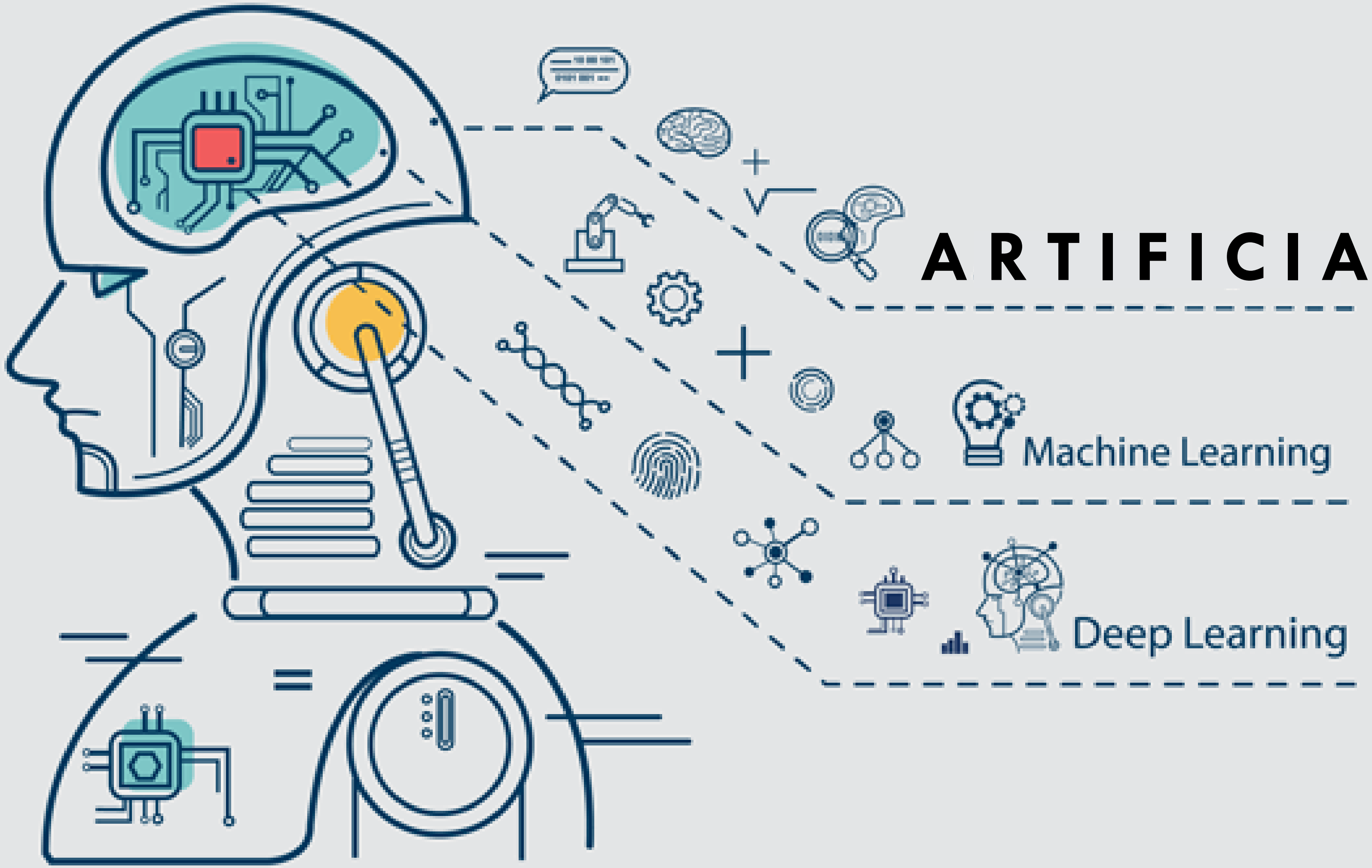
ARTIFICIAL INTELLIGENCE



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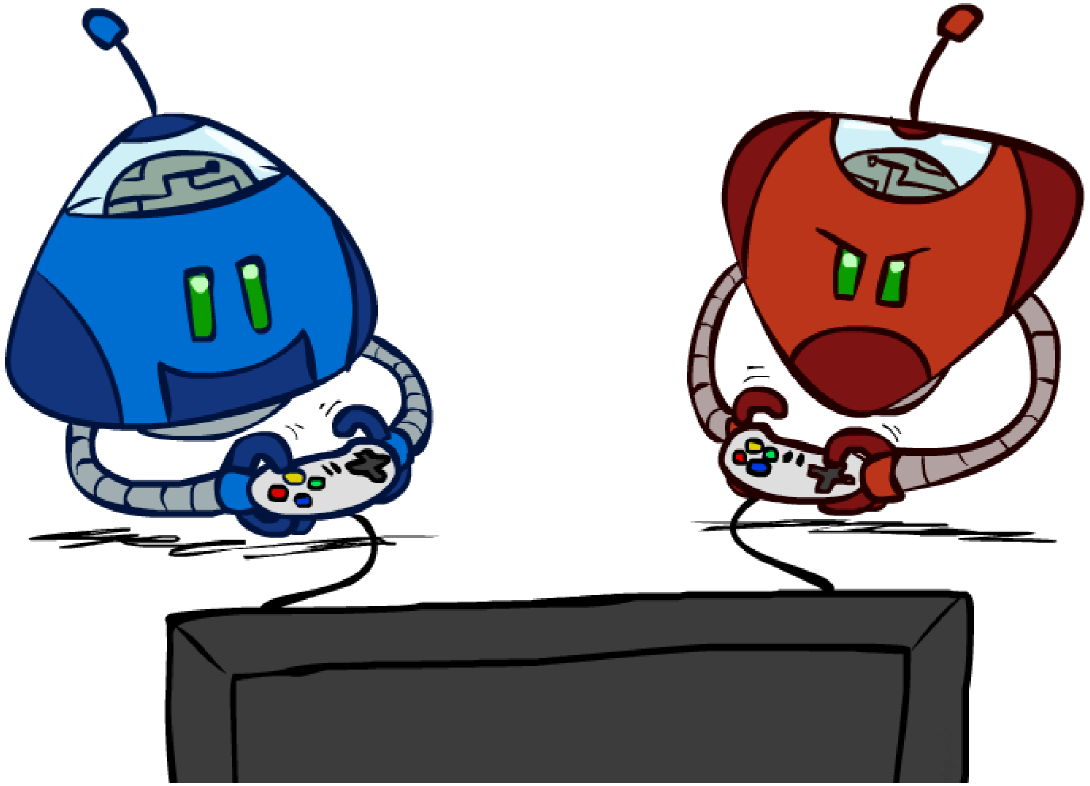
Lecture 6

21st Oct 2023

AI: Representation and Problem Solving

Local Search



Slide credits: Pat Virtue, http://ai.berkeley.edu

Outline

- Beam Search
- Local Beam Search & Variants of Beam Search
- Grid Search
- Simulated Annealing

Beam Search

- Search Algorithms like BFS, DFS and A* etc. are infeasible on large search spaces.

- Beam Search was developed in an attempt to achieve the optimal(or sub-optimal) solution without consuming too much memory.

