

**Dissertation**

*The Social Construction of the MammoGrid: A technological frames analysis of the process of technology adoption*

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## **Abstract**

The past decade has witnessed major increases in computing power, network speed and data storage capacity, having as a result constructed a technology, the Grid technology which can handle large amounts of data, distribute resources, provide transparent communication and collaboration between groups across borders, etc. The medical community has been exploring collaborative approaches for exchanging knowledge and sharing clinical information and data. The MammoGrid project is considered to be one of the first attempts in applying the Grid technology in healthcare and it aims to deploy a European database of mammograms - a prototype version – by using the Grid, to facilitate collaboration and communication between clinicians across the EU. This paper, by using social construction of technology (SCOT) and technological frames as a lens, attempts to examine the socio-technical realities which are influencing and shaping the understandings, expectations, assumptions and knowledge that relevant social groups have about the MammoGrid, as well as how the above elements are shaping their final attitude towards it. Through this investigation, a deeper insight is given concerning the MammoGrid's final adoption by its end-users.

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## 1 Introduction

Commodity computer and network performance have experienced a major increase during the last decade, as a result of faster hardware and more sophisticated software (Baker *et al.*, 2002). This dramatic increase qualitatively changed how the world computes, communicates and collaborates (Grimshaw *et al.*, 1997). However, there are still many problems and fields - like science, engineering and business – that are facing challenges, which cannot be effectively dealt with using the current generation of supercomputers (Baker *et al.*, 2002).

Scientific communities have conducted research on the cooperative use of geographically distributed resources unified to act as a single powerful computer (ibid). These studies have led to the development of *Grid technologies*, which have been widely adopted in computing (Foster *et al.*, 2002). Grid computing promises a world where large, shared scientific research instruments, diverse resources, data, analysis tools, research platforms and people will be closely integrated in dynamic, distributed virtual organizations (Foster and Kesselman, 1999, Allen *et al.*, 2003).

There are many types of Grids and DataGrid is one of them. DataGrid's goal is to deploy the infrastructure that will allow the development of “digital libraries”, where scientists will perform their activities despite their geographical location (Baker *et al.*, 2002, Rajasekar *et al.*, 2002).

The medical community has been exploring collaborative approaches for managing, storing, analyzing image data and exchanging knowledge. The Grid is a promising technology that enables new collaborative approaches for image analysis without the necessity for clinicians to co-locate (McClatchey *et al.*, 2003). The MammoGrid project was one of the first attempts to apply Grid technology in healthcare. It aimed to investigate the feasibility of developing a European database of mammograms, using a DataGrid to support collaboration among clinicians across the EU.

This dissertation is an attempt to underpin the emergence of the Grid technology in healthcare and to explore whether the MammoGrid project, will be well-received by its users, and if not

what are the possible reasons for it. For a better understanding of the situation, social construction of technology (SCOT) with a focus on technological frames (TF) is used as a lens to explain and analyze the socio-technical issues that will form the outcome.

### **1.1 Statement of purpose**

The principal aim of this research is to explore the socio-technical realities, which are influencing and shaping the understandings, expectations and interpretations that different groups have about the MammoGrid and its usage, as well as how these elements are shaping their final attitude towards it. Through this exploration, a deeper insight is given concerning the MammoGrid's final adoption by its users. As Pinch and Bijker (1984, 1987) argue, technology is socially constructed, hence people determine whether they will use it with the different meanings they attribute to it. The concept of different groups with different "readings" of technology, explains the various struggles that might occur during the process of design, development, implementation and use of a system (Howcroft *et al.*, 2004).

Through this research, some insights are gained that might prove valuable for the smoother adoption of the MammoGrid by its users. The MammoGrid is just a step away from becoming a final commercial product, so the results from this research might prove valuable in making the key actors of the project avoid the various problems that could arise in the future concerning the adoption of the MammoGrid.

### **1.2 Structure**

This thesis is organized into the following sections: Firstly, a short introduction is presented followed by a statement of purpose and the research methodology adopted for conducting this dissertation. In Section 2, a literature review of the Grid is portrayed with particular attention being given to the Grid as an information infrastructure, its architecture and defined standards and to the issues encountered by the healthcare community. Section 3, introduces the SCOT theory, mainly emphasizing the concepts of relevant social groups, technological frames, and closure/stabilization. Section 4 provides the case study description, whilst Section 5 presents the

analysis of the case based on the SCOT and technological frames. In Section 6, a discussion concerning the analysis and findings is portrayed, where some lessons concerning the implications for the adoption of the MammoGrid are highlighted. Section 7, concludes the paper and Section 8 outlines the limitations of the research as well as some suggestions for further research.

### **1.3 Research methodology**

Conducting research in the information systems' (ISs) field is pretty complex, because of its composite nature. ISs are social systems, which include both technical and human resources (Land, 1992). Their aim is to manage information, and their behaviour is influenced by goals, beliefs, values and experiences of individuals and groups as well as by the performance of the technology (Angell and Smithson, 1991).

Therefore, the adoption of the positivist approach of calculation and formalization, neglects the culture, the essence and the character of ISs (Myers, 1997). The positivist approach argues that reality is objective and can be described by properties, which are not dependent on the observers and their instruments (Crotty, 2003). However, in social situations, the notion of an objective observer is not appropriate, since observers are constrained by their values and biases and therefore, "subjectivity will obscure any attempt at objectivity" (Angell and Smithson, 1991). Hence, that is why interpretativist research is favoured by most of the researchers in the IS field (Walsham, 1993, 1995). The purpose of interpretativist research is to understand ISs in their social context, thus how they are shaping and are shaped by that context (ibid). Researchers, that adopt the interpretativist approach, assume that social reality is constructed by intentional actions of interacting human beings (Orlikowski and Baroudi, 1991, Cecez-Kecmanovic, 2005). For the purpose of this research, interpretativist research allows us to understand people's expectations, assumptions, understandings about the MammoGrid project, as well as the interdependencies between the various actors.

Qualitative research methods enable researchers to study socio-cultural phenomena, as well as to understand people and the context within which they live. The aim of this research is to attempt

to understand and explain human and social action towards a technology and how this is shaped by a specific context. Thus, it follows that a qualitative and classified under the interpretative epistemology approach is the most appropriate in uncovering specific angles of the situation, such as how the understandings, interpretations, expectations, etc. of key actors concerning the MammoGrid are influenced by their interaction and are also influencing their final attitude towards the MammoGrid.

In an effort to better understand the socio-technical character of the research, the case study was the most appropriate to shed light on this topic, by providing an in-depth narrative (Galliers, 1992, Cornford and Smithson, 1996). Case studies enable the capture of reality in greater detail and analyze more variables than other approaches, something that is very important in this kind of research since there has been little previous work carried out on the Grid from a social perspective.

The majority of the data was gathered from documents, academic journals, and semi-structured interviews. Semi-structured interviews, is one of the most frequently used qualitative methods and can be implemented either in the form of a one-to-one discussion, or as a group activity. They minimise the hierarchical situation and hence they encourage a purposeful conversation. For this research, group interviewing was also conducted, which allowed the observer to understand the way participants interact and influence one another (Hsu, 2002).

Six semi-structured interviews were conducted and each interview lasted on average 1-2 hours. The people interviewed were representatives of the five institutions involved in the MammoGrid project.

The following section provides a literature review concerning the Grid and its relationship with healthcare.

## 2 The Grid is the big thing

Since the development of the Grid is still at its early stages, a major part of the Grid literature is focused on the technologies used, the architecture of the Grid, and the protocols and standards defined and agreed. Hence, preliminary literature searches have revealed little previous work carried out in the social aspect and impact of the Grid technology. However, this paper gives a different contribution, since its focus is on the socio-technical realities which are influencing and shaping the understandings, expectations, interpretations and meanings that key actors have about the MammoGrid, a specific application of the Grid, and how these elements are influencing their final attitude towards it.

### 2.1 Introducing the Grid

The Grid is the “computing and data management infrastructure that will provide the electronic foundation for a global society in business, government, research, science and entertainment” (Berman *et al.*, 2003). Foster *et al.* (2001) described it as a “flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources - what we refer to as virtual organizations.”

