Global Computing: Co-operation of Autonomous and Mobile Entities in Dynamic Environments

Consultation workshop, 21–22 September 2000

Don Sannella, LFCS, University of Edinburgh

This was an invitation-only workshop organized by the Future and Emerging Technologies unit of the European Commission in preparation for the launch of a so-called "proactive initiative" in early 2001. There are 2–3 new proactive initiatives each year, each one providing funding for a cluster of around 15 projects with a total budget of around 20Meuro. The objective of each initiative is to focus resources on a specific visionary and challenging long-term goal of strategic importance. The rules for projects are the usual ones for FET, including the requirement for partners from at least two countries of the European Union. The difference is that projects are required to contribute to the overall goal of the proactive initiative, which is chosen by the European Commission through consultation with the scientific community, and the various projects in a given proactive initiative are supposed to interact with and complement each other. For more information on proactive initiatives, see `http://www.cordis.lu/ist/fetintro.htm#proactive`.

Following a brainstorming meeting on possible theoretical topics in Brussels in January (see *Bulletin of the EATCS* 71:8–13, June 2000), the topic of "global computing" was identified as a promising one for a proactive initiative. This concerns the study of systems of interacting entities (the word "agent" is avoided since it has an existing technical meaning that is too specific) having the following three features:

1. Entities are autonomous and activity is not centrally coordinated.
2. No global information about the state of the computation is available. Information about the environment is uncertain. Any available information may be imprecise.
3. The system is dynamic in the sense that: physical components may move; entities are mobile; the number of components, their connectivity, and the bandwidth of connections may change during computation. These changes may happen unpredictably, perhaps as a consequence of component or network failure.

One large class of examples would be systems composed of mobile entities distributed over the Internet. "Active networks" are another example. A different kind of example might be a future road or air traffic management system where cars or airplanes communicate between themselves and with environment devices in order to make efficient use of the available road or air space.

This proactive initiative is now included in the draft workplan for the IST Programme in 2001 and, barring unforeseen circumstances, a call for proposals is expected in February 2001 with a deadline in May or June, for projects beginning in about January 2002. The aims of this workshop were to begin preparation of the terms of reference and background information for this proactive initiative by identifying and discussing the main research challenges in this area, and to promote awareness of this new initiative. The workshop was organized by the European Commission and was hosted by the Laboratory for Foundations of Computer Science at Edinburgh University and sponsored by the EATCS. About 45 people attended, with broad representation from the relevant research communities in Europe.

The first session began with an introduction by Leonardo Flores, the Commission official responsible for this proactive initiative. He explained the idea of proactive initiatives and the background for this particular one. They are interested in funding high-risk innovative research having a potential for high impact. The Commission regards a call for proposals for a proactive initiative as successful if the proposals attracted involve around 250–300 organizations in Europe. The budget assigned is a function of the response and quality of proposals, with a very successful call leading to a further call later on.

This introduction was followed by three invited talks. All three speakers outlined the challenges presented by the technology that is available now or will be available in the near future. The first speaker was Luca Cardelli of Microsoft Research who focussed on the distinction between synchronous interaction and asychronous interaction. In the case of local interaction, both are possible and synchronous is often more desirable. In the case of remote interaction, only asychronous is possible. Mobility can be used to turn remote-asynchronous interaction into local-synchronous interaction, an example being interaction with a Mars probe that is 8 light-minutes from Earth: real-time remote control is impossible, but one can transmit software that will perform local real-time control. The second invited talk was by Paulo Verissimo of the University of Lisbon who spoke about "informatic individuals" which are mobile, intelligent, autonomous and can perceive and control their environment. The infrastructure provided by current computing models, architectures and programming languages is inadequate for this purpose. He described middleware as a key enabling technology. The final invited talk was by David May of the University of Bristol who outlined a large number of specific challenges, including: scalability to billions of processors and communication channels and exabytes of information; programming languages capable of manipulating animations, video, audio, programs and channels as first-class objects; programming tools with concepts of location and locality built-in; "containing" programs by stopping them from engaging in dangerous forms of communication, interaction and replication; information security; etc. He pointed out that although there are theories for various kinds of concurrent system, there are no theoretical models of the large-scale properties of such systems. The slides of at least two of the invited speakers are available via `http://www.dcs.ed.ac.uk/home/dts/funding`.

The rest of the workshop consisted of three discussions sessions, each devoted to a relatively focused topic and beginning with short introductory statements intended to foster discussion. The first of these was on models and programming, chaired by Don Sannella with statements from Luca Cardelli, Paolo Ciancarini and Mike Wooldridge. The question here was how to program systems of the kind under discussion. High-level programming abstractions are required that can make it much easier to build robust systems of this kind, by focusing attention on the important aspects of the design rather than on the routine details. One way to approach this is to start by looking for a suitable model of computation, where the programming abstractions we seek will conveniently "package" aspects of the model. Since this was the first opportunity for extensive audience interaction there was a lively and wide-ranging discussion going far beyond the boundaries of the topic. The second discussion session was on efficiency and performance, chaired by Josep Diaz with statements from Paul Spirakis, Marios Mavronicolas and Jiri Wiedermann. Many issues were discussed, including: the "cost of anarchy" (selfish behaviour, which corresponds to the notion of Nash equilibrium from game theory, compared with optimal behaviour); how difficult is it to collaborate, taking into account the time required for knowledge about agents to propagate; "quality of service" guarantees and how difficult they are to achieve; locally-computable strategies for coordination problems; network control problems in a non-cooperative setting, and their equilibria; and machine models of global computing. The final discussion session was on security and resources, chaired by Paddy Nixon with statements from Steven Hand, Jörg Kaiser, Vinny Cahill and Paulo Verissimo. The main issues discussed were security and trust, in an environment where data may be anonymous and identity of entities may not be persistent. Although security was identified as a key requirement, it seemed to be generally agreed that it would probably be impossible to achieve in this context. An alternative is selective trust, perhaps via known and trusted third parties, even though opportunities to abuse trust without penalty seem to abound.

The workshop closed with a short summary by Leonardo Flores. He plans to begin working towards a call for proposals in the next few weeks. He will establish a web page soon where information will be available prior to the official publication of the call for proposals. He urged attendees to begin thinking about possible projects now rather than waiting until the call for proposals is published.

My assessment: Proactive initiatives now appear to be the main source of funding from the European Commission for genuine basic research. There is a much greater opportunity for theoretical computer scientists to contribute to this one than to previous ones. It is not yet clear whether the European Commission will fund projects that "only" attempt to gain insight through theoretical study or if consortia in which theorists attempt to solve problems thrown up by a project with practical aims will be strongly favoured. In either case, this is an exciting and very challenging area and probably the best funding opportunity from the European Commission for theoretical computer scientists for a long time. The tendency of the FET unit to come up with future initiatives requiring input from theoretical computer scientists will probably be closely related to the response to the upcoming call for proposals in terms of quantity and quality of proposals.