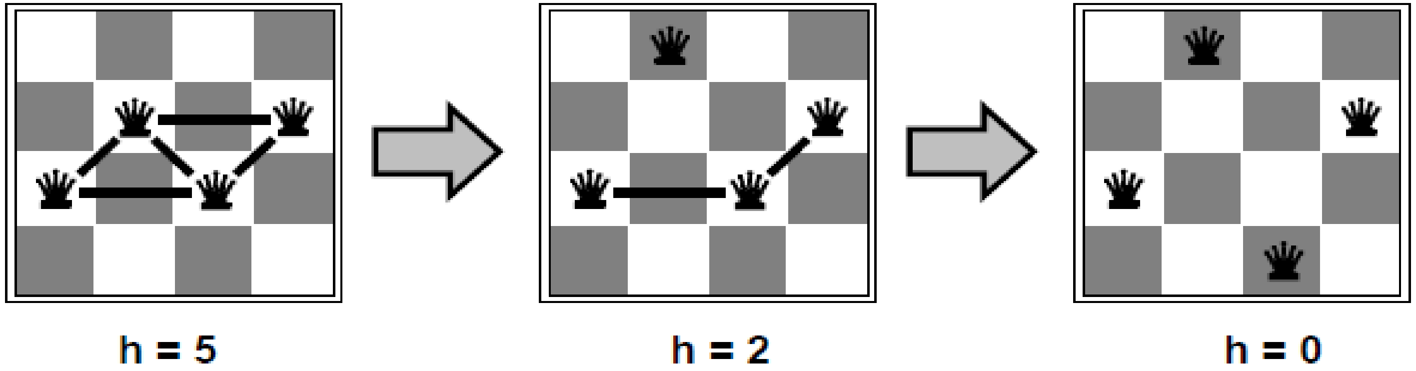
- It is used in many machine translation systems.

Where to use Beam Search?

- In many problems path is irrelevant, we are only interested in a solution (e.g. 8-queens problem)
- This class of problems includes
  - ➢Integrated-circuit design
  - ➢Factory-floor layout
  - ➢Job scheduling
  - ➢Network optimization
  - ➢Vehicle routing
  - ➢Traveling salesman problem
  - ➢Machine translation

N-queens problem

- Put n queens on an n × n board with no two queens sharing a row, column, or diagonal



- move a queen to reduce number of conflicts.
- Solves n-queens problem very quickly for very large n.

