

PGPGrid Virtual Organisation Report

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1 Introduction

This report describes a study of Virtual Organisations (VOs) in the animation industry. In particular, it focuses on the Pepper's Ghost Productions Grid (PGPGrid) VO.

The aims of the PGPGrid VO are briefly introduced in Section 1.1. An introduction to the concept of the VO and how various VOs work, particularly in the animation industry, is then given in Section 2. Simple case studies of VOs are presented in Sections 2.3 to 2.5. The use of Information Technology (IT) and other collaboration-enabling technologies in VOs, is also described. The report goes on to describe the details of the PGPGrid VO in Section 3. The requirements of the PGPGrid VO are described in Section 4, which includes a set of recommendations to fulfil those requirements. Finally, the experiences of the PGPGrid VO are presented and conclusions drawn, in order to provide useful feedback and guidelines for future VO construction and management, to the e-Science community and the animation industry in particular.

This report is the deliverable of *Work Package 1* of the PGPGrid project, which is described in the PGPGrid project proposal [1]. It was written between September 2003 and February 2004, and will be updated with the experiences of the PGPGrid VO before the end of the project in December 2004. The final version of this report will include a study of animation-producing VOs.

1.1 The PGPGrid Project

The PGPGrid project is a collaboration between:

- Pepper's Ghost Productions Ltd. (PGP) [2];
- 3D-Matic Laboratory of The University of Glasgow (3D-Matic) [3]; and
- EPCC of The University of Edinburgh [4].

The PGPGrid VO aims to apply Grid technologies to the production of Computer-Generated Animation (CGA), where a unique method of motion capture is applied to the animation process. This endeavour will enable the VO to study the feasibility of this approach to CGA and the possible impact of Grid technologies on this industry.

The idea behind the Grid is to bring consumers and providers together in a coordinated manner, such that the provision of computing can be modelled on that of other utilities such as water, electricity and telephony.

More specifically, the aims of the PGPGrid project are to determine:

- whether or not the formation of VOs, such as the PGPGrid VO, is a feasible method for future CGA production;
- whether the unique motion capture technology offered by 3D-Matic can be used within an animation VO as part of the animation process; and
- whether it is possible to undertake the animation processes required by 3D-Matic and PGP within a Grid environment using Middleware technologies such as the Globus Toolkit [5].

With respect to utilising a Grid environment, the intention is to determine whether this will enable the use of distributed, and perhaps heterogeneous computing resources. In addition, whether these processes may be controlled remotely when run on such a Grid. And finally, to identify the particular customisations that are required to take advantage of a Grid environment.

Further background on the project partners, details of their roles in the VO, and additional information about the PGPGrid project, are contained in Section 3 and in the PGPGrid project proposal [1].

2 Introduction to Virtual Organisations

In the 1990s, the term *Virtual Organisation* became a buzzword in organisation management studies. Today, the VO is widely recognised as an important phenomenon in the areas of sociology, IT, and commerce, amongst others. Many publications provide useful definitions of VOs and attempt to categorise their attributes. A list of such resources is presented in the Appendix.

Although VOs can take many forms, a general set of attributes can be used to define and motivate a VO. These attributes include:

1. **Composition:** A VO is composed of a group of self-governing bodies, or members, such as organisations, businesses and even individuals. Within the VO, however, these members may be mutually governed by a set of VO policies and rules.
2. **Member Roles:** The spectrum of member roles includes VO administration and management, service provision, supply, consumption, and so on. The spectrum of roles found in any one VO is dependent on its nature and purpose, be it a manufacturing supply chain involving suppliers, manufacturers and haulage companies, or a commercial business activity involving investors, bankers and insurers.
3. **Membership:** The composition of a VO can encompass not only the VO members as defined in 1, and by their roles as defined in 2 above, but also the resources of the VO members, including machinery, computing resources (hardware, software, and applications), finances, human resources, legal rights, and so on. Even individual VO policies and VO deliverables may be considered as VO resources or entities, and therefore, form part of the membership of the VO.
4. **Competencies:** The bodies that compose a VO each have distinctive capabilities that stem from their core competencies. The amalgamation of these distinctive capabilities is a key motivation for the formation of the VO. In addition, the sharing of core competencies between VO members can be mutually beneficial as VOs can then develop new distinctive capabilities.
5. **Goals:** The purpose of the VO is to achieve a shared objective or set of goals, which are mutually beneficial. Each VO member works for the benefit of themselves and the other VO members.
6. **Reacting to Market Opportunities:** VOs are often formed as a result of a new market opportunity, which individual VO members could not take advantage of on their own. It is therefore the case that such VOs disband after the exhaustion of that market opportunity.
7. **Competitive Advantage:** VOs can gain considerable competitive advantages by sharing resources, cutting costs, and improving efficiency and productivity.
8. **Use of Enabling Technologies:** VOs benefit greatly from the use of enabling technologies in communication and collaboration. In recent years, it is becoming evident that novel computing technologies are allowing distributed collaboration and resource sharing on very large scales. For example, it is common today to find scientific collaborations of hundreds of individual scientists from various academic institutions and industrial sectors distributed worldwide, working toward a common end-goal, and using ubiquitous networking technologies including e-mail and video-conferencing. More sophisticated computing technologies, such as the emerging Grid technologies, will allow not only enhanced communication, but also the coordinated and coherent sharing of data, software applications and resources for increased computing capability.

The idea of organisational collaborations and virtual partnerships is nothing new, however. The fact that organisations, businesses and government departments operate within various levels of collaborative partnership, is well recognised in society. So what is it that makes the idea of VOs new?

The increasing use of IT in the 1990s and the development of the Internet and the World Wide Web (Web), combined with the popularity of e-mail, have eased collaboration and intra- and inter-organisational communication. Software applications and tools allow the sharing of data and information as never before. It is perhaps this new development that distinguishes today's VOs from other collaborative environments, such as a manufacturing chain, where each link in the chain is organisationally distinct, yet contributes in a collaboration to achieve one end.

So, VOs are cross-organisational collaborations that utilise innovative IT infrastructures. Why is the existence of VOs important today? Well, the wide availability of IT in today's working environments and the ubiquity of the Internet, have meant that increasingly collaborations are more loosely bound and more flexible. This has led to a radical change in working practices. There is a requirement on organisations to react quickly and effectively to new market opportunities. As a result of this, new challenges are being met more readily and technical and scientific difficulties are being overcome by pooling effort across distinctive domains.

These less rigid collaborative structures, which are formed from distinctive organisations and their resources, will lead to an increase in the speed with which VOs form in order to take advantage of emerging market opportunities. Although still governed by mutual sets of VO policies, the formation of collaborative VOs will allow independent organisations to come together more dynamically, without the need for mergers and acquisitions, or over-complicated legal obligations.

This new model of collaboration will require infrastructure support. The emerging Grid paradigm and technologies promise to evolve the current Internet and related computing infrastructures to provide the support that modern collaborations require. Grid technologies will enable VOs that are formed from independent, autonomous members, to come together to form single virtual entities, sharing data and knowledge in a coordinated and coherent manner.

2.1 The Use of Collaboration Technologies in Virtual Organisations

VOs use collaboration technologies, of which IT comprises a large percentage, to share data and for information accumulation and dissemination. The sharing of data and information between its members is a crucial aspect of the work of any VO, if that VO is to be successful. Without it, VOs could not exist and VO members would regress to being individual autonomic entities.

Traditional collaborative technologies for fast data exchange and information dissemination include the telephone and facsimile. More advanced tools include telephone- and video-conferencing, e-mail, and the medium of *Chat*, which allows on-line users to communicate real-time using a typed text interface. These technologies, however, mostly exist to facilitate human interaction and communication. In order to provide data-sharing and the management of shared computing resources, one must look to the tools and software that exist or are being developed for distributed computing.

The current research and development efforts in Grid technologies has added a new dimension to distributed computing. It has moved the distributed computing paradigm to a more loosely coupled model, where private computing resources within self-managed, independent administrative domains, can be shared and used across organisational boundaries. This new model of distributed computing has been a requirement of VOs since their inception. It allows not only the sharing of resources in more dynamic ways, but also the sharing of information and data without greatly compromising local administrative autonomy.

The vision of Grid Computing promises the availability of abundant computing power. Moreover, access to this source of computing will be made easier through the policies and mechanisms that will govern their use within VOs. Grid Computing promises secure, reliable, coherent and coordinated access to computing resources and the sharing of data and information. This should enable VOs to be more efficient and productive in the execution of their tasks.

2.1.1 Communication Technologies

Communication is key to a successful collaboration. Within the VO paradigm, effective communication will enable the management of the interdependencies between the various organisations involved. Communication is more than just dialogue between individuals, it also involves the meaningful exchange of data and information. Communication, then, crosses into the realm of software applications undertaking meaningful dialogue according to prescribed protocols. This is highly relevant to VOs, where these instances of running software are considered a core part of the VO's definition, such as for the PGPGrid VO.

As already expressed above, communication technologies include the telephone and the facsimile, e-mail, which in addition to providing a means for communications between two parties, also provides the ability for high speed, distributed, one-to-many communication using mailing-lists, and Chat, which as described above, is yet another medium for typed electronic communication. While Chat, like the telephone, is more dynamic than e-mail, it is less imposing than the telephone. Users may indicate the status of their availability on the Chat system using their local Chat client. Other logged-on users will then be able to see who is available for a real-time discussion. There are several Chat protocols, including the most popular of these, Internet Relay Chat (IRC) [6] and I-Seek-You (ICQ) [7].

Other communication methods include telephone- and video-conferencing, which allow a number of parties in different domains to partake in a meeting. Advanced video-conferencing technologies, including the Access Grid [8], allow participants to have real-time streaming of audio and video information from each participating party. In addition, they allow slide presentations and other electronic, graphical applications, to be viewed and remotely controlled by all participating parties. Web-conferencing, such as that provided by PlaceWare Inc. [9], is another medium through which multiple participants can share graphical applications and make presentations. All of these advanced media allow real-time interaction between geographically distributed participants.

Telephone- and video-conferencing are invaluable tools for holding regular meetings. These media are also a valuable means of holding meetings at short notice when face-to-face meetings are not viable. There are, however, a number of important caveats that must be born in mind when using these technologies. The first of these is the unusual group dynamics of these meetings, where participants are not within direct proximity. Here, the sociological and anthropological factors taken for granted in face-to-face meetings, can have a real impact on the proceedings. These factors include body-language, seating positions, and the physical presence of a meeting chair and secretary. Video-conferencing has a tendency for meetings to regress to an audience-speaker presentation model.

The Access Grid technology is a VO-enabling technology, which requires the booking of virtual conference rooms on the web for meeting participants to log into for the duration of their meeting. These virtual rooms can be made secure for privacy. At each Access Grid site, a special Access Grid suite is fitted with strategically positioned cameras, ambient microphone and speaker systems, and a video-wall, which displays the Access Grid suite of the remote participants as seen through their cameras. The aim is to create an environment that is close to holding meetings in a room with all the participants physically present, while participants can be on different continents. The sociology and human factors involved in such Collaborative Virtual Environments have been studied and are the focus of many in the fields of sociology and human interaction. Unfortunately, current Access Grid technologies do suffer technical problems that

make them rather temperamental. For this reason, the financial and temporal overheads of travelling to face-to-face meetings are still deemed worthwhile.

Access Grid facilities are available at two of the three PGPGrid VO member organisations' sites, with the third being able to borrow an Access Grid facility that is within reasonable proximity. The number of Access Grid nodes is growing, with academic centres setting the precedence in the adaptation of this cutting-edge technology. This is to be expected, since academic communities and collaborations are amongst the largest open collaborations.

It is important to note that the current nature of human interaction still favours face-to-face meetings over telephone- or video-conferencing for holding meetings. It may be possible that future technologies allow for a more realistic form of remote-conferencing, which replicates more closely the dynamics of face-to-face meetings than current technologies allow. It is also important to note that changes in human interaction models, that is, the dynamics and modes of meetings, may have to evolve to allow for effective remote-conferencing that can take advantage of future technologies. The Access Grid is one technology that is attempting to move toward a more real-time, video-conferencing based, remote-conferencing environment, with dynamics similar to face-to-face meetings.

