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Summary

The concurrent engineering objective in the multidisciplinary virtual enterprise to co-ordinate parallel business processes is often hampered by deficiencies in exchange and interpretation of information. Important factors for this deficiency are related to the intrinsic complexity of state of the art computer networks, such as network heterogeneity and security measures such as firewalls. In this paper the software system SPINEware is described, which provides a framework to effectively deal with the particular problem areas related to the complex computer networks in multidisciplinary virtual enterprises. To illustrate the merits of SPINEware, the multidisciplinary and concurrent engineering aspects of several international projects in which SPINEware has been used successfully will be described.

Keywords

Knowledge management, middleware, metacomputing, heterogeneous computer networks

Contents

(13 pages in total)

1 Introduction

In concurrent engineering (CE), effective co-operation within and between concurrent business processes relies on a good common understanding of the results of each of these processes by all people involved, and on the seamless integration of these results (Syan and Menon, 1994). This can be facilitated by common ways of working in each of the processes. However, the common working environment for the people involved, which should provide the necessary structure for the common way of working, is often inadequate. Some of the reasons are the different company, division, or even department dependent methods, tools and standards that are used, which are mostly related to a specific discipline. Therefore, for example, the European aeronautical industry, which comprises a highly multidisciplinary consortium of companies, develops common ways of working in the ENHANCE project (ENHANCE, 1998). This is a massive task because it involves nearly all aspects of the complex aircraft lifecycle. Hence in ENHANCE a separate supporting work package has been initiated, which is dedicated to providing methodologies and guidelines for implementation of CE. In European aeronautical industry, being technologically highly advanced and geographically dispersed, Information and Communication Technology (ICT) is an indispensable vehicle for implementation and application of CE methodologies.

One of the main cornerstones of the CE business approach is the ICT infrastructure of the virtual enterprise. The objective in CE to seamlessly integrate the results of parallel business processes requires effective exchange and interpretation of information to ensure efficient co-ordination of these processes and co-operation within and between these processes. The virtual enterprise's ICT infrastructure is essential for facilitating this information exchange among, and interpretation by, each of the involved different disciplines. On the other hand the ICT infrastructure may hinder the exchange and interpretation of information, due to the intrinsic complexity of state of the art computer networks related to, for instance, network heterogeneity and security measures like firewalls.

Consequently, to be successful, the multidisciplinary virtual enterprise faces the situation in which, on the one hand, it strongly depends on state of the art ICT infrastructure, and on the other hand, it has to handle properly the complexity of this ICT infrastructure. It is therefore argued that the problems arising from this complex ICT infrastructure must be well controlled and effectively dealt with. In this paper the particular problem areas in multidisciplinary virtual enterprises are addressed, and a software system that is specifically designed to deal with these problem areas is presented. A user-oriented approach, instead of a computer-system oriented approach, is proposed to take most advantage of the available ICT infrastructure, and exploit the resources in it.

2 Computer networks in multidisciplinary virtual enterprises

Computer networks nowadays form an important backbone of CE. Co-operation between engineers and enterprises - irrespective of geographical location - usually starts by making arrangements for management of the information involved, for controlling the exchange of information among engineers, and for joining the engineers' expertise and the enterprises' computing power. This heavily involves the definition of the computing infrastructure of the virtual enterprise, in which engineers from different disciplines have to work together. Although present hardware and software provides support for establishing the required infrastructure, the users usually get confronted with the technical details of the underlying computing systems and networks. The situation within a single enterprise does actually not differ much from the multi-enterprise case. In order to be more competitive, an enterprise must constantly invest in its computing infrastructure to work more efficiently and to lower the cost of engineering and know-how management. To increase the computing power, new computers, network components and software products are added, and old systems get replaced by faster, more advanced, and fancier ones.

These innovations unfortunately lead to an increase of the complexity of the computing systems. The complexity not only concerns the hardware and system software, but also the end usage. Engineers are usually faced with technical, low-level details emerging from usage of the individual computing systems and the networking involved. Even worse, engineers, who are not computer experts in general, constantly need to familiarise with the ever expanding and changing computing infrastructure, which usually leads to inefficient resource usage. Also, an enterprise – either or not virtual –, using the infrastructure for managing the processes and competence, may suffer from the complexity and the inefficiency arising from it.

