CS 1571 Introduction to AI
Lecture 2

AI applications

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Artificial Intelligence

- The field of **Artificial intelligence**:
  - The design and study of computer systems that behave intelligently
- **AI:**
  - Focus on nontrivial problems that require reasoning and are often solved by humans
  - Goes beyond numerical computations and manipulations
- **Benefits of AI research**
  - Engineering aspect
    - solving of hard problems
  - Cognitive aspect
    - Understanding the nature of human intelligence

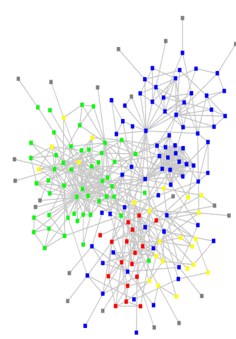
AI applications: Software systems.

- **Diagnosis of:** software, technical components
- **Adaptive systems**
  - **Adapt systems to user needs**
  - **Adapt systems to specific tasks**
- **Examples:**
  - **Intelligent interfaces**
  - **Intelligent helper applications**
  - **Collaborative filtering**
  - **Target advertising**

Search and information retrieval

Web search engines

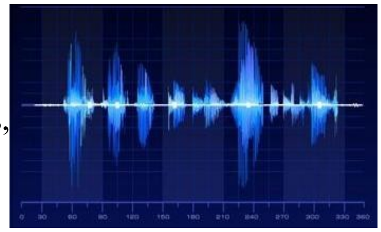
- Improve the quality of search
- Rely on methods/algorithms developed in AI
- Add inferences and knowledge to search queries



Semantic web (or web 2):

- From information to knowledge sharing
- Ontology languages

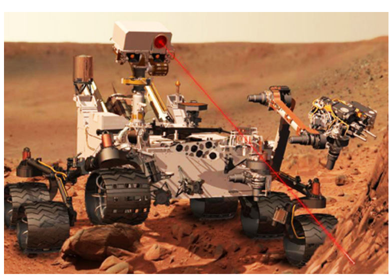
Speech recognition



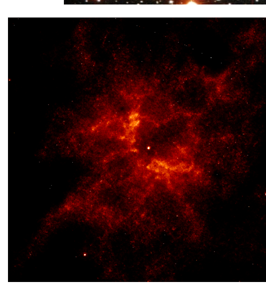
- **Speech recognition systems:**
  - Systems based on statistical models,
  - Hidden Markov models
- **Multi-user speech recognition**
- Voice command/voice activated devices
  - No training – works for many users
- **Adaptive speech systems**
  - Adapt to the user (training)
  - continuous speech
  - commercially available software – (Nuance, IBM)
    - http://www.nuance.com/

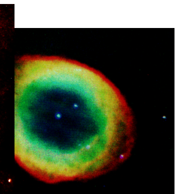
Space exploration

Autonomous rovers, intelligent probes



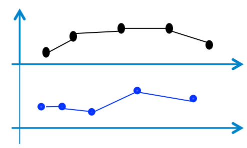
Analysis of sky Survey data

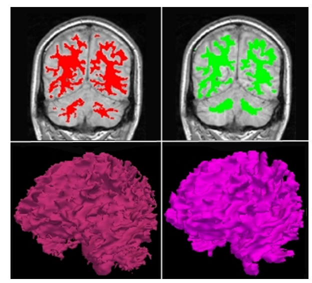


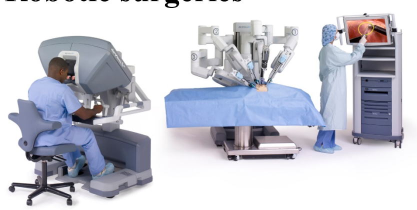


AI applications: Medicine

- **Medical diagnosis:**
  – QMR system. Internal medicine.
- **Patient Monitoring and Alerting:**
  – Cerner
- **Medical imaging**
  – Classification of body structures and visualization
- **Robotic surgeries**