Figure 2.1.1 below presents a high level view of the Grid.

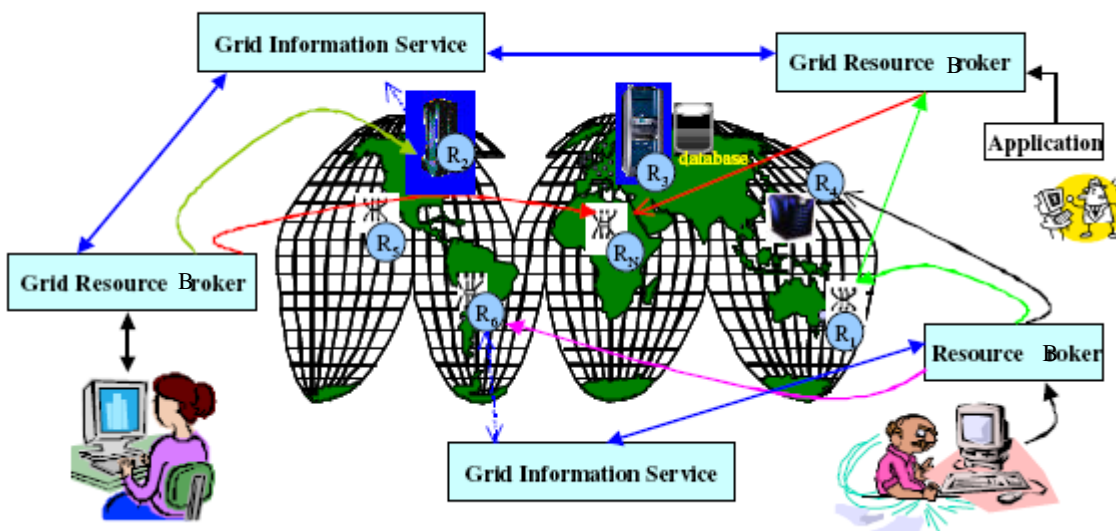


Figure 2.1.1 High level view of the Grid (Baker *et al.*, 2002)

The Grid is an emerging platform which supports on-demand “virtual organisations” for coordinated resource sharing and problem solving on a global scale for data-intensive and compute-intensive applications (Foster *et al.*, 2001). As a term, it arose from an analogy with the electricity power grid. It aims to allow the transparent, seamless and dynamic delivery of computing and data resources when needed, just like electricity (Chetty and Buyya, 2002, Smarr, 2004). It is considered as the next leap in computer interconnectivity. In the same way as we now share files and information over the internet, in the future the Grid will let us share other things, such as computer processing power, storage space as well as information on a global scale (Berman et al., 2003). Hence, its overall motivation is to enable and facilitate this, in order to support large-scale science and engineering (Baker *et al.*, 2002, Perrott, 2002).

Initially, the Grid was focused on sharing computational power and resources for science and engineering only. During the early 1990s, “metacomputing projects” tried to build virtual supercomputers using networked computer systems (Goble and De Roure, 2002). However, the Grid has been developed and has gone beyond this scope. Much progress has been made since then on the construction of such an infrastructure. Now, it can provide benefits to a variety of applications, from medicine to economics (Baker *et al.*, 2002).

Building the Grid is one of the most challenging and exciting efforts in the science and technology community today and that is because it must be done cooperatively, as a community effort (Berman et al., 2003). The Grid is the big thing, the Grid is the future. It is becoming more and more of a first class scientific tool that will have a huge impact on the world. As Smarr (2004) argues, the Grid will change the world so rapidly that the world will not have the time to react and face the challenges and issues presented by the Grid. The social consequences will have the same effect as railroads, with the difference being that now people are not sociologically ready to deal with this speed of change.

## **2.2 An information infrastructure (II)...**

The study of IIs is not new. IIs have been studied from different angles and analytical viewpoints. The term is used to refer to integrated solutions based on the continuing diffusion of information

and communication technologies (Hanseth and Monteiro, 1998). As described by Cordella (2006), IIs are the mixture of the complexity of the information systems used in an organization and the organization's practices and routines.

Hanseth (2002) differentiated between three types of infrastructures: (a) the global universal service infrastructure, (b) the EDI and business sector infrastructures and (c) corporate infrastructures. Thus, it follows that the Grid can be categorized as an emerging global universal infrastructure, as it will ultimately become the foundation upon which many activities and services will be based.

According to Hanseth (2002), in the early days of computing only one application was running on the same computer. As organizations adopted more applications and computers, it became convenient to split applications on the one hand and computer hardware with its basic software on the other. That split was described as one between applications and infrastructures. However, as he argues, the system's concept should not be replaced by the infrastructure's concept. The systems have to be seen as part of larger infrastructures.

IIs are more than individual components and "pure technology", and their successful deployment requires more than a combination of traditional approaches and strategies for the development of information systems (Hanseth and Monteiro, 1998). They are rather socio-technical networks, established through complex socio-technical processes and shaped by events, circumstances, and unpredictable courses of action (Broadbent and Weill, 1999, Cordella, 2006). They are the output of the recursive dynamic interaction between technologies and people (ibid).

Furthermore, they do not start from scratch. Like other infrastructures, an II is designed as an extension and improvement of an already existing one (Hanseth, 1996). They are embedded in other structures, social arrangements and technologies (Star and Ruhleder, 1996). The new and improved elements have to fit into the old. So, the new infrastructure must also be backward compatible with the existing components. In this process the already existing infrastructure, thus the installed base, affects the possible paths of design and development of the new elements, and therefore it becomes self-reinforcing (Hanseth, 1996). From a technical point of view, an

infrastructure is the embodiment of standards so that other technologies and infrastructures can interlink in a standardized way (Star and Ruhleder, 1996). Additionally, IIs are transparent in that they can invisibly support tasks and they can only become visible upon breakdown (ibid).

Information infrastructures are described as *shared* resources or foundations for a community and they cannot be split into separate parts (Hanseth, 2000, Hanseth 2002, Ciborra, 2000). The fact that they are shared implies that their parts are defined as shared standards (Hanseth, 2002). Furthermore, infrastructures are continuously evolving, thus extended and improved a fact that leads to their next characteristic, *openness*. Openness is the lack of borders, hence there is no limit in the number of elements an information infrastructure may include, or in the number of users and areas it may support (Hanseth, 2000, 2002, Ciborra and Associates, 2000). Moreover, the development time of an infrastructure is open since it has no beginning or ending (Hanseth, 2000, 2002).

Additionally, IIs are *heterogeneous*, thus they include technical and non-technical components such as human, social, organizational, etc. They also include sub-infrastructures based on different versions of the same standard or different standards that cover the same functionality (ibid). Standards are a crucial and fundamental part of open IIs (Timmermans and Berg, 1997), since large infrastructures involve users and designers with different ways of thinking (Hanseth 2002). Standards, as described by Ciborra (2002), should be viewed as “complex heterogeneous actor networks made up of a critical mass of users and infrastructure, rather than only technical artifacts”. They are developed to facilitate interoperability among technology and to stabilize IIs. Hence, an infrastructure, whether deliberately designed or emergent, must be *standardized*, which means that standards and mutual agreements concerning its structure should be created beforehand (Hanseth 2002).

Concluding, as presented above an information infrastructure is an evolving shared, open, heterogeneous, standardized installed base.

Foster, Kesselman and Tuecke (2002) created a Grid checklist according to which the Grid is a system which: (a) coordinates resources that are not centrally controlled, (b) uses standard, open,

general purpose protocols and interfaces and finally (c) delivers non-trivial qualities of services. These three criteria clearly apply to the various large-scale Grid applications. Therefore, the Grid is an information infrastructure which has the potential to become a successful one.

Nevertheless, because its heterogeneous components are still visible and the necessary standards have not yet been defined to enable interoperability, a key element in Grid computing, Grid developers still have a long way to go and there are still many things to be done for the Grid to become a successful information infrastructure.

