Keynote at the ACM International Workshop on Grid Computing and e-Science, 21 June 2003, San Francisco.

Incorporating Human Aspects into Grid Computing for Collaborative Work

Kecheng Liu
Department of Computer Science, The University of Reading
Whiteknights, Reading, RG6 6AY, United Kingdom
K.Liu@reading.ac.uk, www.reading.ac.uk/ais

The Emergence of Grid Technology and Applications

The Grid computing technology provides an infrastructure for an integrated computing environment over geographic dispersed areas which use heterogeneous computational platforms. Grids offer common resource-access and operational services across widely distributed virtual organisations (Talia 2002).

The Grid computing involves effort from various disciplines and many sectors, because of its multi-faceted technology and application. Many literatures identify these components in Grid computing:

- At the fabric level, there are local and network resources management. Local resources management: operating systems, job queuing, libraries, TCP/IP UDP, … Network resource management: computers, networks, storage systems, data sources, …
- At the middleware, there are distributed resources bound services: communication, sign-on and security, information, process management, data access, …
- There are development environment tools: languages, libraries, debuggers, monitoring, resource brokers, …
- Applications are mostly realised in the form of portals, in various fields, for example, scientific computation, engineering, collaborative work, e-science, e-business, e-learning, and e-government.

Key features observed in Grid computing are the involvement of multi-actors, large scale distributed and collaborative work in virtually present institutes and individuals on the Internet. As an enterprise involving large scale, distributed and boundary-less collaboration, Grid-based applications require access to resources (typically data, information, knowledge, and computing power). This much extended form of computer supported collaborative work (CSCW) has turned into a reality only when the Internet, distributed computing, supercomputing and other key technologies become available and gradually mature.

This paper will examine the nature of Grid computing as trusted collaboration from the viewpoint of virtual organisations. A Semiotic Framework (Stamper 1996) will be discussed as a guideline for identifying relevant issues in Grid computing. The focus of the paper will be then on understanding human aspects and on a semiotic approach to modelling the semantic, pragmatic and social issues in collaborative work. A suggested model of implementation for incorporating the human aspects into the Grid environment for effective collaborative work is presented in the end.

Virtual Organisations and Collaborative Work

Gazendam (2001, 2002) points out that in English *virtual* means essential, real, what you do not see now, but what exists in practice. This suggests that there is an essence that you cannot perceive as such but you can only see manifestations of this essence.

He also explains that in Dutch as well as in physics virtual means existent as image only, not real, what you see now but does not exist in practice. He comments that the second interpretation is more in line with philosophical approaches like nominalism and Peircean realism (Hausman 1993). So something virtual seems to be something intangible with a status between real and existing as image only. Following this, virtual is something perceptible (e.g. visible), intangible and immaterial, that we can imagine based on perceived images or practical experiences, and with which we can interact using special artefacts.

Mowshowitz (1994) coins the notion of virtual organisations using the metaphor of virtual memory of a computer. Virtual memory is a memory area that is not realised as physical memory space but as addresses referring to the places on a hard disk where data can be stored. Only when these data are actually needed, they are loaded into a special physical memory space. Therefore, this special physical memory space swaps its contents when needed, by preserving the data and jobs temporarily onto the hard disk and resuming the tasks at a later point of time. Mowshowitz's virtual organisation is based on this principle of swapping. An organisation can switch the allocation of concrete resources in order to overcome the physical constraints and be more productive than otherwise. A virtual organisation is "a temporary network of autonomous organisations that cooperate based on complementary competencies and connect their information systems to those of their partners via networks aiming at developing, making, and distributing products in cooperation" (Mowshowitz 1994).

A virtual organisation possesses several key properties:
1. Distribution of resources. Distribution of resources implies differentiation in possession of resources, competences and demands; without these, there would be no need for swapping of appropriate resources for the jobs required.
2. Collaboration between actors (member organisations, organisational components or individuals). Collaboration is essential. Bearing in mind that switching resources for sharing by more than one site, the collaboration itself leads consumption of resources. Therefore coordination between actors must be executed in a precise and reliable manner for optimisation of resource consumption and efficient execution of the jobs.
3. Shared communication protocols. All parties involved must understand each other precisely. They not only use the same language (syntax of the protocols), but also understand the meaning (semantics of communications).
4. Mechanism for task managements and executing coordinated actions. There must be mechanism for swapping between jobs, delivering resources, controlling multi-threaded operations across several sites.