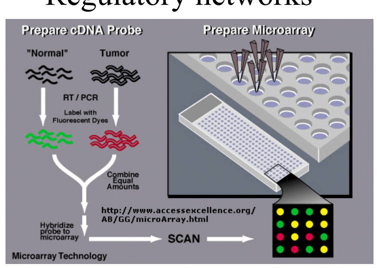


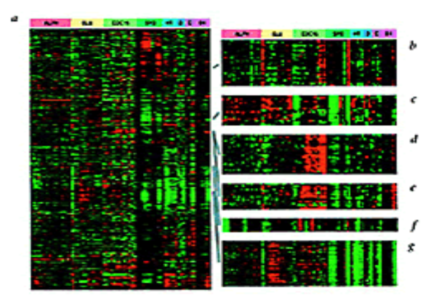




AI applications: Bioinformatics

- **Genomics and Proteomics**
  – Sequence analysis
  – Prediction of gene regions on DNA
  – Analysis of DNA micro-array and proteomic MS profiles: find genes, proteins (peptides) that characterize a specific disease
  – Regulatory networks





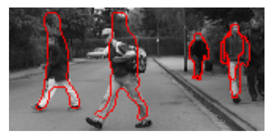
Example of a microarray used in gene sequencing

AI applications: Transportation

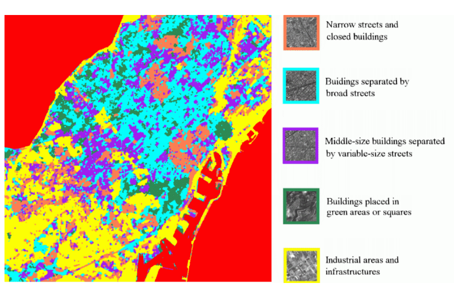
Autonomous vehicle control:

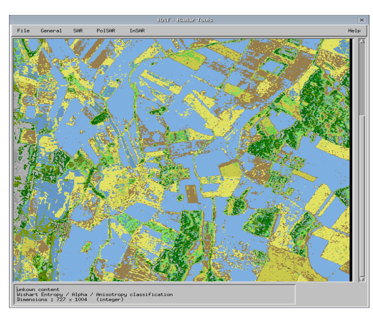
- ALVINN (CMU, Pomerleau 1993)
- Series of DARPA challenges (http://www.c grandchallenge/)
  - 2004, 2005 Drive across Mojave
  - 2007 - DARPA Urban Challenge
- Google autonomous vehicles

- **Pedestrian detection**
- **Traffic monitoring**
- **Navigation/route optimizations**

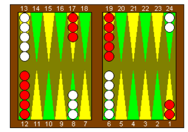


Classification of images or its parts





Game playing



- **Backgammon**
  - TD-backgammon
    - a program that learned to play at the championship level (from scratch).
    - reinforcement learning

- **Chess**
  - Deep blue (IBM) program (defeated Kasparov in 1997)
- **Bridge, Poker**

Natural language processing

understanding/annotation of free text

•Document analysis:
- Automatic classification of articles
- Content extraction/inference
- Email SPAM detection

•IBM's Watson project
- www.ibm.com/**watson**
- Successfully competed against the top human players in Jeopardy

Robots

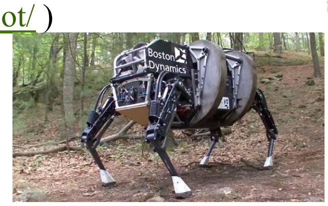
- **Robotic toys**
  - Sony's Aibo


- **Vacuum cleaners**

- **Humanoid robot**
  - Honda's ASIMO

(http://world.honda.com/robot/)

- **Military robots**



Other application areas

- **Handwriting analysis/ detection**
- **Human face detection**
- **Video stream annotation**
- **Object tracking**
- **Music composition, picture drawing**
- **…**

Topics

- **Problem solving and search.**
  - Formulating a search problem, Search methods, Combinatorial and Parametric Optimization.
- **Logic and knowledge representations.**
  - Logic, Inference
- **Planning.**
  - Situation calculus, STRIPS, Partial-order planners,
- **Uncertainty.**
  - Modeling uncertainty, Bayesian belief networks, Inference in BBNs, Decision making in the presence of uncertainty.
- **Machine Learning**
  - Supervised learning, unsupervised learning, Basic learning models

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Problem solving by searching

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Example

- Assume a problem of solving a linear equation

$$3x + 2 = 11$$

Do you consider it a challenging problem?