2.1.2 Data and Resource Sharing Technologies

Whereas the communications technologies described in Section 2.1.1 provide the media that are necessary to foster human interaction in meetings, more sophisticated technologies are required to allow computing infrastructures to communicate in a more powerful way than the current Internet infrastructure allows. The end-goal sought is that of dynamic and automatic data and resource sharing based on a set of policies, between the partners in a VO.

In addition to providing the interconnections required for e-mail, Chat, and video-conferencing, the role of the Internet and the Web should be further acknowledged. In addition to simple web pages that are used for publishing data and information, the web is increasingly providing active services in terms of applications running on computer servers and accessed through web pages. Web Services [10] are the newest in the line of infrastructures aimed at Internet-enabling software application services.

Although still in its infancy, the state-of-the-art in these more sophisticated Internet technologies is being developed under the banner of Grid technologies. These Grid technologies will allow a VO to administer the sharing and use of its data and computing resources according to a set of VO policies, while those data and resources are under the control of individual members of the VO to which they belong.

In order to encourage uniform interfaces and standard practices for the implementation of Grids, the Global Grid Forum (GGF) [11] is currently nurturing work to address various issues which concern Grid technologies, and to write specifications aimed at becoming standards. These specifications will cover issues arising from low level interfaces and infrastructures, and languages and protocols, to higher level architectures, and even Best Practices for operating VOs.

The Globus Toolkit [5] is an example of Grid-enabling software, also known as Grid Middleware. It is a software toolkit that has started to address the issues arising in the use of Grid technologies by VOs. These issues include:

- resource, data, and information discovery, access, and control;
- authentication and authorisation access control and other security issues, such as data encryption;
- resource and compute-job management; and
- data management.

The Globus Toolkit is based upon the emerging Open Grid Services Infrastructure (OGSI) specification [12] from GGF. Its aim is to provide interoperability between various computing platforms, using standard

interfaces based on OGSi. It has been implemented using the Java programming language and provides the ability to manage a heterogeneous computing environment.

The OGSi specification dictates the infrastructure of Grid Services [12]. Grid Services are based on Web Services, and are an appropriate VO-enabling technology in the Grid paradigm. The Grid Services infrastructure is becoming a new tool for collaborations to enable distributed, wide area, application development and deployment, and to allow the sharing of computing resources.

Another example of Grid Middleware is the DCGrid software from Entropia [13]. DCGrid software is specifically aimed at the Microsoft Windows platforms and is designed to Grid-enable native Win32 applications. This Middleware is geared toward the deployment and configuration of computational Grids, and harvesting idle CPU cycles for compute-intensive applications. DCGrid software is proprietary and is not based on Open Standards or specifications.

2.1.3 Software Engineering Technologies

Collaborative software engineering is not new to VOs. There are many tools readily available for distributed software engineering, including the Concurrent Versions System (CVS) [14], visual Integrated Development Environments (IDEs), such as Eclipse [15], and various testing, building and packaging tools that are used both within and outside collaborations. Of course, individual member organisations of a VO will have preferences as to the use of software engineering tools and will be partial to those with which they have experience. It may be useful, however, even a hard requirement, for the whole VO to use a standard set of these tools in order to produce coherent and coordinated software modules with a uniform presentation. To this end, a VO Coding Standards and Style policy, and guidelines for software production, can be invaluable. Except for the latter, VO requirements for software development tools must be weighed up against the personal preferences of VO member organisations for working tools.

There are currently many Open Source [16] software development collaborations that have a presence on the Web, for example those hosted at SourceForge [17]. These collaborations are essentially VOs, and are often formed from individuals in a loosely structured community rather than formal groups associated with organisations and companies. The presence that Open Source collaborations exhibit on the Web is usually in the form of a web site, which incorporates document and software repositories, allows versioning of submitted works, and open reviewing of those works.

With respect to Open Source collaboration web sites, a technology known as Wiki has been getting much attention recently. There are many implementations of Wikis, which are web based repositories for documents and software. According to [18], a “Wiki is a composition system, it's a discussion medium, it's a repository, it's a mail system, it's a chat room, and it's a tool for collaboration.” Wikis allow multiple, distributed users to edit web pages and to upload documents and software using the Wiki infrastructure as a repository. Wikis are loosely managed, yet, powerful VO-enabling tool.

It is important that design documentation follows design patterns and templates that should be specified in a VO's collaboration policies. Use of such policies helps remove ambiguities about the format and schema for designs. For software development, for example, standard UML notations may be used so that designs are concisely presented in standard documents and fully understood by those who need to review and work with them. These templates and schemas may be considered amongst the necessary technologies required by VOs.

If Grid environments are to be successfully utilised as VO-enabling technologies, and if heterogeneous Grids are to become a reality, there must be an emphasis on software companies to change the way in which they engineer, produce and provision software. While today, commercial software is targeted at specific platforms and licensed for limited node usage, in the future, software needs to have unlimited use parameters, including, but not limited to, the number and location of compute nodes utilised. Furthermore, software should be engineered in such a way so as to produce the same results regardless of the executing

platform and environment, where the goal is to use a heterogeneous computing environment to produce the same results on every platform.

2.2 Virtual Organisations in the Animation Industry

Since the early days of animated feature films, large-scale animation production has been undertaken by large studios, including giants such as Warner Bros., MGM, and, of course, the Walt Disney Company. While these studios have been landmarks in the history of animation production, the traditional methods that they have been using are quickly becoming outdated. New production methodologies and animation paradigms are emerging, which even these large producers cannot ignore in favour of their traditional production methods.

Traditionally, animation features have been produced in major studios by large numbers of animators, in an assembly-line fashion. Animation studios allowed for rapid progress in animation art by fostering the collaboration of large teams of animators, albeit under one roof, and by making large scale artistic collaboration viable. Although this method was successful in revolutionising animation techniques, harvesting animation talent, and producing quality art for the big screen, it had many drawbacks that are beginning to be addressed today.

The assembly-line method of animation production favoured by studios has, in the past, led to highly contentious working practices in the animation industry, where strict working regiments have led to employee dissatisfaction. Furthermore, the attribution of credits for the production of animation art and techniques to the studios and producers, instead of to their creators, has led to much conflict. Finally, soaring production costs have resulted in large studios moving their production to cheaper overseas environments, thus benefiting from lower labour costs.

With the advent of technological advances, and in particular the explosion of CGA in the 1990s, the face of the animation industry is being radically reformed. Computer technologies have enabled individual animation artists to retain the credits for their work and enabled many smaller production studios to form and compete in the animation market by existing in a symbiotic relationship with larger studios, who are able to subcontract work to them. These technologies have also enabled flexible collaboration between all parties in animation production collaborations. It should be noted that the transpiration of the benefits of CGA and advanced computer technologies to the smaller players in the animation industry depends very much on the emerging working models involving VOs.

Even with the availability of these new technologies, however, large animation producers have tended to rely on the old model of production, where multitudes of animators and operators, many of whom are hired for the duration of an individual project, are placed in a large warehouse environment to work on that production. This is a model that is not sustainable, especially in view of the autonomy and levels of productivity that individual animators and small production companies can achieve by exploiting advanced technologies.

It is evident, therefore, that the animation industry has much to gain from the formation of VOs. The relationships between the artists and producers, directors and script writers, sound engineers and musicians, and so on, can all be fostered in a richly interactive and flexible environment, which is enabled through appropriate computing technologies and infrastructures. In addition to this, there is a very strong move away from the traditional hand-drawn and painted celluloid-based animation production, towards the much more sophisticated CGA techniques that allow 3D modelling of scenes and characters using increasingly sophisticated software and methods. The availability of digital techniques for the production of every stage of an animation film, from sound to character animation, points to the increasing use of IT and makes the concept of animation VOs evermore viable and attractive. Animation VOs seem to be the future of large scale animation production.

2.2.1 Animation VOs: Fostering Creativity

The effect of animation VOs on small and medium-sized enterprises (SMEs) in the animation industry is profound. Animation VOs will empower SMEs in the animation sector and lead to higher efficiency and greater creativity in animation production. In addition, animation VOs will foster the development of advanced animation techniques by allowing innovators in the field to work in close collaboration with artists and animation companies, in order to turn their research and prototypes into production-quality technologies and techniques for the animation industry. Such collaboration may even be *open collaboration* analogous to the Open Source movement in the software industry [16], which allows individuals, who may be volunteers, to contribute in their own capacity to the production of software technologies from which they will all mutually benefit. The Open Source model of collaboration is a very loosely bound VO model with liberal policies that allow members to come and go as they wish.

The PGPGrid VO is a very good example of an animation VO that allows all of the above. As an example of fostering technology transfer, the 3D-Matic laboratory is developing cutting-edge, 3D movement-capture technologies, which produce 3D mesh-model data from digital streaming video from video cameras. 3D-Matic is a research laboratory based at an academic institution, namely the University of Glasgow. Its aim is to transfer knowledge and technology from its research and prototype developments to industry. Its involvement in the PGPGrid VO provides it with a perfect platform from which to achieve this goal, and in the process bring valuable novel technologies to animation production in order to increase creativity and efficiency in 3D animation production. PGP is a SME animation company that wishes to make use of the techniques developed by 3D-Matic to enhance its creativity and to increase the efficiency of 3D animation at the same time. Through the provision of access to resources, EPCC allows 3D-Matic and PGP to collaborate as a VO operating as a single production entity within a Grid environment. Here, the sharing of the distinctive capabilities of the VO member organisations is evident. The result is a new, overall distinctive capability for the VO, that of highly creative and efficient 3D animation production on-demand, utilising VO-enabling technologies based on a Grid infrastructure.

Autonomy of VO Members

The studio method of animation production has, in the past, stripped individual animators and technicians of the credits for the art and new techniques that they developed, and instead attributed those credits to the studios themselves. This practice is, however, becoming less common as there is a growing number of individuals who wish to retain complete rights and the full credit for their work. In addition, it is often seen as an advantage in many fields to allow individuals to have growing control over their work in order to foster creativity and to boost morale. To this end, whether animation is undertaken by individuals or small companies, there needs to be an environment for collaboration between them.

It is important for VO member organisations to maintain their local autonomy for several reasons:

- without local autonomy, member organisations risk compromising, directly or indirectly, the core competencies that they bring to the VO;
- VO member organisations will have tested methods and policies by which they undertake their work and manage their infrastructures. Challenging these traditions would result in those organisations feeling annexed by the VO, and the introduction of unfamiliar and unwelcome new policies would have detrimental effects on those organisations. In turn, this can have a negative effect on motivation and staff morale;
- local policies and management at the organisational level have been designed through experience and on understanding of the organisational culture. Imposition of uniform umbrella policies upon a heterogeneous organisational environment within a VO cannot possibly take into account the individual needs of the member organisations. This would then jeopardise the goals of each member organisation that are auxiliary to the goals of the VO. If the goals of each member organisation are not accomplished, this could, in turn, have a negative impact on the work of the VO.

The formation of VOs in the animation industry should, therefore, allow individuals and small companies to exist autonomously and to contribute to large collaborative animation productions. In addition, based on specific VO policies, this collaborative environment should allow these autonomous entities to retain intellectual property rights for their creativity.

Allowing Efficiency in Creativity

Animation production in large studios allowed rapid progress in animation technology, animation techniques, and artistic creativity, by allowing artistic collaboration. With the advent of television, however, even the large studios could not produce animation of high artistic quality within the tight budgets and production schedules that were presented to them. As a result of this inability to keep up with the pace of television production, the quality of animation was severely affected.

With new working practices in the VO paradigm, which will foster medium to large-scale collaborations, and with the help of state-of-the-art CGA, it should be possible for animation VOs to produce high quality animation of high calibre art within tight timescales. It should again be noted, that one of the advantages of VO formation is that a VO can quickly exploit market opportunities. Television can demand very tight time constraints from the point of inception of an animation product to the delivery of that product. If traditional studio working practices are to be used, the quality of the product will suffer accordingly. High speed development and implementation of CGA, in close collaborations of artists, can overcome the limitations of quality that are caused by tight time budgets. This can be done by allowing experimentation and fostering natural creative processes. The formation of appropriate VOs and the overcoming of the technical limitations that they face, using appropriate VO-enabling tools and resources, is the key to this process.

