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COMPETITION AS AN ORGANIZATIONAL PRINCIPLE FOR MASSIVELY PARALLEL COMPUTERS?

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Abstract

We discuss the idea of using competition as a guiding principle for organizing a parallel computer. We argue that competitive interactions are ubiquous in many systems and deserve to be looked at in parallel computing. We outline some relevant questions which have to be answered in this context.

1 Introduction

Physicists tend to consider computation from the point of view of first principles. What is information?, the relation between information and negative entropy, the minimum energy required for a certain computation are typical questions addressed from that point of view [1] - [4].

In this paper we want to look at computation from another point of view. With the advent of massively parallel computers of 10^3 to 10^6 processing elements (PEs) over the next decade [5, 6], the study of computation as a problem of organization becomes more and more pressing. Here shall present preliminary ideas which are intended to serve as a starting point for further investigation.

2 Computation as Interaction

Computation in the approach advocated here is not longer seen as outcome of the activity of a single logical or processing element working on some input data [7, 8], but rather as an emerging phenomenon of a large number of active processing sites working in parallel [9].

In this area of organizational questions, emphasis lies on the interaction between PEs, instead of on a single PE's detailed features. It is thus believed that the nature of an interaction will determine the outcome of a computation to a higher degree than will the structure of a single element. Programmable matter [10] and discrete attractors systems [11] are two examples of studies in this field. This philosophy has also been adopted in physics by the interdisciplinary approach called Synergetics [12]. Qualitative changes in the behaviour of a system as the number of interacting elements increases is a typical phenomenon studied.

One aspect of introducing an interaction between computationally active entities is that it induces changes over time. Interactions can never be considered to be instantaneous but require time for the interaction signals to travel from sender to receiver. This is due to the fact that there is a limit on signal speed in any physical system according to Maxwell's electrodynamics and Einstein's Special Theory of Relativity. A natural consequence is that computation itself becomes a process in time, paving the way for notions like "information processing" which imply a step-by step refinement of information in real computer applications.

In physical terms, equations of dynamical systems may be helpful in describing and predicting computational processes. Many of the laws of physics are indeed concerned with the dynamics of interactions between natural entities, such as particles or bodies. The forces between massive particles or electrically charged particles, for instance, have been studied under this aspect and have led to an enormous body of scientific knowledge on local interactions.

A change of perspective may be helpful to see the relevance of interactions in the realm of computation. If we do not classify interactions into attractive vs.

repulsive ones, as it is done traditionally in physics, but into competitive vs. cooperative ones, we can see their usefulness immediately. For example, gravitation could be seen as a competitive interaction of gravitating masses, trying to attract other locally available masses.

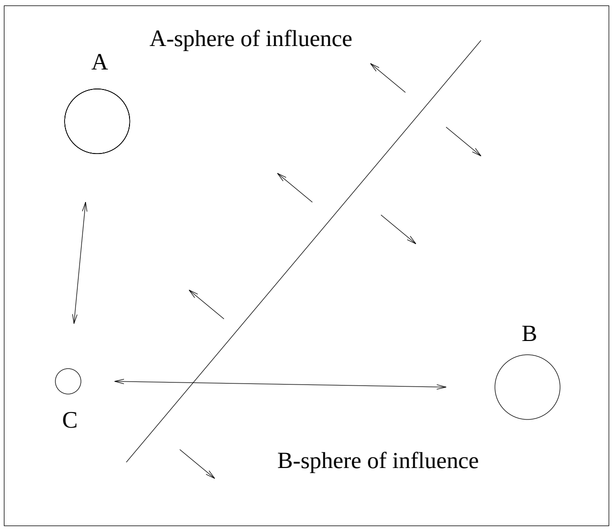

Figure 1: Two massive bodies A and B compete for C via gravitational interaction. The spheres of influence signal the borderline of their respective win in the competition.

3 Competition vs. Cooperation

Competitive interactions are very wide-spread in natural and even in artificial systems. Besides physical interactions, chemical and biological entities can be considered to interact competitively with each other. Population biology [13] as well as ecology provide useful examples of competitive interactions as do sociological systems like economy or human activities like arts or fashion [14].

On a very fundamental level, the two primary requirements for a competitive system are (i) separable entities, the agents of interaction, and (ii) limited resources. As soon as entities need access to resources, they have to interact either directly or indirectly with each other, thus constituting a sort of competition.

Cooperative interactions, on the other hand, seem to reflect a more sophisticated degree of organization in a finite system, since they require some of the separable entities to set aside their natural tendency to compete for the more abstract aim of achieving a common benefit [15].

4 Competitive Computation

Turning again to computation, we realize that Computer Science traditionally has emphasized cooperative aspects of the interaction between processing elements. We would like to argue here that it is time for a fresh look at some radically simplified competitive interactions. After all, cooperation may emerge as a higher level behaviour of some more elementary competitive processes.

In this context, the following questions pop up:
• Would it be possible to organize computation in a massively parallel computer based on competitive interactions?
• What are the separable entities that could play the role of competing entities? PEs, processes, software agents?
• What resources are limited in a computation and what could therefore serve to mediate competition? Are storage space, computation time and access to input examples?
• In what sense are today's parallel computers or software ideas already a reflection of such a competitive organization?

Without going into details, let us mention one example where it seems that competition is already realized today: In the LINDA system [16] a resource of tasks is available for computational processes. Whichever process shows up first gets access to the task and is able to block competitors from also having access to the same task. For the sake of consistency a competitive interaction of processes is implemented in this way, mediated by the resource pool of available tasks. Incidentally, competition helps to avoid redundant work represented by multiple processing of the same task by different processes.

In hypothesizing that it may be possible to set up a competitive parallel computer, what would be the simplest realization of the principle?

By answering these questions we may have also shed some new light on the problem of a symbiosis of physics and computation in general

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