Overview of Tabu Search

The word tabu (or taboo) comes from Tongan, a language of Polynesia, where it was used by the aborigines of Tonga island to indicate things that cannot be touched because they are sacred.

According to Webster's Dictionary, the word now also means "a prohibition imposed by social custom as a protective measure" or of something "banned as constituting a risk."

The basic concept of tabu search as described by Glover (1986) is “a meta-heuristic superimposed on another heuristic”. The overall approach is to avoid entrainment in cycles by forbidding or penalizing moves which take the solution, in the next iteration, to points in the solution space previously visited (hence “tabu”). The tabu search is fairly new, Glover attributes its origin to about 1977 (see Glover, 1977). The method is still actively researched, and is continuing to evolve and improve.

The tabu method was partly motivated by the observation that human behavior appears to operate with a random element that leads to inconsistent behavior given similar circumstances. As Glover points out, the resulting tendency to deviate from a charted course, might be regretted as a source of error but can also prove to be source of gain. The tabu method operates in this way with the exception that new courses are not chosen randomly.

Instead the tabu search proceeds according to the supposition that there is no point in accepting a new (poor) solution unless it is to avoid a path already investigated. This insures new regions of a problems solution space will be investigated in with the goal of avoiding local minima and ultimately finding the desired solution.

The tabu search begins by marching to a local minima. To avoid retracing the steps used, the method records recent moves in one or more tabu lists. The original intent of the list was not to prevent a previous move from being repeated, but rather to insure it was not reversed.

The tabu lists are historical in nature and form the tabu search memory. The role of the memory can change as the algorithm proceeds. At initialization the goal is make a coarse examination of the solution space, known as "diversification", but as candidate locations are identified the search is more focused to produce local optimal solutions in a process of "intensification". In many cases the differences between the various implementations of the tabu method have to do with the size, variability, and adaptability of the tabu memory to a particular problem domain.

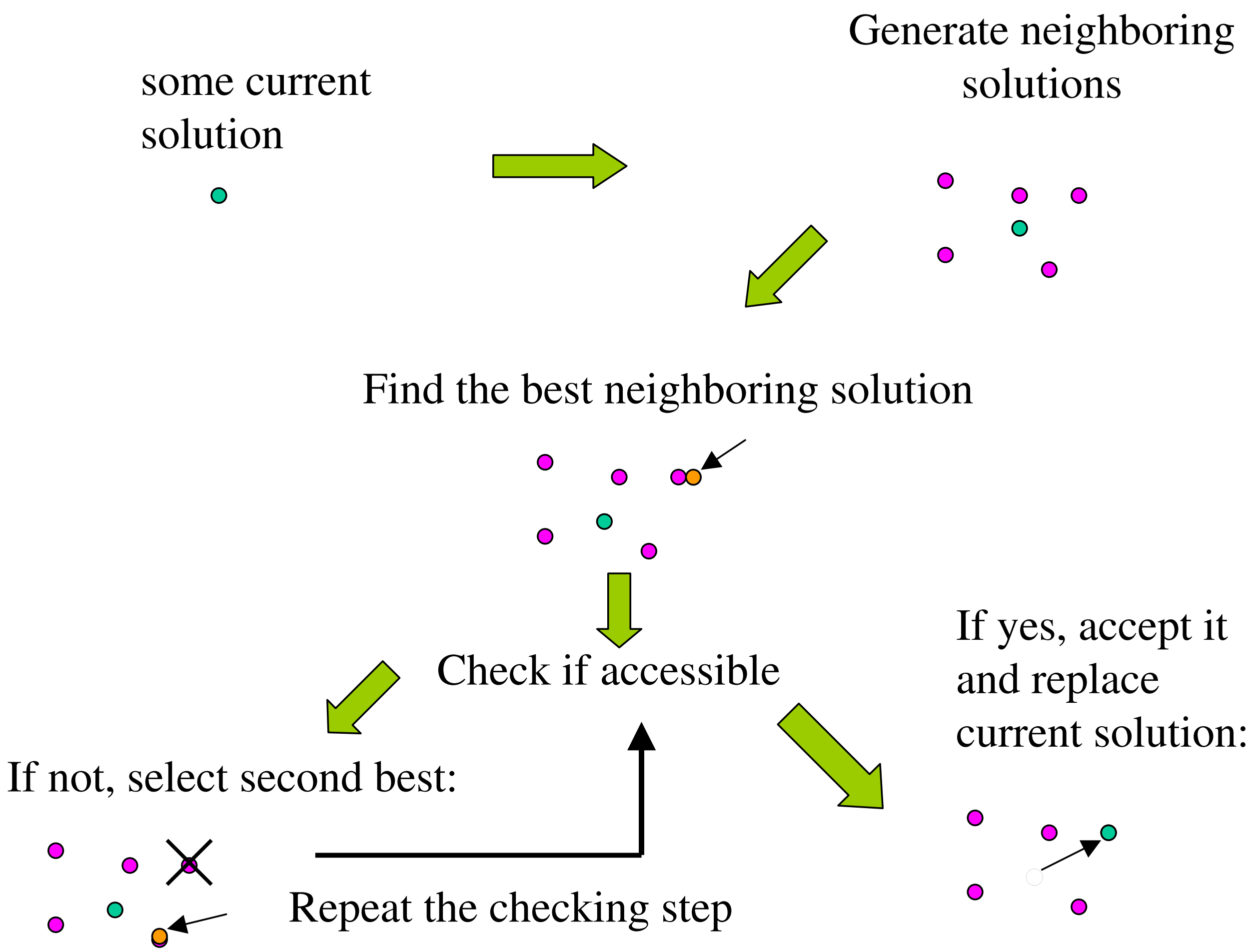
The tabu search has traditionally been used on combinatorial optimization problems. The technique is straightforwardly applied to continuous functions by choosing a discrete encoding of the problem. Many of the applications in the literature involve integer programming problems, scheduling, routing, traveling salesman and related problems.