2.2.2 Animation VOs: Harnessing Computing Resources

Although CGA can allow large-scale animation production, it involves extremely compute-intensive processes. Producing animation models and applying rendering in order to flesh out those models using various ray-tracing software applications can take a relatively long time with the current computing infrastructures. If animation VOs are to exploit a dynamic market and undertake animation production on short time-scales, they will need to have access to ample computing resources on-demand, to allow them to experiment and produce animation art of high quality.

Animation VOs can benefit greatly from having VO members who are able to provide large compute, data, and network computing resources at short notice for the duration of a project. Furthermore, they may benefit from the temporary ownership of many application licenses for animation software tools for the duration of that project. The aim would be to move away from a model where each small company or individual could only work with the limited resources that they own, towards one where they are able to make use of the resources of other VO members. Here the power of resource sharing becomes apparent, both in the availability of the necessary resources at short notice and for relatively small time-scales compared with owning them outright, and in the economic model that this working environment provides for the mutual benefit of the VO members. Considering this economic model, VO members without large resources will benefit from hire rather than the purchase of resources, and those with the resources will benefit from renting out their resources.

It is important to recognise that the working model introduced above will require a well understood paradigm for setting up VOs, administering, managing and working within them. Best Practices are necessary in order to enable the construction of a VO according to its unique requirements. Within this paradigm, an appropriate computing infrastructure is required to allow these Best Practices to be implemented. If VOs are to be truly dynamic in formation, this computing infrastructure will have to adopt standard specifications for protocols and languages. It is the aim of developing Grid technologies to deliver such a computing infrastructure built on emerging standards, and to allow VO construction according to a set of Best Practices.

2.2.3 The Use of IT in VOs in the Animation Industry

As in every industry, the animation industry has moved forward along with technological advances that directly or indirectly affect its work. Direct technological advances include those that change the techniques for animation production itself. Many examples may be found in the work of Max Fleischer, a pioneer of animation production and its many novel techniques in its early days. One example is Fleischer's invention of the Rotoscope [19], which allowed animation to be modelled on real action captured on film using actors and real settings. Indirect technological advances in the motion picture industry, including the advent of audio in film production, have also led to changes in the animation production industry.

Today, when CGA is prominent in the animation industry, direct technological advances, such as the development of novel motion capture techniques that enable more realistic animation, dominate changes in animation production. In addition, animators have a plethora of software tools to transform mesh models based on real motion capture into animation. The indirect technological advances that affect the current animation production processes, include advances in computing technologies. This is particularly important when taking into consideration the fact that the various processes involved in CGA are all extremely compute-intensive, to the extent that mistakes in the production process can be extremely costly.

Additionally, faster networks can aid the transport of large quantities of data between the geographically distributed resources of VO member partners. New infrastructures for autonomic machine communication can revolutionise working procedures. Advanced scheduling and compute-fabric management protocols, schemas, and techniques can enable efficient and coordinated use of IT infrastructures and computing resources. As previously stated, these are being developed within the realm of Grid technologies.

The importance of CGA techniques and the role of Grid Computing in the animation industry have, thus, been stated. As a result of the rising prominence of Grid Computing and the benefits that it brings to VOs and their IT infrastructures, and because of the revolutionary impact and financial benefits that it can bring, the animation industry needs to become more involved in the development of Grid standards in order to address its own primary concerns at the early stages of Grid infrastructure development. As an industry, the animation sector needs to evaluate, at an early stage, how it can benefit from VO environments and Grid Computing. It then needs to raise any emerging issues with the developing Grid community in order to address them in the evolving Grid infrastructures.

The Impact of Grid Technologies on the Animation Industry

We have already discussed traditional methods of animation production by large studios. In addition, we have declared that the devolution of animation production to autonomic production units will enhance both creativity and productivity, the latter being achieved by giving animators control in the creative decision making process and the rights and credits for their work, thereby increasing motivation. This devolution process in the animation industry is already taking shape. There are a myriad of animation SMEs that are able to produce work on their own by harnessing the power of CGA technologies. Indeed, a great number of individuals have, in recent years, begun to produce software applications and toolkits that enable them to undertake computer-generated graphics and animation production. By making this software readily available as Freeware and Shareware, these individuals have enabled numerous others to do the same. Their tools include translators and data mappers, which allow many data formats to be used with a plethora of commercial and customised software tools, as well as modelling and rendering applications.

The Grid infrastructures that will enable animation VOs, will be based on standard interfaces that will use a set of Grid protocols, languages, and application programming interfaces (APIs) to connect geographically distributed computing domains in a uniform way. When this promise is delivered, technology developers will be able to take advantage of this great resource to enhance the performance of their software. In turn, this increased performance can be exploited by small companies that have previously been forced to work within the limited means of their small, privately owned set of resources, to match the productivity of larger

firms that have exclusive access to large sets of resources. For the animation industry, this will mean that, increasingly, smaller production companies and individuals will be able to match the high creative standards of larger studios. This will be done by carrying out experimentation that was previously extremely costly and inefficient, and also through high productivity enabled by advanced software tools and access to an abundance of affordable computing resources. This should lead to the devolution of creativity in the animation production industry that was alluded to above, and a revolution in the logistics and working practices in large animation production.

Perhaps more important will be the changes to the current working environments of VO like partnerships and how they use the current IT infrastructures that are available to them. Even with the seemingly high network bandwidths on the Internet, delivered through broadband and high-speed academic and government networks, organisations are still unable to share data efficiently using suitable, standard, high-level protocols. It is a key goal of Grid technologies, by providing standard interfaces and protocols, to enable a rich and seamless distributed computing environment where end-users can share data efficiently and on-demand.

An example will aid to illustrate this point. Within a VO, each member has a distinctive capability that is required by that VO. The product of the distinctive capability of one of the VO members, who we will refer to as 'A', is a database that will be the starting point in the workflow that governs the work of the VO, and has to be shared between the VO members. Today, it is possible to share that database in several ways.

1. 'A' could conceivably give the other VO members access permission to a set of its resources, and hence to the database.
2. 'A' could send the database, and relevant metadata about its contents, in an e-mail to the other VO members.
3. 'A' could publish the database on the web, privately, for the other VO members to access.

All these methods are, however, general solutions for use and do not aid in the automation of the process that the VO seeks. It is possible for the VO to create a customised infrastructure using the Internet, in order for 'A' to publish its work, or the other VO members to access it, dynamically and automatically. This would require the VO to create a set of protocols and the infrastructure to support it, which is neither cheap nor trivial. It is this solution that should be made readily available by Grid technologies, leaving the VO to concentrate on the production of the final work, rather than having to build the necessary infrastructures to do that work.

For animation VOs also, Grid technologies will bring generic infrastructure that will enable powerful custom environments based on their specific requirements. Current CGA technologies may then be enhanced for security, accessibility, integrability, high performance, and reusability, in potentially complex VO environments. All this should enable animation VOs with many member organisations to work together on collaborative productions, seamlessly and more efficiently, bringing with it high financial benefits for the VO members.

2.3 Case Study One: The DAMAGE Project

The DAMAGE (Digital Asset Management For Animation For Global Entertainment) project [20] is funded by EUREKA. According to [21], "EUREKA is a pan-European network for market-oriented, industrial R&D." The goal of the DAMAGE project is stated as being: "Research and development of software to 'track' animation elements across sites, allowing co-operative animation production. This will allow European partners to collaborate together efficiently in European and U.S. projects" [20].

The project summary [22] is available from the EUREKA web site and states: "This project seeks to research and develop a collaborative working methodology, based on the development of an Asset

Management system (assets are the ‘elements’ of animation either in drawings, sound, backgrounds, colour schemes, special effects, etc. – a 2 hour animation may have more than 2 million assets in 50 different ‘forms’).”

The DAMAGE project is both an animation VO itself and a technological tool provider for enabling animation VOs. It aims to develop and employ tools, for distributed, collaborative animation production in an animation VO. More specifically, the project aims to design, develop, and implement a prototype Asset Management system, which is deployed on a geographically distributed infrastructure, with built-in redundancy to enable failure management and disaster recovery across sites. The ultimate aim of the DAMAGE project in developing the distributed Asset Management system is to provide cost effectiveness of animation production in large collaborative environments.

The Asset Management system will be in the form of a distributed and secure database system that is targeted at the requirements of the animation industry. The database must allow automatic update of asset contents by end-user tools and production processes. In addition, it must allow multi-level access control for access to, and the updating of, asset data and related information. Furthermore, the database must allow for an approval process where stored assets can be approved by the appropriate people.

Once developed, the DAMAGE Asset Management system can be licensed to animation companies for use. It can then be used by animation companies to collaborate in VOs for large scale animation production. Such a system will enable smaller animation companies to collaborate effectively with larger studios within a VO setting. It will be, thus, a valuable VO-enabling technology in the animation industry.

2.3.1 The DAMAGE VO Logistics

The DAMAGE project is a collaboration between four project members based in the United Kingdom (UK) and Belgium. These collaboration partners are:

- **Ealing Studio Enterprises Ltd., UK [23]:**
 - lead the project;
 - provide expertise on commercial film production and management to the collaboration.
- **Limburgs Universitair Centrum/Expertise Centre For Digital Media, Belgium [24]:**
 - in charge of requirements capture for the workflow and database for the Asset Management system.
- **Androme, Belgium [25]:**
 - collaborate with Limburgs Universitair Centrum to model the workflow for the system and provide workflow simulations.
- **Vanguard Animation UK Ltd., UK [26]:**
 - has the role of a client;
 - provide end-user feedback on both the user requirements specification and the theoretical models for the system;
 - will undertake implementation and end-user testing of the system.

2.3.2 The DAMAGE VO Experience

2.4 Case Study Two: The CUSTODIEV Project

The CUSTODIEV (Creative Use of Style and Technology in Ordering the Design and Interactive Evaluation of the Vision) project [27] is an animation VO. Its aim is to develop a framework that includes a virtual centre for hosting cross-organisational collaborative animation production, using Internet technologies. The goal of the project is broadly stated as follows [27]:

“...[to take] advantage of new technological developments, [to] establish new models of development that engage with the relevant communities in a manner designed to foster collaboration and the creation of new works. We need to create an institutional framework that is both a virtual centre for the development of animation technology by ‘creative pull’ ..., and at the same time is a production studio specializing in animation projects which push the creative frontiers using new techniques and technologies.”

The CUSTODIEV VO will produce new animation methods and technologies nurtured by the process of *creative pull* [28] – where creative requirements will drive technological developments. Further, the VO will provide a virtual forum and support a distributed virtual studio, and will induce low cost animation production. The key motivation of the CUSTODIEV VO is to engage the artistic and technical communities by using the Internet as a collaboration medium, in order to foster the process of creative pull. The technologies developed will include those that allow new animation methods to be used, such as 3D performance capture using custom hardware and software, and more general software tools for artists and animators. In turn, these new technologies will enable animation VOs to form and competitively exploit market opportunities.

2.4.1 The CUSTODIEV VO Logistics

The CUSTODIEV project is led by the University of Glasgow and is a collaboration between six partner organisations. These organisations and their contributions, as stated in [29], are:

- **University of Glasgow, UK [3]:**
 - will develop performance capture data-path, which involves model fitting, and recasting for in-betweening;
 - will develop open production tools: storyboard and animatic tools; and
 - will establish stable platforms for Internet-mediated production.
- **Limburgs Universitair Centrum (LUC-EDM), Belgium [24]:**
 - will develop drawn input data-path for narrative drawing: involves model sheet management, high-level in-betweening and non photo-realistic rendering of photographic material.
- **Centre de la Bande Dessinee et de l'Image (CNBDI), France [30]:**
 - will establish virtual and physical centres, forum and model for engagement with creative and technical communities via the Web; and
 - will develop photo-real models and virtual sets for creative production, and non-photo-realistic processes for stylisation.
- **Siriol Limited, UK [31]:**
 - will develop non-photo-realistic styles from photo-realistic input and use these in creative production;
 - will use and evaluate open production model by creative pull; and
 - will lead evaluations with user group.