The three most significant characteristics that contribute to the complexity of today's computing infrastructures are distribution, heterogeneity, and system-level – instead of user-level – integration (Baalbergen and Van der Ven, 1999). *Distribution* involves all aspects resulting from the infrastructure being a network of interconnected computers. In practice, the infrastructure forces the end user to be aware of the fact that several computers are, and usually must be, involved in the engineering process. For example, for a particular engineering simulation, pre- and post-processing is usually performed on graphical desktop systems, whereas the computing is assigned to a mainframe or supercomputer. Inter-enterprise networking also gives rise to security issues, such as firewalls, authentication, and encryption, which may burden the engineer with even more complexity arising from extra measures to be taken. *Heterogeneity* concerns the confrontation of the end user with a variety of hardware (e.g., byte ordering, sizes and ranges of numerical values), computer systems varying from highly interactive desktop systems to batch-driven number-crunching super computers, operating systems (e.g., Windows, Linux, and UNIX in many different flavours), applications, and data

formats. *Integration at the system level* – as opposed to the user level – refers to the availability of a large set of low-level utilities that indeed support the usage of interconnected computers (e.g., FTP for exchange of files, TELNET for remote login, and SAMBA for sharing files systems). However, these utilities still leave much detail to the end user or cover only part of the networking details.

SPINEware aims to provide a coherent and total solution for the low-level details emerging from distribution, heterogeneity, and system-level integration (Baalbergen, 1998). Its approach is to provide users involved in the multidisciplinary process, such as engineers, project managers and support staff, with an application and end-user oriented, easily customisable, single computer (metacomputer) instead of a system-oriented network of stand-alone computers to which the user must adapt himself or herself. The metacomputer, being tailored for the user, contributes to easy and efficient operation, and hence to acceptation, of new systems by novice as well as expert users.