Basics of Tabu Search

- A heuristic search method
- Tabu restricts some search of neighboring solutions
- Aspiration allows exception of the tabu
- Accessible Solutions
  - The solutions that are not in the tabu list, or in the tabu list but satisfy aspiration conditions.

Basics of Tabu Search

(continued)



Tabu Search

General Tenets:

1. Tabu search is a local search strategy with a flexible memory structure.

   In this context, we can categorize Branch and Bound and Simulated Annealing as

   - Branch and Bound has a rigid memory structure

   - Simulated annealing has no memory structure (it relies on randomization)

2. Tabu search has two prominent features:

   - Adaptive memory

   - Responsive exploration strategies

3. Main feature

   - Always move to the best available neighborhood solution point, even if it is worse than the current solution point.

4. Tabu list:

    - Maintain a list of solution points that must be avoided (not allowed) or a list of move attributes that are not allowed. This is referred to as the tabu list.

    - Update this list based on some memory structure (short-term memory).

5. Aspiration Criteria

    - Allow for exceptions from the tabu list, if such moves lead to promising solutions.

6. Intensification and diversification

   Diversification: Search the unexplored area of the solution space by

   - Increase tabu tenure
   - Change tabu restriction, etc.

7. Long Term Memory

   - Frequency based memory/Recency based memory
   - Adaptive Memory Programming (AMP)

First Level Tabu Search

In a first level tabu search approach, the following issues should be considered:

1. Solution representation and evaluation
2. Neighborhood structure/Move mechanism
3. Move Attribute (used for tabu classification)
4. Tabu status and duration (tenure)
5. Aspiration criteria
6. Stopping criteria
7. Initial Solution (systematically obtained, randomly generated, number of restarts)

Tabu Tenure

How to decide tabu duration (tenure)?

- Empirical evidence shows that effective tabu tenure depends on the instance (size, etc.)

- An effective range for tabu tenure can be determined experimentally

- Static versus Dynamic tabu tenure

Aspiration Criteria

Choices for aspiration criteria

- Better than the best found so far

- Aspiration-by-default

  Once a first level tabu search algorithm is designed and implemented, we can incorporate other features to enhance the algorithm.

