Chapter 14

Solving Problems

Definition of Problem Solving

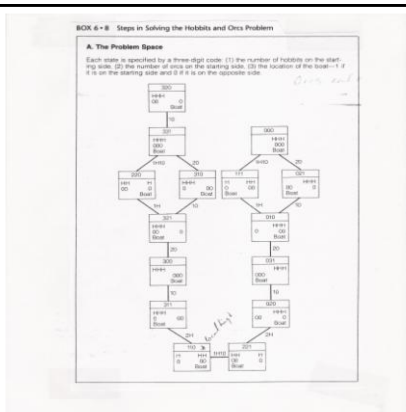
- Newell & Simon, 1972: problem solving as searching for a path to solution
- Initial state, Goal state, Intermediate states
- Set of operators (moves) to go from one state to another
- Path constraints (some moves not allowed, limited time, etc.)
- Problem space = set of possible problem states or moves that S consider
  - Problem solver's mental representation
- Note: "True" problem space not the same as S's problem space

Heuristics

- Definition of Problem Solving: Finding a path through the problem space from start to goal.
- Can't search exhaustively → use heuristic to identify likely paths
- Hill-climbing
- Means-ends analysis
- Working backwards

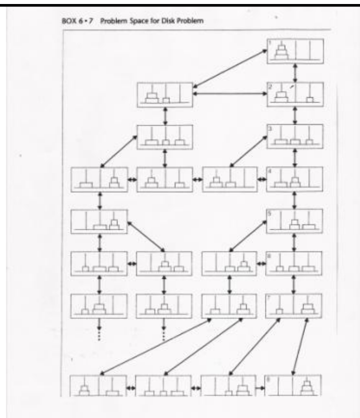
Hill Climbing

- Select next move according to greatest movement towards goal
- See Handout on Hobbits & Orcs problem
  - Start State 331 (3 hobbits, 3 orcs & boat on start side)
- Best move sometimes is move away from goal
  - See state 110 (2 hobbits 2 orcs & boat on goal side)
  - Need to make 'backward' move 1 hobbit & 1 orc back to starting side
- Move against goal of moving everyone to right-hand side. (Not consistent with hill climbing heuristic.)
- Long response times to make 'backwards' move



Means-Ends Analysis

- Set up goal & try to find operation to achieve goal
- Find differences between goal and start state, goal → find operator reduce or eliminate difference.
- If goal blocked, set up subgoal to remove block
- → hierarchical nesting of goals
- → breaks complex problem into number of easier problems
- Used in computer simulation of logic problem solving



Means-ends Analysis - 2

- Goal 1 is to get largest disk (D3) on 3rd peg
  - 2 disks on top of D3 → Goal 2: move D2
  - Can't move D2 because of D1 → Goal 3: move D1
  - 2 possible moves for D1. Move D1 to Stake 3
- Goal 3 achieved. Return to Goal 2.
- Can move D2 to empty stake. Goal 2 achieved

Means-ends Analysis - 3

- Return to Goal 1. Can't move D3 because stakes have smaller disks
- Goal 4: Move D1 to go on top of D2. Goal 4 achieved
- Goal 1: Move D3 to 3rd stake.
- Etc.

Working Backwards

- Geometry proofs
  - What do you need to prove goal?
    - Congruent triangles, parallel lines etc?
    - Can you prove requirement from givens? What do you need to prove requirement?
  - See problem about water lilies p. 451 of text
- Means-ends analysis involves working forward
- Working backwards requires setting goals like Means-ends analysis.

Pictures, Diagrams & Images

- Verbal and pictorial formats present different info.
- Pictures, diagrams, images include spatial info
- Z score problems
  - Given mean = 80, sd = 7, what proportion of scores are above 68?
  - Must draw normal curve & mark in relevant areas.