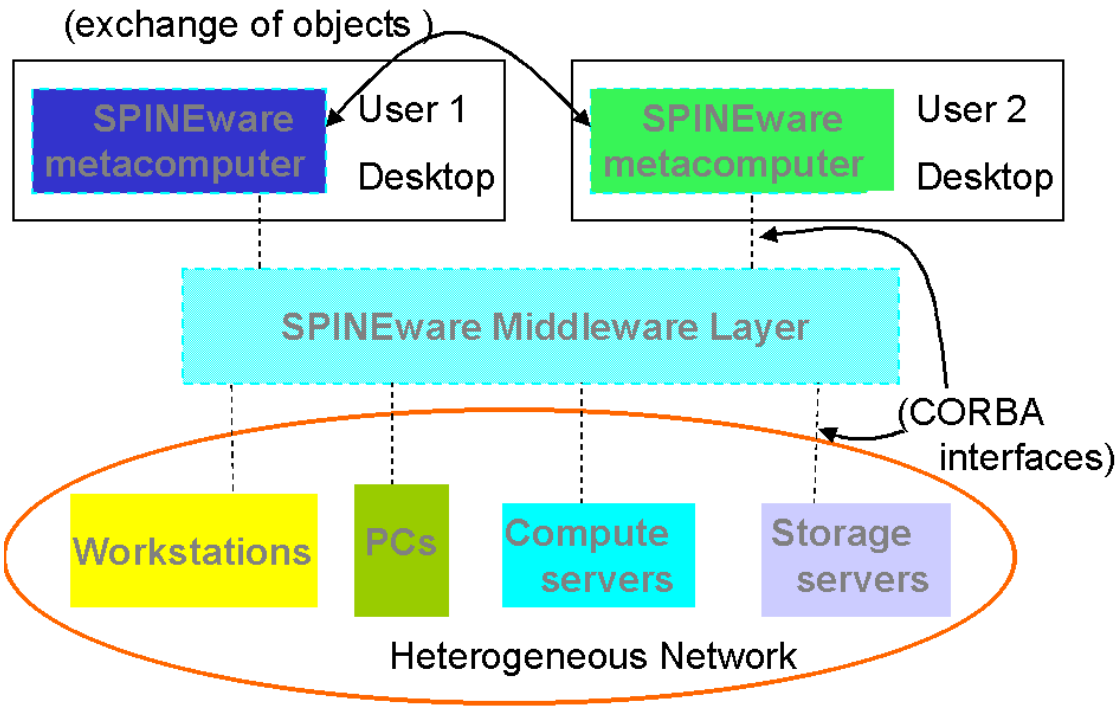

Figure 1 SPINEware provides user-oriented metacomputers

Moreover, the metacomputer enables an enterprise to preserve, reuse, and even accumulate its engineering knowledge, thus allowing an enterprise to be competitive and to deal with floating staff. As such, the metacomputer is an indispensable tool to support the business processes.

3 SPINEware

SPINEware is a facility that provides and combines tools and middleware software to support the construction and usage of working environments on top of heterogeneous computer networks (Baalbergen and Van der Ven, 1999). A working environment realised using SPINEware presents a local- or wide-area computer network as a single, easy to use computer on the user's desktop computer. This working environment, or metacomputer, provides uniform and network-transparent access to the information, applications, and other resources available from the computer network. A SPINEware-based working environment may be tailored to particular end usage and application areas. Its graphical desktop system enables its user to operate the metacomputer via point-and-click and drag-and-drop operations on icons in windows, instead of command-line based, system-oriented style as yet found in many engineering environments.

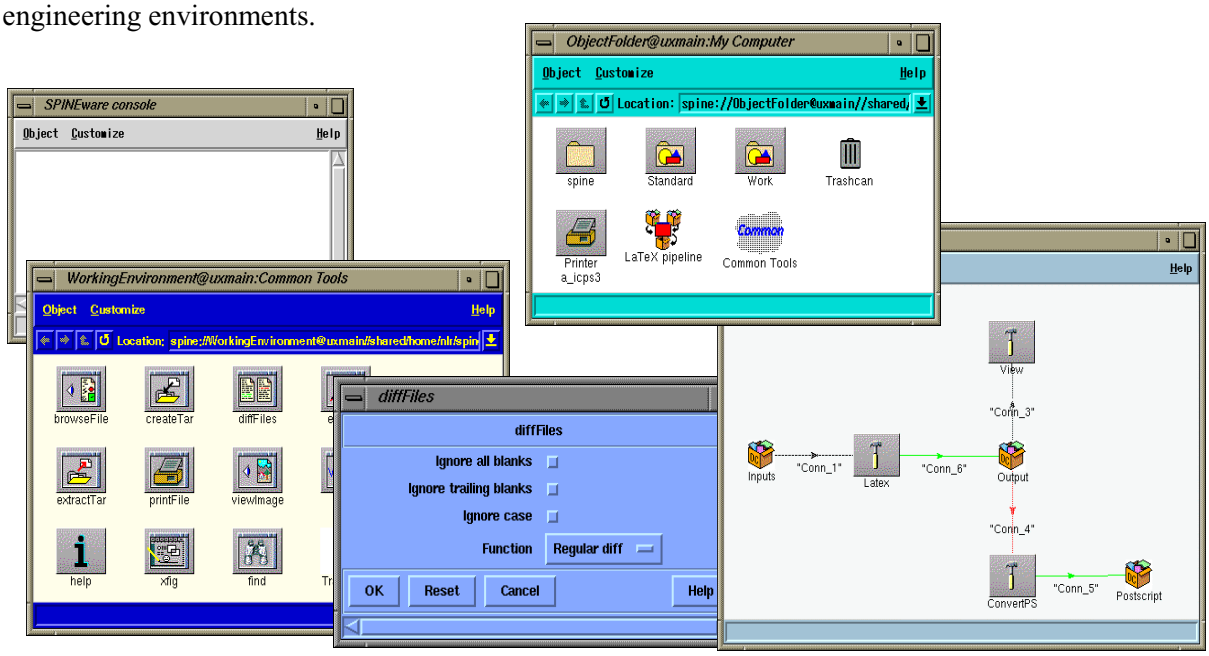

Figure 2 Example of some components of the SPINEware GUI

The metacomputer may also be accessed via the Web interface, which enables remote access through native Web browsers. The metacomputing capability, the tailoring facilities, and the user-oriented desk top system capabilities enable the realisation of powerful and easy-to-use application environments that enable non-computer experts to fully exploit the potentials of the underlying computer infrastructure.

