elements of it would be revived in the 1980s.

Symbolic

When access to digital computers became possible in the middle 1950s, AI research began to explore the possibility that human intelligence could be reduced to symbol manipulation. The research was centered in three institutions: CMU, Stanford and MIT, and each one developed its own style of research. John Haugeland named these approaches to AI "good old fashioned AI" or "GOFAI".

Cognitive simulation

> Economist Herbert Simon and Allen Newell studied human problem solving skills and attempted to formalize them, and their work laid the foundations of the field of artificial intelligence, as well as cognitive science, operations research and management science. Their research team used the results of psychological experiments to develop programs that simulated the techniques that people used to solve problems. This tradition, centered at Carnegie Mellon University would eventually culminate in the development of the Soar architecture in the middle 80s.

Logic-based

Unlike Newell and Simon, John McCarthy felt that machines did not need to simulate human thought, but should instead try to find the essence of abstract reasoning and problem solving, regardless of whether people used the same algorithms. His laboratory at Stanford (SAIL) focused on using formal logic to solve a wide variety of problems, including knowledge representation, planning and learning. Logic was also focus of the work at the University of Edinburgh and elsewhere in Europe which led to the development of the programming language Prolog and the science of logic programming.

"Anti-logic" or "scruffy"

Researchers at MIT (such as Marvin Minsky and Seymour Papert) found that solving difficult problems in vision and natural language processing required ad-hoc solutions – they argued that there was no simple and general principle (like logic) that would capture all the aspects of intelligent behavior. Roger Schank described their "anti-logic" approaches as "scruffy" (as opposed to the "neat" paradigms at CMU and Stanford). Commonsense knowledge bases (such as Doug Lenat's Cyc) are an example of "scruffy" AI, since they must be built by hand, one complicated concept at a time.

Knowledge-based

When computers with large memories became available around 1970, researchers from all three traditions began to build knowledge into AI applications. This "knowledge revolution" led to the development and deployment of expert systems (introduced by Edward Feigenbaum), the first truly successful form of AI software. The knowledge revolution was also driven by the realization that enormous amounts of knowledge would be required by many simple AI applications.

Sub-symbolic

During the 1960s, symbolic approaches had achieved great success at simulating high-level thinking in small demonstration programs. Approaches based on cybernetics or neural networks were abandoned or pushed into the background. By the 1980s, however, progress in symbolic AI seemed to stall and many believed that symbolic systems would never be able to imitate all the processes of human cognition, especially perception, robotics, learning and pattern recognition. A number of researchers began to look into "sub-symbolic" approaches to specific AI problems.

Bottom-up, embodied, situated, behavior-based or nouvelle AI

Researchers from the related field of robotics, such as Rodney Brooks, rejected symbolic AI and focused on the basic engineering problems that would allow robots to move and survive. Their work revived the non-symbolic viewpoint of the early cybernetics researchers of the 50s and reintroduced the use of control theory in AI. This coincided with the development of the embodied mind thesis in the related field of cognitive science: the idea that aspects of the body (such as movement, perception and visualization) are required for higher intelligence.

Computational Intelligence

Interest in neural networks and "connectionism" was revived by David Rumelhart and others in the middle 1980s. These and other sub-symbolic approaches, such as fuzzy systems and evolutionary computation, are now studied collectively by the emerging discipline of computational intelligence.

Statistical

In the 1990s, AI researchers developed sophisticated mathematical tools to solve specific subproblems. These tools are truly scientific, in the sense that their results are both measurable and verifiable, and they have been responsible for many of AI's recent successes. The shared mathematical language has also permitted a high level of collaboration with more established fields (like mathematics, economics or operations research). Stuart Russell and Peter Norvig describe this movement as nothing less than a "revolution" and "the victory of the neats."

Integrating the approaches

Intelligent agent paradigm

An intelligent agent is a system that perceives its environment and takes actions which maximizes its chances of success. The simplest intelligent agents are programs that solve specific problems. More complicated agents include human beings and organizations of human beings (such as firms). The paradigm gives researchers license to study isolated problems and find solutions that are both verifiable and useful, without agreeing on one single approach. An agent that solves a specific problem can use any approach that works — some agents are symbolic and logical, some are sub-symbolic neural networks and others may use new approaches. The paradigm also gives researchers a common language to communicate with other fields—such as decision theory and economics—that also use concepts of abstract agents. The intelligent agent paradigm became widely accepted during the 1990s.

