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Viral systems: A new bio-inspired optimisation approach

Pablo Cortés*, José M. García, Jesús Muñuzuri, Luis Onieva

Seville University, Ingeniería Organización, Escuela Superior Ingenieros, Camino de los Descubrimientos s/n, Sevilla 41092, Spain

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Abstract

The paper presents a new approach to deal with combinatorial problems. It makes use of a biological analogy inspired by the performance of viruses. The replication mechanism, as well as the hosts' infection processes is used to generate a metaheuristic that allows the obtention of valuable results. The viral system (VS) theoretical context is described and it is applied to a library of medium-to-large-sized cases of the Steiner problem for which the optimal solution is known. The method is compared with the metaheuristics that have provided the best results for the Steiner problem. The VS provides better solutions than genetic algorithms and certain tabu search approaches. For the most sophisticated tabu search approaches (the best metaheuristic approximations to the Steiner problem solution) VS provides solutions of similar quality.

Keywords: Virus; Optimisation; Metaheuristic; Artificial intelligence; Steiner tree

1. Introduction

In real life, most problems are combinatorial. For this type of problem, the available algorithms usually present weaknesses. The mathematically rigorous algorithms (as branching or cutting techniques) tend to be too slow while ad hoc heuristics often produce poor solutions. Since the last decades of the past century, metaheuristics and Artificial Intelligence (AI) have been trying to deal with these difficulties. This is the case of simulated annealing (see [1,2] for the first references), Genetic Algorithms (firstly described by Holland [3], Holland et al. [4] and Goldberg [5]), Tabu Search (defined by Glover [6,7]) or more recently the use of agent technology (see [8,9] for a survey including wide bibliography in the field). The use of agents to deal with optimisation problems is a new and incipient framework. The Network of Excellence "AgentLink" funded by the European Commission under its Fifth Framework Information Society Technologies programme has edited a report describing the current state-of-the-art of agent technologies and identifying trends and challenges that will need to be addressed over the next 10 years to progress in the field and realise the benefits [10].

Recently, artificial immune systems (AIS) have arisen. They are computer algorithms inspired by the principles and processes of the vertebrates immune system. The algorithms typically exploit the immune system's characteristics of learning and memory to solve a problem. They are coupled to AI and closely related to genetic algorithms. Processes simulated in AIS include pattern recognition, hypermutation and clonal selection for B-cells, negative selection of T-cells, affinity maturation and immune network theory. AIS began in the eighties with Farmer et al. [11].

* Corresponding author. Tel.: +34 95 448 6153; fax: +34 95 448 72 48.
E-mail address: pca@esi.us.es (P. Cortés).

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In this paper, we propose the use of a biological analogy based on viral infection. Not much research has been carried out using viral analogies. We have been able to find very few papers proposing the use of viruses, all of them as part of genetic algorithms. For instance, Kubota et al. [12] propose them as part of a specific operator in genetic algorithms, and Saito [13] has described the use of genetic algorithms which make use of a virus evolutionary theory (GAV), and an algorithm based on the conception of horizontal evolution caused by virus infections. GAV is carried out by attacking a chromosome by a number of viruses, and having the genes of the chromosome recombined by the attack. The infection is allowed when the evaluation value goes up, but it falls into local minima easily. In order to escape from these local minima, an infection which makes the evaluation value worse in a small rate under small probability is allowed as well. All these approaches do not fit with our definition of Viral System (VS) as a new metaheuristic.

Here, we introduce a new optimisation approach that makes use of several ideas from multi-agent systems (MAS), as well as from other well-known AI approaches. In our proposal, we consider that the viruses are part of a general infection, where each virus tries to behave to its own benefit, but resulting in the benefit of the VS.

A generic optimisation problem can be defined as (1), and its complexity is typically NP-complete [14]

$$\text{Min}\{f(x) : g_i(x) \leqslant 0,\ \forall i = 1, \ldots, n\}, \tag{1}$$

where x is the set of feasible solutions of the problem, $f(x)$ is the objective function, and $g_i(x) \leqslant 0$ are the problem constraints. The objective function and the constraints are not necessarily linear, and the variables could be integer or continuous.

Based on this problem, the next section of the paper follows with the description of the biological analogy that we will use to solve the problem in Section 2, the description of the approach in Section 3, and the results for a collection of trial problems in Section 4. Finally, we review the main aspects in the conclusion section.

2. Biological analogy description

2.1. Generic definition of virus

Viruses are intracellular parasites shaped by nucleic acids, such as DNA or RNA, and proteins. The protein generates a capsule, called a capsid, where the nucleic acid is located. The capsid plus the nucleic acid shape the nucleus-capsid, which defines the virus. Fig. 1 depicts different types of viruses.

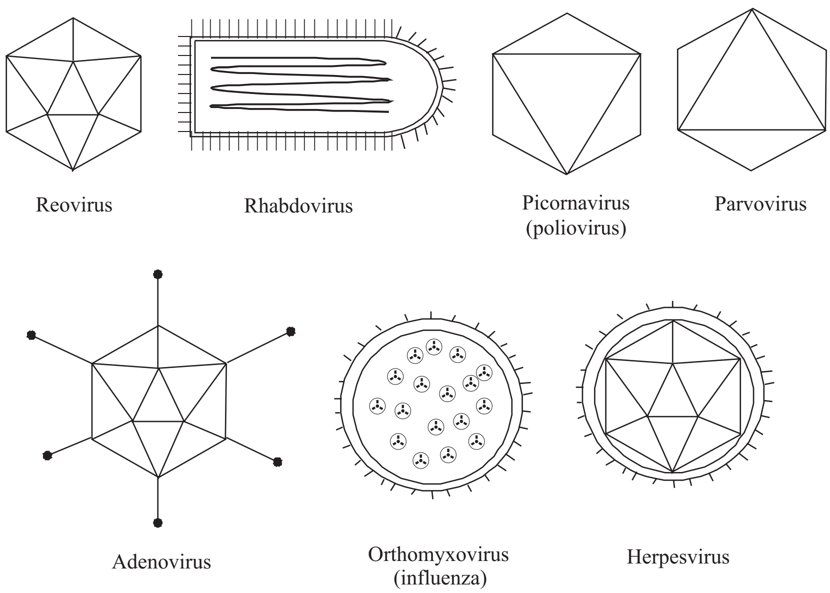

Fig. 1. Some types of known viruses.