Example

- Assume a problem of computing the roots of the quadratic equation

$$3x + 2 = 11$$

Do you consider it a challenging problem?

Hardly, we just apply the ‘standard’ formula or procedure to solve:

$$ax + b = c$$

$$x = (c - b) / a$$

$$x = 3$$

Solving problems by searching

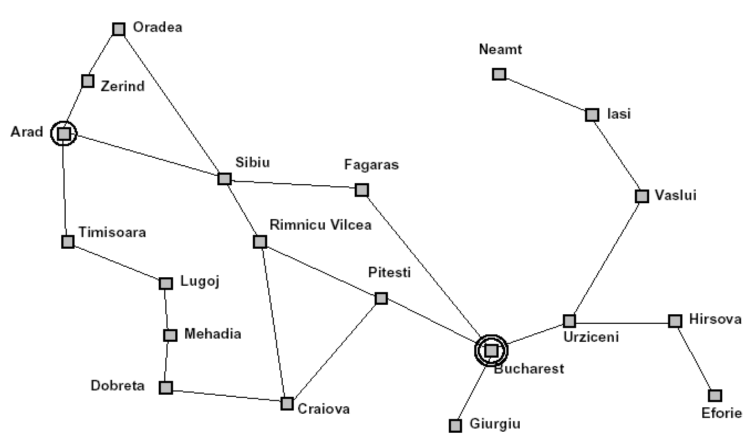
- Some problems have a straightforward solution
  - Just apply a known formula, or follow a standardized procedure

    Example: solution of the linear or quadratic equations
  - Hardly a sign of intelligence

- More interesting problems do not have a straightforward solution, and they require **search**:
  - more than one possible alternative needs to be explored before the problem is solved
  - the number of alternatives to search among can be very large, even infinite

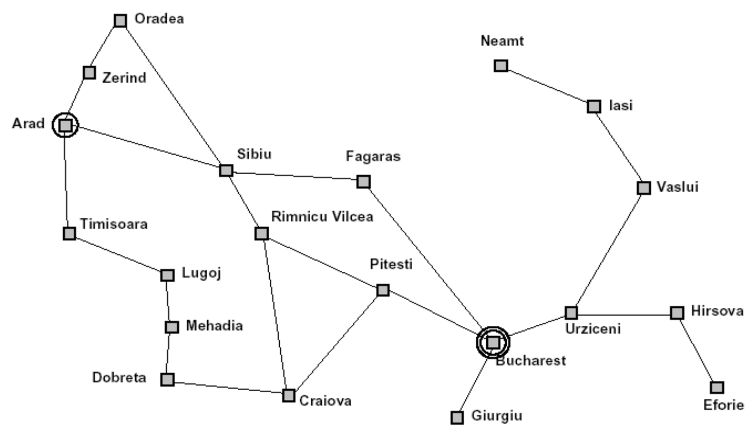
Search example: Route finding

- Find a route (path) from one city to another city



Example. Traveler problem

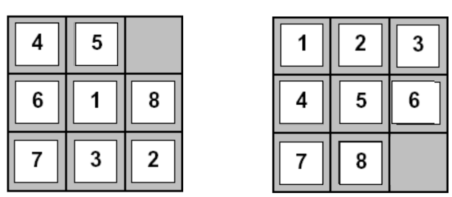
- Another flavor of the traveler problem:
  - find the route with **the minimum length** between S and T



Example. Puzzle 8.

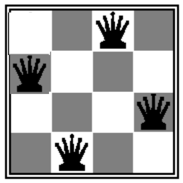
- Find the sequence of move of tiles from the initial game position to the designated target position

Initial position **Goal position**

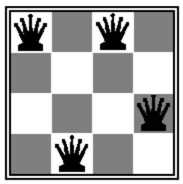


Example. N-queens problem.