- **Androme, Netherlands [32]:**
 - will build drivers to bridge from electrophoretic display device (EPD) pads to PC operating systems;
 - will build the drawing and photograph display management for EPD input; and
 - will build the core in-betweenener.
- **Philips Components, Netherlands [33]:**
 - will develop EPD system as EPD pad through three cycles of development. This involves developing the EPD output function and stylus-based input for simulating drawing.

It is evident that each partner in the CUSTODIEV VO brings its own set of core competencies to the VO. This will enable the production of the prototype techniques and tools, using new technologies developed through creative pull, which the VO seeks. These tools will enable animation collaborations within virtual environments, and facilitate a VO model for animation production.

The AnimationForge Project

The CUSTODIEV VO uses the web as a medium to facilitate an Open Source style animation forum called AnimationForge. The AnimationForge project [34] is a deliverable of the CUSTODIEV VO. AnimationForge provides a framework and a forum for artists and technology providers to collaborate in an Open Source environment, which fosters technological development through the process of creative pull. This will help to meet the technical requirements of the animation industry as identified by animators and other artists.

2.4.2 The CUSTODIEV VO Experience

The user group, or customer base, of the CUSTODIEV VO is made up of a number of small professional animation organisations, which are primarily from Europe. Through interactions with this group, the CUSTODIEV VO has realised that the animation industry, at least at the smaller end of the scale, is rather conservative with regards to the methods employed for collaborative animation production and in their working logistics. Most of these small animation organisations have a tendency to adopt more traditional production methodologies, where individuals are hired and brought into the organisation for the duration of a production based upon their reputations. This is very much the opposite of the VO model, where emphasis lies on forming temporary relationships in loosely bound environments of autonomous organisations. The VO model is one that the CUSTODIEV project is keen to exploit and promote. They aim to bring together various autonomous organisations with diverse technical and creative competencies, using the Internet and other advanced technologies as a medium for collaboration and to facilitate distributed animation production.

In addition to the conservative methods favoured by smaller animation organisations, CUSTODIEV have found that these organisations seem to be immune to computing advances. They regard Internet based technologies and computing software as necessary evils, which, other than for conventional uses, they wish to use as little as possible. They overwhelmingly use general, proprietary, third-party software from large vendors, and are not keen to get involved in Open Source collaboration projects with the aim of developing custom software tools to fit their special requirements, or to enable VO type collaborations. In short, and perhaps due to the lack of financial and temporal budgets for research and development activities, these organisations are living within the technological bounds of off-the-shelf products. They appear not to be keen on developing new technologies to cater for their particular needs in order to push back the boundaries of animation production techniques and their creative possibilities.

The CUSTODIEV VO is trying to create a virtual centre for the development of creative projects with new technological requirements. Due to their conservative nature, CUSTODIEV's current user group of small

animation organisations are proving difficult to engage with, and as a result CUSTODIEV is attempting to approach larger, studio-based animation organisations that are keen to exploit new technologies and techniques for 3D animation production. These larger organisations require competent, cutting-edge technology providers to deliver the tools that they need.

2.5 Case Study Three: The OGSA-DAI Project

The OGSA-DAI (Open Grid Services Architecture – Data Access and Integration) project, whilst not an animation VO, is a very good example of a collaboration which has utilised the VO model. As such, the OGSA-DAI VO consisted of a number of geographically distributed, independent and autonomous organisations and individuals. It also used distributed resources and cutting-edge technologies for the development of advanced technologies that were in turn VO-enabling technologies themselves. The OGSA-DAI VO was dynamic at the intra-organisational level, in that within each organisation the roles and tasks of individuals involved in the work, and those individuals themselves, changed with time.

The OGSA-DAI VO was formed in order to take advantage of an emerging market opportunity. With the heralding of Grid activities worldwide, and the emphasis on VO formation as a model of modern collaboration, Grid and other VO-enabling technologies are becoming greatly sought after. There are many diverse areas for the development of such technologies, but the OGSA-DAI VO realised early-on that there was an opportunity to provide data-centric technologies based on a new emerging Grid infrastructure: that of Grid Services. In addition to concluding that there was a need for its proposed technology, the OGSA-DAI VO had crucially realised that there was research funding available for such an activity, which they duly took advantage of. Perhaps most importantly for the OGSA-DAI VO, was the presence of the required database and data expertise in the UK, where the greater majority of its member organisations were based. Without the latter as a core competency, the VO would not have been competitive in its target market.

The new set of distinctive competencies that the OGSA-DAI VO attained, allowed it to have a competitive edge over its rivals. In their case, the OGSA-DAI VO was able to create the ability to drive Grid technology standards. This in turn led to the high visibility of their software and the high speed of uptake of their developed technology. The heterogeneity of the VO, which consisted of academic and industrial partners, played a crucial role in their ability to drive standards, since this activity is a community process involving non-proprietary technologies. In addition, the OGSA-DAI VO took advantage of the distinctive capability arising from the strength of the reputation of its individual members in producing high quality and robust software technologies. This was compounded by their individual reputations for cutting-edge research, especially within the OGSA-DAI VO's field of interest.

Although the development of the OGSA-DAI software deliverables did not require a VO and could have been undertaken by a single autonomic organisation, the OGSA-DAI project was undertaken by a collaboration that was set up using the VO model. There are a number of reasons for this, including:

- the exposure of individuals within single organisations to others within the VO, providing a powerful means for cooperative networking;
- the security gained by industrial partners in a chiefly research based project, through limiting the allocation of their own valuable resources, by taking advantage of the existing research infrastructures of research oriented academic organisations, and by providing a large amount of in-kind contributions to the project instead of hard capital investment;
- the available funding was won on the basis of the project being run as a collaborative VO involving industrial and academic partners, with industrial funding matching the level of State funding as a prerequisite.

The OGSA-DAI project's main deliverable was a software technology that was based on the Grid Services paradigm [12]. This deliverable was designed to enable VOs to access and integrate data in a heterogeneous

and distributed data resource environment, and to enable VOs to share that data in a coordinated and coherent fashion.

As part of the definition of the OGSA-DAI VO, their customer base should also be considered. The users of the OGSA-DAI Grid Services based software are primarily the e-Science community, and to a growing extent the e-Commerce community and technology service providers. The e-Science and e-Commerce communities include those who are involved in the application of advanced computing technologies, including Grid technologies, to the scientific and commercial sectors, respectively. Their specific need for this software is to enable them to set up dynamic VOs. The OGSA-DAI software fulfils the requirement of such VOs to share data and perhaps the information attained from that data.

2.5.1 The OGSA-DAI VO Logistics

The OGSA-DAI VO was conceived at the end of 2001. Although the VO was officially started at the beginning of 2002, the full integration of the VO took a few months. This is typical of VO behaviour, where VO members can join when they are ready, in order to fulfil their role within the VO. It is usually a requirement of single organisational entities, however, that all parts of the organisation, or machinery, be in place for that entity to function.

The OGSA-DAI VO's member organisations, and their contributions, as stated in [35], were:

- **EPCC, University of Edinburgh, UK [4]:**
 - provided software engineering effort;
 - provided Grid standards development effort;
 - undertook client requirements capture;
 - provided links to research experience and the academic domain;
 - provided community training skills for user training courses;
 - had a strong link to the National e-Science Centre for attracting project funding.
- **IBM, Hursley, UK [36]:**
 - provided software engineering effort;
 - provided Grid standards development effort;
 - undertook client requirements capture;
 - provided close relationship with database experts.
- **IBM, Almaden, US [37]:**
 - provided Grid standards development effort;
 - provided database expertise;
 - provided links to research experience in the industrial domain.
- **UK e-Science Grid Support Centre [38]:**
 - provided user support for the OGSA-DAI software through a user mailing-list and the administration of the OGSA-DAI web site.
- **National e-Science Centre, UK [39]:**
 - provided publicity, and general administrative support;
 - provided buildings and space resources for meetings and training courses;

- provided information dissemination.
- **e-Science North West, University of Manchester, UK [40]:**
 - provided Grid standards development effort;
 - provided research and development of higher level systems for the OGSA-DAI software;
 - provided database expertise;
 - provided links to research experience and the academic domain;
 - provided strong links with other e-Science projects for requirements capture and user base feedback.
- **North East Regional e-Science Centre, University of Newcastle upon Tyne, UK [41]:**
 - provided Grid standards development effort;
 - provided research and development of higher level systems for the OGSA-DAI software;
 - provided database expertise;
 - provided links to research experience and the academic domain;
 - provided strong links with other e-Science projects for requirements capture and user base feedback.
- **Oracle, UK [42]:**
 - provided high level programme management;
 - provided Grid standards development effort;
 - provided negotiation skills at the management level;
 - provided industrial exposure and publicity.

In addition to these member organisations, one individual was in charge of observing the technical progress of the VO, with a view to reporting back to the UK's Grid Database Task Force, who were the originators of the OGSA-DAI concept.

The complexity of the OGSA-DAI VO comes into its own when one considers the management structure of the VO. This management structure follows an hourglass model, with a top heavy upper-management layer, a thin intermediary programme-management layer, and a bottom heavy developer and technical-management layer, as illustrated in Figure 2.

The upper-management layer consisted of:

- the team of project proposers from the VO's member organisations;
- the Project Management Board, which was made up of the directors of the VO member organisations and was in charge of the overall strategy for the OGSA-DAI VO;
- the OGSA-DAI Technical Advisory Group, which was made up of upper-management from the VO's member organisations and was in charge of the technical direction of the OGSA-DAI VO; and
- the UK's e-Science Technical Advisory Board, who oversees e-Science activities and funding in the UK and is in charge of the overall strategy for e-Science in the UK.

The programme-management layer consists of the VO's Management Committee. This committee is chaired by the programme manager and includes the project managers, commercial director, and the centre directors at each of the VO's member organisations. Finally, the technical-management and development

layer consists of the aforementioned technical managers at each of the VO's member organisations and their respective development teams. Interaction between the upper and technical-management layers is through the programme-management layer.

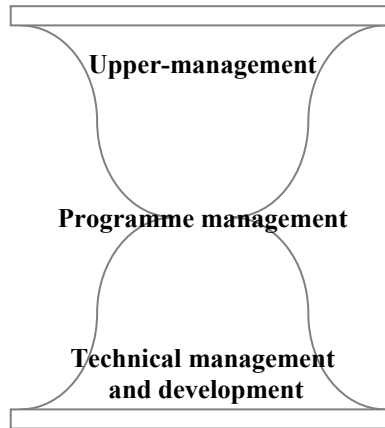


Figure 1: The OGSA-DAI hourglass management structure.

It is important to note that while the upper- and programme-management layers encompass the entire VO, the technical-management and development layer is composed of largely autonomous teams within each organisation. The overall management of the OGSA-DAI project was the remit of the programme manager who chaired the VO's Management Committee.

The tools that were used to enable the VO included:

- IT and other communication technologies, including:
 - conventional post;
 - telephone for personal communications;
 - telephone-conferencing;
 - e-mail, including management and user mailing-lists;
 - internal (private) and external (public) project web sites;
 - the TWiki web based Wiki collaboration hosting technology [43];
 - the Internet Relay Chat (IRC) Chat technology [6];
 - the NetMeeting video conferencing technology [44]; and
 - the Access Grid video conferencing suite technology (although the lack of wide-scale availability and its temperamental nature lowered the frequency of use of this technology).
- Software development technologies, including:
 - the Bugzilla software bug tracking system [45];
 - the Concurrent Versions System (CVS) technology for software revision control; and
 - the Eclipse Integrated Development Environment (IDE) and WebSphere development environment [46].
- Management technologies, including:
 - the Microsoft Excel spreadsheet software;
 - the Microsoft Word word-processing software;
 - the Microsoft Project project-management software;
 - process documents, including:
 - project plans, including Gantt charts;
 - project definitions;
 - work plans; and

- project coding standards;
- Action-Lists; and
- telephone-conferencing.

The OGSA-DAI VO coordinated its activities and operated through a diverse set of meetings. These included:

- quarterly Programme-Management Board and OGSA-DAI Technical Advisory Board, Access Grid or face-to-face meetings;
- weekly Management Committee, or Programme-Management Board, telephone-conferences;
- quarterly face-to-face meetings of the entire OGSA-DAI VO;
- individual internal meeting programmes were followed by each of the VO's member organisations, using telephone- and video-conferencing in addition to face-to-face meetings; and
- need driven, small scale, ad hoc meetings were held within and between development teams, using telephone-conferencing and IRC.