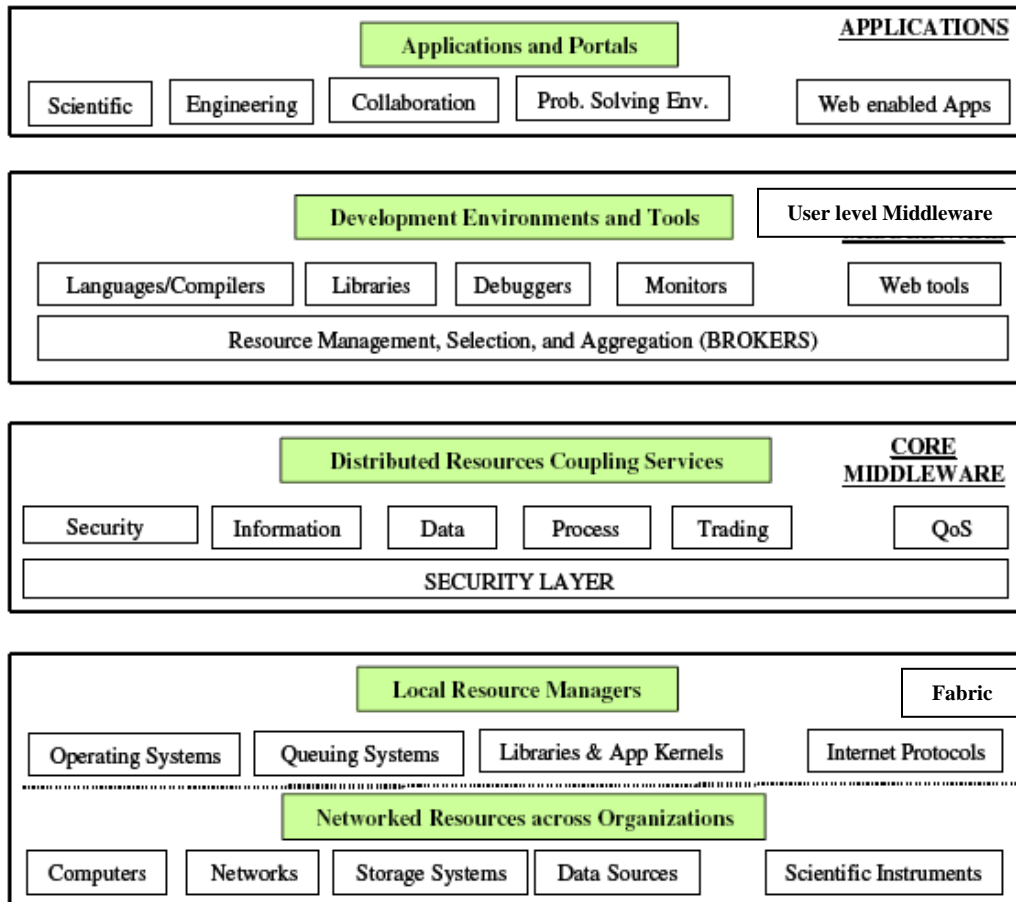
### **2.3 Grid architecture and standards**

The problem that underlies the Grid concept, as Foster *et al.* (2003) present it, is “the coordinated resource sharing and problem solving, in dynamic, multi-institutional virtual organizations”. The Grid deals with direct access to computers, data and other resources. This sharing is controlled with resource providers and consumers, who define clearly what is shared, under what conditions, etc (*ibid*). The set of institutions and individuals defined by such rules form the virtual organizations (VOs). VOs vary in scope, size, structure and purpose. However, they all have a similar set of requirements, such as the need for extremely flexible sharing relationships and specific levels of control over how shared resources are used (Cooper and Muench, 2000). Current technologies do not address those requirements, and so it is here that Grid technologies enter the picture. The development efforts within the Grid community have produced protocols, services and tools that address the challenges arising from building VOs (Foster *et al.*, 2003).

The Grid architecture is defined by taking into consideration that VOs require effective sharing relationships among different actors. Hence, the Grid needs to interoperate with various software, hardware, platforms, languages and programming environments, across organizational boundaries (*ibid*). It follows that interoperability is a central issue that needs to be addressed by the Grid architecture. Interoperability means common protocols, so the Grid architecture is a “protocol architecture”, with protocols defining how participants in the VO interact, negotiate and manage sharing relationships in order to achieve a specified behaviour (*ibid*). Overall the Grid architecture needs to be open and facilitate scalability, interoperability, portability and code

sharing (Foster, 2003). The standard protocols in combination with application programming interfaces (APIs) and software development kits (SDKs) create the middleware, which provides the abstractions required for the creation of a usable Grid (Foster *et al.*, 2003).

Figure 2.3.1 below presents the Grid architecture and components.



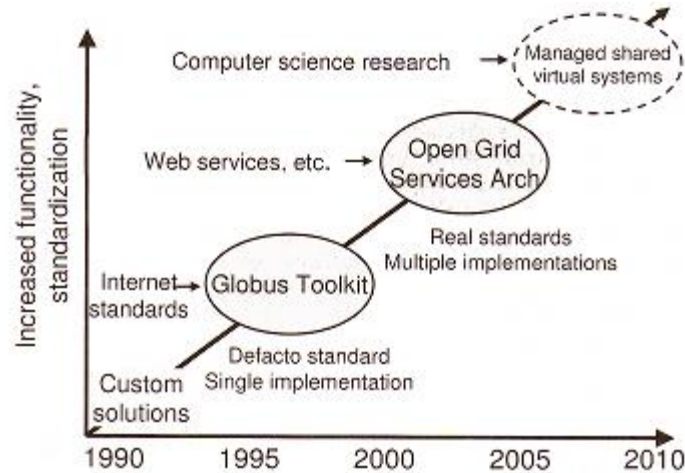
*Figure 2.3.1 The Grid architecture and components (Baker et al., 2002)*

Historically, the success of most technologies has depended on the availability of a number of agreed-upon standards (Wladawsky-Berger, 2004). IT today, is moving in that same direction with the rise of open standards and the trend towards open software. Standardization is the only way to integrate the diverse plethora of technologies (ibid). Standards bring the kind of flexibility and modularity that allow the new technology to be absorbed and managed smoothly, and make the new technology be seen as an unremarkable tool, as a black box, thus permitting

people to pay attention to what it does, rather than what it is (ibid). Open Grid protocols are a promising integration of technologies, files, applications, IT resources, etc., enabling global sharing of these resources beyond what has so far been possible with the Web. Furthermore, they will also permit management tools to range over the enormous heterogeneous infrastructure and make it mass adopted. After having the infrastructure standardized, the protocols will permit the delivery of computing services when and where needed, thus on demand.

The realization of the enhanced capabilities that the Grid has to offer, has increased its interest, and hence increased the importance of true standards (Foster and Kesselman, 2004). That is the reason why, the global grid forum (GGF) was established in 1998. The GGF is an international community and standards organization, which allows standards to be developed. Some of the first tries of the GGF was the open source globus toolkit (GT2), the “de facto” standard software infrastructure for Grid computing. The GT2 was focusing on the interoperability, APIs and services, as well as on providing solutions to problems, such as resource discovery, authentication, etc. (Foster *et al.*, 2002). During 2002, the open grid services architecture (OGSA) emerged. The OGSA is an extension of the GT2 concepts; it is a true community standard with multiple implementations that “aligns the Grid computing with industry initiatives in service oriented architecture and web services” (Foster and Kesselman, 2003, 2004). It not only defines standard interfaces and behaviours, but it also provides a framework with various interoperable and portable services. Building on OGSA’s service-oriented infrastructure, an expanding set of interoperable services, an increased degree of virtualization, richer forms of sharing, etc. will be achieved (ibid). This major step forward in 2002 has brought the Grid community a step closer towards the fulfillment of the Grid vision.

Figure 2.3.2 below shows the evolution of Grid standards.