To support flexibility, openness, and easy extendibility of SPINEware as well as the SPINEware-based working environments, state of the art technologies and software are applied. In particular, the CORBA (Common Object Request Broker Architecture) standard is applied to facilitate the integration of commercial and other third-party software and to reuse the object-

oriented support and communication services provided by software implementations of the standard. A SPINEware-based working environment provides a suitable basis for the realisation of the computing infrastructure of virtual enterprises, since the underlying network may span several enterprises, irrespective of geographical distribution and computing network size.

4 Multidisciplinary, multi-site and multi-company collaborative work

The on-going tendency towards the CE business approach in industry requires a continuous effort to intensify multidisciplinary co-operative ways of working. In large high tech industry like the aeronautical industry, this development is not restricted to only different collocated departments within companies, but is more oriented towards multi-site, and even multi-company, multidisciplinary collaboration. For each of these aspects, specific complications regarding the ICT infrastructure, as mentioned in section 2, arise. As such, multi-site work typically requires distributed networks, with the heterogeneity and transparency issues related to it. Multi-company work requires use of wide-area networks, with the typical security and accessibility issues. Multidisciplinary collaborative work requires effective facilitation by collaborative working environments. The first two aspects have been addressed in the SPINEware system description in section 3. The following sections describe how SPINEware has been, and still is, successfully used to support multidisciplinary collaborative work.

5 MDO - Multidisciplinary Design and Optimisation

In the early 1990's it was already recognised that the way forward in European aeronautical industry was by application of CE principles in order to both improve aircraft design and development processes, and reduce development time scales and costs. The MDO project (Allwright, 1996; MDO, 1996) was launched in 1996 with the purpose to demonstrate the viability of an integrated engineering environment for multidisciplinary design, analysis, and optimisation of simplified but realistic large civil aircraft. The main disciplines involved were aerodynamics, structural mechanics and ICT. The latter was mainly responsible for the coherence of the activities. This was achieved by implementing the ICT procedures used in each of the disciplines into a single coherent MDO engineering environment, which was based on SPINEware. Important to note is that this engineering environment was developed concurrently with the on-going design activities, and was made available to all partners involved.

In the MDO project it was recognised that the most relevant aspects of concurrent multidisciplinary design, as opposed to the sequential mono-disciplinary approach, were to accurately capture the MDO process, to decrease dependency on individual team members, and

to provide control mechanisms on different levels of the calculation process (Vogels et al., 1998a). SPINEware offered the functionality and the flexibility to account for each of these aspects in the MDO engineering environment. An important conclusion from the MDO project was that, due to the required iterative improvements of the MDO process, ICT is not just supporting the other disciplines but is one of the MDO core activities. Other interesting conclusions were that the use of integrated product models and automatic multidiscipline model generators was essential for the different disciplines to collaborate effectively, and that the open and flexible engineering environment was essential for the integration and exchange of data and processes (Vogels et al., 1998b). These aspects are supported by SPINEware.
The experiences from the MDO project will be further exploited in other projects, in particular the MOB project (MOB, 2000). This project focuses on the development of a computational design engine (CDE) for multidisciplinary design and optimisation, applied to blended-wing-body aircraft configurations. Like in the MDO project, in MOB an integrated engineering environment, the CDE, will be developed based on SPINEware. The aim in MOB, however, is to develop the CDE as a single environment accessible from different sites of different partners, and supporting more integrated analysis and automated data exchange on the basis of STEP.