Find a configuration of n queens on an n x n board such that queens do not attack each other



A goal configuration



A bad configuration

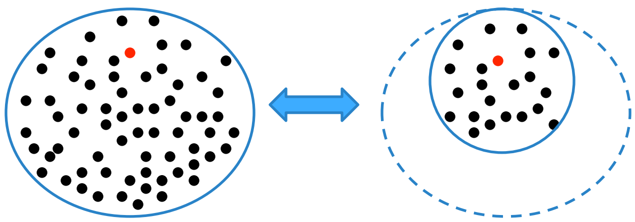
A search problem

is defined by:

- **A search space:**
  - The set of objects among which we search for the solution
  - **Example:** routes connecting two cities, or the different N-queen configurations
- **A goal condition**
  - What are the characteristics of the object we want to find in the search space?
  - **Examples:**
    - Path between cities A and B
    - Path between A and B with the smallest number of links
    - Path between A and B with the shortest distance
    - Non-attacking n-queen configuration

Search

- **Search (process)**
  - The process of exploration of the search space
- **The efficiency of the search depends on:**
  - **The search space and its size**
  - Method used to explore (traverse) the search space
  - Condition to test the satisfaction of the search objective (what it takes to determine I found the desired goal object



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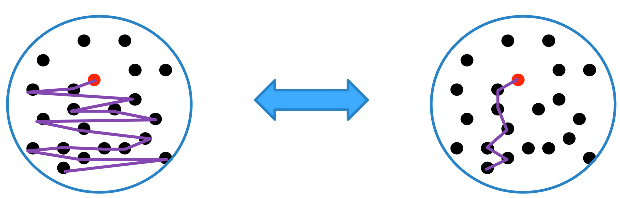

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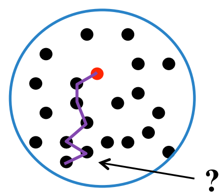
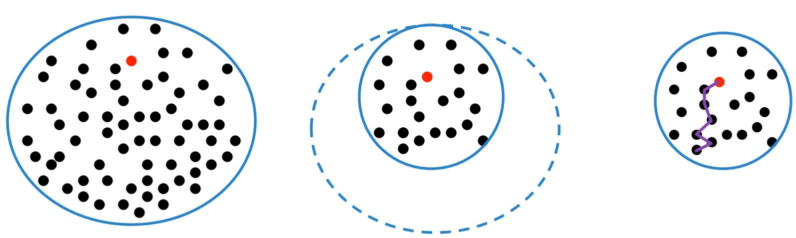


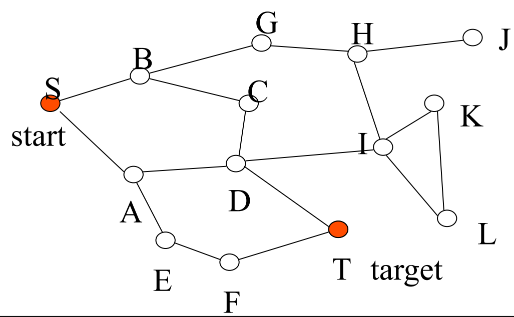
Search

- **Search (process)**
  – The process of exploration of the search space
- **Important**
  – We can often influence the efficiency of the search !!!!
  – We can be smart about choosing the **search space**, the **exploration policy, and the design of the goal test**



Graph representation of a search problem

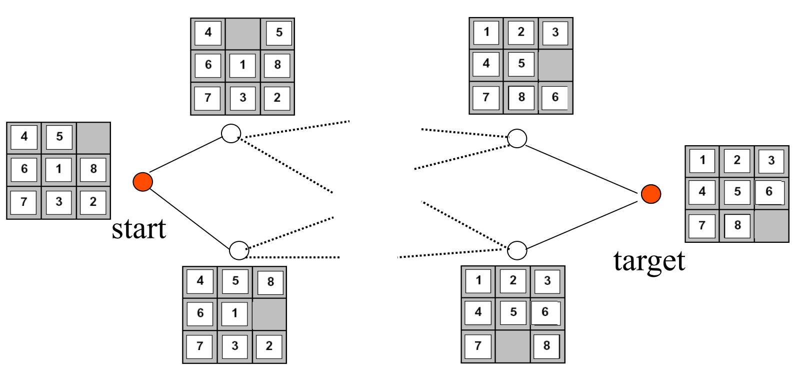
- **Search problems can be often represented using graphs**
- **Typical example: Path finding**
  - Map corresponds to the graph, nodes to cities, links valid moves via available connections
  - **Goal:** find a path (sequence of moves) in the graph from S to T