**Figure 2.3.2** *The evolution of Grid standards (Foster and Kesselman, 2004)*

However, Foster and Kesselman (2004) argue, that “much more remains to be done, before the full Grid vision is realized”. Before we can have a successful Grid, there is a need for a functional, secure, standardized Grid, with a true user community (Schopf and Nitzberg, 2002). The transition to this new environment requires better software tools. The development of more superior standards is a must in order to provide a uniform and homogeneous interface to Grid services (ibid). Moreover, the development of Grid software must be made easier and the basic functionality must become the “default”, not the “exception”. Additionally, a major requirement is the creation of a user community and the formation of incentives for organizations to be a part of the “user-centric environment” (ibid).

Nevertheless, beyond the technical problems posed by the Grid, there are also socio-political issues that need to be addressed before the Grid vision can be fulfilled. Schopf and Nitzberg (2002) present some of the socio-political challenges which include the cooperation and communication between different groups involved with the Grid, the resistance which might be caused by administrators and users for the upgrading of software and tools, the difficulty in getting funding and the need for variance management and deployment issues.

Furthermore, as Wladawsky-Berger (2004) argues, another major problem that the Grid community needs to address is the matter of simplicity. Standardization and integration do not mean simplicity. The growing volume of technology and the expansion of the heterogeneous

infrastructure, no matter how smoothly integrated, lead to levels of complexity. The industry needs to find ways to deal with that complexity in order to make the infrastructure perform more efficiently and to keep it from interfering with the user.

## **2.4 Why healthcare needs the Grid...**

Medical diagnosis relies increasingly upon images (Amendolia *et al.*, 2004). Digital images represent important amounts of information collected by healthcare institutions about patients and their medical conditions (Rogulin *et al.*, 2004).

Breast cancer as a medical condition and mammograms as images, are very complex and vary considerably across the population. It is very important to understand this variability in order to be able to study breast cancer and improve the usefulness of mammography breast screening (Estrella *et al.*, 2004, Solomonides *et al.*, 2003). Hence, a geographical distributed database, which allows efficient management of data, enhanced analysis, quality control and the spread of pathologies and knowledge across the world, is considered to be a valuable tool for clinicians (Rogulin *et al.*, 2004).

For this vision to be achieved, the right tools and technologies are necessary. An infrastructure is required to make available the large amounts of data and information to all the healthcare institutions around Europe. It should also include standardization software which will enable the comparison of images from different patients and health centers, as well as a detection system that will help in visual diagnosis, etc (Hauer *et al.*, 2003). The benefits gained from such a pan-national infrastructure will be unconceivable, not only because it will help clinicians to develop new common collaborative approaches to the analysis of mammographic data, but also because in the future it will be able to be generalized and used for any medical condition (Rogulin *et al.*, 2004).

Grid infrastructure is promising to resolve many of the difficulties in facilitating medical image analysis, and more specifically it can allow clinicians to collaborate and cooperate without having to co-locate (ibid). It can provide medical applications with architecture, for easy,

transparent access to distributed and heterogeneous resources, across different hospitals. In particular the Grid can address some of the following issues relevant to medical domains: data distribution, heterogeneity, data processing and analysis, security and confidentiality and finally standardization and compliance (Rogulin *et al.*, 2005).

The following section provides a description of the theoretical framework applied to the research.

### **3 Social construction of technology**

#### **3.1 Why SCOT**

Technologies are never purely technological; they are also social and have social implications. The shaping of a technology is also the shaping of a society, so it is impossible to try and separate the technical from the social relations (Bijker and Law, 1994). The technological deterministic argument sees technology as an autonomous entity, which has its own inner logic and develops in its own direction (Williams and Edge, 1996). On the other hand, the social constructionist argument suggests that technology has no inherent, necessary meanings, but interpretative flexibility and it develops within discourses and conflicts of various social groups (Bijker, 1995). Technology is thus shaped not only by societal structures and power relations, but also by the “emotional commitment of individuals”. Particularly technologies embody social, political, physiological, and professional commitments, skills, prejudices, possibilities and constraints. Hence, technology is not a static thing, but rather a collection of meanings that are contested by different groups (ibid).

For this research, SCOT was found to be the most appropriate approach, since it can offer a deeper understanding on how the interpretations, understandings and interactions among different groups are influencing and eventually shaping their final attitude towards a technology (Pinch and Bijker, 1987, Orlikowski, 1992, Mitev, 2005) – in our case MammoGrid, and therefore give an insight on whether MammoGrid will be adopted by its users.

According to SCOT, technology is not just constructed in labs, but in society and through its use also (Howcroft *et al.*, 2004). Hence, technology is embedded in social systems and therefore the adoption or lack of the technology is determined by social factors (Bijker, 1995, 1997). Furthermore, technologies do not succeed or fail because of any inherent essence of technology (Kline and Pinch, 1996). The success of a technology depends on the meanings attributed to it by different social groups. These groups can contest the meaning of the technology, as well as challenge its design (ibid). Additionally, SCOT rejects the notion that the diffusion of a technology can be quantified. Technologies are not unchanging artefacts; rather they have a fluid

character and despite the fact that they might be superior and very well designed and developed, their success cannot be assumed or taken for granted (Pinch and Bijker, 1987).

Moreover, SCOT argues that different groups are different networks of meanings, rituals and social relations. Since technology is a “bundle of meanings”, the diffusion of a technology will be equivalent to the “diffusion of a shared bundle of meanings” (Bijker, 1997). Therefore, the adopting society should be transformed before the “bundle of meanings” can be accepted (Dafoe, 2005).

### **3.2 Main concepts of SCOT applied for the purpose of this research**

- ***Relevant social groups (RSGs)***

RSGs are the key starting point in SCOT. The interaction between and within them is critical for the development and existence of a technological artifact (Bijker, 1995). Hence, it is very important to take the artifacts as they are viewed by RSGs, to understand technological design, development, implementation and use (Howcroft *et al.*, 2004). Furthermore, all members of each RSG share the same set of meanings, interpretations and understandings for a specific artifact and this set can be used to give an explanation to the particular development path that the artifact takes (Pinch, 1995, Howcroft *et al.*, 2004).

- ***Technological frames (TFs)***

A specific version of TFs, which is the one going to be followed in this research, was introduced by Orlikowski and Gash (1994). As they argue, TFs are important in understanding technological development, use and change in organizations, as well as the social problems associated with the implementation and use of IIs. TFs concern the assumptions, expectations and knowledge that members use to understand technology. These elements are influencing and shaping the way in which a technology is embedded in their work context, as well as their choices regarding the design and use of the technology. Hence, it is really important to understand people’s interpretations in order to understand their final attitude towards technology. The members of a specific RSG have both individual interpretations, as well as a set of common core interpretations and beliefs. Socialization and training can be seen as an attempt by members to

promote the use of a particular TF. Furthermore, a technological artifact may be interpreted differently by multiple social groups, since people try to interpret new technologies in terms of their existing TFs, thus imposing assumptions and knowledge they had from previous familiar technologies. However, inconsistencies (incongruence) in the TFs between the RSGs of a community can create problems in developing, implementing and using technology, as well as a breakdown in communication, lack of participation by its users, etc. Therefore, it is of major importance that such conflicts be resolved and a common consensus be reached beforehand.

- ***Closure and stabilization***

A multi-group design process can face many problems, deriving from the different interpretations that lead to conflicting images of the artifact. When closure occurs, no further design modifications are necessary. That happens either because RSGs reach a common consensus, or as one group's interpretation dominates over the form and interpretation of the artifact (Klein and Kleinman, 2002). In this way, the above interpretation becomes the dominant form of technology, which leads to the stabilization of the artifact in its final form (Pinch, 1995, Kline and Pinch, 1999). However, closure and stabilization might not be final, since new problems might appear. This might also be the case, when RSGs are forced by a dominant group to reach a consensus (Bijker, 1997).

The following section provides the case study description.

## 4 Case study: the MammoGrid project

This section provides a description of the MammoGrid project's case.

