Adaptive Cooperative Algorithms
ECE 457A

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Our Goal

Why Bother taking this Course?

- I have done many programming courses, and
- I know how to program in more than one programming language, and
- I know algorithms and data structures, and
- I have written many programs!

There are problems and there are problems!

- There are problems that are Computable.
- There are many computational problems in our real life that are computable within a reasonable amount of time. For this type of problems we seek algorithms that can deterministically search for optimal solutions in reasonable time.
- Computability is the ability to solve a problem n an effective manner.
- We tend to speak of these types of problems as P or Polynomial problems.

There are problems and there are problems!

- There are problems that are well-defined:
- In a well-defined problem, the given state of the problem, the goal state of the problem, and the allowable operators (or moves) are each clearly specified
- Traditional algorithms and programming techniques work well for solving computable well-defined problems.
- Most likely, the types of problems you have tackled in the past.

Figure: Well Defined Problems

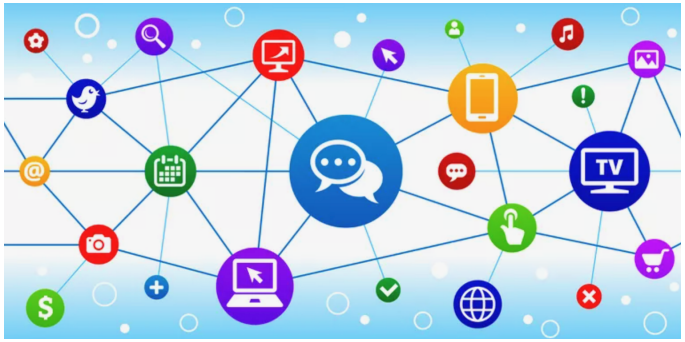
There are problems and there are problems!

- There are problems that are hard to compute.
- We refer to this type of problems as NP problems, which stands for nondeterministic polynomial time. Which is the set of problems whose solutions can be verified in polynomial time.
- Vast majority of NP problems whose solutions seem to require exponential time are what?s called NP-complete, meaning that a polynomial-time solution to one can be adapted to solve all the others.
- NP-complete problems are fairly common in real life, especially in large scheduling tasks. The most famous NP-complete problem, for instance, is the so-called traveling-salesman problem.

Figure: Hard Problems

Hard to compute problems

(a)

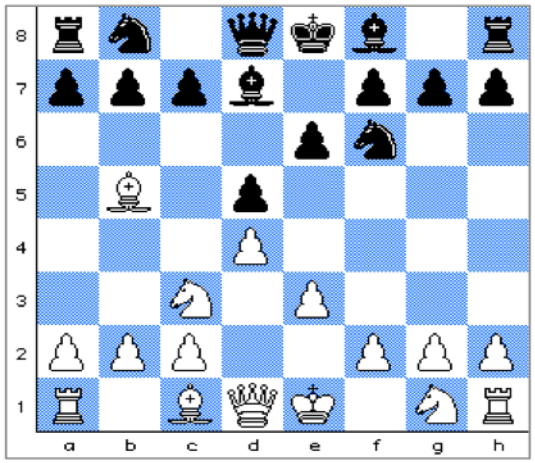


(b)

- Transportation
- Communication
- industrial production
- administration, writing, bookkeeping
- technological advances, sciences
- entertainment

But many problems in these applications are complex enough

Well-defined but Computationally Hard Problems



(a)

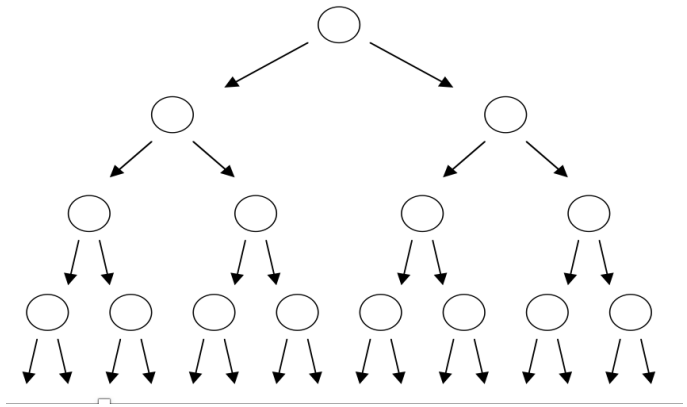


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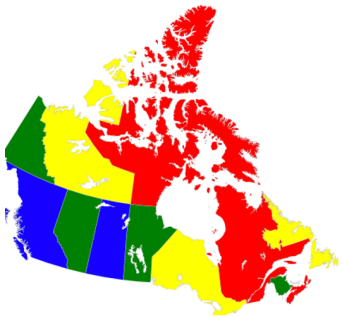
Figure: Well-defined Hard Problems