Agent architectures and cognitive architectures

Researchers have designed systems to build intelligent systems out of interacting intelligent agents in a multi-agent system. A system with both symbolic and sub-symbolic components is a hybrid intelligent system, and the study of such systems is artificial intelligence systems integration. A hierarchical control system provides a bridge between sub-symbolic AI at its lowest, reactive levels and traditional symbolic AI at its highest levels, where relaxed time constraints permit planning and world modelling. Rodney Brooks' subsumption architecture was an early proposal for such a hierarchical system.

Tools

In the course of 50 years of research, AI has developed a large number of tools to solve the most difficult problems in computer science. A few of the most general of these methods are discussed below.

Search and optimization

Many problems in AI can be solved in theory by intelligently searching through many possible solutions: Reasoning can be reduced to performing a search. For example, logical proof can be viewed as searching for a path that leads from premises to conclusions, where each step is the application of an inference rule. Planning algorithms search through trees of goals and subgoals, attempting to find a path to a target goal, a process called means-ends analysis. Robotics algorithms for moving limbs and grasping objects use local searches in configuration space. Many learning algorithms use search algorithms based on optimization.

Simple exhaustive searches are rarely sufficient for most real world problems: the search space (the number of places to search) quickly grows to astronomical numbers. The result is a search that is too slow or never completes. The solution, for many problems, is to use "heuristics" or "rules of thumb" that eliminate choices that are unlikely to lead to the goal (called "pruning the search tree"). Heuristics supply the program with a "best guess" for what path the solution lies on.

A very different kind of search came to prominence in the 1990s, based on the mathematical theory of optimization. For many problems, it is possible to begin the search with some form of a guess and then refine the guess incrementally until no more refinements can be made. These algorithms can be visualized as blind hill climbing: we begin the search at a random point on the landscape, and then, by jumps or steps, we keep moving our guess uphill, until we reach the top. Other optimization algorithms are simulated annealing, beam search and random optimization.

Evolutionary computation uses a form of optimization search. For example, they may begin with a population of organisms (the guesses) and then allow them to mutate and recombine, selecting only the fittest to survive each generation (refining the guesses). Forms of evolutionary computation include swarm intelligence algorithms (such as ant colony or particle swarm optimization) and evolutionary algorithms (such as genetic algorithms and genetic programming).

Logic

Logic is used for knowledge representation and problem solving, but it can be applied to other problems as well. For example, the satplan algorithm uses logic for planning and inductive logic programming is a method for learning.

Several different forms of logic are used in AI research. Propositional or sentential logic is the logic of statements which can be true or false. First-order logic also allows the use of quantifiers and predicates, and can express facts about objects, their properties, and their relations with each other. Fuzzy logic, is a version of first-order logic which allows the truth of a statement to be represented as a value between 0 and 1, rather than simply True (1) or False (0). Fuzzy systems can be used for uncertain reasoning and have been widely used in modern industrial and consumer product control systems. Subjective logic models uncertainty in a different and more explicit manner than fuzzy-logic: a given binomial opinion satisfies belief + disbelief + uncertainty = 1 within a Beta distribution. By this method, ignorance can be distinguished from probabilistic statements that an agent makes with high confidence.

Default logics, non-monotonic logics and circumscription are forms of logic designed to help with default reasoning and the qualification problem. Several extensions of logic have been designed to handle specific domains of knowledge, such as: description logics; situation calculus, event calculus and fluent calculus (for representing events and time); causal calculus; belief calculus; and modal logics.

Probabilistic methods for uncertain reasoning

Many problems in AI (in reasoning, planning, learning, perception and robotics) require the agent to operate with incomplete or uncertain information. AI researchers have devised a number of powerful tools to solve these problems using methods from probability theory and economics.

Bayesian networks are a very general tool that can be used for a large number of problems: reasoning (using the Bayesian inference algorithm), learning (using the expectation-maximization algorithm), planning (using decision networks) and perception (using dynamic Bayesian networks). Probabilistic algorithms can also be used for filtering, prediction, smoothing and finding explanations for streams of data, helping perception systems to analyze processes that occur over time (e.g., hidden Markov models or Kalman filters).