Tabu Search Method

Source: *Tabu Search: A Tutorial*

by: F. Glover

INTERFACES 20, 1990, pp 74 – 94

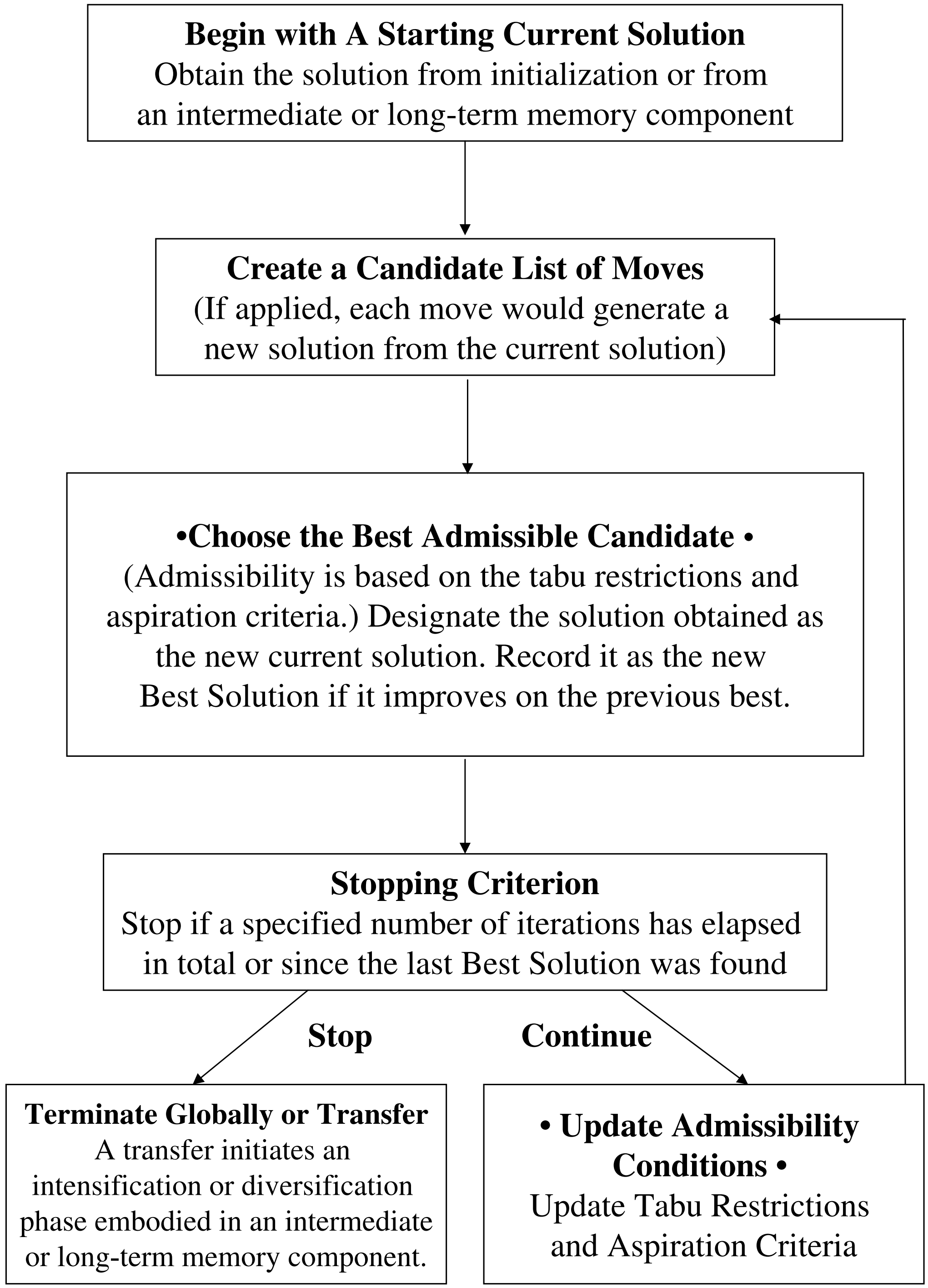


Figure 1: Tabu search short-term memory component.

