07/5201 GOSSIP-BASED STRATEGIES IN GLOBAL OPTIMISATION

Type of activity: Medium Study (4 months, 25 KEUR)

Background and Motivation

Global optimisation is the task of finding the absolutely best value of a nonlinear function under given constraints. Such a task is crucial to several basic space related applications ranging from spacecraft trajectory optimisation ([1],[2],[3]) to the programming of spacecraft design decision support systems [4] to antennae design and more. Due to the heavy computational cost of many global optimisation tasks, algorithms are often deployed in computer networks [5], mostly in parallel computers but also in distributed computing environments. This way the "curse of dimensionality", affecting the majority of global optimisation problems, is alleviated and solutions can be found in reasonable times.

The use of computer networks to solve computationally demanding tasks in general has been investigated broadly for several decades now. Diverse software solutions are already available from different communities. Among them, the most famous are the volunteer based ones, especially the BOINC infrastructure [6]. A different platform is the ACT-DC [7], a general purpose distributed computing environment developed for use in the internal network of the European Space Agency and used experimentally in the past for relatively small tasks such as ionospheric data processing, nanostructured material design and spacecraft trajectory optimisation.

In most of the implementations of distributed computing environments, the different CPUs are coordinated in a centralized (master-slave) fashion while the task gets distributed by the central server according to a selected strategy. This type of network topology ("star"-like) is, though, neither the only one possible nor necessarily the best. It seems that there are no scientific publications on the effect of the network topology on the efficiency of different global optimisation algorithms. Besides, the number of different networks configurations proposed is constantly increasing. They are used for different purposes by peer-to-peer (P2P) systems [8]. These systems are fully decentralized, highly autonomous and easily scalable. The decentralization makes the network fault tolerant, efficient and sometimes cheap (since there is no need to maintain a server).

In the same direction, the gossip communication model [9], is a way to broadcast messages within a network in an asynchronous fashion. The main properties of this approach are: democratic, scalable, robust and reliable. There are several ways to implement this kind of communication: In the push-pull model the active thread initiates communication and receives peer state. The passive thread mirrors this behaviour. The active nodes randomly select some other nodes (this is an important component of the model, determines the performance and the reliability of the protocol) to exchange data. The overlay topology (i.e. "who is connected to whom") of this network could dynamically change over time. This has a major impact on many functions that can be used in P2P networks, e.g. load balancing [10], data aggregation [11] and global optimisation [12], just to mention some. A P2P implementation of a global optimisation

algorithm (namely the Particle Swarm Optimisation) using gossip communication model has been published recently [12] with some first promising results.

Research and Study Objectives

The aim of this study is to investigate and develop global optimisation algorithms in networks without a central management, e.g. P2P networks.

At first, single algorithms should be deployed and tested. Particle Swarm Optimisation [13], Genetic Algorithms [14], Simulated Annealing [15], Differential Evolution [16] are some suggestions, but any other effective algorithm can be taken into consideration. Different overlay topologies and information exchange should be tried. The ACT shall provide the test problems to test the algorithms performances.

In a second step, a collaborative approach should also be tried where each computer knows at least two algorithms and exchange via the network the information on which one of the two has been more effective, thus biasing the probability that the connected computers will use it in the following iterations. This would establish an approach similar to the DiGMO algorithm [17] already utilized in a centralized network. Such a collaborative approach proved to bring a substantial improvement in the algorithmic performance.

A successful study should therefore:

- Study decentralized networks topologies in relation to the performance and distribution of generic global optimisation algorithms.
- Link the overlay topology and the type of information exchanged to the actual performances of the various algorithms.
- Choose one overlay topology and at least two algorithms that can be deployed successfully on it.
- Develop a collaborative strategy where the different nodes share information also on the algorithm performance, thus biasing their choice in the following iteration.
- Study and test the algorithm convergence.

Implementation of a collaborative learning approach (see Vinko & Izzo [17]) in a non hierarchical network is an expected result of the study. In this environment the peers are sharing not only information on the global search, but also historical knowledge on the performance of different global solvers they have been trying. Following the study, the algorithms are planned to be made available to the research community in an open manner.

References

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