Problem Solving by Analogy

- Donnelly & McDaniel, 1993
- See text page 484, 3rd 3ed, not in 4th ed.
- Literal version - description of stars spinning faster as they shrink → conservation of momentum
- Analogy version – reference to figure skater spinning
- Analogy instruction helped

D Problem Solving by Analogy - 2

- Duncker's Tumour problem
  - Inoperable tumor in stomach. Treat with radiation which destroys healthy tissue. How maximize tumor destruction & minimize damage to healthy tissue?
  - Solution: Have multiple low intensity rays through healthy tissue. Focus rays on tumor.
- Gick & Holyoak: Analogies: General attacking a fortress by dividing soldiers & sending them over different routes.
- → improved solution of tumor problem: 75% vs 10%

Failure to Find (Retrieve) Analogy

- Gick & Holyoak: Some Ss told to think about General & Fortress problem, others not.
  - Not told: 30% solutions
  - Told: 75% solutions
- Similar finding with Hobbits & Orcs & Jealous Husbands
- Ss often know of relevant analogies but fail to retrieve them unless instructed

Failure to Find (Retrieve) Analogy - 2

Surface structure – elements in problem (e.g. hobbits & orcs, tumors & radiation)

- Deep structure – underlying principles (e.g. always keep an orc in the boat; approach focal point from many different directions)
  - Garden problem: Circular flower bed
  - What analogies come to mind?
- Retrieve analogies through surface structure, similar elements.
- Then have to map analogy to current problem

Improving Use of Analogy

- How improve use of analogies
- Gick & Holyoak: give Ss two training problems with same underlying principle as tumor & fortress-general problems
- Ss more likely to use analogy
- Cummins: algebra word problems
- Have Ss analyse training problems separately or compare them. Comparing → Ss more likely to notice underlying principles.
- See sample problems.

Failure to Find (Retrieve) Analogy - 4

- Needham & Begg
  Told Ss to remember problems or told Ss to understand solutions so they could explain them
- Remember group: 69% test problems correct; Understand group: 90% correct
- → attention to deep structure (underlying principles) essential for transfer
  - Use variety of problems with different surface structures but same deep structure to teach a principle.

- Reading by Thomas & Lleras
  - Ss did two-string problem. (Two strings hang from ceiling. S must tie them together but can't reach 2nd string when holding the first.
  - Several objects on the table (wrench, paperback book, dumbbells) can be used.
  - Ss either swung arms or stretched.

Analogies & Expert Problem Solving

- Novices categorize problems in terms of surface structure (objects in the problem)
- Experts categorize in terms of deep structure (principles or methods used to solve)

Analogies & Expert Problem Solving - 2

- Novick & Holyoak:
- Gave Ss training problems which used particular math principle.
  - Numbers evenly divisible by other numbers
    - E.g. What is the lowest number that is 3 more than a number divisible by 2, 3, 6, and 11?
- Problems in text p. 490, 3rd ed. or handout
- SAT math scores, but not SAT verbal scores correlated with use of math analogies on test problems

Chunking & Subgoals

<u>Chase & Simon</u>

- Memory for positions of 20 chess pieces
- Compared chess novices, good players & masters
- Chess positions random or real game positions
- Results: a) Random position: no differences between groups
  - b) Real game positions: Masters best, novices worst

Chunking & Subgoals - 2

- Experts recognize complex patterns (e.g. chess game positions, medical symptoms) → chunks
- Novices see chess pieces, individual medical symptoms unconnected
- Experts recall chess positions (medical symptoms) in organized groups which relate to various strategies

Chunking & Subgoals - 3

- Experts can better "organize" chess pieces (or medical symptoms) into meaningful chunks → better memory

Chunking & Subgoals - 4

Reasons chunking helps

- Reduces memory load
  → frees processing resources
- Focus on large patterns & how related
  - See overall structure of problem, not details
  - Helps identify key elements, create subgoals, keep track of strategies
- Chess experts don't consider large number of moves
  - Consider only most promising moves in current situation

Nature of Expertise

- 10 years needed to become ‘expert’
- Experts have more knowledge, different type of knowledge
- Experts know many “patterns”
- Experts’ knowledge organized – cross referenced → better retrieval

(not in 4th ed)