- NP hard Problems (e.g., Traveling Salesman Problem)
- Action Response Problems (Chess Playing)

It may Sound as A Simple Problem



Map Coloring

The four color theorem, or the four color map theorem, states that, given any separation of a plane into contiguous regions, producing a figure called a map, no more than four colors are required to color the regions of the map so that no two adjacent regions have the same color.
Adjacent means that two regions share a common boundary curve segment, not merely a corner where three or more regions meet.
If you were to program a computer agent to 4-color a map for you, what general steps would you take?

Well defined, but hard to solve, NP-Complete

There are problems and there are problems!

There are problems that are ill-defined

... those that do not have clear goals, solution paths, or expected solution.

Definition

An ill-defined problem is one that deals with complex issues and thus cannot easily be described in a concise, complete manner. Furthermore, competing factors may suggest several approaches to the problem, requiring careful analysis to determine the best approach.

Drawbacks of Traditional Techniques

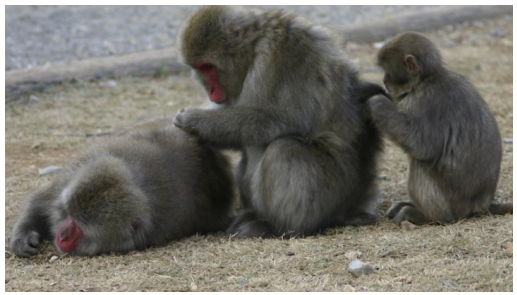
Computational Tasks have to be

- well-defined
- fairly predictable
- computable in reasonable time with serial computers

Hence Computational intelligence

Computational intelligence is a branch of computer science studying problems for which there are no effective computational algorithms. Biological organisms solve such problems every day: extracting meaning from perception, understanding language,solving ill-defined computational vision problems thanks to evolutionary adaptation of the brain to the environment, surviving in a hostile environment. However, such problems may be solved in different ways.
Computational Intelligence Paradigms: Theory & Applications using MATLAB By S. Sumathi, Surekha Paneerselvam

AI Problem Solving: Adaptation and cooperation



(a)

(b)

Figure: Adaptation and Cooperation

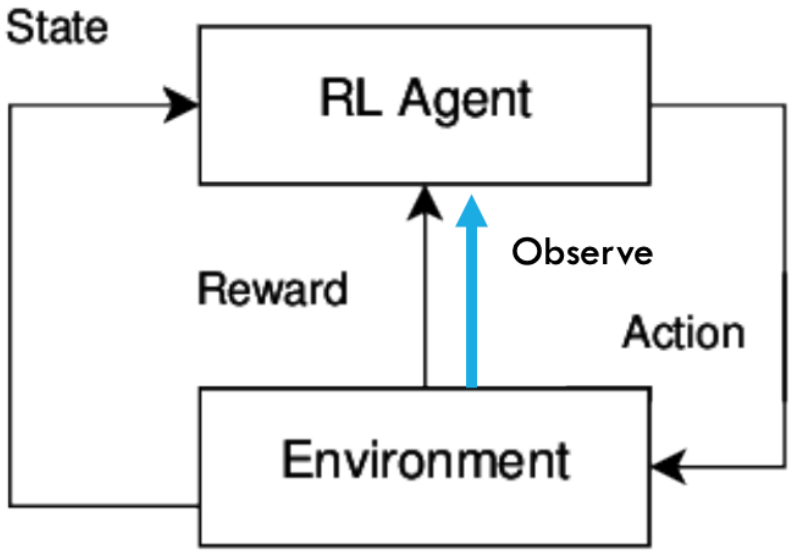
The ability of machines to mimic human behavior and abilities is evolving and demonstrating success in various applications.

hence the emergence of computing domains such as AI, Machine learning, deep learning, and biologically inspired computing. An important aspect of the human problem solving is adaptation to changes and new learning, and the ability to cooperate with others to tackle complex problems.