The OGSA-DAI VO was set up using a legally binding Collaboration Agreement. This agreement contained the collaboration protocols that the VO followed, including non-disclosure and intellectual property policies. The management structure and related policies were also clearly set out at the start of the project.

2.5.2 The OGSA-DAI VO Experience

Except for a single computer server, all of the hardware and software resources that were used by the VO's member organisations were already owned by them. This server was purchased and used as a single point of access for the VO. It hosted the VO's software development and collaboration technologies. It was the host to the IRC and Twiki technologies that the VO used, as well as the internal web site of the VO. In addition, it hosted the software development environment of the VO, including CVS, and an administrative instance of a MySQL database that served the Bugzilla software. The software development environment included the software integration and package building software that the VO required in order to integrate the disparately developed software packages from across the VO. It would appear that such a central server is very useful for a VO to enable a single and common point of access for the VO to operate as single virtual entity, especially for software development activities.

Many of the software tools that the VO used are free and widely available. These include the Eclipse IDE and other Java development tools, including the Apache Ant software building tool [47] and the JUnit unit testing framework [48] for software development testing. The reason for using this software was that the VO had a requirement for the tools that it used to be freely available to its user base. This was due to the fact that the OGSA-DAI software was designed as Open Source Middleware, which its users required to extend and adapt for their own particular needs.

The beneficiaries of the OGSA-DAI VO included its member organisations as listed above, the project funding body to whom the VO was directly responsible, and its end-users. The member organisations of the VO received exposure and publicity as a result of their work and the successful production and uptake of their technology. They also gained immense technical experience as a result of working on this new technology. The project's funding body received global exposure following the successful completion of the project. The end-users of the OGSA-DAI deliverables, i.e. the e-Science community and Grid developers in the UK and further afield, benefited from the VO-enabling software produced by OGSA-DAI and from being early adopters of the Grid Services infrastructure, for some of whom the OGSA-DAI software was the first exposure. In addition, the training courses ran by the VO to train its users in the design and use of its software and to obtain feedback from course attendees in terms of requirements,

desirable features, and bug fixes, were mutually beneficial. This training activity also served to educate the user community in the broader philosophies of the Grid paradigm.

The OGSA-DAI VO obtained the initial set of product requirements for its software using an electronic questionnaire that was distributed to a targeted customer base of early-adopters. These early-adopters were the front line of the broader customer base that the VO was targeting, and played a crucial role as part of the VO in validating the work-in-progress. This attribute of the OGSA-DAI VO was a valuable part of the quality assurance (QA) for its deliverables. In this way it ensured that the issues which directly concerned its users were addressed. During the working lifetime of the VO, its customer base continued to provide requirements for its software. To facilitate this, the OGSA-DAI VO had to ensure that they had the opportunity to provide this feedback. This was done through the above mentioned training courses that the VO provided for its user base and the user specific electronic mailing-list that was set up in order to support them.

It should be noted that 25% of the VO's efforts were directed toward the development of standards specifications for data access and integration within the GGF [11]. This effort was deemed necessary for the success of the VO. The OGSA-DAI software was designed for use by a developing Grid and e-Science community. As such, it was important that this target community understood that this software was based on developing standards that allowed them to build interoperable and lasting frameworks. The conformance of the OGSA-DAI software with developing standards, meant that the time and effort spent by the user community at the developing stages of the software, and the feedback and specification of requirements that they provided for the software, was a worthwhile investment for them in the long run. This paradigm gives even more meaning to a VO where the user base and the customers are integral to the VO, and is preferred to one where the final products are provided without customer consultation.

The VO's deliverables included documentation describing the design and implementation of the software, and user manuals. These documents were periodically released with the software to aid in the uptake and understanding of the OGSA-DAI design and implementation. This also served to keep their user-base up-to-date with the evolving nature of the software and the specifications being developed.

The OGSA-DAI deliverables are all Open Source and can be accessed through the OGSA-DAI VO's web site [49]. This web site provides a central point of access for the user community to obtain, not only the deliverables of the VO, but also information about the VO itself, including its status. Although the OGSA-DAI VO has now, to a large extent, disbanded, its web site continues to provide support for the uptake of its work. This is an important element of service that VOs must provide, for although VOs may be temporary in their existence and their project lifetimes are relatively short, they must continue to present a nominal long-term presence. This must continue for at least as long as they are required to support a user group of their project's deliverables. This is a crucial step for the acceptance of the VO model. Since permanent organisations in theory provide indefinite support for their products and services, the temporary nature of VOs may provide a hollow image that could repel potential customers. A useful approach would be to devolve the VO's support activities at the end of its lifetime, to one, or a subset of its member organisations. This will have to be stated as part of the VO's formation policies.

The OGSA-DAI VO found that as a result of the diversity in the financial charging models and human resource management models of various member organisations, constraints were imposed on the dynamism of the VO with regard to staff allocation and effort management. These issues, in addition to differences in the working cultures and mentality of the member organisations in a VO, must be taken into account when setting up a VO. They impose radical constraints in the dynamic nature and evolution of VOs, limiting their productivity and efficiency. If the cultural history of member organisations is not taken into account when forming VOs, their management and work may quickly disintegrate into chaos.

It is important to note that despite the successful use of many collaboration technologies for remote interactions, the OGSA-DAI experience has proved that there is, as yet, no substitute for face-to-face meetings in terms of bringing autonomous organisations together to work as a single entity VO. This will remain the case until the norm for organisational collaboration, as a culture for cooperative working, changes to embrace more virtual environments, including sociological and legal aspects. Perhaps more

important will be the machine-human interfaces being developed, as catalysts in accelerating these processes of change. These interfaces are a subset of what we have been referring to as VO-enabling technologies above.

3 The PGPGrid Virtual Organisation

The PGPGrid VO is a collaboration between three member organisations:

- Pepper's Ghost Productions Ltd. (PGP);
- 3D-Matic Laboratory of The University of Glasgow (3D-Matic); and
- EPCC of The University of Edinburgh.

As with all modern collaborations, the PGPGrid VO is highly dependent on computing technologies. As a result of this dependency, the definition of the VO includes the computing technologies that it uses, as well as any that it produces. This way of defining a VO is common in the Grid paradigm, where both hardware and software resources, including applications and infrastructure-enabling tools, are considered part of the VO. In our analysis of the requirements of the PGPGrid VO, therefore, we will take into consideration as part of the VO's definition, not only the project members in terms of the participating organisations and the individuals working within them, but also the VO-enabling technologies. Furthermore, our definition will include the resulting deliverables of the VO, including reports, software, and the final deliverable of an animation film, which will be the result of a novel prototype, Grid-enabled 3D CGA system. Hence, this report, as a deliverable of the PGPGrid project, is considered part of the VO's definition. The construction of the PGPGrid VO, therefore, must take into account all of these entities and the relationships between them.

The 3D-Matic laboratory produces computer-generated three-dimensional (3D) mesh models of the motion of real human subjects. Motion capture is achieved using eight sets of three TV cameras, two monochrome and one colour, which are positioned statically around the subject being filmed in a studio. The mesh models which are produced can be viewed from any direction. This has the effect of producing almost any camera angle and is equivalent to an animator being able to position a camera anywhere they wish after the process of motion capture. This results in enormous creative opportunities while cutting the overheads of re-shoots.

The production of these 3D mesh models is a two step process using in-house software. These processes are called *ranging* and *modelling*. Figure 2 shows the overall process for the production of a model for one frame of motion capture, using ranging and modelling. The computer-generated mesh models that are produced by 3D-Matic can then be used by PGP to create animation by the addition of scenery and textures to the models, prior to rendering each frame using third party rendering software, such as 3D Studio Max's internal renderer [52].

The processes of ranging and modelling are both computationally intensive tasks. For each captured frame, eight processes are used for ranging, one for each pair of monochrome cameras from the eight sets that are used for motion capture. During the ranging process, the data from each pair of monochrome cameras is analysed in order to calculate the positions in three dimensions, of a set of points on a speckled pattern that was projected with light onto the subject during motion capture. A method of parallax correction is used for this calculation. The data from the eight ranging processes are then merged in a single modelling process, to produce 3D mesh models for each frame. It should be noted that the colour camera in each of the eight sets of cameras is used to capture the skin textures and tones of a subject. This can be subsequently used in the rendering process. The ranging and modelling processes can be performed remotely, with respect to 3D-Matic's laboratory, on distributed resources that may be accessed using Grid Middleware such as the Globus Toolkit.

The process of rendering, which is also significantly computationally intensive, can be performed remotely, with respect to PGP, on distributed resources that may be accessed using Grid Middleware. Rendering can

be performed on separate frames concurrently. Depending on the rendering software used, rendering may also be performed on segments of a frame in parallel.

The parallel natures of the ranging, modelling, and rendering processes, added to the fact that frames of motion capture and animation can be produced in parallel, result in an animation production process that can take advantage of a rich environment of distributed resources. The ability to undertake these processes in parallel, in a heterogeneous environment of computing platforms and using state-of-the-art Grid Middleware, is of particular interest.

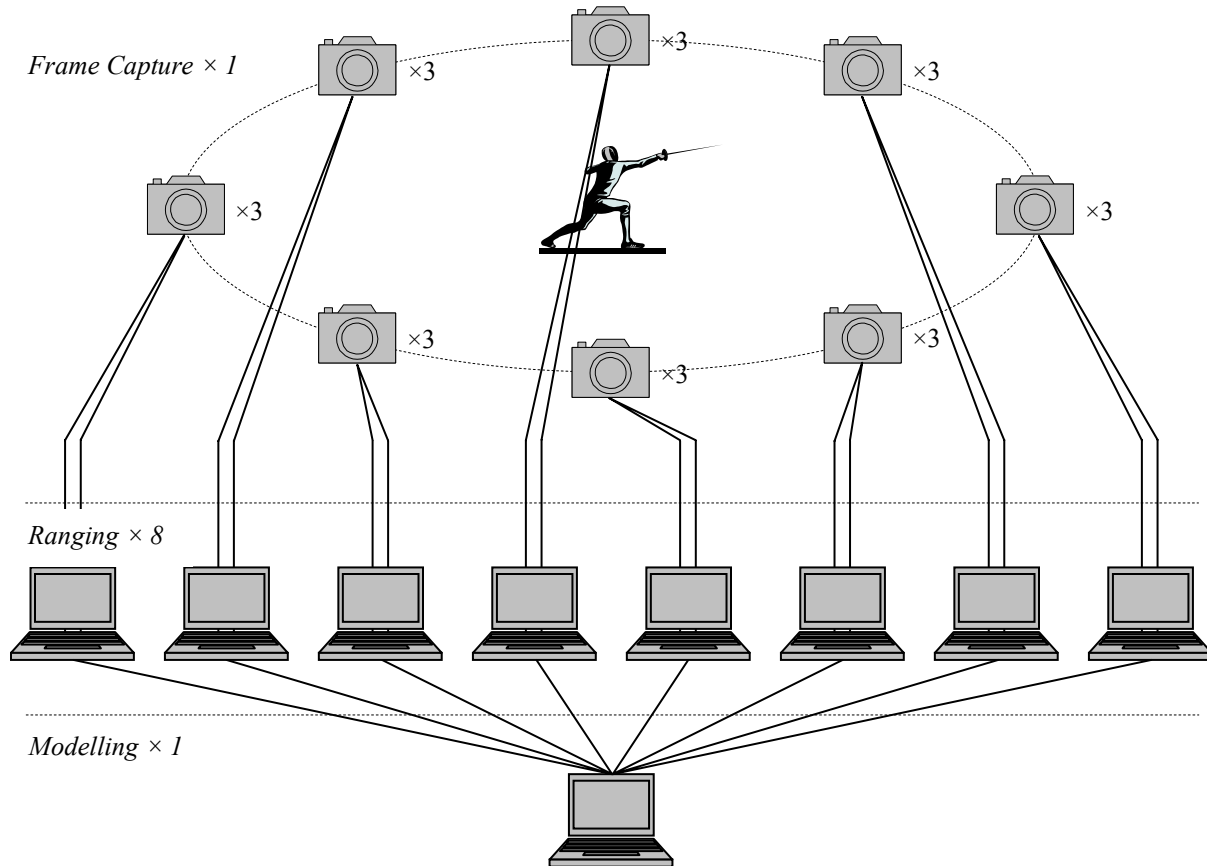


Figure 2: The schematic of the system used by 3D-Matic for motion-capture. At the top, eight sets of three cameras are shown, two monochrome and one colour. Also shown is the current set up for the process of *ranging*, where data from the two monochrome cameras in each set are analysed as a separate process for each frame. In the process of *modelling*, the ranging data from all of the eight ranging processes performed per frame, are merged into a single model for that frame.