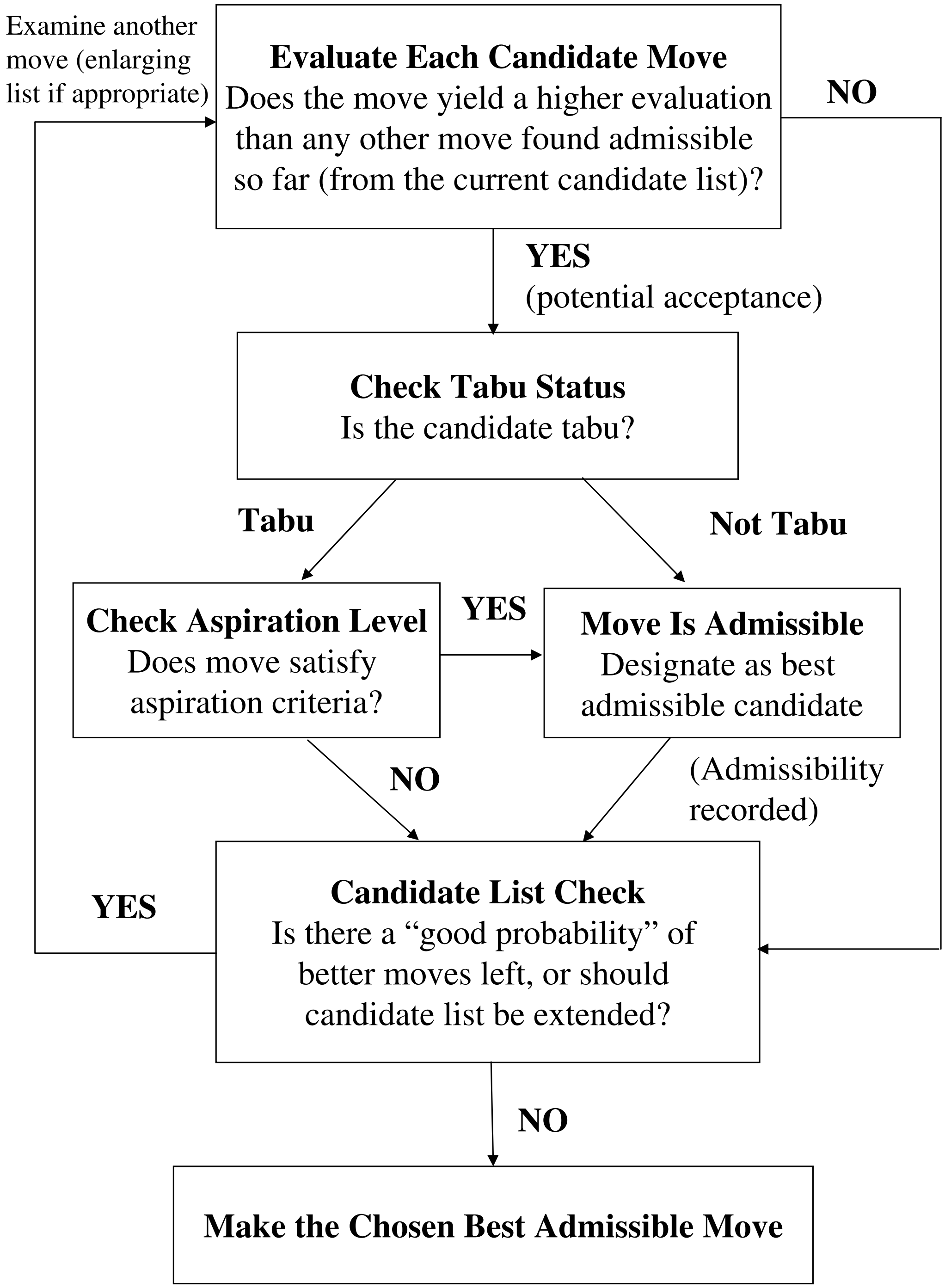


Figure 2: Selecting the best admissible candidate.

