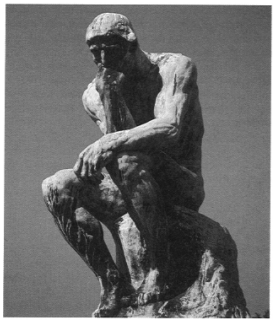
Problem Solving



Terminology

- Problem solving
  - Goal is not readily available
  - Use knowledge to reach goal
- Initial state
  - State you are in when you encounter problem

Terminology: Problem Space

- Set of choices
  - Found at each step of solving the problem
- Includes
  - Initial, intermediate, and goal states
  - Knowledge being applied to problem
  - Knowledge that *could* be applied
  - External devices, objects, resources
- Range on continuum from large to small

Terminology: Operators

- Legal operators or moves performed during problem solving
- Classes
  - Algorithms
  - Heuristics

Algorithm

- Precise rule
  - Always yields a correct solution to the problem
- Frequently slow and inefficient
  - Exhaustive search
    - Search entire problem space
    - Difficult for humans
    - Easy for computers

Heuristic

- Rule of thumb
  - Likely, but not guaranteed, to generate solution
- Selective search of problem space
  - Examine only those parts likely to lead to solution
- Example – multiple choice tests
  - "B" or "C" answers the most frequent

Terminology: Goal state

- Ultimate solution to problem
- Problem defined in terms of goal state specification
  - Well-defined problems
  - Ill-defined problems

Well-defined and Ill-defined Problems

- Well-defined
  - Clear goal
  - Small set of information to start
  - Guidelines or rules
- Ill-defined
  - Unclear goal
  - Starting information, operators or both are vaguely specified
  - Many real world problems

Types of Problems

- Problems of arrangement
- Problems of inducing structure
- Problems of transformation
- Insight problems

Problems of Arrangement

- Present objects
  - Require problem solver to arrange objects
    - Satisfy criterion
  - Only a few arrangements result in solution
- Anagrams

Arrangement Problem Skills

- Fluency in generating possibilities
  - Generate many potential solutions
  - Discard inappropriate solutions
- Retrieval of solution patterns
  - Anagram example –words from memory
- Knowledge of constraining principles
  - Anagram example – relative frequency of words in the language

Problems of Inducing Structure

- Finding a pattern among a fixed set of relations
  - Some objects given
    - Figure out how objects relate
- Examples
  - Series extrapolation
  - Analogy
  - Progressive matrices

Inducing Structure Skills

- Identifying relationships among components
- Fitting relationships into patterns

Problems of Transformation

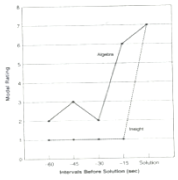
- Changing initial state until it matches goal state
- Supply goal state
- Example
  - Book burners and & book lovers problem
- Skills
  - Planning

Insight Problems

- Insight problems (Tower problem)
  - Solution suddenly enters the mind
    - Immediately recognized as correct
  - Restructure conceptualization of problem
- Non-insight problems (anagram problem)
  - Solve problem gradually
  - Reasoning skills and routine procedures
- Solution accompanied by an "AHA!" experience

Solutions to insight problems

- Metcalf & Wiebe (1987) studied insight problems
- Compared insight to algebra problem solving
  - "Warmth ratings"



Insight Controversy

- Some researchers question the concept of insight
- Propose
  - Gradually work towards a solution
  - Solution just "feels" different
- Some non-insight problems solved by restructuring

Approaches to Studying Problem Solving

- Classic approach
- Computer simulation
- Verbal Protocols

Classic Problem Solving Research

- Gestalt psychologists
  - Perception and the structure of patterns
  - Arrangement problems
- Kohler (1925) & Sultan
  - Cage contained sticks and boxes
  - Rearrange objects to get fruit

Computer Simulation

- Develop computer programs for problem solving
  - Based on human problem solving performance
- Examine
  - Sequence of steps
  - Constraints
  - Representation

Computer Simulation

- Computer model created
  - Based on theory of human problem solving performance
- Computer modeling
  - Mimic human performance
    - Good understanding of problem solving performance
  - Fails to accurately model performance
    - Theory needs to be revised