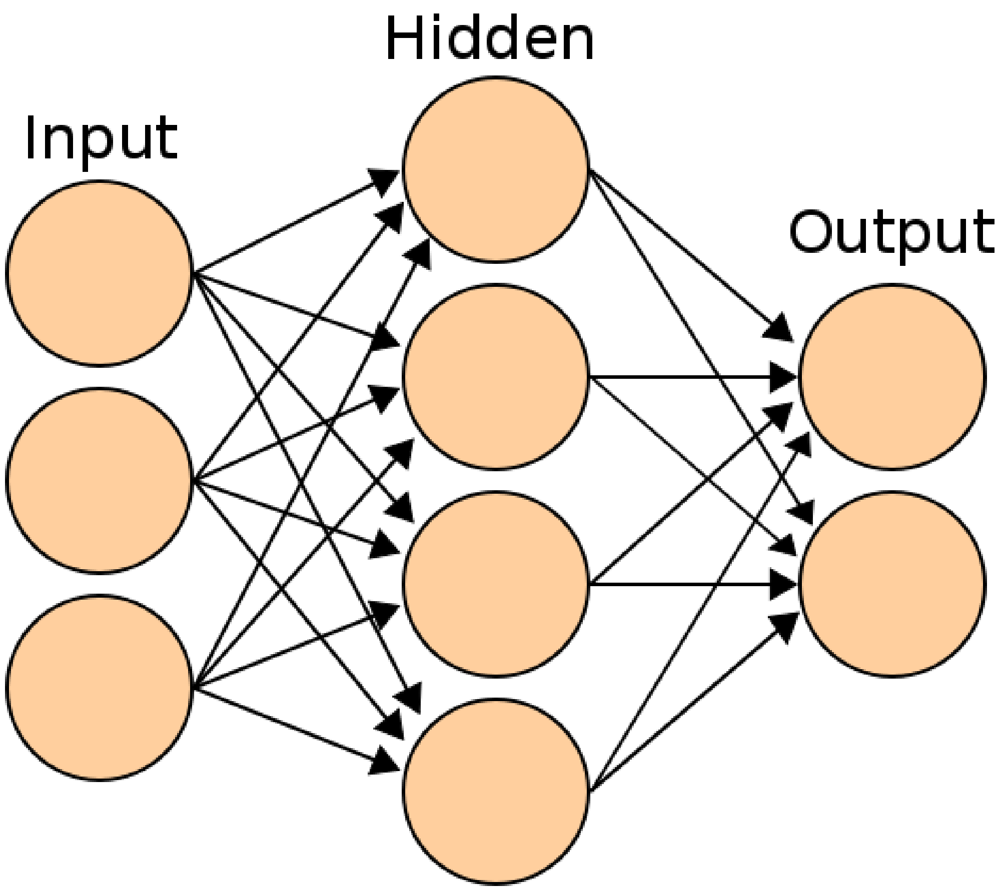
A key concept from the science of economics is "utility": a measure of how valuable something is to an intelligent agent. Precise mathematical tools have been developed that analyze how an agent can make choices and plan, using decision theory, decision analysis, information value theory. These tools include models such as Markov decision processes, dynamic decision networks, game theory and mechanism design.

Classifiers and statistical learning methods

The simplest AI applications can be divided into two types: classifiers ("if shiny then diamond") and controllers ("if shiny then pick up"). Controllers do however also classify conditions before inferring actions, and therefore classification forms a central part of many AI systems. Classifiers are functions that use pattern matching to determine a closest match. They can be tuned according to examples, making them very attractive for use in AI. These examples are known as observations or patterns. In supervised learning, each pattern belongs to a certain predefined class. A class can be seen as a decision that has to be made. All the observations combined with their class labels are known as a data set. When a new observation is received, that observation is classified based on previous experience.

A classifier can be trained in various ways; there are many statistical and machine learning approaches. The most widely used classifiers are the neural network, kernel methods such as the support vector machine, k-nearest neighbor algorithm, Gaussian mixture model, naive Bayes classifier, and decision tree. The performance of these classifiers have been compared over a wide range of tasks. Classifier performance depends greatly on the characteristics of the data to be classified. There is no single classifier that works best on all given problems; this is also referred to as the "no free lunch" theorem. Determining a suitable classifier for a given problem is still more an art than science.

Neural networks



A neural network is an interconnected group of nodes, akin to the vast network of neurons in the human brain.

The study of artificial neural networks began in the decade before the field AI research was founded, in the work of Walter Pitts and Warren McCullough. Other important early researchers were Frank Rosenblatt, who invented the perceptron and Paul Werbos who developed the backpropagation algorithm.

The main categories of networks are acyclic or feedforward neural networks (where the signal passes in only one direction) and recurrent neural networks (which allow feedback). Among the most popular feedforward networks are perceptrons, multi-layer perceptrons and radial basis networks. Among recurrent networks, the most famous is the Hopfield net, a form of attractor network, which was first described by John Hopfield in 1982. Neural networks can be applied to the problem of intelligent control (for robotics) or learning, using such techniques as Hebbian learning and competitive learning.