Example

Source: *Modern Heuristic Techniques for Combinatorial Problems*

Edited by: C.R. Reeyes

Chapter 3: F. Glover and M. Laguna

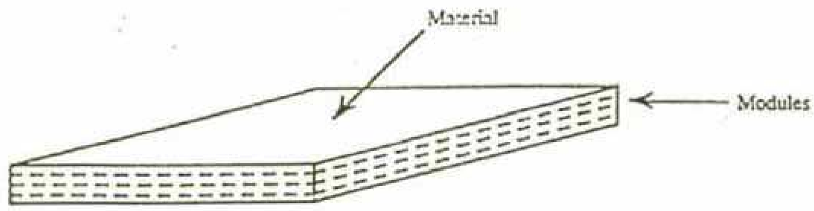


Figure 3.1: Modules in an insulating material

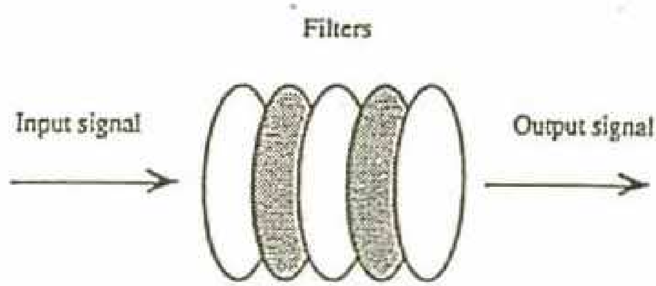


Figure 3.2: Filtering sequence

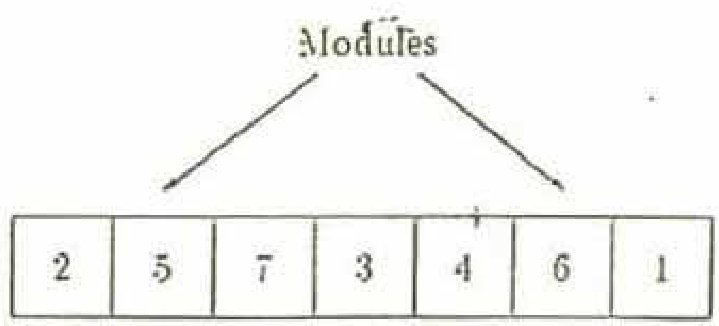


Figure 3.3: Initial permutation

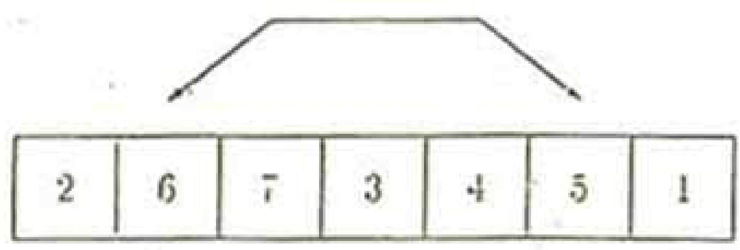


Figure 3.4: Swap of modules 5 and 6

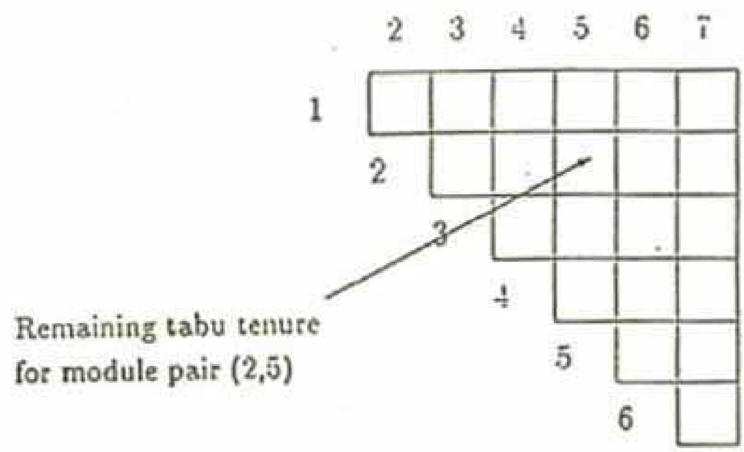


Figure 3.5: Tabu data structure for attributes consisting of module pairs exchanged

Iteration 0 (*Starting point*)

Current solution

2	5	7	3	4	6	1

Insulation Value=10

Tabu structure (All entries zero)