These above properties enable a virtual organisation to realise its potential and maintain its competitiveness. Much resemblance exists between a virtual organisation and a Grid environment, as metaphorically they share a common conceptual model.

An Organisational Semiotics View of Information Systems

Semiotics is the study of signs that examines the nature and properties of all kinds of signs (Peirce, 1931/35). Signs are basic units for human and machine-based communication. A sub-discipline of semiotics, Organisational Semiotics, is emerging to study the properties and behaviour of signs in organisational contexts and business practice (see Liu *et al*. 2001, 2002). From the perspective of organisational semiotics, an organisation is essentially an information system. This is because in the organisations, information is created, stored, and processed for communication and coordination and for achieving the organisational objectives.

The semiotic framework (Stamper 1996) summaries all the important aspects relevant to IT systems and their effective use in an organised environment (Figure 1). The lower three levels are related to the technology or the IT platform, whereas the upper three levels are concerned with the effect of the IT systems, or human information functions.

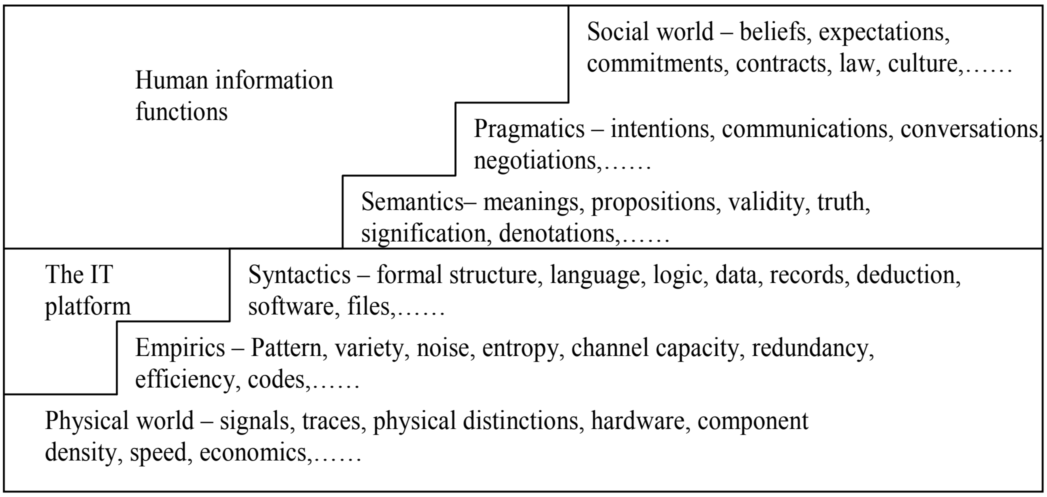

Figure 1. The Semiotic Framework (Stamper 1996)

Following the theory of Organisational Semiotics (Stamper 1973; Liu *et al*. 2001, 2002), the Grid can be studied from physical, empirical, syntactical, semantic, pragmatic and social aspects. The first three aspects, concerned with the technical functionality of the Grid infrastructure, have been studied more extensively than the other three. Our work places the emphasis on the latter three aspects of Grid, which are particularly relevant to the use of the Grid technology. The semantics of the Grid refers to behavioural aspects, such as functionality, available services, service properties and technical constraints. It includes all possible behaviours of service available within the Grid and of the service request. (We call these *repertoire of behaviour*, *patterns of behaviour*, or *affordances* - Gibson 1979) Pragmatics is concerned with how the Grid is used in business practice, particularly relevant issues being collaboration processes and degrees of accesses (determined by responsibility, obligation, right and privilege). The social aspect is concerned with institutional policies, organisational guidelines, cultural patterns and accepted practices, particularly within a local user community.

