Introdução à Meta-heurística

Natural Computing

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Summary

Natural Computing

What is Natural Computing?

- Natural Computing uses nature as a source of inspiration or metaphor for the development of new computational techniques used to solve complex problems.
- **Metaphor**
  - A figure of speech in which a word or phrase literally denoting one kind of object or idea is used in place of another to suggest a likeness or analogy between them (e.g. "drowning in the money").
  - They do not necessarily include all the details of a natural system. Simplifications are needed.

Natural Computing

- **Nature-inspired computing:** Evolutionary Algorithms, Collective Intelligence, Artificial Neural Networks, Artificial Immunological Systems, Artificial Endocrine Systems.

Evolutionary Algorithms

- Genetic Algorithms
- Genetic Programming
- Grammatical Evolution
- Evolutionary Strategies
- Evolutionary Programming

Natural Computing

Collective Intelligence

- Ant Colony Optimization
- Particle Swarm Optimization (PSO)

Artificial Neural Networks

- MLP - Multi-layer Perceptrons
- RBF- Radio Basis Function Net
- SOM - Self-Organizing Maps

Natural Computing

- Natural Computing (NC) is composed of stochastic methods.
- They do not guarantee that the optimal solution will be found, but the near-optimal one.
- Most methods present a declarative way of solving a problem (what to do), in contrast to procedural methods (how to do it).

Natural Computing

Scenario 1

- What is your problem?
- I think the solution is an algorithm inspired by nature.

Scenario 2

- I think the solution is an algorithm inspired by nature.
- What is your problem?

Natural Computing

- Optimization did not begin with NC.
- NC is not always the best alternative to an optimization problem.
- There is a lot of research in mathematics and operational research to find optimal or near-optimal solutions to various problems.
- **Example:** Differential Calculus is a great method for optimizing functions.

Travelling Salesman Problem (TSP)

Travelling Salesman Problem (TSP)

- Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city exactly once and returns to the origin city (Hamiltonian circuit of lower cost)?
- It is an NP-hard problem in combinatorial optimization, important in operations research and computer science.
- The TSP has several applications even in its purest formulation, such as planning, logistics, and manufacture of microchips.

Travelling Salesman Problem (TSP)

- Slightly modified, it appears as a sub-problem in many areas, such as DNA sequencing. In these applications, the concept city represents, for example, customers, soldering points, or DNA fragments, and the concept distance represents travelling times or cost, or a similarity measure between DNA fragments.

- TSP can be modelled as an undirected weighted graph, such that cities are the graph's vertices, paths are the graph's edges, and a path's distance is the edge's weight. It is a minimization problem starting and finishing at a specified vertex after having visited each other vertex exactly once.

Travelling Salesman Problem (TSP)

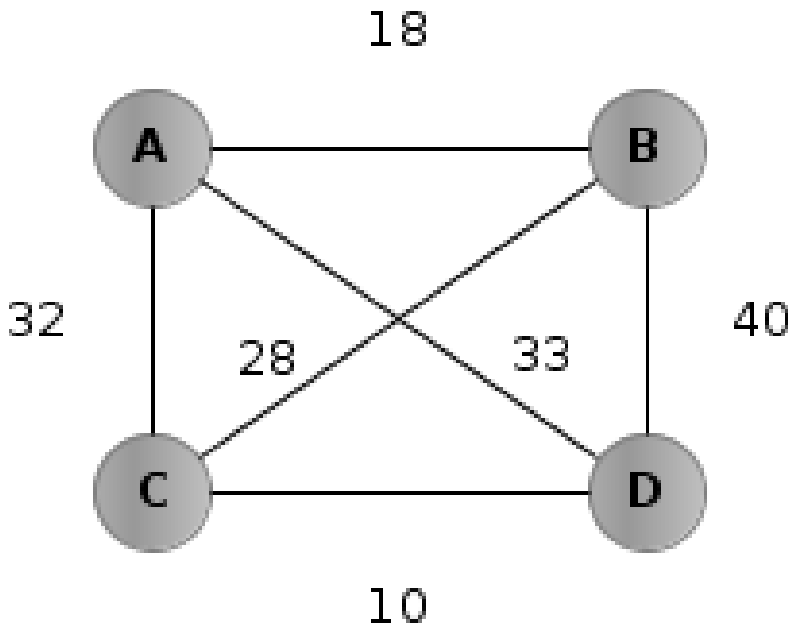

Figure: A graph representing a TSP.