Machine Translation

- To select the best translation, each part is processed.
- Many different ways of translating the words appear.
- The top best translations according to their sentence structures are kept.
- The rest are discarded.
- The translator then evaluates the translations according to a given criteria.
- Choosing the translation which best keeps the goals.
- The first use of a beam search was in the Harpy

Beam Search

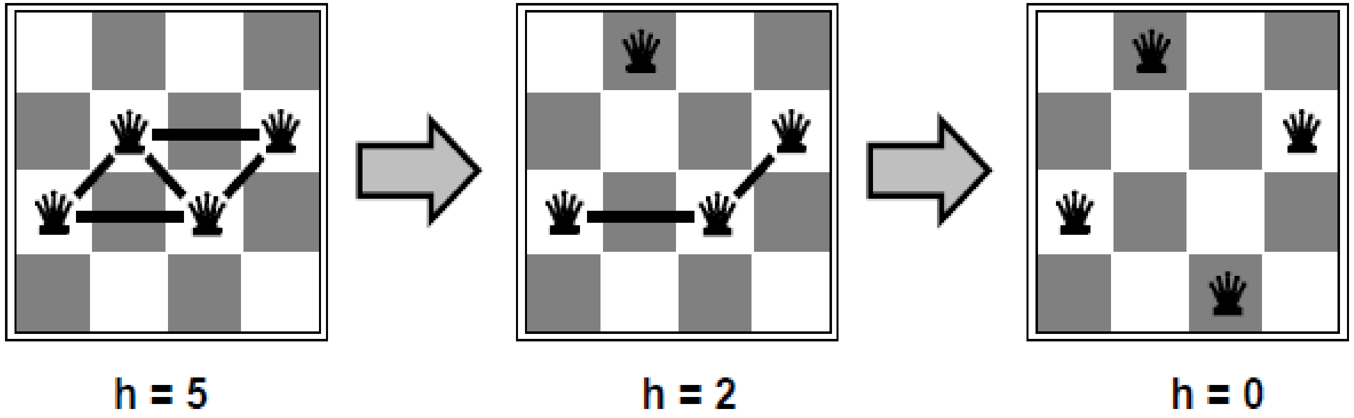
- Is heuristic approach where only the most promising ß nodes (instead of all nodes) at each step of the search are retained for further branching.
- ß is called Beam Width.
- Beam search is an optimization of best-first search that reduces its memory requirements.

Beam Search Algorithm

```
OPEN = {initial state}
 while OPEN is not empty do
     1. Remove the best node from OPEN, call it n.
     2. If n is the goal state, backtrace path to n
   (through recorded parents) and return path.
     3. Create n's successors.
     4. Evaluate each successor, add it to OPEN, and
   record its parent.
     5.  If |OPEN| > ß , take the best ß nodes
   (according to heuristic) and remove the others
   from the OPEN.
done
```

Example of Beam Search

- 4-queen puzzle
- Initially, randomly put queens in each column
- h = no. of conflicts
- Let ß = 1,and proceed as given below



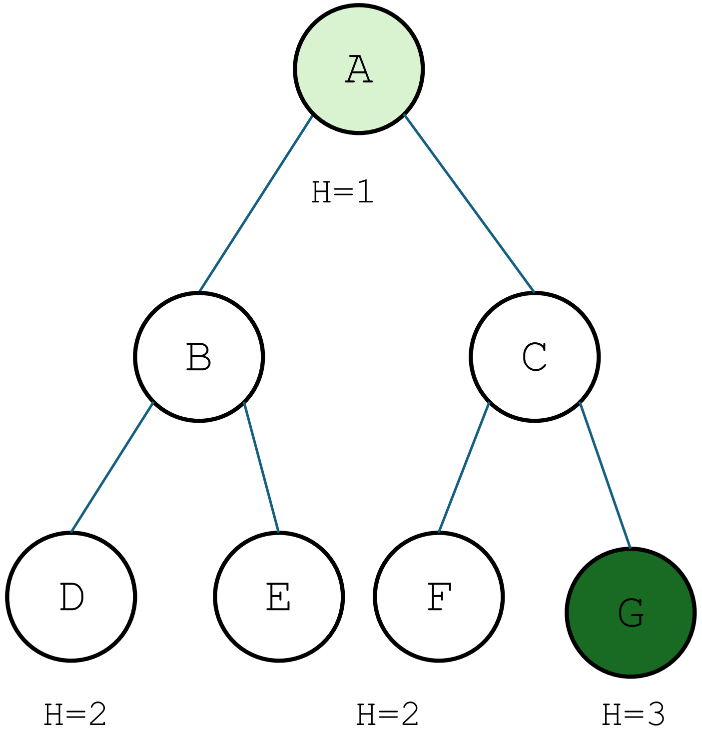
Beam Search vs. A*

- In 48-tiles Puzzle, A* may run out of memory since the space requirements can go up to order of 10^{61}.
- Experiment conducted shows that beam search with a beam width of 10,000 solves about 80% of random problem instances of the 48-Puzzle (7x7 tile puzzle).