The Human Aspects of Grid Computing

Much work can be found in Grid fabric, middleware and programming tools for developing Grid applications (e.g. Foster et al. 2001, 2002; Laszewski 2002). These correspond to the issues characterised in the lower three layers in the Semiotic Framework in Figure 1. Meanwhile a need for methods for the semantic, pragmatic and social aspects of the Grid computing has been identified (Liu and Harrison 2002). The development of these methods has been based on the early work on information systems (Liu 2000, Stamper 1973, 1996) and computer supported collaborative work (Liu *et al.* 2001). The methods are intended to assist systems designers to understand and specify the users' requirements for Grid services, taking into account the tasks, objectives and even intentions of the users in the context of large scale and multidisciplinary collaborations. These requirements models will enable the services available and role-based access levels within the Grid to be specified and incorporated into the service delivery and management mechanism.

Semantics in Grid computing often refers to the programme semantics. They are normally represented and implemented directly as part of the service, or provided via a library linked to the application. Typically, external services do not provide semantics beyond those the operating system provides. Thus, Foster *et al*. (2002) recommend that each application must have functions of semantics and lifetime management. To achieve this, a strong mapping must be established between computational behaviour and human behaviour. Therefore a semantic model to capture the behaviour of human users in the business domain is the foundation, and the mapping mechanism can assist derivation of the computational semantic models. The semantic analysis and specification must cover both provision and exploitation of Grid resources by representing the behaviour of the providers and requesters. The semantic models then directly define the resource management mechanism for detection, allocation, creation and lifetime management of Grid services.

The pragmatic aspect is not often studied explicitly in Grid Computing, thought some work has been seen in this area (e.g. Grove 2003) as its importance has been increasingly seen. Pragmatics is concerned with understanding of the business context of the users and the support for collaborative work. It involves modelling the roles and access to Grid services according to users' responsibility, obligation, right and privilege. Identification of roles of all registered users involved and determination of major collaboration processes will lead to an effective resource access and control model. Linking to the resource access and control model, members within the Grid environment can act as if in a virtual organisation, and resources can be shared across multiple heterogeneous platforms for collaboration.

The social analysis involves modelling of the social, organisational and cultural rules that govern the use of the Grid. The institutional policies and accepted common practice in a community may have a profound impact on the conduct of collaborative work through certain workflow and collaboration processes. Perceived benefits and drawbacks may influence an institution to promote or to inhibit collaborative practices. When building a virtual organisation to achieve collective benefits, we must understand an institution's positions and policies. On the basis of this understanding, we must identify essential rules of the institute and incorporate them into the e-infrastructure to promote the sharing of resources within the virtual organisation while the individual institution's interest and integrity is maintained.

Modelling the Human Aspects

Using the terminology of semiotics, the computational behaviour, exhibited in the forms of system functionality, is *representamen* of some *object* . The semantics is the relationship between the representamen and the object, established by *interpretant*. The challenge in computation is caused by the subjectivity of the relationship, i.e. given an object, different person may interpret differently therefore derive a different meaning. This is more evident in Grid computing as it involves multiple stakeholders working in a shared environment.

To overcome the subjectivity of semantics, one may have to integrate the pragmatic and social aspects into the model. This is achieved in a semiotic process (i.e. semiosis) of knowledge engineering. Figure 2 illustrates how the social interaction determines the pragmatic and semantic processes. The relationship between the computational behaviour and human behaviour is the semantics; while the pragmatics is captured in the processes of denotation and connotation. The social aspect rests on the top of the triangle. The whole semiotic process is governed by the subjective knowledge of business domain and organisation, and cultural and institutional rules. The individual's position in the organisational and work setting in turn defines the role and responsibility when he/she is involved in collaborative work using the Grid infrastructure.