### 4.1 How everything started...

In the last few years, many Grid projects on health related issues have been funded at national and European levels. The MammoGrid project is one of these and it focuses on using existing Grid technologies (Rogulin *et al.*, 2005). The project was activated in late 2002 and it was alive for 3 years. The project's successful deliverable has since been taken over by a Spanish company, which is trying to deploy it into a large-scale product of commercial value.

The project was a collaboration of many institutions from which five were highly involved: Addenbrookes Hospital (Cambridge/UK), Udine Hospital (Italy), University of the West of England-UWE (Bristol/UK), Mirada Solutions Company (Oxford/UK) and CERN (Switzerland), the world's largest particle physics laboratory. The techniques developed for analyzing data at CERN were very similar to the techniques needed in the medical field. Therefore, the idea was to adapt these advanced techniques to medicine and mammography was their choice.

### 4.2 Project's objectives and deliverables

The most important aim of the project was to examine the feasibility of developing a Grid-enabled database of mammograms to support collaboration between clinicians across the EU. Breast cancer is considered to be the leading cause of death from cancer in women. What doctors needed was the capability of exchanging and storing data in a distributed way, without losing any information from the mammograms. The Grid technology was considered to be the most promising approach for fulfilling their needs: *"The project wanted to allow doctors to exchange information and data, mostly mammograms, in a transparent way, across borders, between hospitals, allowing them to perform many tasks, like epidemiological studies. The computing power to analyze the data was not that big. In this sense we needed a DataGrid."*

The ultimate goals of the project were: (1) to provide the finding and comparison of similar breast cancer cases, together with some information on the diagnosis, treatment, success of the case, etc., (2) to be used for epidemiology studies and as a teaching aid, as well as (3) to be used in a real-time basis; hence when in the surgery room, doctors would be able to communicate and collaborate through the MammoGrid.

Some of the main objectives of the MammoGrid are shown in table 4.2.1 below:

**Table 4.2.1 MammoGrid's objectives (Amendolia et al., 2004)**

1.-	To evaluate current Grid technologies to requirements for Grid-compliance in a pan-European mammography database.
2.-	To implement the MammoGrid database, using novel Grid-compliant and Federated-Database technologies.
3.-	To provide a standardization system that enables comparison of mammograms dependent on scanner settings, and to explore its place in the context of medical image formats (DICOM).
4.-	To develop software tools to automatically extract image information that can be used to perform quality controls on the acquisition process of participating centres (e.g. average brightness, contrast).
5.-	To develop software tools to automatically extract tissue information that can be used to perform clinical studies (e.g. breast density, presence, number and location of micro-calcifications) in order to increase the performance of breast cancer screening programs.
6.-	To use the annotated information and the images in the database to benchmark the performance of the software described in points 3, 4 and 5.
7.-	To exploit the MammoGrid database and the algorithms to propose initial pan-European quality controls on mammographic acquisition and ultimately to provide a benchmarking system to third party algorithms.

The MammoGrid project used existing Grid infrastructure provided by CERN, in order to make possible distributed computing on a nationwide scale (Hauer *et al.*, 2003). The deliverable was a software prototype, capable of allowing complex epidemiological studies, statistical and computer aided detection (CADe) analyses and the deployment of versions of the image

standardization software (Rogulin *et al.*, 2005). The prototype is considered to be a success, despite its small failures and the fact that some features have not been developed, e.g. it is not user friendly. The project was very ambitious. Nevertheless, it is one of few cases in which European money went into a project which was not just something to be put on the shelf, but it was something that could be worked out from commercial companies and become a useful and sellable product: “...*The prototype is a success. It was one of the first cases of development of a Grid system which was aiming to be used by society...Of course there were technical problems...But they could be seen as the normal glitches and the small failures that happen when you develop a prototype system...*”

### **4.3 Collaborators’ part in the project**

The MammoGrid project was partly an idea conceived by Professor Amendolia working at CERN, so CERN was the coordinator of the project. It was not just providing the grid, but it was also leading the project: “*CERN was actually the crucial part of the project... CERN had the skills to do this...*”

Mirada Solutions was the commercial company involved in the project. The company’s role was the adaptation of their already created standard mammogram form (SMF) software for computer assisted detection and diagnosis to meet the MammoGrid’s requirements.

The UWE was responsible for gathering a very comprehensive system user requirements capture and for the development of the database work. The requirements process was carried out in consultation with the user community at Udine and Addenbrookes hospitals.

The hospitals involved were the end-users of the project. They were providing the information and medical data, which were put into the MammoGrid, as well as the requirements and feedback to the developers: “*We were just the end-users. Without us the software doesn’t mean anything...*”

#### 4.4 Conflict of interests...

The fact that there were five different institutions, involving people from different backgrounds and having conflicting priorities and expectations for the project, made the collaboration more difficult and the gap existing between them more visible; something that was holding back the project. However, although they were involved for different reasons in the project, only one thing linked them together: *“Each institution applies for funding... People are meeting together for a common purpose: the funding...It is just business...”*

Nevertheless, even though the project was a success in the end, most of the collaborators feel disappointed in terms of poor teamwork and leadership as well as the fact they had given more input and effort in comparison with what they had received in return.

#### 4.5 Growing pains...

The problems that arose during the development and implementation were:

<b>Technical problems</b>	The group from CERN, that had developed the grid technology, had not taken into account a lot of the requirements of medical computing, for example security and confidentiality. Additionally, there were problems with the GridBox technologies. Udine hospital in Italy couldn't "talk" to its own GridBox; therefore, doctors from Udine had to go to Cambridge in order to see their images, as well as Cambridge's images.
<b>Agreement problems</b>	The collaborators of the project did not agree on a set of procedures for software development, which made the development even more frustrating. Furthermore, as argued by one of the interviewees, actors were not visualizing the benefits received from the project and that had as a result not to put much effort in making agreements and things successful.
<b>Sharing of medical data</b>	Hospitals hesitated to share medical data. The data belonged to the hospitals and doctors wanted to use them for publishing research papers. Therefore, doctors didn't want to lose the value of that possibility.
<b>Feature problems</b>	The gathering of user requirements proved to be difficult, especially when developers were trying to make clinicians understand that once features are defined, they need to be developed, tested and reviewed before the next round of features come up. There were numerous situations whereby the set of features were agreed, gathered, but the list kept on increasing while development was happening, without proper control. That ended up with clinicians frustrated, since they felt that, Mirada Solutions, was not doing its job, and was not delivering the software to them. However, Mirada Solutions supports that clinicians did not realize that the list of features they were asking for, necessitated excessive man power in development in comparison to what was budgeted for in the project.
<b>Shift in Mirada Solutions' objectives</b>	During the course of the MammoGrid, Mirada Solutions was acquired by a large company (CTI). That created many problems, and tensions arose during the development, since the priorities of the company shifted dramatically away from the MammoGrid project and Mirada Solutions stopped providing any input to the project.

Plenty of problems were faced during the development and implementation of the system, which led to the deployment of a not so perfect prototype. The problems did not only arise because of Mirada Solutions' disorientation, but also because the end-users were not ready to accept such a system: *“Hospitals are not yet ready to deal with this system; in fact they are not even ready to deal with the NHS project (the electronic patient record). Hospitals also need to upgrade their equipment, technologies, etc...”*

In concluding, even though there were many problems during the life-cycle of the project, collaborators did succeed. They managed to finish the project in the end. Moreover, due to the possibility that it could work better in the future, a Spanish company decided to take over. The concept of the MammoGrid is good, it uses one of the best technologies so far and the prototype can successfully be transformed into a useful commercial product, so the potential is certainly there. Nonetheless, it needed more teamwork, strong leadership and well-defined collaboration processes.

The following section provides the analysis through the lens of SCOT and TFs.

## 5 Analysis and findings

In this section, a specific focus will be given to the characteristics of the identified RSGs involved in the MammoGrid project, as well as on how these groups are influencing one another. Furthermore, a comparison on the elements of the RSGs' TFs will be presented, in an effort to capture congruence or incongruence and the possibility of closure and stabilization. This will shed light on the question as to whether the MammoGrid, as a final product, will be smoothly adopted by its users.