Travelling Salesman Problem (TSP)

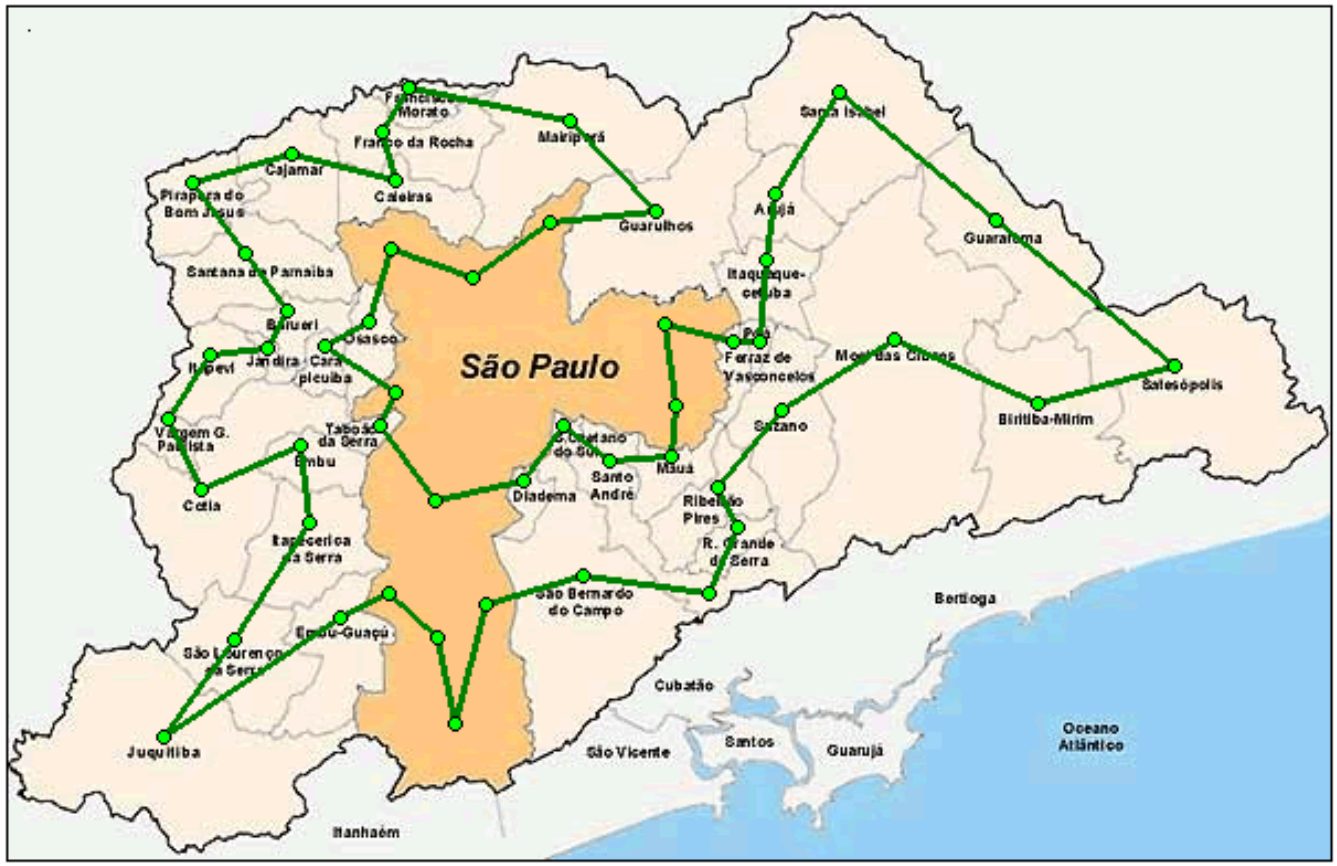

Figure: Graph with 50 points distributed on a map of São Paulo. Imagine for example that one person needs to travel through all these points with a helicopter carrying vaccines to be distributed. There are many solutions to the problem, among them the one shown in this figure. Source: `http://www.siscorp.com.br/siscorpnews/sexta_edicao/assunto_marco.htm`

Travelling Salesman Problem (TSP)