In addition to being compute-intensive processes requiring lots of CPU power, both the modelling and rendering processes are data-intensive. As such, these processes require lots of storage space on disk. There are also requirements for appropriate networking infrastructures and high bandwidth for large data transfers on-demand. Unfortunately, the networking infrastructure in the UK is still such that high bandwidth

networks are as yet uncommon. This leads to network bottlenecks at the end-user domains, especially for small companies such as PGP.

The PGPGrid VO has facilitated the management of the work of its member organisations by dividing up the tasks of the project into a number of well defined and, to a large extent, independent Work Packages (WPs). In this way, the management of the interdependencies between these tasks has been divided into a number of smaller units based on these WPs. It would be prudent to note that each of the PGPGrid project's WPs involves only two of the three member organisations of the VO. This is especially helpful for managing the tasks involved in each WP, since two-way collaboration and management is easier than three-way. It is helpful, therefore, for the work of a VO to be factored into a number of WPs, each of which would involve as smaller a number of VO members as possible.

In large VOs, which may consist of tens or hundreds of autonomous VO member organisations and individuals, the practice of dividing the work into well distinguished WPs is particularly important. Otherwise, the complexity of such collaborations could lead to eventual deadlock in decision making processes. This problem may be further evaded by imposing a hierarchy to a VO's structure, such as that described in Section 2.5 for the OGSA-DAI VO, where certain organisations or cross-organisational committees rank higher than others in the management and the decision making processes. A balance must be struck, however, between the imposition of umbrella policies on all VO members by higher ranking organisations, and allowing those VO members to maintain their autonomy.

The PGPGrid project is managed on two main levels. Although the PGPGrid project has a primary investigator, who is based at 3D-Matic, at the upper-management level the VO is jointly managed by the Project Management Board. This board consists of a manager at each of the VO's three member organisations. VO management issues are discussed and decisions are made at a bimonthly project partners' meeting. At the organisational level, each of the project managers oversees the tasks of their respective organisation. As already mentioned, the work of the VO is divided into a number of distinct and largely independent WPs. This makes the management of each of the deliverables easier to undertake, leaving the management of the interdependencies between the WPs and the deliverables as a more focused effort between all of the project managers.

At each of the member organisations, the local manager will manage a number of technical and administrative staff who undertake the work of that organisation within the VO. The management strategy for the management of staff and assignments in each organisation will depend on its preferred project and line management methods.

More focused technical meetings take place on a more ad hoc basis in order to address particular issues that may be hindering the progress of work, or which may need addressing before further decisions can be taken on the direction that the VO or a particular WP must take.

While established practices within individual organisational sites have seen many years of experience, cross-collaborative delivery of project objectives is still fairly new with respect to VOs, especially those involving novel computing technologies such as the PGPGrid VO. Project deliverables, be they documents, intermediary software tools, or finished products, involve multiple participants. Within the PGPGrid VO, where the project tasks are broken down into WPs each of which is the responsibility of two of the three member organisations, deliverables have to be produced in collaboration. This involves communication using the tools discussed in Section 2.1.1 and in addition the VO-enabling technologies for the production, monitoring and QA, and reviewing of project deliverables.

The following subsections give more details of the PGPGrid VO members and their roles within the VO.

3.1 *Pepper's Ghost Productions Ltd.*

PGP is a character-based creative properties company. It exists to take advantage of the shift in technologies to deliver those properties across a wide range of established media. In the PGPGrid VO, PGP's role is the creator and owner of animated character assets. PGP is effectively the end-user and commercial exploiter of the technology that the PGPGrid project seeks to develop.

PGP have experience with the production of high quality 3D CGA across a wide range of genres and media, including computer games, e-books and web sites. In addition, PGP bring their experience of the real-world implications of the technologies associated with Digital Media production to the VO.

PGP's experience has led to the development of the PG Studio™ production management tool [50] for the animation industry. This tool is a good example of the use of developing technologies in the animation industry. It is a VO-enabling tool for the animation industry. It enables multiple site, multiple project, production management for animation production. PG Studio™ allows for flexible production planning on a per project basis. It incorporates a scheduler to allow time and financial budget management, in addition to providing a high level view of the virtual Production Shop for the allocation of fixed resources across multiple productions. PG Studio™ supports cross-site collaboration, allowing geographically distributed project members to share the data that they have created in a coordinated way. It also provides the means for remote communication between project members, facilitating intra-VO communication.

3.1.1 PGP's Role in the PGPGrid Project

PGP will work with 3D-Matic and EPCC individually on independent parts of the project. In their work with 3D-Matic, PGP will provide requirements and direction for the production of the body conforming software for the modelling process, which follows motion capture using video. This conforming software will allow animation sequences, as opposed to single frame shots, to be modelled. Overall, PGP will need to ensure that the 3D models and sequences provided by 3D-Matic are compatible with their production and rendering environments.

In collaboration with EPCC, PGP will ensure that a suitable distributed rendering environment is established that will allow them to have control over remote resources supplied by EPCC. This environment may be based on appropriate Grid interfaces within a Grid framework. In this effort, PGP will bring rendering experience and end-user requirements to the VO. Additionally, PGP will provide the requirements of the rendering software to be used on a geographically distributed compute-farm of many disparate computing clusters.

3.1.2 PGP's Motivations in the PGPGrid Project

The PGPGrid project can have a potentially large impact on PGP's business and their model of animation production. The extremely compute-intensive task of rendering is one of PGP's main production processes. Currently, PGP is limited to their proprietary rendering compute-farm. If more computing resources are required for a particular production, PGP may wish to outsource the rendering process to any number of companies that specialise in providing large compute-farms for such jobs. Outsourcing, however, would mean that PGP would have to give up their control over the rendering process, and could not carry out adequate dynamic QA of that process. Any flaws in the rendering or overall animation processes, therefore, would have to await the return of the final rendered product before being detected. A more suitable model would be for PGP to have on-demand access to remote, distributed rendering resources beyond the capabilities of their own compute-farm, and for them to maintain control over those resources for QA of the

rendering processes. This model is one that the vision of Grid Computing purports to support, and one that the PGPGrid project aims to prototype as a proof-of-concept infrastructure.

Dynamic access to spare resources on-demand would enable PGP to build a new business model based on rent-on-demand computing services with much more power than PGP's own resources. Such a model would enable artists to improve their creative experimentation without a detrimental impact on a project's time budget, although this may prove more costly in terms of renting resources. Perhaps more interesting would be the ability to add topical material and references in productions within short time periods of the occurrence of some current affairs, by utilising the availability of external resources for fast, on-demand, production.

Other likely outcomes of this new production model include:

- reduced turnaround time on productions;
- cost reduction through savings on the procurement and maintenance of proprietary hardware resources, and even possibly software and licenses;
- increased creativity of animators and artists through experimentation;
- increased quality of final productions through more rigorous quality assurance, allowing for corrective action on-demand;
- reduction of overall cost in production through higher efficiency;
- increase of turnover commensurate with higher efficiency and increased work loads, enabled through collaboration in VOs, and the use of external resources on-demand and with low overheads.

PGP will also take advantage of the unique and cutting-edge 3D motion capture technology offered by 3D-Matic. In active collaboration with 3D-Matic, PGP stands to gain a competitive advantage over its rivals, by providing its own requirements to 3D-Matic in order to drive the development of their technology toward its own needs. Using this new technology, then, PGP will be able to open new creative dimensions in the animation sector that will make its productions more distinct, with the hope of buy-in from the animation industry that will enable it to grow its business.

3.2 The 3D-Matic Laboratory of The University of Glasgow

According to [3], "3D-Matic is a research laboratory of the Department of Computing Science, University of Glasgow. The purpose of 3D-Matic is to address the needs of SMEs wishing to gain access to advanced 3D non-contact digitisation techniques by connecting industrialists with research groups and researchers working in that field." To this end, 3D-Matic aims to promote the application of 3D imaging from research to a wide area of use in mainstream industries, such as the animation industry, and to commercially exploit the capabilities of the novel technologies that it develops.

Through research carried out at the 3D-Matic laboratory, 3D-Matic aims to:

- target proof-of-concept and similar prototype development funding, in order to turn research output into a form suitable for use by industry.
- commercialise prototyped technology via the most appropriate routes.
- form strategic relationships with 3D imaging hardware suppliers.
- develop bureau services for 3D dynamic image capture and validation and testing of 3D imaging systems.

3.2.1 3D-Matic's Role in the PGPGrid Project

3D-Matic will work with PGP and EPCC individually on independent parts of the project. In their work with PGP, 3D-Matic will provide the capability for 3D image capture of actors using their laboratory facilities and homegrown application software suite. In addition to their facilities and software, 3D brings many years of 3D image capture and manipulation experience to the PGPGrid VO.

In collaboration with EPCC, 3D-Matic aims to develop a work scheduling and allocation protocol within a Grid paradigm, which will enable them to farm out compute-jobs to a geographically distributed and heterogeneous environment of computing clusters. This Grid protocol is being developed to work with an interface to the 3D-Matic applications, which will allow the 3D-Matic applications to be used in other environments and independently of the aforementioned Grid protocol, if desired. In this effort, 3D-Matic will represent the end-user with a set of requirements and provide technical development aiming to fulfil them.

With respect to providing 3D image capture and model construction technology for the PGPGrid project, 3D-Matic's effort includes:

- the delivery of body conforming software to provide suitable model data to PGP for animation and rendering;
- the provision of 3D-Matic facilities for motion capture of actors for the project; and
- the delivery of image sequence models to PGP.

With respect to the Grid-enabling of their software application environment, 3D-Matic's effort on the PGPGrid project includes:

- the design of the work scheduling and resource allocation Grid protocol for farming compute-jobs based on the 3D-Matic application, to Grid resources;
- the implementation of the work scheduling and resource allocation Grid protocol in collaboration with EPCC;
- the design and implementation of the parallelised 3D-Matic software application for processing images into 3D mesh models, so that advantage can be take of faster turn around time for frame processing of image sequences, enabled by a Grid environment of distributed computing resources.

3.2.2 3D-Matic's Motivations in the PGPGrid Project

The primary goal of 3D-Matic is the transfer of novel 3D imaging technology to British industry. The PGPGrid project is an important platform from which to do this. The 3D body motion capture and 3D mesh model construction techniques being developed by 3D-Matic are revolutionary. Their application to the animation industry is an important step forward, both for CGA techniques, and for 3D-Matic in meeting their primary objective of technology transfer.

The potential of real-time motion capture and animation, including the processes of real-time modelling and rendering of film sequences, is a very real prospect for the future. This would make use of distributed computing infrastructures that will be present in Grids. 3D-Matic stands to gain considerable experience and technology from the parallelisation of its software application and its adaptation to exploit Grid technologies and infrastructures. This is a crucial step toward forming dynamic VOs in order to deliver

high quality and creative entertainment products, including animation, on-demand. 3D-Matic stands to gain a competitive edge over its rivals, by offering such services to clients that will in turn give them a competitive edge.

A by-product of Grid-enabling their application to provide scalable, high speed, animation production based on their motion capture technologies, will be the experience that 3D-Matic will gain from the development of the Grid based communications protocol used by its application processes. It is planned that this protocol will be generic enough to be employed by other applications to operate within Grid infrastructures.

3.3 EPCC of The University of Edinburgh

EPCC was founded by the University of Edinburgh in 1990 as a technology transfer centre for novel computing solutions. As such, EPCC is committed to developing computing standards and to turning its research activities and cutting-edge technologies into industrial strength solutions through consultancy. The result is the attainment of a rich spectrum of experience and capabilities on which to draw from in their consultancy work.