### 5.1 Identification and characteristics of the relevant social groups

During the period of studying the project, the following groups were identified as the most vital in the life-cycle of the project:

#### *a. Developers' group*

This group comprised two institutions, the particle physics group from CERN and the team of academics and PhD students from UWE. The team from UWE was based at CERN during the deployment of the project, which made them share similar expectations, understandings and assumptions, concerning the MammoGrid, with the Particle Physicists: “...*My University's contribution is easy to confuse with that of CERN, because all of our people were based at CERN... We were working with them all the time...*”

Particle physicists are always a few years ahead in terms of computing and this is because they are interested in how technology can deliver their scientific goals (Hlistova, 2004). They are always focused and very pragmatic in the way they develop technology (ibid), and that is one of the reasons why they have a reputation for getting things done properly: “...*CERN succeeds... there could be delays and small problems in developing technologies, but they always manage to solve them...*”. They pursued the opportunity to be involved in the project, because they wanted to provide the knowledge they had acquired for so many years from fundamental physics to something that could benefit society at large. It was something challenging for them, intellectually stimulating and they felt that they did something good. Furthermore, they wanted

to answer those saying that physicists kept all the knowledge to themselves and that they only cared about solving their own problems.

The team of academics involved people with backgrounds in computer science, information systems, etc. Their interest was focused on research. As a team they had the technical skills, as well as the academic knowledge to deal with projects, such as the MammoGrid. The project was an opportunity for them to deal more with the development of the Grid, get involved in a European project and use the knowledge acquired from previous projects based at CERN.

***b. Commercial group***

The commercial group comprised Mirada Solutions, a small startup company of 10-15 people. They had invested mostly their own labor and capital for the creation of the company. Therefore, they were just interested in doing business, growing as a company and making money. At that stage, they were focused on two projects: image fusion and mammographic image processing. However, at the beginning, the computing competency and technical skills of the group were not so high, so the MammoGrid project was an opportunity for them to: (1) get access to the Grid technology and get the technical expertise and core competencies for any advanced product using the Grid and (2) expand their panel of collaboration partners, so that data and clinical expertise would be available: *“The main expectation for us was to demonstrate that we can access remote data through the Grid and perform state-of-the-art visualization for it. Commercially, it was important for us to be visible as technical leaders.”* Nevertheless, while the project was still running, the company was taken over by a much larger company (CTI); consequently, their focus changed and mammography stopped being central to their activities. Due to this disorientation, the resources they provided, from then on, were very restricted.

***c. End-users’ group***

Clinicians were the end-users of the project. There was no computing competency or technical skills within the team. Furthermore, their interests had nothing to do with commercial work, and they did not want to get involved with things like “it’s just business” or “money”. Their goals as a community were three-fold. Firstly, to improve the techniques for breast cancer diagnosis.

Secondly, to push forward the frontiers for using software in healthcare and thirdly to promote teamwork among hospitals for clinical research.

## 5.2 Dominant group...?

In terms of a dominant group within the team, the interviewees had different opinions. The view of the end-users, as well as that of the commercial group, was that there was no dominant group, which could influence the others. They believed this, because the interaction between them was minimal, since they were not working on the same part of the project. Each group was centrally controlling its own bit. However, when they had to reach an agreement, all five of them agreed. Of course there were compromises, but all the decisions were mutually agreed. They all understood that the important things had to be done: *“Sometimes the compromise was in favor of one site... but there was never a boss saying that now you will do this...”, “We were all equal...the clinical people couldn’t work without the technical team and the technical team didn’t have a product without having backup from the clinical people. Without clinical testing, the software was useless...”*

However, the strong technical team had a different opinion. They also felt that decisions were mutually agreed, but they believed that they could lead and influence the others easily, though the commercial group was the most difficult to be influenced: *“CERN and UWE led easily the team. CERN was certainly influential because CERN was handling the money given from the EU...”*

Nonetheless, all RSGs believed that the stronger and leading actor of the project was the EU: *“There was clearly a leader and that was the European community...if we didn’t deliver, we wouldn’t get the money and the project would stop ...”*

### 5.3 Elements of technological frames

Four domains were found to characterize the interpretations, understandings and expectations that the interviewees had about the MammoGrid:

- a) ***Issues around initiation and impact:*** it includes the knowledge and experiences that RSGs have about the MammoGrid technology, as well as their expectations about its importance and likely impact.
- b) ***Nature of technology:*** it refers to RSGs' understandings of the technology's capabilities and functionalities.
- c) ***Technology in use:*** it refers to RSGs' understandings of how the MammoGrid will be used on a day-to-day basis and the consequences associated with such a use. Furthermore, it includes the actual end-users' experiences concerning the prototype's ease of use, efficiency, etc.
- d) ***Issues around the final output:*** it refers to RSGs' expectations, assumptions and needs concerning the final output of the project.

### 5.4 Technological frames analysis

#### I. Issues around initiation and impact

***Developers' group:*** Even though the two teams within the developers' group shared most of their understandings, expectations and assumptions concerning the MammoGrid, they initiated the project for slightly different reasons. The high impact expectations that the grid technology could have in medicine, was the primary reason the MammoGrid project was initiated from the particle physicists. The grid developed at CERN, and the high advanced techniques particle physicists were using, could be adapted in the medical field and lead to a very important output. Being the developers of the grid, their knowledge and experience were immense, a fact that reinforced their expectations regarding the importance of the MammoGrid and the changes it could bring to the structure of the hospitals (e.g. upgrade in their technologies, start using software for collaborative diagnosis, etc.): *"You cannot even imagine what the MammoGrid can do and will do in the future as a final product...It can save lives...This approach is clearly the future of communication in medicine"*. On the other hand, the team of academics expected that the MammoGrid would not only help improve breast cancer diagnosis, etc, but if the output was

successful, it could be adapted and used for other applications in medicine, as well as to provide an insight into other projects (e.g. HealthGrid). Therefore, these expectations concerning its impact, together with the fact that the team had experience and knowledge concerning the Grid from previous projects based at CERN, made the team initiate the MammoGrid project.

**Commercial group:** Their expectations concerning the impact that the MammoGrid could have on the strategy, structure, status of their company and on their way of doing business, were the primary reasons the project was initiated by them. Being a part of a small company, they had little technical expertise and had no previous experience about the Grid. However, from what they had heard, they knew that it could help them bring a revolution to their company. It could provide them with the technical expertise they badly needed and commercially it would make them visible as technical leaders.

**End-users' group:** Clinicians wanted a system that could provide the solution to most of the problems surrounding breast cancer today. Due to their background, no technical expertise existed within their team and nobody knew what the Grid technology was. They were introduced to the idea of the Grid and what it could do in medicine by the developers' group. Having understood the importance of such a technology and the impact it could have, if successful, in saving lives, they accepted to initiate the project and collaborate with the other institutions: *“The system will be able to project cancer risk, improve the diagnosis; it will be able to do so many things...”*

## **II. Nature of technology**

**Developers' group:** The whole group knew from previous experience and knowledge that the MammoGrid would facilitate communication between doctors across the world, a capability that at the time did not exist in healthcare. Furthermore, it would facilitate the sharing of data and information, mostly mammography data, across hospitals linked to the system, in a transparent way and without a loss in their quality. The system would also have the functionality of bringing data from all around the world into one place. The group's previous experience with the Grid helped them understand those functionalities and so they immediately started to adapt the already existing Grid to meet the MammoGrid's requirements. However, their interpretations around

MammoGrid made them emphasize more on the advanced technical capabilities and leave others aside: “...*The system was conceived and designed with specifications, which were aiming at making the system user-friendly and automated. However, not all of these functionalities were implemented, but we had said from the beginning that some aspects could be left behind*”. Furthermore, the assumption that the nature of technology and its potential value were obvious, as well as the fact that the doctors were in a continuous communication with them, led them to suppose that the MammoGrid did not require a formal implementation and training plan.