Software as an agent

What elements are involved?

- The problem
- The Agent(s)
- The Environment



Real Life has it all

Computable and well-defined
Well-defined but hard

ill-defined, and

ill-defined and hard

this course

LEARNING OBJECTIVES

- ✔ Motivate the need for algorithms that exhibit a degree of intelligence: logical, computational, and biologically inspired.
- ✔ Introduce the concepts of cooperation and adaptations and how they are influencing new methods for solving complex problems.
- ✔ Study meta-heuristics, evolutionary computing methods, swarm intelligence, ant-colony algorithms, particle swarm methods. reinforcement learning,
- ✔ Illustrate the use of these algorithms in solving continuous and discrete, and machine learning problems
- ✔ Learn how to design adaptive and cooperative algorithms for solving a wide range of hard real-life problems.

Scope

- The course addresses ill-structured problems and the need for computational intelligence methods.
- It introduces the concepts of heuristics and their use in conjunction with search methods, solving problems using heuristics and metaheuristics, constraints satisfaction.
- The course also introduces the concepts of cooperation and adaptations and how they are influencing new methods for solving complex problems.
- The course discusses how the concepts of cooperation and adaptation are manifested in nature and how such models are inspiring new types of solution methods.

Topics

Engineering problems are Optimization Problems:
Engineering by definition is a search task where the goal is to find a solution to an optimization problem [that is a given quantity/objective is optimized subject to a set of constraints].