Advantages of Computer Simulation

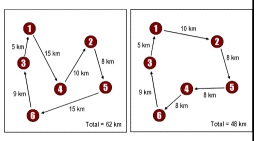
- Forces researchers to be explicit & specific
  - No generalizations
  - Pay attention to details
- Can be used to make predictions
  - Tested on human subjects

Disadvantages of Computer Simulation

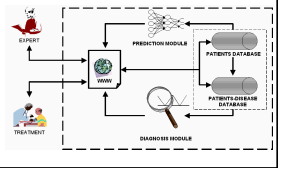
- "Just get the program running"
  - No longer mimics human performance
- Forced to work on artificial or very simple problems
  - Examine limited and artificial types of problem solving

Real Problems

- Traveling Salesperson Problem
  - Each city in a network of connected cities must be visited exactly once.
  - The goal is to find the shortest trip



- Medical diagnoses



Verbal Protocols

- "Think out loud" data
- Provides information
  - Sequence of steps taken during problem solving
  - Constraints observed
  - Heuristics used

Verbal Protocols (cont.)

- Messy/Noisy data
  - Great deal of information
  - Very rich data set
- Problem solving graphs
  - Transcribed, transformed, and reduced protocols
  - Trace mental representation of problem
  - Show possible states and operators
    - Applied to knowledge in each state
    - Change the state

Problem Representation

- Symbols
- Lists
- Matrices
- Hierarchical Tree Diagram
- Graphs
- Visual Images

Symbols

Solve the following problem: Mary is ten years younger than twice Susan's age. Five years from now, Mary will be eight years older than Susan's age at that time. How old are Mary and Susan? (The answer is found in the discussion in the text.)

- Use symbols to represent variables in problem
  - Algebra

Symbols

- Use symbols to represent variables in problem
- Best for problems with quantifiable variables
- Disadvantages
  - Difficult to use with ill-defined problems
  - Difficult to translate words into symbols

Matrices

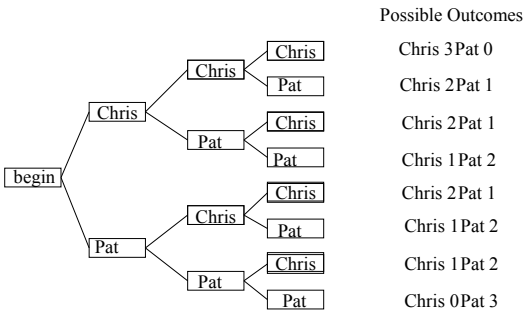
- Chart
- Shows possible combinations of problem
- Usefulness
  - Complex problems with categorical information

Hierarchical Tree Diagram

- Uses tree-like structure
- Specifies every possible outcome
- Useful for assessing probability of outcomes

Hierarchical Tree Diagrams. Suppose that you are playing a coin game with two children, Chris and Pat. You toss each of three coins. If it's heads, the coin goes to Chris; if it's tails, it goes to Pat. What is the probability that one child will get to keep all three coins? Solving this problem with a list format typically leads to an incorrect response (Keren, 1984).

Hierarchical Tree Diagram



Possible Outcomes

Chris 3 Pat 0
Chris 2 Pat 1
Chris 2 Pat 1
Chris 1 Pat 2
Chris 2 Pat 1
Chris 1 Pat 2
Chris 1 Pat 2
Chris 0 Pat 3

Visual Images

- Images are free from rationality
  - Escape from boundaries of traditional representations
- Images are concrete
  - Can serve as symbols for more abstract concepts

Problem Solving Heuristics

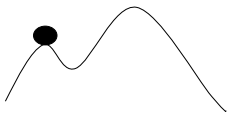
- Hill climbing/ Simple search
- Means-ends
- Working backwards
- Analogy

Simple Search / Hill Climbing Heuristic

- Examine all possible operators to identify all possible next states
- Compare each of these states to the goal state
- Choose the state that is closest to the goal state