**Commercial group:** The group learned about the Grid while searching for a technology to support the two projects they were working on at the time. They knew that the Grid could bring a revolution in communication and sharing of data. From what they had heard, the MammoGrid would have capabilities of storing large amounts of data and get everything centralized, something that would give them the opportunity to develop better algorithms for their projects and make their SMF software work even better. However, after the company was bought by CTI most of the things the group had to deliver were delayed and of low quality.

**End-users’ group:** Even though clinicians had nothing to do with technologies, they knew what they needed from this one. They understood that this technology would support communication and collaboration between doctors from hospitals connected to the MammoGrid and would have the capability of gathering and storing large amounts of data in one place. Furthermore, it would have the functionalities of facilitating teaching and use on a real-time basis; hence, when in the surgery performing an operation, clinicians would be able to collaborate. Moreover, since they had little experience with technologies, they expected that a formal implementation and training plan would be conducted.

### **III. Technology in use**

**Developers’ group:** The understandings and assumptions of the whole group concerning how the MammoGrid would be used on a day-to-day basis were: (1) for comparison of similar breast cancer cases, (2) for epidemiological studies and (3) as a second opinion doctor: “...*The system is capable of looking around and picking up similar cases, bringing all the information needed for epidemiology studies in one place...and it also has the potential to be better or at least as*

*good as a doctor in diagnosing cancer, so that would make it an extremely good candidate to be used as a second opinion doctor*". Due to their prior involvement with the Grid, they knew that the actual problems clinicians might face were in terms of security and confidentiality. However, the academic team within the group was also concerned with the fact that hospitals might not be able to take the informed consent from the patients in order to use their data for research: *"If you want to use this project in real life, you need to ensure that the data you are using has been consented..."*

**Commercial group:** Their expectations and assumptions concerning how the MammoGrid would be used on a daily basis were not so clear. They knew that the project could help them commercially and that was the only thing they cared about. They had in mind how it could be used, but their views were not as clear as the other two groups: *"...I guess a clinician reads a case using the MammoGrid workstation, uses the visualization protocols, and exports them to another clinician if there is a need for a second reading..."*. Since their experience and knowledge concerning the Grid technology were minimal, they were not sure what the consequences of the actual usage of the MammoGrid could be. They only argued that one possible problem could be the fact that hospitals might not wish to share their data: *"...All institutions work for themselves. You have to give them something in return. You really need to give them value in return for what they are giving you..."*

**End-users' group:** Clinicians understood that the mammograms would be put into the GridBox technology automatically, and then they would be able to search certain mammograms by certain criteria. Furthermore, by sending specific suspicious areas from mammograms in the MammoGrid, the system would be able to find similar cases, together with information about the diagnosis, treatment and success of the case. They expected that the system could be used as a second opinion doctor, as a teaching aid, as well as to be used in some way when inside the surgery. Their main concern regarding the problems associated with its use, were in terms of security and confidentiality, but as they argued, they were confident that the developers would achieve something extremely safe. The prototype was delivered to the doctors and put into use. However, doctors found it extremely hard to cope with and disseminate into their daily work, since it was not user-friendly and could not do what it was supposed to do. There were many

technical problems, it did not provide automated procedures and the hospitals could not communicate with each other. Generally, doctors were not very pleased with the result: “...*It is not user-friendly and automated; we cannot communicate with Udine because of technical problems, so there is no one to use it with...*”

#### **IV. Issues around the final output**

***Developers’ group:*** Both teams’ expectations concerning the final output were that it was just a prototype; hence some basic capabilities, such as doing things automatically and being user-friendly were not so important to them. However, particle physicists’ expectations were that they wanted to provide all the knowledge acquired from fundamental physics to develop a useful prototype, with the potential to become a commercial product used by society: “...*We hope to see the son of MammoGrid based on a commercial grid used by doctors in an efficient way... We know that it is quite difficult to be adopted, especially at the beginning... But just look at medicine and how it is today compared with 20 years ago... It can happen*”. On the other hand, academics were most concerned with the development of a successful prototype, since that would provide them with a large number of PhDs and publications. Therefore, the work done in the project could be used and continued by others.

***Commercial group:*** The group’s expectations, concerning the final output, were more in terms of acquiring technical expertise throughout the development of the system, rather than expecting something from the actual prototype itself. What they really needed was to be visible as technical leaders in the market field, after the end of the project. Their goal was achieved, since they were acquired by CTI at first, and later by Siemens.

***End-users’ group:*** Clinicians’ expectations about the final output was a system that could improve clinical diagnosis, project cancer risk accurately, be used in a real-time basis (surgery) and as a teaching tool: “*Imagine a room full of young radiologists and clinicians teaching them... That would be something fantastic...*”. Furthermore, they expected the system to be user-friendly and do things automatically.

## 5.5 Outcome of the technological frames analysis... *congruence or incongruence?*

As shown from the above analysis, the relevant social groups had differences in some of the elements of their technological frames.

Nevertheless, some of the most important conflicts were between the end-users' and the developers' group's TFs. For example, the end-users expected that a formal implementation plan and training would be taking place, since Grid technology was something extremely new to them. However, that did not happen since the developing team assumed that: *"...Doctors were working with us, so in a sense the training was automatic. We didn't apply any formal training plan, since when we had specific pieces of software, which were delivered and installed in the hospitals, we sent people from the technical part to explain to the doctors what they had to do..."*

Additionally, the end-users expected that the final output would be a user-friendly, automated system, able to be used as a teaching aid, as well as to be used in a real-time basis communication (surgery). That was something developers did not have in mind and that was the reason why they did not include it as a functionality of the system: *"...We didn't develop the system to be used in surgery, but if doctors want it then we can do it. You just put the computer screens and the devices in the surgery, you link all the MammoGrid units, hit the button and then you see everything online at the same time..."*. Moreover, clinicians expected that the system would work efficiently. However, that was not the case: *"The reality was that the MammoGrid was not efficient enough to enable the clinicians to use it in real time workflows. It proved too slow."*

As Orlikoskwi and Gash (1994) argue, incongruent TFs can create problems and difficulties in developing, implementing and using technologies, which is the case here. The incongruence presented above, in the elements of the TFs of the RSGs can explain all the problems and difficulties that arose during the development, implementation and use of the MammoGrid prototype.

Table 5.3.1 below summarizes the technological frames of the relevant social groups.

