Introduction

Winter 2024

Preface

- This course is designed to introduce the general concept of computational intelligence, with focus on meta-heuristics and optimization
- We do not intend to cover all the meta-heuristics
- Emphasis is placed not only on the algorithms but also on performance evaluation and parameter setting
- Students are expected to be able to develop and implement algorithms to solve problems in their own professional domains

Requirement and Goals

- Proficient or familiar with one programming language (C, C++, VB, Python, or Matlab)
- Learn to develop and validate programs based on pseudo-code and specific algorithms.
- Interpret and implement published studies

Optimization

- Objective(s): to minimize a function
  (may not have a closed-form expression)
- Constraints
- Decision variables
- Simply put: we want to find a set of decision variables to make the objective function smallest while satisfying constraints

Maximize $f(x) = x \sin(10 \pi x)+1;\ -1 \leqq x \leqq 2$

Traditional ways

- Use gradient information to go for steepest descent

  Descends along a function by taking steps in the opposite direction of the gradient of that function (minimization)

- Use deterministic rules to find the best (or better) solutions

  Works on the activities with the shortest durations first to reduce waiting time

Definition

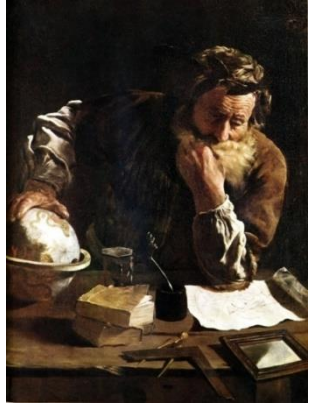
- **Computational intelligence (CI)**
  - the theory, design, application, and development of biologically motivated computational paradigms emphasizing meta-heuristics, genetic algorithms, evolutionary programming, neural networks, fuzzy systems, and hybrid intelligent systems in which these paradigms are contained.

IEEE Computational Intelligence Society

Meta-Heuristics

- **Meta-heuristics** are used to solve computational (usually optimization) problems by black-box procedures in a hopefully efficient way.
- A meta-heuristic refers to a master strategy that guides and modifies other heuristics to produce solutions beyond those that are normally generated in a quest for local optimality
- The name combines
  - "meta" ("beyond") and
  - "heuristic" (*heuriskein*, "to find")

Tale about “heuristics”



- Ancient Greek Archimedes was asked to

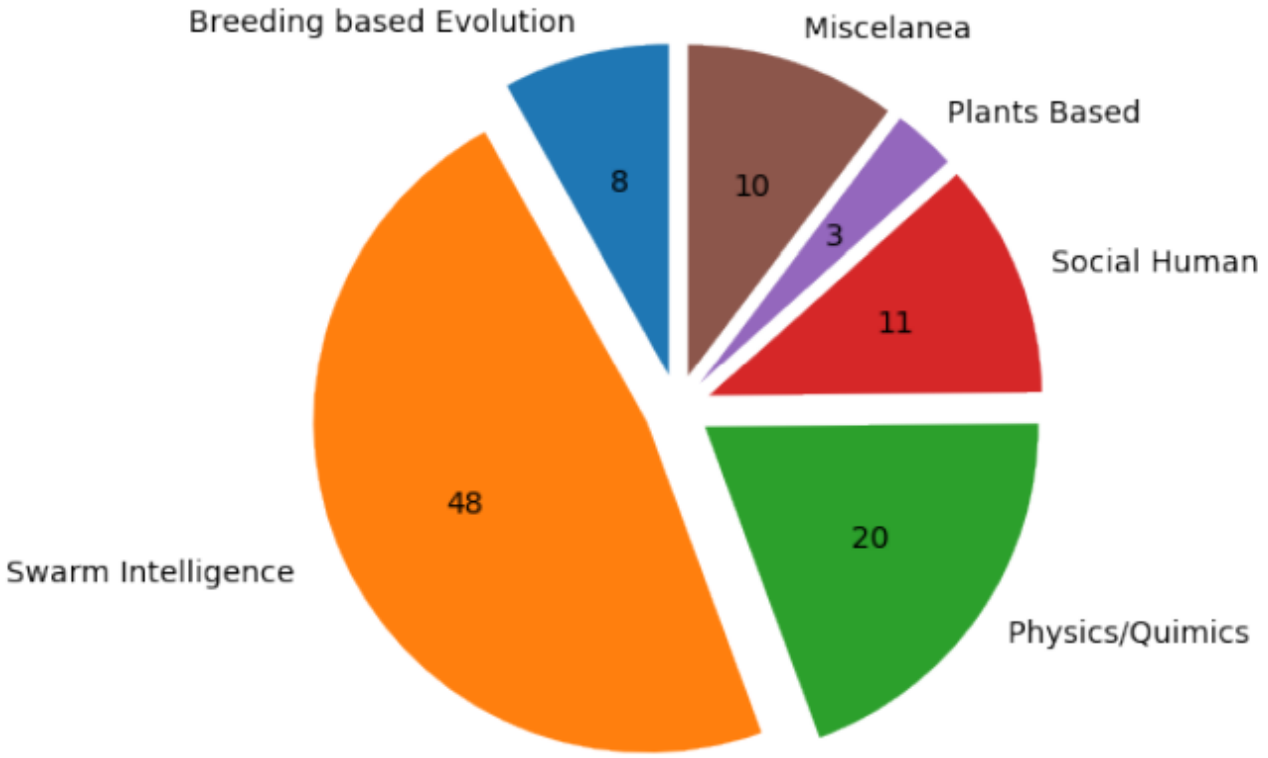
  determine whether a new crown was of solid gold, or whether silver had been added by a dishonest goldsmith
- Archimedes had to solve the problem without damaging the crown, so he could not melt it down to measure its density
- While taking a bath, he noticed that the level of the water rose as he got in. He realized that this effect could be used to determine the volume of the crown, and therefore its density after weighing it.
- He then took to the streets naked, so excited by his discovery that he had forgotten to dress, crying "**Eureka!**“ (past tense of “*heuriskein*”)