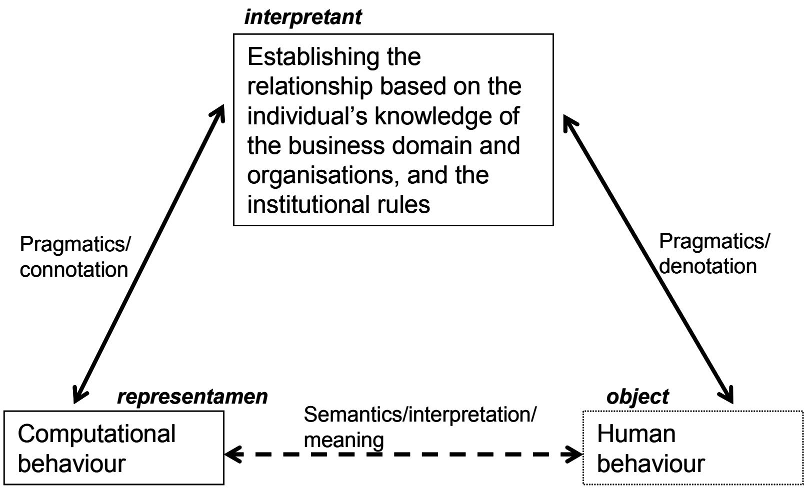

Figure 2. Integrated modelling of semantic, pragmatic and social aspects.
The dotted line between the computational behaviour and human behaviour indicates the subjectivity of the interpretation.

Embedded the Human Aspects into the Grid Computing

The effectiveness of the Grid computing can be enhanced by incorporating the integrated model of semantic, pragmatic and social aspects (SPS model) into the Grid infrastructure, as proposed in Figure 3. The portals provide an access point of entry which allows integration and sharing of information and data, application and services by the users (Laszewski 2002).

In the proposed model of implementation (Figure 3), each user, or user group if they share an agent, will have an SPS model in which their roles, responsibilities, tasks, objectives and intentions are represented; all application services available in the Grid will be described in one SPS model in terms of functions, abilities, access limit and constraints. Information/data sources in the Grid will be described in another SPS model in terms of contents, access allowance and privilege required. Finally, the behaviour of the portal itself is defined by an SPS model. All these SPS models specify the semantic, pragmatic and social properties and constraints imposed on those entities. Users can be geographically distributed. Collaborative work within the Grid environment will be supported by agents and other components, as explained below.

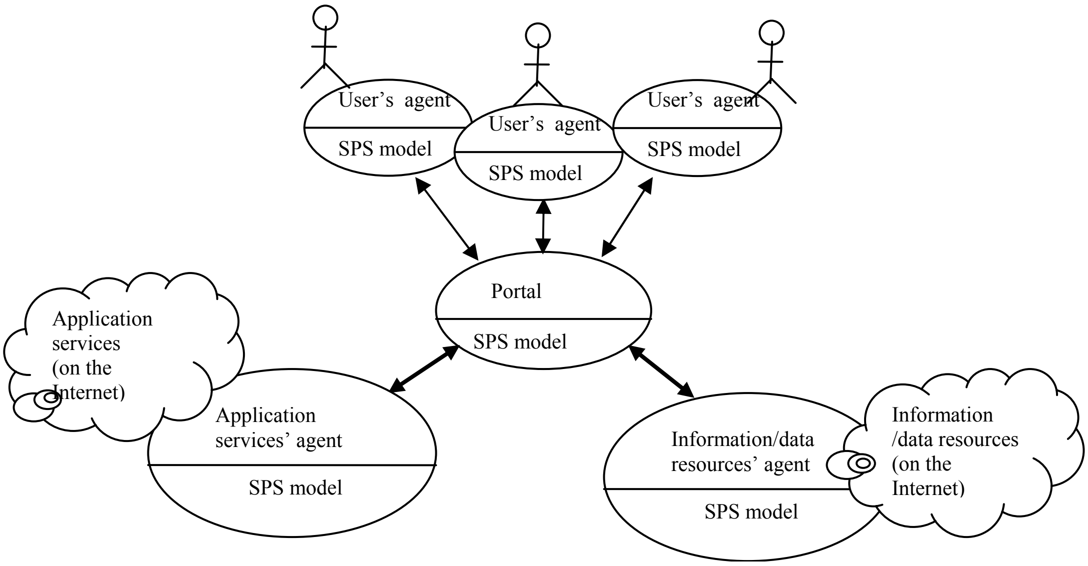

Figure 3: Incorporating the human aspects to the Grid infrastructure.

User agents – to capture and interpret the user's requests. The SPS model – an ontology representation with extended specifications of responsibility and institutional norms, defines the user's roles and behaviour.

Application services – the SPS model specifies all the services available on the Grid, with extension of responsibility and social/institutional constraints.

Information/data resources – the SPS model specifies the location and availability of these resources with extension of social/institutional constraints.

The portal – the portal itself makes reference to the SPS model which serves as policies for defining levels of access (typically responsibility, obligation, privilege and right). It will allocate and manage the Grid services.