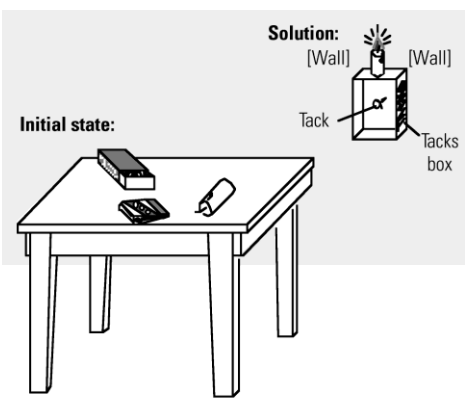
Nature of Expertise – 2

- Experts → means-ends analysis (working forwards towards subgoal)
- Novices use working backwards more
- Experts can select subgoal, know where subgoal leads.
- With unfamiliar problems, experts use working backwards
- Experts – automated (proceduralized) frequent routines
  - Not bogged down in procedural details
  - Require less memory → demand on processing resources

(not in 4th ed)

Ill-defined vs. Well-defined Problems

- Recreational problems well-defined: start state, goal, operations clearly defined
- Real-life problems: exact nature of goal not clear, operations not clear
  - E.g. Improve educational system
    - More or better-trained teachers, more technology, broader or more focused curriculum, focus on basic skills or applications of those skills, more choice on courses or less?
- Experts spend more time defining problems than do novices



Functional Fixedness – Duncker's Study

General procedure

- Group 1: uses critical object in normal function (paper clip to hold sheets of papers, pliers to unscrew bolt)
- Group 2: uses alternative object
- Main Task: S required to use critical object in unusual function (weight in pendulum problem, twist paperclip into hook for hanging light object, small box used as candle holder)
- Preutilization inhibits 'creative' use of object
- Object's function has been '*fixed*'

Einstellung or Problem-solving Set

- Set of attitudes, beliefs & assumptions the problem solver makes
- Luchins' Water Jars Problems
- 3 water jars, irregular shapes

1. A = 18, B = 47, C = 2 Goal: 25
2. A = 21, B = 127, C = 3 Goal: 100
3. A = 14, B = 163, C = 25 Goal: 99
4. A = 18, B = 43, C = 10 Goal: 5
5. A = 9, B = 42, C =6 Goal: 21

Einstellung or Problem-solving Set

6. A = 18, B = 48 C = 4 Goal: 22
7. A = 23, B = 127, C = 3 Goal: 20
8. A = 15, B = 39, C = 3 Goal: 18
9. A = 28, B = 76, C = 3 Goal: 25

Einstellung - 2

- Ss quickly realize that solution is same for first 5 problems (B – A – 2*C)
  - Apply same formula to Problems 6 & 7 which have simpler solution
  - Apply same formula to Problem 7. Doesn't work. Overlook simple method (64% of Ss failed to solve)
- Ss easily 'routinize' problem solution, fail to consider easier solution methods
- Ss fail to solve simple problem because of Einstellung

Problem-Solving Set

- Assumptions about problem which direct solution attempts
  - Nine-dot problem: Ss assume that lines must stay within the square
- Triangle within a circle problem
- Circular garden problem
- Set often useful – restricts focus to likely approaches
  - Insight problems misdirect attention
- Try 16–dot problem, 25-dot problem

Creativity

Characteristics of Creative People

- Knowledge & skills in relevant domain
- Creative people are intelligent
- Take risks (in chosen field), tolerate criticism
- Deal with ambiguity, like complexity
- Individualistic, don't follow the crowd
- Motivated by pleasure in their work
- Hard working, highly productive

Creativity - 2

- Supportive environment – financial support, work place, tools, time
- Critical knowledge available, creative person puts the right ideas together
  - E.g. Charles Darwin, Watson & Crick

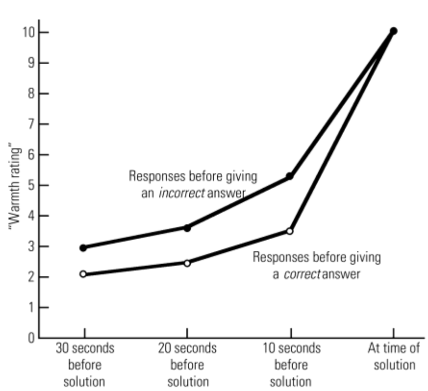
Incubation & Illumination

Wallas (1927)