Jeff Hawkins argues that research in neural networks has stalled because it has failed to model the essential properties of the neocortex, and has suggested a model (Hierarchical Temporal Memory) that is loosely based on neurological research.

Control theory

Control theory, the grandchild of cybernetics, has many important applications, especially in robotics.

Languages

AI researchers have developed several specialized languages for AI research, including Lisp and Prolog.

Evaluating progress

In 1950, Alan Turing proposed a general procedure to test the intelligence of an agent now known as the Turing test. This procedure allows almost all the major problems of artificial intelligence to be tested. However, it is a very difficult challenge and at present all agents fail.

Artificial intelligence can also be evaluated on specific problems such as small problems in chemistry, hand-writing recognition and game-playing. Such tests have been termed subject matter expert Turing tests. Smaller problems provide more achievable goals and there are an ever-increasing number of positive results.

The broad classes of outcome for an AI test are: (1) Optimal: it is not possible to perform better. (2) Strong super-human: performs better than all humans. (3) Super-human: performs better than most humans. (4) Sub-human: performs worse than most humans. For example, performance at draughts is optimal, performance at chess is super-human and nearing strong super-human and performance at many everyday tasks (such as recognizing a face or crossing a room without bumping into something) is sub-human.

A quite different approach measures machine intelligence through tests which are developed from *mathematical* definitions of intelligence. Examples of these kinds of tests start in the late nineties devising intelligence tests using notions from Kolmogorov complexity and data compression. Two major advantages of mathematical definitions are their applicability to nonhuman intelligences and their absence of a requirement for human testers.

Applications

Artificial intelligence techniques are pervasive and are too numerous to list. Frequently, when a technique reaches mainstream use, it is no longer considered artificial intelligence; this phenomenon is described as the AI effect.

Competitions and prizes

There are a number of competitions and prizes to promote research in artificial intelligence. The main areas promoted are: general machine intelligence, conversational behavior, data-mining, driverless cars, robot soccer and games.

Platforms

A platform (or "computing platform")is defined as "some sort of hardware architecture or software framework (including application frameworks), that allows software to run." As Rodney Brooks pointed out many years ago, it is not just the artificial intelligence software that defines the AI features of the platform, but rather the actual platform itself that affects the AI that results, i.e., we need to be working out AI problems on real world platforms rather than in isolation.

A wide variety of platforms has allowed different aspects of AI to develop, ranging from expert systems, albeit PC-based but still an entire real-world system to various robot platforms such as the widely available Roomba with open interface.

Philosophy

Artificial intelligence, by claiming to be able to recreate the capabilities of the human mind, is both a challenge and an inspiration for philosophy. Are there limits to how intelligent machines can be? Is there an essential difference between human intelligence and artificial intelligence? Can a machine have a mind and consciousness? A few of the most influential answers to these questions are given below.

Turing's "polite convention"

> *If a machine acts as intelligently as a human being, then it is as intelligent as a human being.* Alan Turing theorized that, ultimately, we can only judge the intelligence of a machine based on its behavior. This theory forms the basis of the Turing test.

The Dartmouth proposal

> *"Every aspect of learning or any other feature of intelligence can be so precisely described that a machine can be made to simulate it."* This conjecture was printed

in the proposal for the Dartmouth Conference of 1956, and represents the position of most working AI researchers.

Newell and Simon's physical symbol system hypothesis

"A physical symbol system has the necessary and sufficient means of general intelligent action." Newell and Simon argue that intelligences consists of formal operations on symbols. Hubert Dreyfus argued that, on the contrary, human expertise depends on unconscious instinct rather than conscious symbol manipulation and on having a "feel" for the situation rather than explicit symbolic knowledge.

Gödel's incompleteness theorem

A formal system (such as a computer program) can not prove all true statements. Roger Penrose is among those who claim that Gödel's theorem limits what machines can do.

Searle's strong AI hypothesis

"The appropriately programmed computer with the right inputs and outputs would thereby have a mind in exactly the same sense human beings have minds." John Searle counters this assertion with his Chinese room argument, which asks us to look *inside* the computer and try to find where the "mind" might be.

The artificial brain argument

The brain can be simulated. Hans Moravec, Ray Kurzweil and others have argued that it is technologically feasible to copy the brain directly into hardware and software, and that such a simulation will be essentially identical to the original.