Meta-heuristics

- In addition to the algorithms introduced here, more than 300 have been proposed
  - Bees algorithm (2005)
  - Fireflies Optimization (2008)
  - Cuckoo Search (2009)
  - Bat algorithm (2010)
  - Krill Herd (2012)
  - Dolphin Echolocation (2013)
  - Symbiotic Organisms Search (2014)
  - Sine Cosine Algorithm (2016)
  - Jellyfish Search (2020)
  - Pilgrimage Walk Optimization (2023)

https://aisearch.github.io by Orta and Fausto

Classification



Source:
Comprehensive Taxonomies of Nature- and Bio-inspired Optimization: Inspiration versus Algorithmic Behavior, Critical Analysis and Recommendations

General Concept of Metaheuristics

1. Generate initial solutions randomly
2. Evaluate the solutions in terms of objective function
3. Select "good" solutions among possible solutions
4. Produce new solutions based on "good" solutions (key: allow some "not-so-good" solutions to be produced)
5. Return to Step 2 until stopping criterion is met

Ages of my three sons

- A professor met his friend, a mathematician
- The professor asks his friend to guess the ages of his three sons
- The first hint is "The product of the sons' ages is 36"
- The second hint is "The sum of the sons' ages is equal to the number of windows in that building on the street"
- The mathematician still cannot get the answer, so he is given the third hint "The oldest son has blue eyes"
- What are the sons' ages?

Illumination

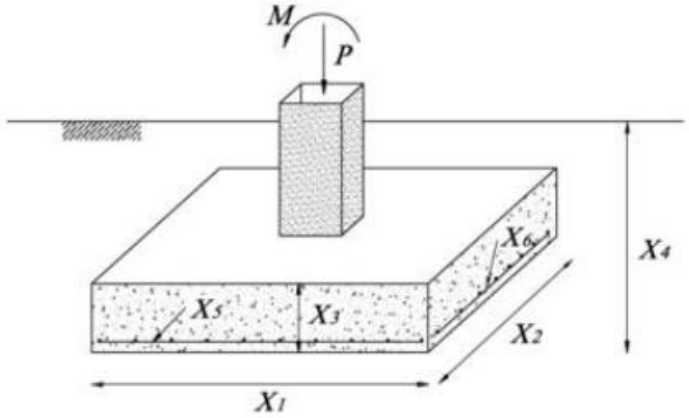
- A problem seems to be hard until someone comes up with a solution
- Things may look irrelevant but turn out to be all connected
- Objects follow “certain” rules of operations