Graph search

- **Less obvious conversion:**

  Puzzle 8. Find a sequence of moves from the initial configuration to the goal configuration.
  - nodes corresponds to states of the game,
  - links to valid moves made by the player



Graph search problem

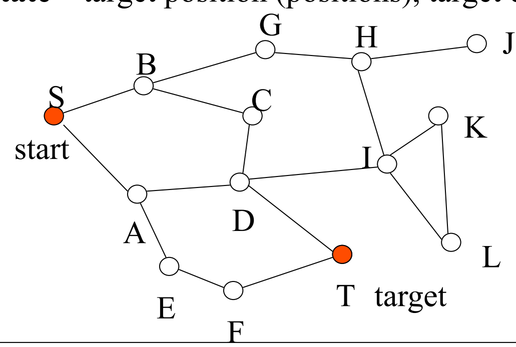
Four components:

•**States** - game positions, or locations on the map that are represented by nodes in the graph

•**Operators -** valid moves

•**Initial state** – start position, start city

•**Goal state** – target position (positions), target city (cities)



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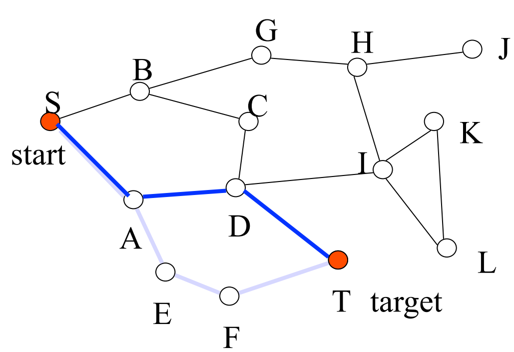
Graph search

- **More complex versions of the graph search problems:**
  - Find the minimal length path

    (= a route with the smallest number of connections, the shortest sequence of moves that solves Puzzle 8)



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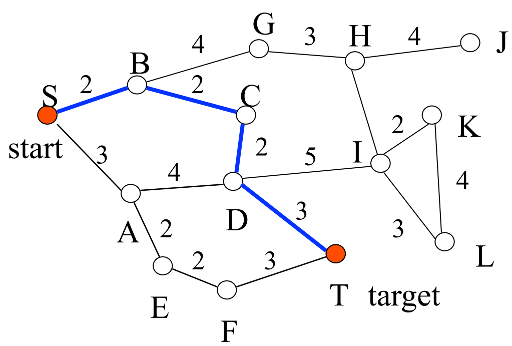
Graph search

- **More complex versions of the graph search problems:**
  - Find the minimum cost path (= a path with the shortest distance)



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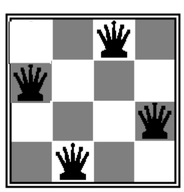
N-queens

Some problems are easy to convert to the graph search problems

- **But some problems are harder and less intuitive**
  - Take e.g. N-queens problem.



Goal configuration

- **Problem:**
  - **We look for a configuration, not a sequence of moves**
  - **No distinguished initial state, no operators (moves)**

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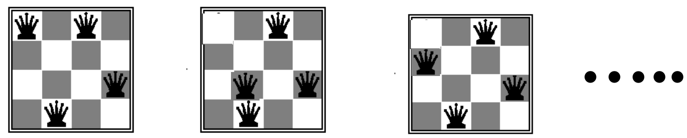
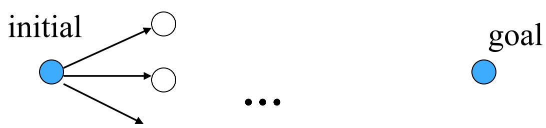
N-queens

How to choose the search space for N-queens?