In addition to providing novel computing solutions, EPCC is a service provider of high performance computing. It also provides consultancy for software and algorithm design, and software parallelisation and optimisation for supercomputers. Further to the provision of high performance computing services locally, the University of Edinburgh, through EPCC and in conjunction with the Central Laboratory for the Research Council's Daresbury Laboratory, runs a 1280 node, Power4 processor IBM supercomputer known as HPCx [51]. HPCx can deliver a sustained performance of 3.5 Teraflops.

A large fraction of EPCC's current activities include research and development projects involving Grids. As part of these activities, EPCC contributes to the standards development processes within GGF, where specifications are being provided for the design and construction of Grids. This gives EPCC considerable experience in developing Grid technologies and Grid-enabling specific applications, with the added capability of feeding requirements back into the standards development process within GGF.

3.3.1 EPCC's Role in the PGPGrid Project

EPCC will work with PGP and 3D-Matic individually on independent parts of the project. EPCC has access to a number of computing resources, which it aims to provide to the PGPGrid project. Within a Grid framework, which is to be established as part of the project, EPCC will provide the computing capability required for both the compute-intensive processes of model construction as carried out by 3D-Matic, and animation and rendering as carried out by PGP.

The requirement of dynamic on-demand access to computing resources is a key part of the PGPGrid requirements. EPCC will provide experience of Grid research and development to establish the required Grid environments, which will host the modelling and rendering processes. In addition, this Grid environment will enable 3D-Matic to employ its work scheduling and resource allocation Grid protocol in order to farm out its compute-jobs.

In order to enable remote rendering on a Grid, EPCC will study the requirements of this process in terms of the available computing and software resources. EPCC will then design and implement the necessary infrastructure and, in conjunction with PGP, deploy the rendering environment. EPCC will develop tooling in order to utilise this environment, which will enable remote control of the rendering process.

EPCC will work with 3D-Matic to design and implement their work scheduling and resource allocation Grid protocol. EPCC will provide the resources for 3D-Matic to utilise for their computational and storage

needs, and use their protocol in a Grid environment. EPCC will provide consultancy to 3D-Matic, to allow them to Grid-enable their applications appropriately.

In conjunction with PGP, EPCC will study the paradigm of the VO using current knowledge and a number of case studies based on other VOs, in order to apply known practices and existing experiences to the PGPGrid VO. Indeed, this report is the result of this study, and aims to produce an account of the experiences of setting up the PGPGrid VO and its working practices. It is the intention of EPCC to provide a possible Best Practices document in the shape of this document, which will be useful to other VOs in the animation industry.

By exploiting the Grid paradigm, EPCC aims to provide significant computing resources to a VO where individual partners would otherwise be very limited in access to such resources. The provision of high performance computing resources within a Grid paradigm is a core competency of EPCC as a member of the VO, and is the key factor for EPCC's membership of the PGPGrid VO. EPCC's experience in Grid technologies and infrastructure building, compounded by their access to high performance computers and experience in providing computing services, makes a strong case for their involvement within the VO.

3.3.2 EPCC's Motivations in the PGPGrid Project

The PGPGrid VO and project will provide EPCC with additional opportunities to evaluate the current state of Grid technologies and tools. EPCC will gain invaluable experience from the development and deployment of the Grids for 3D-Matic's application and protocol, and for PGP's rendering needs. These experiences will put EPCC in good stead for future consultancy and development projects involving Grids. In addition, EPCC stands to gain a great deal from learning about the animation industry, so that it may work in this sector in future.

It is important to note that the experience of setting up the PGPGrid VO and studying other collaborations in the animation industry, will also provide EPCC with good experience in order to provide consultancy in VO construction and management in future.

4 PGPGrid VO Requirements and Recommendations

This section presents the requirements of the PGPGrid VO and a set of recommendations for the construction and management of the VO, which are based on those requirements.

A description of the comprehensive definition of the PGPGrid VO was given in Section 3. With this definition in mind, the requirements of the PGPGrid VO have been divided into four categories, which are described in the following sections. These include the logistical requirements of the VO, including those for VO management, meeting-logistics and communication, and a section for the requirements for collaboration tools and VO-enabling technologies. The latter includes the software and hardware requirements that the VO needs to work as a unified entity and to achieve its goals.

4.1 Management of the PGPGrid VO

The management structure of the PGPGrid VO was described in Section 3. The management of the VO involves the management of its tasks, both at the organisational level and at the VO level. At the VO level, management is undertaken mutually by all member organisations. Within each member organisation, they can exercise autonomy in managing their tasks and staff. This is on the premise that they are able to coherently interact with the other member organisations, and uniformly manage the interdependencies between themselves.

Management Requirements

The management of the interdependencies between VO member organisations requires that a certain understanding be reached between local managers at each of the member organisations. This understanding will be represented by the facilitation of the policies of each member organisation, allowing them to remain autonomous, while abiding by a set of new common policies that the VO needs in order to bring uniformity to its management and to achieve its objectives. These new VO policies govern the way in which it functions as an entity. They include policies relating to management hierarchies within the VO, communications channels, and the chain of responsibility across the VO.

The PGPGrid VO is small enough that an organisational hierarchy is not required. Nor is it desired given the diverse organisational cultures of the VO members, all of which require their independence. This is compounded by the nature of the tasks at hand, which are research driven in nature. The overall management of the VO is, therefore, undertaken by an overseeing Project Management Board whose members consist of a manager at each of the VO's member organisations. Further, the project partners involved in any one task, all have the same weighting for management and decision making.

Management Recommendations

The management of the PGPGrid VO should be based on a number of common VO policies. These common policies should apply to all of the VO's member organisations and individuals. They will allow members to work together within a unified VO to meet their goals. These policies should ideally be captured in a Collaboration Agreement. This Agreement does not usually include consumers of the deliverables of the VO, unless they have commissioned and instigated the VO. While a set of common VO policies are necessary, the organisational autonomy of VO members must be facilitated through mutual appreciation of each organisation's internal culture and policies.

It is recommended that a set of VO specific policies governing its management and organisation be agreed and included in an appropriate document to complement the existing Collaboration Agreement. This document may or may not be legally binding. These policies should address the following issues:

- the management structure of the VO;
- the technical and project standards used by the VO;
- the intellectual property rights of VO member organisations;
- the product licensing issues that may concern the VO; and
- the confidentiality and disclosure agreements concerning the VO.

It is highly recommended that the details of the VO specific policies cover the following points:

- The production of deliverables, including documents and software code;
 - this policy should be implemented using distinctive VO document templates and VO specific coding standards. The latter should specify the style and format of produced software code, in addition to software engineering practices such as design and testing methodologies, for example *Test Driven Development*.
- The dissemination of information and deliverables;
 - this policy should be captured in the design of a communications framework, which should involve VO-enabling technologies such as the use of a web site as a document repository.
- The means and channels of communication within the VO;
 - this policy should be captured in a set of recommended technologies, such as electronic mailing-lists and Chat technologies, for inter- and intra-organisational communications and specific policies on when and how to use them.

- The methods for internally reviewing deliverables and mechanisms for providing feedback;
 - this policy should be captured in a set of procedures that allow the VO to methodically review draft documents, software code, and final deliverables, and to provide feedback using standard means and formats. For example, by using the document *change tracking* facility of the Microsoft Word software.

4.2 Meeting-Logistics in the PGPGrid VO

This section addresses the requirements of meeting-logistics within the PGPGrid VO. This includes meetings which are internal to each of the member organisations, meetings between individuals working on a task, or partners' meetings between all of the VO's member organisations. These logistics include the frequency of various meetings and the medium over which the meetings should take place.

Meeting-Logistics Requirements

The PGPGrid VO's member organisations need to meet several times a year in face-to-face meetings in order to report on the status of work and to steer the course of the VO. In addition, there is a need for developers across the VO to meet as and when necessary to discuss the work at hand. This latter requirement for ad hoc meetings substantiates the need for some of the more technologically advanced communications media previously mentioned in Section 2.1.1, especially when face-to-face meetings are not possible.

Any discussion regarding the course of action which should be taken within each WP and its progress, must involve focused discussion by the partners involved. A set of meetings to enable this will need to take place as dictated by the progress of each WP.

Meeting-Logistics Recommendations

It is important to take into account the experience of the OGSA-DAI VO as described in Section 2.5. Specifically, the OGSA-DAI VO found that there was no communication medium to facilitate meetings, which was as effective as face-to-face meetings for bringing autonomous organisations together to work as a single VO. For key meetings, therefore, the overheads associated with travelling to face-to-face meetings are deemed worthwhile, compared to the inconveniences of remote-conferencing facilities. This being the case, and considering the small size of the PGPGrid VO, with its member organisations within relatively close proximity of one another, it is possible for the VO to meet frequently for face-to-face VO management meetings and for technical discussions. The latter may be confined to specific WPs, each of which involve only two of the three organisations.

From a management perspective, all three VO member organisations are equal in the running of the project with respect to decision making and responsibility for deliverables. Although the chair of the Project Management Board, being the principle investigator of the PGPGrid project, could oversee the bimonthly VO partners' meetings that involve all of the VO members, these meetings are chaired by the local manager of the host organisation.

It is recommended that the PGPGrid VO minute all inter-organisational meetings, no matter what their format, and that these minutes be based on a standard template. Meeting minutes need to include a Risks section and Action-Lists of the actions attributed to various individuals or member organisations, so that there are no ambiguities as to the particular tasks agreed upon in meetings. The critical importance of meeting minutes cannot be overstated. All meeting minutes should be disseminated via an appropriate electronic mailing-list.

Other than the bimonthly partners' meetings, face-to-face technical meetings are required. These meetings can take place whenever a topic of discussion arises. This provides the consistent focus that any issues require for discussion, which would be missing from the e-mail and Chat media due to the staccato-like nature of their discourse.

For ad hoc meetings for the discussion of detailed issues concerning various WPs, it is recommended that developers make use of the communications technologies discussed in Section 4.3 below. If need be, various issues can be escalated to the level of the WP face-to-face meetings, such as those suggested in the previous paragraph.

4.3 Communication within the PGPGrid VO

This section addresses the communication needs of the PGPGrid VO. Whether for meetings, for discussions, or for information dissemination, communication methods and tools are an important factor governing the efficiency and productivity of a VO.

Communication Requirements

The various meetings that the PGPGrid VO will undertake, impose a set of requirements for communication methods and technologies. These requirements need to be fulfilled for the successful management of the VO and to facilitate those meetings.

Although the work of the VO is well divided into largely independent WPs, each of which involve only two of the three VO member organisations, it nevertheless serves a useful purpose for all project partners to be aware of the progress and architecture of the whole project, including dissemination of the progress of individual WPs. An appropriate communication framework should ensure the constant notification of VO members regarding progress across the VO.

Communication Recommendations

Within the PGPGrid VO, every individual has access to networked computers and, therefore, the use of e-mail and Chat technologies. The PGPGrid project VO should continue to use an appropriate set of electronic mailing-lists for project-wide communication and to keep all VO members in touch with the progress on various WPs. Further, these mailing-lists are an effective means of opening discussion on particular issues. If more dynamic and real-time discussions are required, such as on various low-level design aspects, Chat technology can play an important role as a communications medium and should be used in conjunction with telephone-conferencing.

The PGPGrid VO holds a bimonthly project partners' meeting. This partners' meeting should serve for the dissemination of information, including progress on various WPs and design decisions, and to highlight common administrative and technical issues. In addition, the partners' meeting should provide a useful face-to-face forum for the planning required on a project-wide scale. The bimonthly meetings should be enhanced by the use of the project-wide electronic mailing-list, through which communications should be sent to every individual member of the VO, and a separate mailing-list for the Project Management Board.

It should be noted that due to the problems of e-mail Spam, e-mail latency and e-mail overload, the telephone has proved a crucial tool in communications between individual VO members for every day use. In addition, where the topic of discussion has been particularly technically challenging, the telephone has again been the tool of choice in order to communicate the issues. The telephone provides the urgent attention that is sometimes required by the task at hand. It is recommended that telephone meetings also be minuted as described above.