6 Enhanced Aeronautical CE: The ENHANCE project

Later in the 1990's even larger scale CE initiatives were put in place. In the aeronautical sector the ENHANCE project, launched in 1999, is about the largest in size. The full range of the aeronautical life cycle is addressed, with emphasis on the development process. Common ways of working are to be developed and agreed upon by all industrial parties involved. This large scope allows for global investigation of more generic business processes, which, when considered in more detail, can become quite complex. In the context of complex multidisciplinary business processes, workflow management systems are generally considered as adequate control mechanisms. Many different workflow management systems are currently commercially available and in use in industry. Two main issues that arise from this situation are under investigation in the ENHANCE project: how can the different workflow management systems currently in use, best be integrated into the virtual enterprise? And how can the used engineering tools be easily integrated into that workflow environment?

7 Workflow management support for business processes

ICT integration as facilitated by SPINEware is a pre-requisite for supporting the CE business process. In addition, multidisciplinary CE business processes, which are characterised by many

parallel activities with complex interdependencies, require tools for managing the process itself. Here workflow management systems emerge. A workflow management system provides procedural automation of a business process by managing the sequence of activities and invoking the appropriate human and ICT resources associated with the various steps of the business process (Workflow Management Coalition, 2000). The workflow system should provide a shared and up-to-date process view across the various companies and disciplines involved within the business process. In order to be effectively used, a workflow management environment should also provide facilities for easy integration of the engineering tools that are being invoked by the process, and the engineering data that is created and used in the process, independent of their location within the Virtual Enterprise. SPINEware offers facilities to end-users to easily integrate their software tools that are required in the end-user's workflow process via intuitive graphical user interfaces.

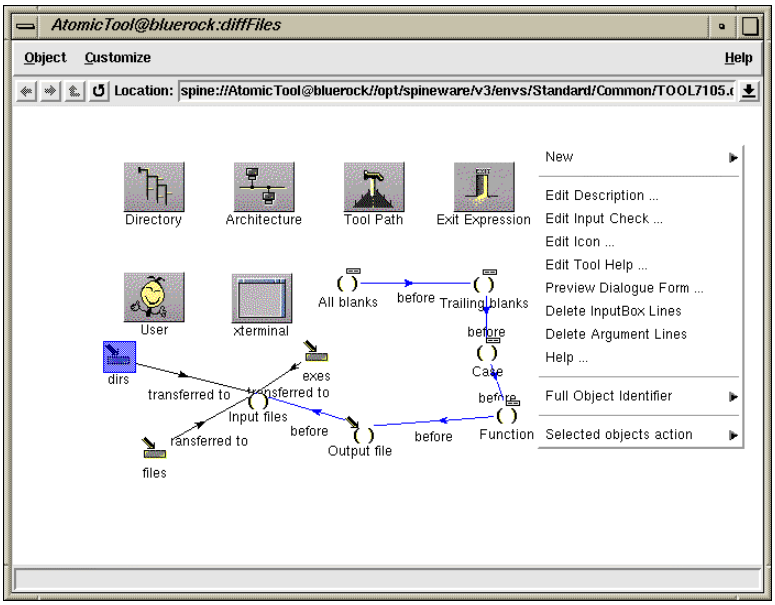

Figure 3 SPINEware offers an intuitive GUI for easy integration of engineering software tools

In addition SPINEware offers facilities to end-users to easily compose, edit and execute automated workflows their integrated their software tools that are required in the end-user's workflow process via intuitive graphical user interfaces.