Term Project

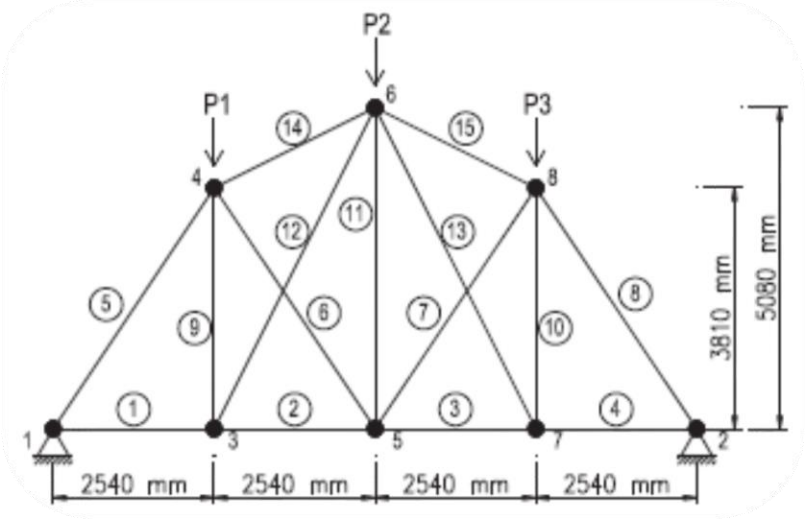
- Students are organized in teams (≤5 people).
- Each team will define and formulate an optimization problem, and develop a metaheuristic algorithm for the solution.
- The computational performance of the algorithm should be reported, in comparison with existing solution or another algorithm.
- It is encouraged that the project is related to your study or practical applications.
- Please talk to your advisor to determine a suitable topic.
- Submit your team members next week.

Previous works (1)

Topology optimization

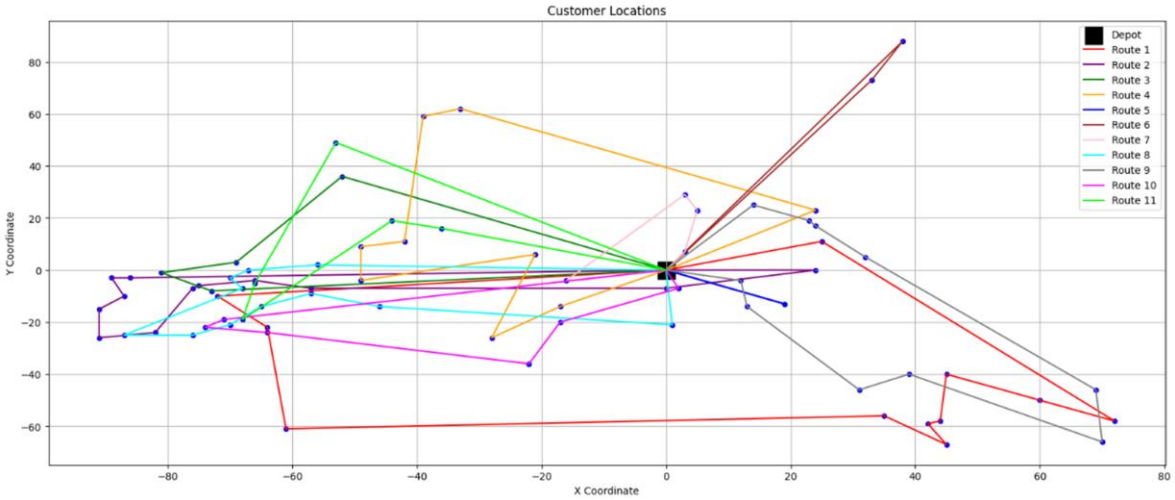


Design optimization

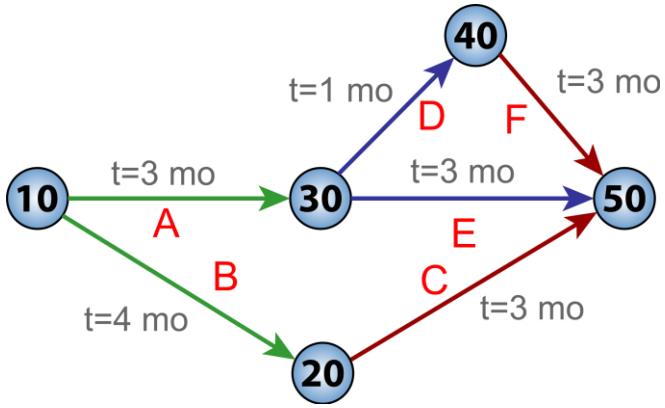


Size optimization

Previous works (2)



TSP/VRP



Scheduling

Prediction/Classification

Input #1	Input #2	Input #3	Output
…	…	…	X
…	…	…	O
…	…	…	O