	2	3	4	5	6	7
1						
2						
3						
4						
5						
6						

Top 5 candidates

Swap	Value	
5,4	6	*
7,4	4	
3,6	2	
2,3	0	
4,1	-1	

Iteration 1

Current solution

2	4	7	3	5	6	1

Insulation Value=16

Tabu structure

	2	3	4	5	6	7
1						
2						
3						
4				3		
5						
6						

Top 5 candidates

Swap	Value	
3,1	2	*
2,3	1	
3,6	-1	
7,1	-2	
6,1	-4	

Iteration 2

Current solution

2	4	7	1	5	6	3

Insulation Value=18

Tabu structure

	2	3	4	5	6	7
1		3				
2						
3						
4				2		
5						
6						

Top 5 candidates

Swap	Value	
1,3	-2	T
2,4	-4	*
7,6	-6	
4,5	-7	T
5,3	-9	

Iteration 3

Current solution

4	2	7	1	5	6	3

Insulation Value=14

Tabu structure

	2	3	4	5	6	7
1		2				
2			3			
3						
4				1		
5						
6						

Top 5 candidates

Swap	Value	
4,5	6	T*
5,3	2	
7,1	0	
1,3	-3	T
2,6	-6	

Iteration 4

Current solution

5	2	7	1	4	6	3

Insulation Value=20

Tabu structure

	2	3	4	5	6	7
1		1				
2			2			
3						
4				3		
5						
6						

Top 5 candidates

Swap	Value	
7,1	0	*
4,3	-3	
6,3	-5	
5,4	-6	T
2,6	-8	

Iteration 26

Current solution

1	3	6	2	7	5	4

Insulation Value=12

Tabu structure (Recency)

	1	2	3	4	5	6	7
1				3			
2							
3	3					2	
4	1	5					1
5		4		4			
6			1		2		
7	2			3			

(Frequency)

Top 5 candidates

Swap	Value	Penalized Value	
1,4	3	3	T
2,4	-1	-6	
3,7	-3	-3	*
1,6	-5	-5	
6,5	-4	-6	