In addition to a set of irreplaceable face-to-face management, status and technical meetings, the VO should use telephone-conferencing for more frequent contact. Weekly or fortnightly telephone conferences are

recommended between VO partners working on the same WP. These telephone-conferences should serve as a forum for the discussion of technical issues, and to provide a continuous stream of status updates so that feedback can be provided immediately. This would mean that the progress of a WP can be closely monitored to ensure that it is moving in the right direction. Without this frequency of contact, it is possible for organisations participating on a WP to evolve their work internally, without the collaborating partner being aware of the direction of the progress of that WP. This can lead to misunderstandings between WP partners and result in delays and incompatible deliverables.

To complement the frequent telephone-conferences, the VO should make use of Chat technology for ad hoc technical discussions. One-to-one telephone contact may be used in situations where a more dynamic discussion is required. The Chat medium as a communication tool becomes more useful when ideas need to be bounced around for feedback, where displaced individuals are collaborating closely on a deliverable. This is particularly important at the design stages of a deliverable. This is because, while implementation can be undertaken in relative isolation according to appropriately detailed design and specification documents, it is not possible to produce a collaborative design in isolation. Chat technology provides the additional benefit of the automatic logging of interactions for future reference.

In terms of video-conferencing requirements for the PGPGrid VO, due to the close geographical proximity of the VO's member organisations, the large frequency of already planned face-to-face meetings, the use of a VO-wide electronic mailing-list, and the largely independent nature of the tasks undertaken by the VO members, there is little requirement for this technology. It is possible, however, for video-conferencing to be used, perhaps in the form of Access Grid.

It is imperative to note, that all of these communications media may be used in tandem to enhance understanding and interaction. Within the PGPGrid VO, it is often found that the combination of e-mail and telephone best suit personal communication, while Chat may allow more dynamic real-time interactions.

4.4 Collaboration Tools and VO-Enabling Technologies

It has already been established in the preceding subsections, that the web and e-mail are invaluable collaboration tools for communication within the PGPGrid VO. This section attempts to describe other technological requirements of the PGPGrid VO in terms of additional collaboration tools, including the software and hardware that is required to deliver its work. Additionally, these technologies will be used for managing project deliverables, including QA, and for assessing the progress of the project against its milestones.

Tools and Technologies Requirements

As part of its work, the PGPGrid VO will produce a number of software applications. The production of these deliverables requires tight management by the VO, so as to ensure the quality of the software and the compatibility of the interfaces between the disparate pieces of the applications produced within and across various WPs. The VO also requires a means for archiving and subsequently publishing their work, which includes the software that they produce. Many Open Source collaborations use web sites such as SourceForge [17] for this purpose.

The work of the VO is broadly divided into two major components, which relate to the two steps of the 3D CGA process. The first step is that of the production of digital mesh models of characters and scenery, and the second step is that of the process of rendering, which applies textures and lighting to those models. These processes were described in more detail in Section 3, for the PGPGrid project. The requirements for each of these processes include the software and hardware that are required in order to develop the infrastructure to host and perform these processes.

In addition, there are a number of requirements that are necessary in order to bring the two processes of modelling and rendering together through the use of Grid interfaces. This will then enable the formation of

an assembly-line production environment for the production of 3D CGA over a distributed system. Further, the use of Grid technologies for resource acquisition will satisfy the compute-intensive processes involved. The use of Grid technologies imposes many requirements for novel technologies, many of which are either under development or have yet to be developed. The development of any new Grid related technologies will need to be undertaken by the PGPGrid VO.

The processes of modelling and rendering are also data-intensive. This means that they require and produce large quantities of data. It is desirable that the data reside at the execution environment. This would alleviate the need to dynamically move large amounts of data at run-time (streaming), when network congestion could cause processors to wait idle for the data to arrive. This would, however, require that the data be moved to the execution environment before processing can begin and, therefore, requires disk space where the execution of computational processes will take place. As part of the modelling work, the project aims to investigate the effects of streaming data, as opposed to scheduling their arrival at the place of execution.

An important issue for the PGPGrid VO, and indeed for any VO undertaking advanced IT work, is that of the portability and adaptability of third-party and custom software within the VO. This issue becomes even more important when software is required to run in a heterogeneous environment where the platform of the executing machine is unknown *a priori*. There are a number of requirements that arise as a result of this. Primarily, there is a need to ensure that the software that is to run on a Grid of heterogeneous resources is portable and can be executed on the available platforms. Secondly, there is a need to ensure that the various pieces of software that need to interact, that is, those which have a requirement to communicate data to one another, use protocols, languages, and data formats that are compatible and portable within a heterogeneous computing environment. And finally, there is a need to ensure that commercial software licences for use within a Grid environment are appropriately configured for distributed use.

Tools and Technologies Recommendations

For the management of software deliverables, including production, reviewing, and integration prior to release, and to ensure their quality, the VO should make effective use of the technologies introduced in Section 2.1, including CVS and an appropriate IDE. In addition, the VO should abide by a set of software coding standards, including coding style guidelines. Indeed, CVS has been successfully used at EPCC as a repository for the development and versioning of document deliverables. The use of IDEs provides increased productivity and efficiency, in addition to aiding the production of uniformly presented and implemented software. Modern IDEs, such as the Eclipse IDE which is especially good for Java development, can be configured to abide by the coding styles and standards that the VO may wish to use.

It is important to bear in mind that it is helpful if design documentation follows design patterns and templates. These should be specified in the VO's collaboration policies. This would remove ambiguities about the format and schema for designs, and help to avoid misunderstandings between project members when communicating those designs. It is recommended that for software development, standard UML notations be followed so that designs are concisely presented in standard documents and unambiguously understood by those who need to review and work with them.

For the management of the work of the VO, the project management tools used by the OGSA-DAI VO and mentioned in Section 2.5 should be considered. They include the following:

- the Microsoft Excel spreadsheet software;
- the Microsoft Word word-processing software;
- the Microsoft Project project-management software;
- process documents, including:
 - project plans, including Gantt charts;
 - project definitions;
 - work plans; and
 - project coding standards;
- Action-Lists; and

- telephone-conferencing.

The use of a Wiki based web site would provide an ideal medium as a repository for the work of the VO, and to distribute that work for reviewing within the VO and beyond, as it would also serve for externally publishing that work. In addition, Wikis can provide versioning capabilities for archiving. Such a technology would allow distributed administration of the web site with access for all VO members. The use of electronic mailing-lists can then facilitate a notification mechanism, whereby other VO members are notified of the change of state of the Wiki system, including, for example, the availability of new versions of documents for review.

The PGPGrid VO will need to construct two Grid environments, one for modelling and one for rendering. These Grid environments will be the key VO-enabling technologies for the work of the PGPGrid VO. These Grid environments should feature remote compute-job execution and data transportation for those jobs, in addition to scheduling the data and the jobs. They will enable dynamic resource provision on-demand when resources are available.

In order to work within the Grid environments that the PGPGrid project requires, the VO needs to design suitable protocols for the interactions between resources and resource consumers. The latter will be in the form of custom client applications, which will also be designed and implemented as part of the project. Resources can be given Grid Service based interfaces that will allow them to advertise their existence and state. In addition, these interfaces can be used as end-points for communication using the protocols implemented by the VO.

In order to deliver the Grid infrastructure that the PGPGrid VO requires for the distributed production of 3D CGA, the VO should gain leverage from existing Grid Middleware technologies. The most common of these is the Globus Toolkit. The VO can build higher level applications that will use the Globus Toolkit's core low level functionalities, which are based on the Grid Services paradigm. In addition, the VO must implement a protocol that can be facilitated by a set of Grid Services. This protocol should allow interactions between application entities deployed across the VO. These entities include the aforementioned higher level applications and will enable transaction management and remote control of the processes, in order to take advantage of a uniform, coordinated, and coherent infrastructure. For the PGPGrid VO, where access to the resources of the VO that are distributed across the private domains of the VO's member organisations is a critical requirement, the use of Grid Service based interfaces provides a powerful means of enabling virtual access to those resources for all VO members regardless of their organisational affiliations.

The PGPGrid VO has a number of ways in which to overcome the issues associated with software use in distributed environments such as Grids. The homegrown software produced by the VO is implemented in the Java programming language and as a result can be used on any platform that supports Java. The wide availability of Java and its late machine-language binding mechanisms, which make use of intermediary byte-code and platform dependent interpreters, mean that it is an ideal programming language for heterogeneous Grid environments. The VO should continue to develop and use, as far as possible, platform independent technologies, including Java and XML, and software architectures.

The main third-party software that the PGPGrid VO uses is the rendering software that is required by PGP in order to produce animation sequences from the models provided by 3D-Matic. This software is 3D Studio Max's internal renderer [52]. The PGPGrid Rendering Environment Report [53] presents a survey of available computing systems and rendering software for the project. It concludes that 3D Studio Max's internal renderer is the most suitable and readily available for the project. The licensing for this rendering software is such that it can be used in distributed environments by the owner of the license. The VO will need to provide a remote and distributed rendering environment that makes use of the multi-node licenses issued with this software.

Appendix: Literature Resources on Virtual Organisations

The following list of resources provide references to literature, including publications, on Virtual Organisations.

- Chris Kimble is a lecturer in Information Technology and Management in The Department of Computer Science at the University of York. His teaching web pages include:

Virtual Organizations: A new organizational form or just “business as usual”?

http://www-users.cs.york.ac.uk/~kimble/teaching/mis/Virtual_Organisations.html

This is a valuable source of references on VOs.

- SocioSite is the Social Science Information System based at the University of Amsterdam and has a “Sociology of Organization” web page with numerous references to VOs. It is located at:

<http://www2.fmg.uva.nl/sociosite/topics/organization.html> ,

- Virtual Organization Net (VoNet) at:

<http://www.virtual-organization.net/>

has resources including:

- the “Journal of Organizational Virtualness”;
- a discussion forum;
- a literature source at:

http://www.virtual-organization.net/CGI/resource/res_lit_search.asp ;

- and a definition source at:

http://www.virtual-organization.net/CGI/resource/res_def_start_anzeige.asp .

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- [4] EPCC of The University of Edinburgh web site: <http://www.epcc.ed.ac.uk/>
- [5] The Globus Alliance web site: <http://www.globus.org/>
- [6] One of many Internet Relay Chat (IRC) web sites: <http://www.irc.org/>
- [7] One of many I-Seek-You (ICQ) web sites: <http://web.icq.com/>
- [8] The Access Grid web site: <http://www.accessgrid.org/>
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- [18] The Cunningham & Cunningham, Inc. Wiki web site: <http://c2.com/cgi/wiki>
- [19] The Digital Media FX Features web site: <http://www.digitalmediafx.com/Features/maxfleischer.html>
- [20] The Digital Asset Management For Animation For Global Entertainment (DAMAGE) project page on the EUREKA web site:
<http://www.eureka.be/ifs/files/ifs/jsp-bin/eureka/ifs/jsps/projectForm.jsp?enumber=3062>
- [21] The "about EUREKA" page on the EUREKA web site:
<http://www.eureka.be/ifs/files/ifs/jsp-bin/eureka/ifs/jsps/publicAboutEureka.jsp>
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<http://www.eureka.be/servlets/PDFResult?prjid=3062&xsl=projectFO.xsl&format=pdf>
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- [38] The UK e-Science Grid Support Centre web site: <http://www.grid-support.ac.uk/>
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- [40] The e-Science North West web site: <http://www.esnw.ac.uk/>
- [41] The North East Regional e-Science Centre web site: <http://www.neresc.ac.uk/>
- [42] The Oracle UK web site: <http://www.oracle.com/uk/>
- [43] The TWiki web site: <http://twiki.org/>
- [44] The NetMeeting web site: <http://www.microsoft.com/windows/netmeeting/>
- [45] The Bugzilla project web site: <http://www.bugzilla.org/>
- [46] The WebSphere Software Platform web site:
<http://www-306.ibm.com/software/info1/websphere/index.jsp?tab=highlights>
- [47] The Apache Ant web site: <http://ant.apache.org/>
- [48] The JUnit web site: <http://www.junit.org/index.htm>
- [49] The OGSA-DAI VO web site: <http://www.ogsadai.org.uk>
- [50] The PG Studio web site: <http://www.pgstudio.com/>
- [51] The HPCx web site: <http://www.hpcx.ac.uk/>
- [52] The 3D Studio Max (3ds max) software from Discreet: <http://www.discreet.com>
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