Local maxima

- Local maxima can cause hill-climbing heuristic to fail
- Consider only a limited range of choices
  - Look one move ahead
- Many solutions require moving away from a goal to ultimately achieve it



Means-Ends Heuristic (Forming Subgoals)

- Divide the problem into smaller problems
- Solve smaller problems
- Means – ends
  - Figure out ends for each sub problem and the means by which those ends will be achieved
- Sometimes solving subgoals requires the formation of other subgoals

- Main Problem: Getting from New York to San Francisco
  - Subgoal 1: Get on plane to San Francisco
    - Subgoal 1a: Get to airport
      - Solution: Use map to drive to airport
    - Subgoal 1b: Get on plane
      - Sub-subgoal: Find plane
        - » Solution: Consult arrival/departure boards

Working Backwards

- Start from goal
- Determine what needs to be done for goal to be true
- Repeat at each step
- Useful
  - # states preceding goal is small
  - # states following start is large

Analogy

- Using a solution to an earlier problem to help solve a new one
  - Very common method of problem solving
- Target domain
  - The problem you are trying to solve
- Source domain
  - The problem or domain you use as an analogy to solve the current problem

Problem Structure

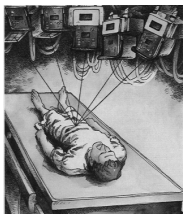
- Require us to ignore the surface details of a problem
- Need to determine problem structure
- Problem isomorphs
  - Same underlying structures and solutions
  - Different surface details

Retrieving Correct Source

- The use of analogy requires application of appropriate source analog
- Sometimes difficult to retrieve appropriate analog from memory
- Gick & Holyoak (1980)
  - Examined the use of analogies in problem solving in two studies

Gick & Holyoak (1980) Study 1

- Parade problem and then Radiation problem
  - 49% solution rate
- Attacking General problem and then Radiation problem
  - 76% solution rate
- Radiation problem alone
  - 8% solution rate

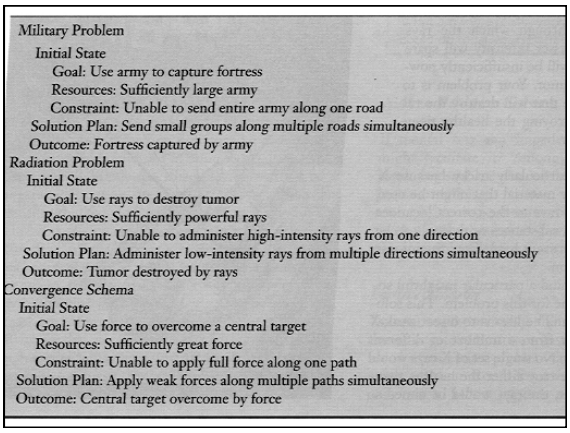


Gick & Holyoak (1980) Study 2

- Read the Attacking General problem and its solution and then solve the Radiation problem
- Hint
  - 92% solution rate
- No hint
  - 20% solution rate

Creation of a general schema

- Schema creation aids in solving problem isomorphs
- Gick & Holyoak (1983)
  - Formation of convergence schema requires that people compare two analogous stories
  - Makes them think about the solution in general terms



Barriers to Problem Solving

- Problem solving involves some sort of obstacle to overcome in the process of reaching a goal
- Fixation
  - An impediment to problem solving
  - When fixated, you are stuck on some aspect of a problem which blocks your ability to reach a solution

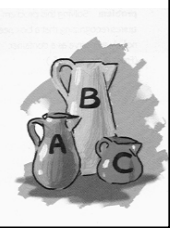
Perceptual fixation

- Involves perceptual (visual/spatial) assumptions about the problem domain that blocks your ability to reach a solution

Mental Set

- Rule-based fixation
- Getting stuck on a set of rules to solve a problem

Problem	Given jugs of these sizes: A	B	C	Measure out this much water:
1	21	127	3	100
2	14	46	5	22
3	18	43	10	5
4	7	42	6	23
5	20	57	4	29
6	23	49	3	20
7	15	39	3	18



Functional Fixation

- Getting stuck on a particular use for an object
- Can't see different use for an object which will enable you to solve the problem