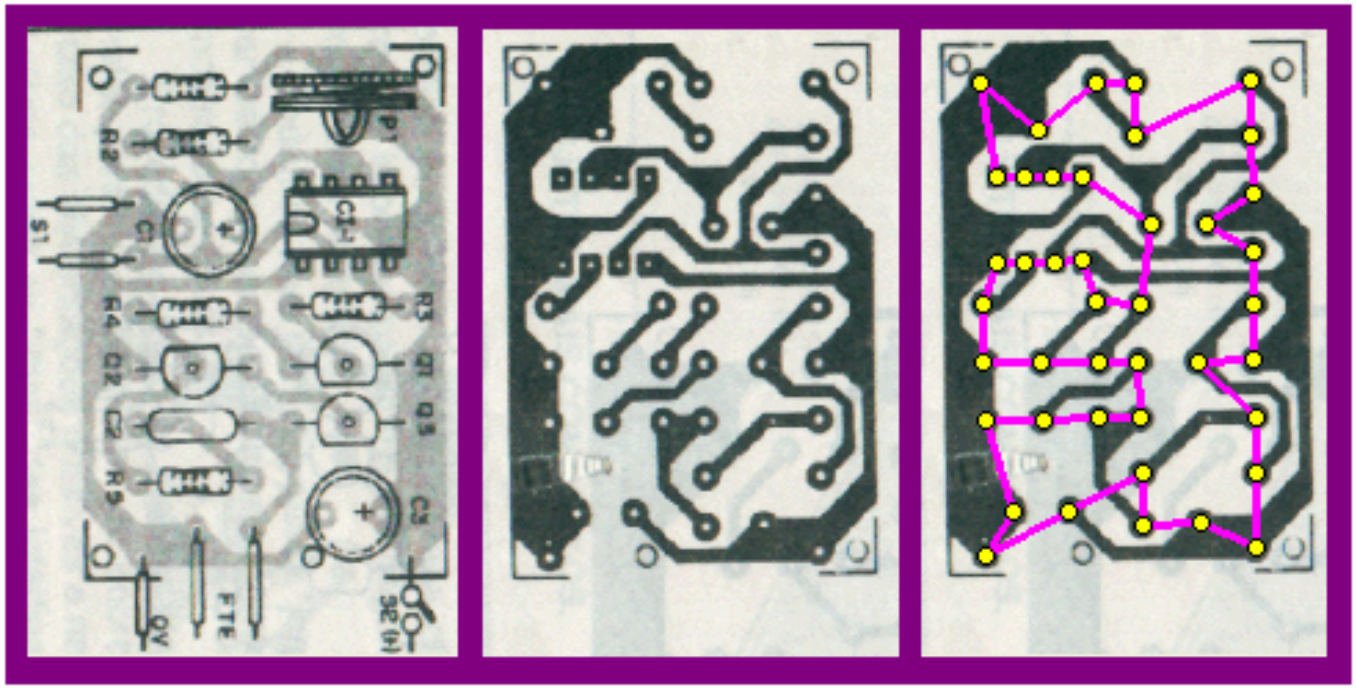

Figure: A Hamiltonian circuit to be traversed by a tool responsible for drilling a printed circuit board. Source: `http://www.siscorp.com.br/siscorpnews/sexta_edicao/assunto_marco.htm`

Travelling Salesman Problem (TSP)

Evolutionary Algorithms

- Based on Darwin's theory of evolution.
- Natural Selection and Genetic Variation.
- An individual is represented by a vector of integers (each number represents a city).
- The best individual (solution) is one who passes through all cities within the shortest distance.

Travelling Salesman Problem (TSP)

Artificial Neural Networks

- SOM (Self-Organizing Maps).
- Network input is the coordinate (x, y) of a city.
- The output is the set of cities (size k).
- Unsupervised training.

Travelling Salesman Problem (TSP)

Ant Colony Optimization

- We assume a fully connected graph (there is an edge between each city pair (i, j).
- Pheromone is associated with edges.

Natural Computing - Features

Natural Computing - Features

Where to apply NC?

- Complex problems, involving several variables, non-linear, and dynamic.
- Problems where it is not possible to guarantee that an optimal solution will be found.
- Where the problems are difficult to model, such as pattern recognition and classification, but where there are examples that can teach the model to the system.

What is Natural Computing?

- Natural Computing (NC) is an interdisciplinary and multidisciplinary area that involves concepts and models of chemistry, physics, and biology.
- The same concept can have different meanings in each of these areas.

Natural Computing - Features

What is a template?

- A (schematic) description of a system, theory, or phenomenon, which takes into account their known or inferred properties, which can later be used to further study its characteristics.
- In NC, computational models are usually simple to understand, but rich enough to generate interesting and meaningful behaviours.
- In creating a model, we select the characteristics and laws that govern the behaviour of the studied phenomenon, and this selection is guided by metaphors.

What is a metaphor?

- Metaphor (from the Greek): Use of a word in a different sense from its own by analogy or similarity [Dic. Michaelis].
- Neural Networks - follow the same basic principles as the human brain.
- Artificial immune systems to create an immune system for the computer?

Natural Computing - Features

Features

- Collectivity versus Agents
- Parallel and distributed processing.
- Interaction.
- Adaptation.
- Feedback.
- Self-organization.
- Emerging behaviour.

Natural Computing - Features

Collectivity versus Agents

Most of the methods studied are based on collectivity:

- Populations of individuals.
- Insect societies.
- Flocks of birds.
- Networks of neurons, etc.

Composed by agents:

- Have a minimum degree of autonomy and identity.
- Able to act upon themselves and the environment.
- Able to communicate with the environment.

Natural Computing - Features

Parallel and distributed processing

In nature, parallel and distributed processing is evident:

- Brain processing.
- Immune responses.
- Evolution of species, etc.

Natural Computing - Features

Interaction

- By pheromone (indirect).
- Physical contact (direct).

Adaptation

- The ability of the system to change its responses to stimuli according to the environment.

Learning

- The act or process of gaining knowledge, understanding, or skill through experience, study, or interactions.

Natural Computing - Features

Evolution

- It occurs when an individual or a population of individuals reproduces (inheritance) and undergoes genetic variations.

To learn, we do not necessarily need awareness:

- Insects learn to look for food.
- The immune system learns to fight disease-causing agents.

Natural Computing - Features

Feedback

- It happens when the response to a stimulus has some kind of effect on the original stimulus.

Types of feedback:

- Negative: the response decreases the original stimulus.
- Positive: the answer increases the original stimulus.

Natural Computing - Features

Self-organization

- grains of sand forming dunes.
- ants acting collectively to obtain food.
- cells acting together to generate an immune response, etc.

Pattern formation occurs through internal system interactions, without direct intervention from the external environment.

References

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