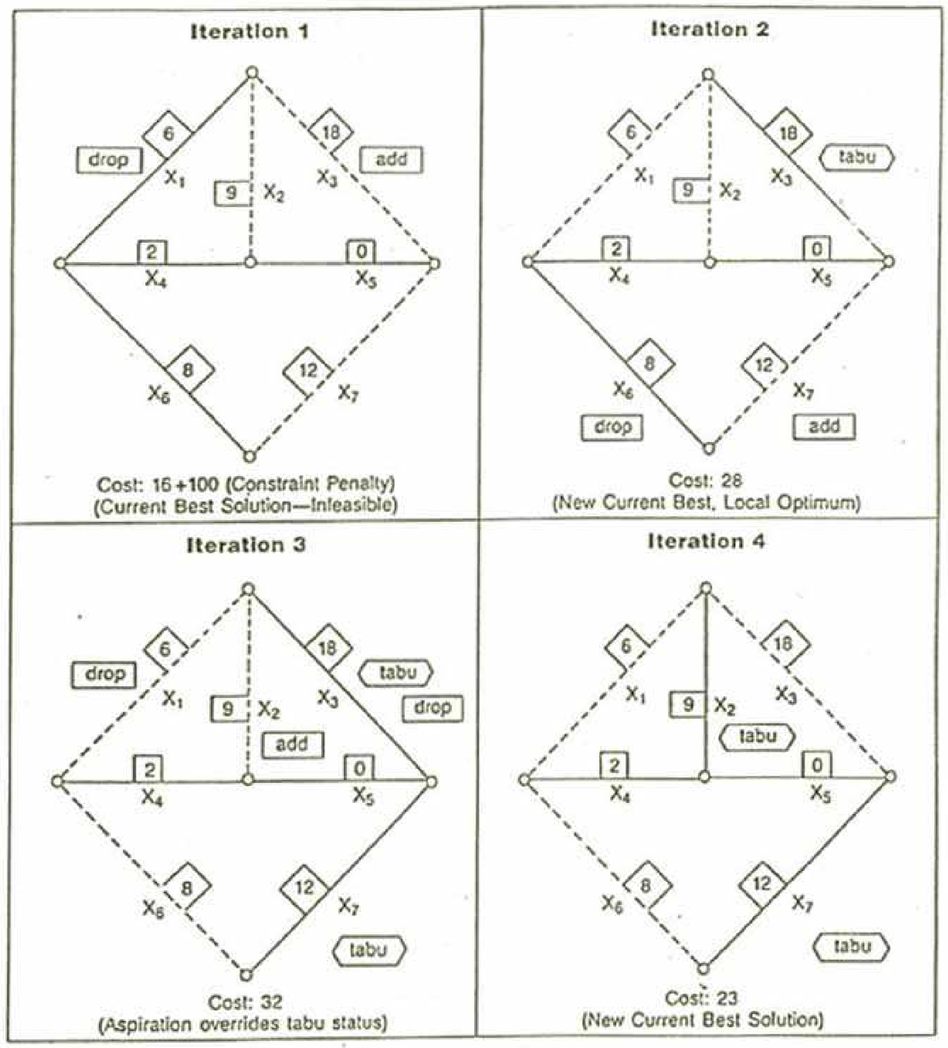


Figure 3: Illustrated solution: minimum-cost trees. The choice rule is select the least-cost admissible "edge swap". The tabu restriction is forbid dropping one of the two most recently added edges (these edges are designated tabu). The aspiration criterion is override the tabu restriction if the swap produces a new "current best solution". (Constraints: $X_1 + X_2 + X_6 \leq 1, X_1 \leq X_3$. Violation penalty = 50.)

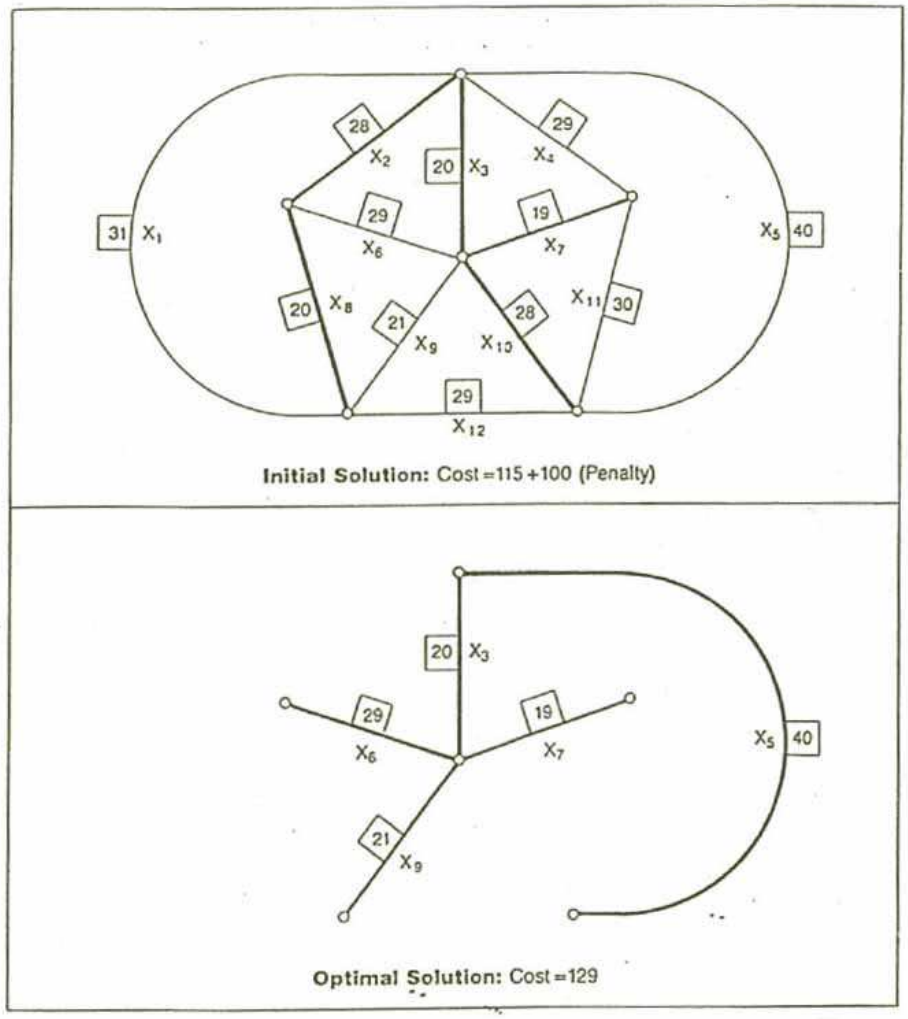


Figure 4: Relevance of longer-term memory and diversification minimum-cost tree problem. Added constraints are $X_9 \leq X_7, X_3 + X_7 \leq 2X_5$. (Unit violation penalty $= 50$.)

References

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