Summary and Future Work

The Grid computing offers a great opportunity for collaborative work in a secure and trusted environment that shows clear advantages over other information and communication technologies. The Grid technology has dramatically shortened the distance between our daily practice and the notion of a virtual organisation. The impact of such an emergent technology and its application in all domains of science, engineering, research, education, business, governance and commerce is significant. However, much current work has mainly focused on the technical aspects of the Grid computing, and there is a need for effective methods for dealing with social and organisational issues.

Organisational semiotics offers a theoretical basis for developing methods for analysing and capturing semantic, pragmatic and social issues in requirements models for Grid supported collaborative work. Incorporating the human aspects into the Grid infrastructure will enhance the effectiveness of Grid supported collaborative work within the virtual organisational settings. The model of implementation for Grid supported collaborative work is being prototyped for validation and demonstration.

References

Grove, J. (2003), Legal and Technological Efforts to Lock Up Content Threaten Innovation, CACM, 46(4) 21-22.

Foster, I., C. Kesselman, S. Tuecke. (2001), The Anatomy of the Grid: Enabling Scalable Virtual Organizations. International J. Supercomputer Applications, 15(3).

Foster Ian, Carl Kesselman, Jeffrey M. Nick, Steven Tuecke (2002), Grid Services for Distributed System Integration, CACM, June, 37-46.

Gazendam, H. W.M. (2001), Semiotics, Virtual Organisations, and Information Systems. In: Kecheng Liu. Rodney J. Clarke, Peter Bøgh Andersen, and Ronald K. Stamper (eds.). *Information, Organisation and Technology: Studies in Organisational Semiotics.* Boston: Kluwer Academic Publishers: 1- 48.

Gazendam, H. W.M. (2002), Information System Metaphors, *Open Semiotics Resource Center: The Semiotic Frontline*, www.semioticon.com, 25 pp.

Gibson, James (1979), The Ecological Approach to Visual Perception, Houghton Mifflin, Boston

Hausman, C. R. (1993), Charles S. Peirce's Evolutionary Philosophy, Cambridge University Press, Cambride.

Laszewski, G. v. (2002), Grid Computing: Enabling a vision for collaborative research, accessible from: http://www.globus.org/cog/documentation/papers/

Liu, Kecheng (2000), *Semiotics in Information Systems Engineering*. Cambridge University Press, Cambridge.

Liu, Kecheng, Rodney Clarke, Ronald Stamper, Peter Anderson (editors) (2001). *Information, Organisation and Technology: Studies in Organisational Semiotics - 1*, Kluwer, Boston.

Liu, Kecheng, Rodney Clarke, Peter Anderson, Ronald Stamper (editors) with El-Sayed Abou-Zeid (2002), Organizational Semiotics: evolving a science of information systems, Proceedings of IFIP WG8.1 Working Conference, Kluwer, Boston.

Liu, K. and R. Harrison (2002), Embedding "Softer" Aspects into the Grid (Poster), Proceedings of EUROWEB 2002 - The Web and The GRID: from e-science to e-business, St Anne's College Oxford, 17-18 December 2002. Eds: Brian Matthews, Bob Hopgood, Michael Wilson, The British Computer Society, pp179-182.

Liu, Kecheng, Lily Sun, Alan Dix & Mohan Narasipuram (2001), Norm Based Agency for Designing Collaborative Information Systems, *Information Systems Journal*, 11, 229-247.

Mowshowitz, A. (1994), Virtual Organisation: A vision of management in the information age. The information Society, 10(4) 267-288.

Peirce, C.S. (1931-35), *Collected Papers (1931 - 1935)*, edited in 1960 by Hartshorne, C. and Weiss, P., Harvard, Harvard University Press.

Stamper, R.K. (1973), *Information in Business and Administrative Systems,* Wiley, New York and Batsford, London.

Stamper, R.K. 1996, Signs, Information, Norms and Systems, in Holmqvist, P., Andersen, P.B., Klein, H. and Posner, R. (Eds.), *Signs of Work,* Walter de Gruyter.

Talia, D. (2002), The Open Grid Services Architecture: where the Grid meets the Web, IEEE Internet Computing, Nov/Dec, hppt://computer.org/internet