- Described stages of creative problem solving
  - Preparation, active conscious work
  - Incubation – no conscious thought
  - Intimation – feeling of being close
  - Illumination – sudden insight
  - Verification – testing & evaluating the idea
  - Stages not in forward sequence – Ss loop back
- Steps 1 & 5 involve taught skills (System 2 thinking)
- Some problems solved without incubation period; some problems never solved
- Sometimes – sequence of mini-insights

Illumination – Metcalfe

- Gave Ss insight problems (like the circular garden problem)
- Ss gave ratings of warmth (closeness to solution)
- Examine ratings at 10-sec intervals before solution
- Ratings low, & rise suddenly just at solution.
- Consider correct & incorrect solutions separately

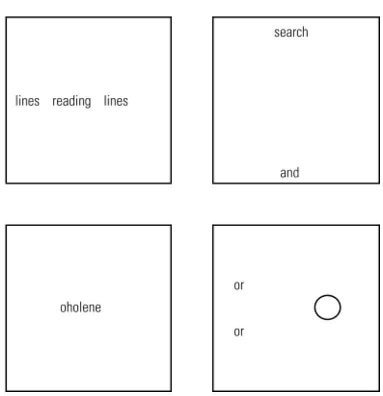


Metcalfe - 3

- Ss with *incorrect* solutions slightly more confident
- Ss can't tell if they really on verge of solution or not
- Solution really comes "out of the blue".
- 'Aha!' phonomenon: sudden retrieval of problem-relevant information because of cue in environment (See Thomas and Lleras article) or possibly free association
- Similar to tip-of–the-tongue phenomenon
- Activation of idea to try with no guarantee of success

Incubation

- Incubation – break from problem,
  - Usually more effective to continue work, breaks disruptive
- Break – exposure to cues in environment that prime relevant info or trigger retrieval, S learns something relevant
- Smith & Blankenship: break allows dissipation of inappropriate approach or set.



Smith & Blankenship

- Presented rebus problems plus misleading cues
- Control Ss – 1 minute per problem
- Incubation Ss – 30 sec per problem, then had second try (30 sec) at all missed problems
- Incubation Ss more likely to forget misleading cue & more likely to solve the problem
- Incubation period → loss in activation of inappropriate approach or set

What is creativity?

Illumination

- Discovery of new possibilities for solution
  - New learning, or cues have primed old (unretrievable) memories
- Dissipation of fatigue, inappropriate approaches or sets
- Creative people not "different", similar memory strategies, heuristics etc. as "normal" people
- Like experts – have a lot of knowledge in domain, knowledge is interconnected & retrievable, many different strategies
- Broad knowledge in other domains – may see analogies in "irrelevant" areas

- End of lecture

Penney – Incubation effects

- Ss given 10-letter word & had to rearrange letters to make words of 5 letters or more
- Ss worked until they couldn't produce any more words
- In Expts 1 & 2 length of break manipulated (15 min, 3 hrs, 24 hrs)
- Ss did word-stem completion task before returning to anagram task. Words relevant or not to anagram task.

Penney – Incubation effects - 2

- Expts 1 & 2: Ss produced new words after break → suggests break allowed old activation to decay & new associations to be activated.
- Break of 2 hours better than 15 min, but longer break not more beneficial.

Penney – Incubation effects - 3

- Exp 3 – relevant or irrelevant cues varied within Ss
- NO break or 30 min.
- More new responses after 30-min break than after no break
- Effect of relevant words during interval significant

Creativity: Summary

- Creativity requires domain=specific expertise & wide general knowledge
  - Domain specific skills, techniques, strategies
- Creative artists, musicians, scientists etc intrinsically motivated.
  - Notice task-relevant cues
- Extrinsic motivation (money, fame, fear of losing job etc.) works against creativity
- Need time → incubation effect

Computer Simulation Models

- Newell & Simon developed computer simulation model: General Problem Solver or GPS
- Advantage of simulation: model is fully specified
- GPS designed to use same strategies as humans (means–ends analysis), make similar errors
- GPS solved symbolic logic problems

Production Systems

- Goal, Set of conditions + Action
  - If conditions A, B, C, D, E met, do X
  - If conditions A, B, D, E, G met, do Y
- Summary: Computer Models
  - Able to solve many types of problems
  - Can develop models that simulate the errors people make, pattern of response times etc.