Completeness of Beam Search

- In general, the Beam Search Algorithm is not complete.
- Even given unlimited time and memory, it is possible for the Algorithm to miss the goal node when there is a path from the start node to the goal node (example in next slide).
- A more accurate heuristic function and a larger beam width can improve Beam Search's chances of finding the goal.

Example with ß=2



Steps:

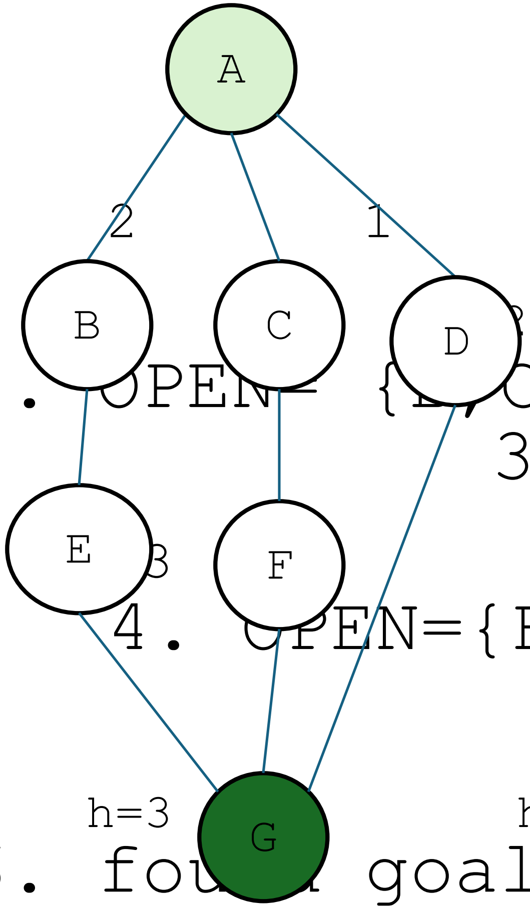
1. OPEN= {A}
2. OPEN= {B,C}
3. OPEN={D,E}
4. OPEN={E}
5. OPEN={}

Clearly, open set becomes empty without finding goal node .
With ß = 3, the algorithm succeeds to find goal node.

Optimality

- Just as the Algorithm is not complete, it is also not guaranteed to be optimal.
- This can happen because the beam width and an inaccurate heuristic function may cause the algorithm to miss expanding the shortest path.
- A more precise heuristic function and a larger beam width can make Beam Search more likely to find the optimal path to the goal.

Example with ß=2



Steps:

2

1. OPEN= {A}

h=3

2. OPEN= {B,C}

3. OPEN={C,E}

2

3

4. OPEN={F,E}

5. OPEN={G,E}

h=1

6. found goal node, stop.

4

3

Path : A->C->F->G

Time Complexity

- Depends on the accuracy of the heuristic function.
- In the worst case, the heuristic function leads Beam Search all the way to the deepest level in the search tree.
- The worst case time = ***O(B*m)***

    where *B* is the beam width and *m* is the maximum depth of any path in the search tree.

Space Complexity

- Beam Search's memory consumption is its most desirable trait.
- Since the algorithm only stores *B* nodes at each level in the search tree,

  the worst-case space complexity = ***O(B*m)***

  where *B* is the beam width, and *m* is the maximum depth of any path in the search tree.
- This linear memory consumption allows Beam Search to probe very deeply into large search spaces and potentially find solutions that other algorithms cannot reach.

Applications of Beam Search

- Job Scheduling - early/tardy scheduling problem
- Phrase-Based Translation Model

Local Beam Search

- Local beam search is a cross between beam search and local search (special case of beam search β =1).
- Only the most promising ß nodes at *each level* of the search tree are selected for further branching.
- remaining nodes are pruned off permanently.
- only ß nodes are retained at each level, the running time is polynomial in the problem size.

Variants in Beam Search

- Flexible Beam Search:
  - In case more than one child nodes have same heuristic value and one or more are included in the top B nodes, then all such nodes are included too.
  - Increases the beam width temporarily.
- Recovery Beam Search
- Beam Stack Search
- BULB (Beam Search Using Limited Discrepancy Backtracking)

Conclusion

- A beam search is most often used to maintain tractability in large systems with insufficient amount of memory to store the entire search tree.
- Used widely in machine translation systems.
- Beam Search is neither complete nor optimal.
- Despite these disadvantages, beam search has found success in the practical areas of speech recognition, vision, planning, and machine learning (Zhang, 1999).