- Ideas? **Search space:**
  - all configurations of N queens on the board



- **Can we convert it to a graph search problem?**
- We need states, operators, initial state and goal condition.



N-queens

Search space:

- all configurations of N queens on the board

- **Can we convert it to a graph search problem?**
- We need states, operators, initial state and goal state.

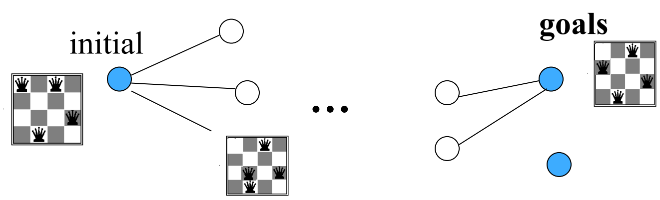
States are: N-queen configurations
Initial state: ?
Operators (moves)?

N-queens

Search space:

– all configurations of N queens on the board

- **Can we convert it to a graph search problem?**
- We need states, operators, initial state and goal condition.



Initial state: an arbitrary N-queen configuration
Operators (moves): change a position of one queen

N-queens

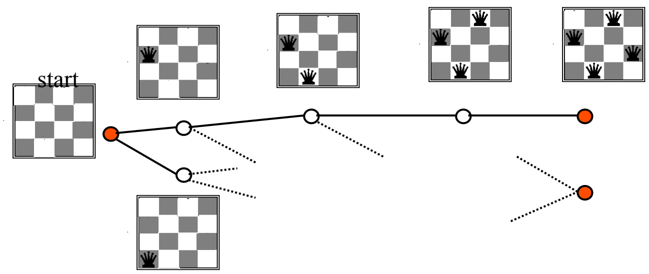
Is there an alternative way to formulate the N-queens problem as a search problem?

- Ideas?

N-queens

Is there an alternative way to formulate the N-queens problem as a search problem?

- **Search space:** configurations of 0,1,2, … N queens
- Graph search:
  - States configurations of 0,1,2,…N queens
  - Operators: additions of a queen to the board
  - Initial state: no queens on the board

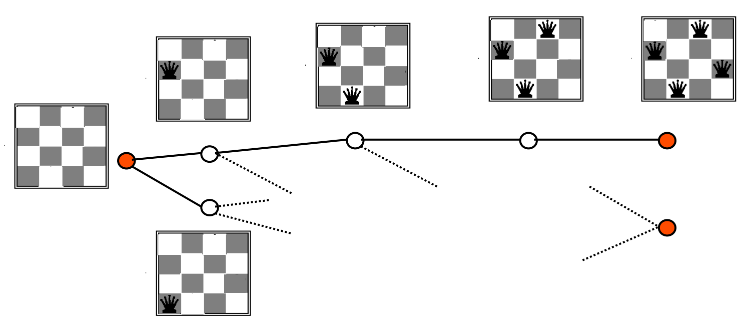


Graph search

N-queens problems

- This is a different graph search problem when compared to Puzzle 8 or Path planning:

  We want to find only the target configuration, not a path



Two types of graph search problems

- **Path search**
  - Find a path between states S and T
  - **Example:** traveler problem, Puzzle 8
  - **Additional goal criterion:** minimum length (cost) path
- **Configuration search (constraint satisfaction search)**
  - Find a state (configuration) satisfying the goal condition
  - **Example:** n-queens problem
  - **Additional goal criterion:** "soft" preferences for configurations, e.g. minimum cost design

Graph Search Problem

Search problems that can be often represented or converted into a graph search problems:

- **Initial state**
  - State (configuration) we start to search from (e.g. start city, initial game position)
- **Operators**:
  - Transform one state to another (e.g. valid connections between cities, valid moves in Puzzle 8)
- **Goal condition:**
  - Defines the target state (destination, winning position)
- **Search space** **(**the set of objects we search for the solution) **:**
  - is now defined indirectly through**:**

    the initial state + operators