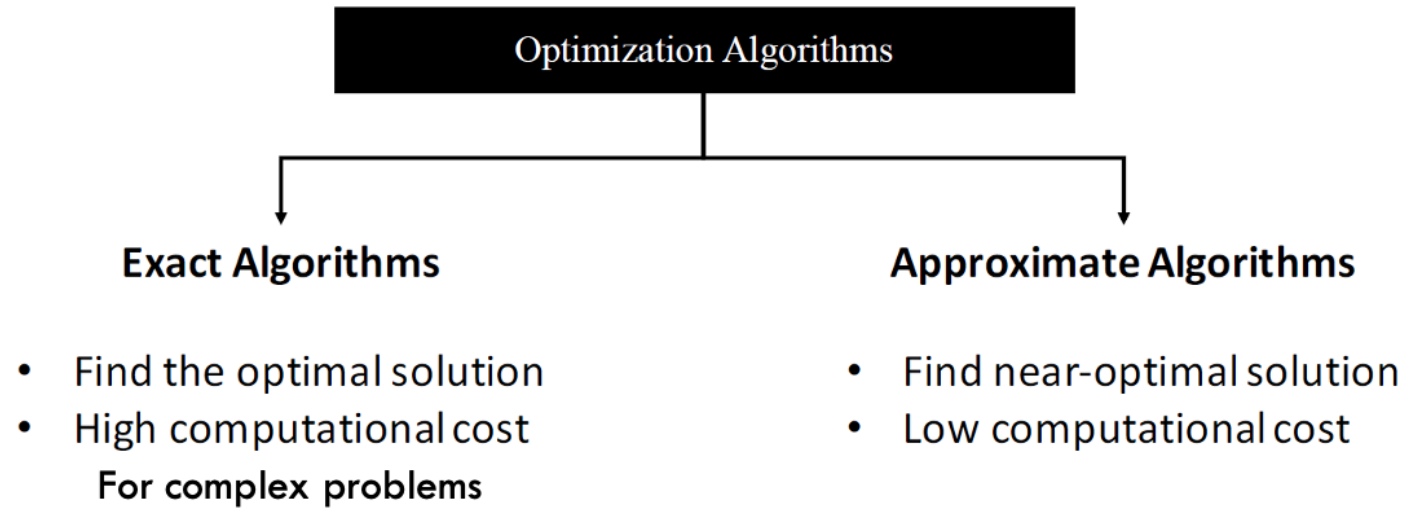


Figure: Optimization Algorithms

scope

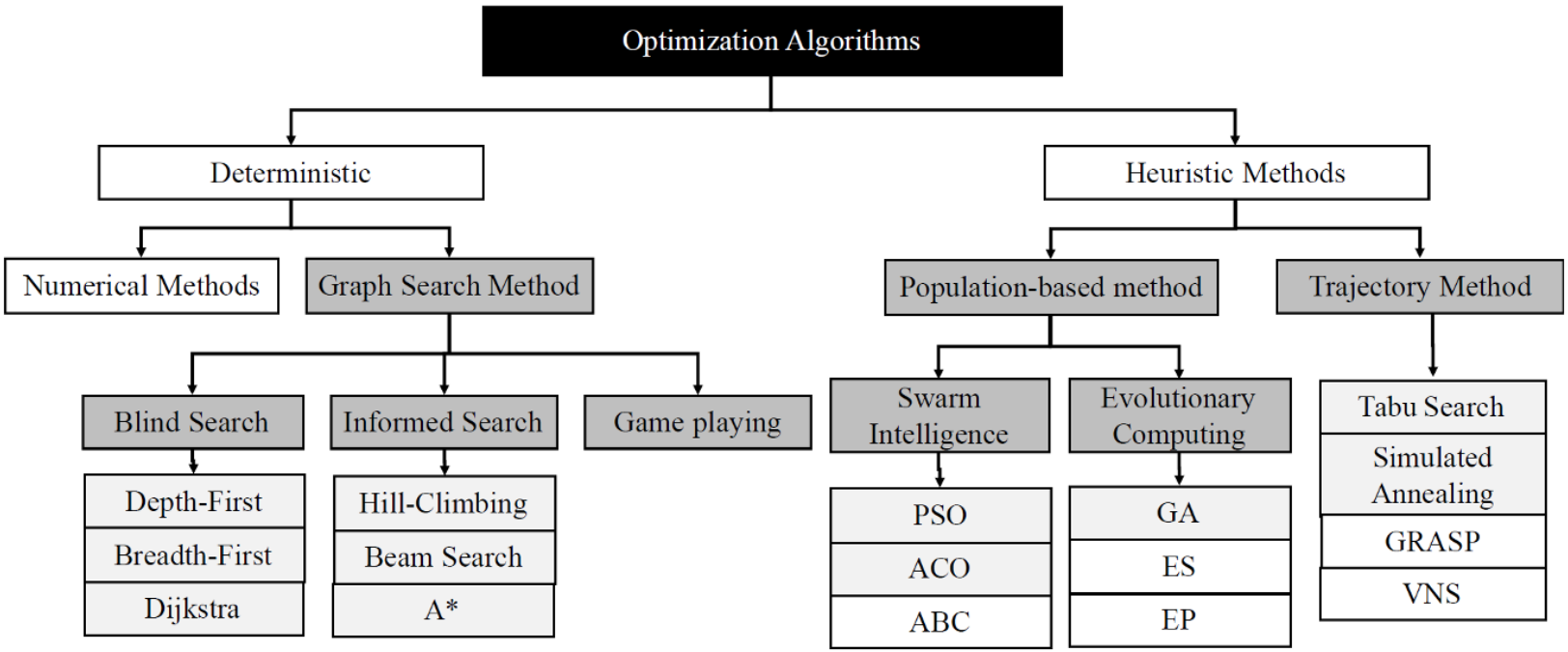


Figure: Optimization Algorithms

Topics

- search algorithms,
- game playing,
- constraints satisfaction,
- meta-heuristics,
- evolutionary computing methods,
- swarm intelligence,
- ant-colony algorithms,
- particle swarm methods,
- Adaptive and learning algorith
- Machine Learning

Workload Timeline:Assignments (Due Dates and Topics)

Assignment 1	Sep. 27^{th}:11:59PM	Problem Formulation, Classical G
Assignment 2	Oct. 11^{th}:11:59PM	Games, Trajectory Methods:SA, T
Assignment 3	Oct. 30^{th}:11:59PM	Population Methods: GA, AC
Assignment 4	Dec. 1^{st}:11:59PM	PSO, GP

Workload Timeline:Quizzes

Course Evaluation

The final course grade will be calculated using the following categories:

Assessment	**Percentage of Final Grade**
Assignments (4)	40 %
Quizzes (4)	20 %
Final Examination	40 %