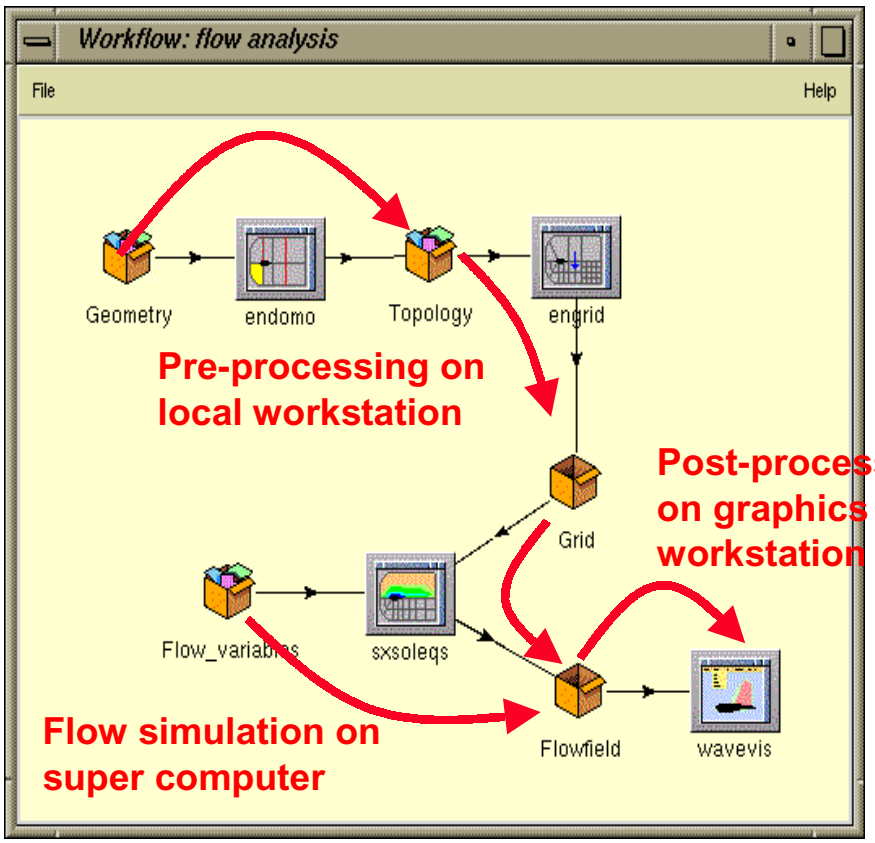

Figure 4 Easy composition and automatic execution in heterogeneous network of engineering workflows

Also third party tools like complete workflow management systems, can be easily connected to the SPINEware environment via the CORBA-concept based SPINEware interface.

Thus SPINEware can be used as one of the building blocks of an enterprise-wide workflow management environment in order to control the use of the engineering tools and to access the data anywhere in the network.

Recent developments at NLR have resulted in such an integrated workflow management environment by linking an engineering workflow system to the SPINEware middleware environment. This CoSpine environment will be evaluated in the ENHANCE project. The ENHANCE project, as described before, is aiming at improving the European aeronautical industry competitiveness by streamlining and defining the best practices through the whole supply chain when developing and producing a new aircraft. One of the main objectives of ENHANCE is to define the new common ways of working in Europe for aeronautical product development throughout the entire lifecycle of the aircraft, and throughout the whole aeronautical supply chain. State of the art ICT, and in this context more specific, workflow management technology is needed to support the CE environment developed within the

ENHANCE project. One of the ENHANCE activities led by NLR is the development of a multi-company workflow management environment for this purpose.
Besides the need to be able to access the engineering tools and data involved within the process, interoperability between different workflow management systems is also a critical issue in such a multidisciplinary and multi-company environment, because participants of the CE business process stick to their own workflow management system. This issue has been recognised by the Workflow Management Coalition, and they propose standards for interoperability of distributed and heterogeneous workflow management products. Within ENHANCE some of these proposed standards will be deployed, the final goal being to demonstrate that independent, heterogeneous workflow management systems can co-operate on a common business process that is being distributed across the distant sites of the virtual enterprise. The benefit for the participants of the workflow process is that the decision on the choice of their workflow management system is less business critical because companies can still use the workflow management system adopted for their internal work for co-operation in a multi-company environment. CoSpine will be included and demonstrated within the ENHANCE multi-company workflow management environment.

8 Conclusions

SPINEware has proven in several multidisciplinary multi-partner projects to provide solutions to several critical problems related to the complexity of state of the art ICT infrastructures. Because state of the art ICT infrastructure is considered as a key process area of the multidisciplinary virtual enterprise, it is essential to have good control over the ICT infrastructure and to fully exploit its possibilities. SPINEware offers the facilities to achieve these goals. As an illustration some examples of these facilities offered by SPINEware have been presented in this paper.

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