**Table 5.3.1 Contrasting the relevant social group's technological frames around the MammoGrid**

	Developers' group	Commercial group	End-Users' group
Issues around initiation and impact	<p><u>Particle physicists' team:</u> Impact in terms of improvement in clinical diagnosis, helping society in general but also an opportunity for the hospitals to change their structure, upgrade their technologies in order to be able to facilitate collaboration through the Grid.</p> <p><u>Academics' team:</u> Impact in terms of improving breast cancer diagnosis but also in terms of the useful information the MammoGrid could offer to other projects as one of the first applications in healthcare using the Grid as an infrastructure.</p>	Impact in terms of the changes it could offer in the status, the technical expertise of the company as well as in the way they did business.	Impact in terms of solutions provided to most of the problems around breast cancer today, as well as to the improvement in clinical diagnosis and treatment.
Nature of technology	<ol style="list-style-type: none"> <li>(1) communication and collaboration between doctors.</li> <li>(2) sharing of data and information.</li> <li>(3) storing large amounts of data.</li> <li>(4) get everything centralized.</li> <li>(5) No formal implementation and training plan found to be necessary.</li> </ol>	<ol style="list-style-type: none"> <li>(1) communication and collaboration between doctors.</li> <li>(2) sharing of data and information.</li> <li>(3) storing large amounts of data.</li> <li>(4) get everything centralized.</li> </ol>	<ol style="list-style-type: none"> <li>(1) facilitate communication and collaboration with doctors from hospitals connected to the MammoGrid.</li> <li>(2) storing large amounts of data.</li> <li>(3) get all data in one place.</li> <li>(4) capability to be used as a teaching aid technology.</li> <li>(5) facilitate a real-time basis usage (surgery).</li> </ol> <p>They expected that a formal implementation and training plan would be conducted.</p>
Technology in use	<p><u>Both teams:</u></p> <ol style="list-style-type: none"> <li>(1) for comparison of similar breast cancer cases.</li> <li>(2) for epidemiological studies.</li> <li>(3) as a second opinion doctor.</li> </ol> <p><u>Particle physicists' team:</u> Actual Consequences from daily use: issues of security and confidentiality.</p> <p><u>Academics' team:</u> Actual consequences from daily use: issues of security and confidentiality as well as that hospitals may not be able to take the informed consent from the patients in order to use their data for research.</p>	<p>No clear view of how the MammoGrid would be used.</p> <p><i>Actual consequences from daily use:</i> hospitals to be convinced to share their data with other hospitals.</p>	<ol style="list-style-type: none"> <li>(1) for comparison of similar breast cancer cases.</li> <li>(2) for epidemiological studies.</li> <li>(3) as a second opinion doctor.</li> <li>(4) as a teaching aid technology.</li> <li>(5) in real-time basis (surgery).</li> </ol> <p><i>Actual consequences from daily use:</i> issues of security and confidentiality.</p>
Issues around the final output	<p><u>Both teams:</u> Their expectations were that the output was only just a prototype, so issues like being user-friendly or automated were not so important for them.</p> <p><u>Particle physicists' team:</u> provide all the knowledge acquired from fundamental physics to develop a prototype, that is useful and with potential to become a sellable commercial product.</p> <p><u>Academics' team:</u> a successful prototype that will allow them to produce many publications and fund many PhDs.</p>	They wanted to gain as much technical expertise on the Grid technology, so that they could be visible as technical leaders.	<ol style="list-style-type: none"> <li>(1) the system would improve clinical diagnosis and treatment</li> <li>(2) used as a teaching aid</li> <li>(3) support a real-time basis communication with doctors from other hospitals, when in the surgery room performing an operation.</li> </ol> <p>They expected it to be user-friendly and do everything automatically.</p>

## 5.6 Closure and stabilization

Although there were conflicts in the TFs of the different groups, and despite the problems that arose during the development, the project is now finished and its deliverable is considered to be successful.

In order for the RSGs to manage to finish on time, a “form” of closure and stabilization was achieved in terms of their interpretations for the MammoGrid. This closure and stabilization was achieved, not because they managed to reach a common consensus, but because the strongest actor of the project, the leader, the EU, “forced” them to.

The RSGs knew that if they did not deliver what they had promised and what the EU was paying for, they would not get the money and they would have to explain why this happened. Therefore, all RSGs reached a form of closure and stabilization, because in a way they had to. They put aside their expectations and understandings concerning the MammoGrid, and they all worked together in order to manage to deliver: “...*What needs to be done, has to be done to deliver; if it wasn't being done, then we would all work as a team to get it done...If one of us failed, all five of us failed. We had to make sure that all five of us would succeed, otherwise we would all be giving back our money.*”

## 6 Discussion

The MammoGrid project is considered to be one of the first attempts in applying the Grid technology in healthcare. Consequently, the fact that the prototype delivered has all the potentials of becoming a useful and sellable product plays a very important role in the revolution of using software for clinical diagnosis and treatment in healthcare in general.

As discussed above, the problems RSGs faced during the development, implementation and use of the prototype were plenty. But still, they managed to reach a form of closure and stabilization, leaving aside their expectations and understandings and working together in order to deliver. However, when the prototype was delivered, the end-users were not so pleased with the results, since their expectations were different, and that is one of the reasons clinicians do not use it in their daily work. Nevertheless, the prototype has all the potential of becoming better and even reaches a point where it can gain commercial value and be sold to hospitals. This is the reason the Spanish company decided to take over the project. Now the Spanish people are in the process of transforming the prototype into a final product.

Due to the fact the groups were forced to reach closure, the conflicting TFs did not disappear; they still exist and they might “haunt” the users’ interaction with the final system, no matter how perfect it will be. Therefore, even if the Spanish company might use well-defined methodologies and deploy something perfect, the users’ reaction towards the system might not be the desirable one, if things stay like they are. As Pinch and Bijker (1987) argue, technologies, even if they are just prototypes, are socially constructed. They embody their RSGs’ expectations, constraints, interests and knowledge. Hence, even if a form of closure and stabilization is forced to be achieved beforehand, the possibilities of the conflicting frames to reappear are high, a fact that might lead to difficulties concerning the adoption of the technologies, and their diffusion in the users’ work practices.

Thus, the Spanish company should learn from the mistakes and problems that arose during the development and implementation of the MammoGrid project and try to avoid them. They firstly need to solve the incongruence in the TFs of the RSGs involved in the MammoGrid, since the

prototype embodies all the constraints and conflicts that the previous groups attributed to it. Moreover, they must be ready to confront any conflicts that might appear in the TFs during the development of the final system, as well as making sure that the developers will fully understand the expectations of the end-users and that the end-users will expect reasonable and pre-determined functionalities from the system. The end-users, with the different meanings they attach to the technology, determine its success or failure. Hence, it is very important, to diminish the gap between the developer's and users' beliefs, understandings and expectations. Technology is considered as a text which is read in different ways by various actors (Brey, 1997). As Orlikowski and Gash (1994) argue, "People's interpretation of a technology is critical to understanding their interaction with it. To interact with technology, people have to make sense of it; and in this sense making process they develop particular assumptions, expectations and knowledge of technology, which then serve to shape subsequent actions towards it". Therefore, the developers' task should be to understand how particular readings of the technology by different groups come to prevail and not to select a particular reading and present it as the correct reading.

Nevertheless, incongruence or congruence in the TFs can only be seen as one of the elements that can be used to explain the adoption of a technology. Many other factors are also influencing that process. For example, a new technology cannot be easily stabilized and be seen as a black box, hence be adopted by the users, if it does not become legitimate and accepted as a "social fact", through institutionalization (Silva and Backhouse, 1997). Furthermore, the diffusion of new innovations, not just in healthcare, but in every community, requires changes not only in the structure, but also in the mindsets of the users, something that takes time and needs a lot of effort to be achieved.

## 7 Conclusion

The application of IT in healthcare is relatively new. However, proliferation of IT in medicine will continue, addressing clinical demands and providing increasing functionality.

The purpose of this paper was to examine the case of the MammoGrid project, a project which aimed to investigate the feasibility of developing a European database of mammograms, using Grid technology to support collaboration between clinicians across the EU. Specifically, the focus of concern was to examine whether the MammoGrid would be well-received by its users after its development as a final product, using as a lens concepts from SCOT and TFs. The framework applied here, is a particularly useful analytical tool, which helped the researcher to examine how people act around technology and why.

The MammoGrid project has faced challenges created from the interplay between the medical and computer sciences, and it has witnessed both the excitement and disappointment of the user community, whose expectations from the new paradigm were very high. The first interaction with the prototype was not so pleasant. Clinicians did not find it user friendly, their expectations concerning some functionalities the prototype would offer had not been met and technical problems were obstructing communication between the hospitals connected to the MammoGrid.

As presented through the analysis, although a form of closure and stabilization was reached, the incongruence in the TFs of the RSGs might hinder the end-users' attitude towards the final system. Nevertheless, the Spanish company that has now taken over the project has great possibilities in avoiding this, if it avoids previous problems, solves the incongruence in the TFs of the already existing social groups and diminishes the gap between their developers' and users' "readings" of technology.

## **8 Limitations and further research**

The size of European projects and the number of people involved make a detailed study within the limited scope of the thesis very challenging, since the information acquired is much more than the one the researcher could assimilate to their thesis. Furthermore, the access to interviews was not easy, since the project involved institutions from all around Europe. Even though six interviews with representatives from all of the institutions involved in the project might be seen as an adequate number, the researcher feels that more interviews could have been done in order to present a clearer picture.

Additionally, due to the nature of the chosen research method - an interpretative case study - the analysis and findings presented, may be limited by the researcher's bias. It has always been argued that "the interpretative approach reflects the researcher's bias, since the interpretation of the data relies largely on the researcher's conceptual apparatus and theoretical position within the research area" (Lin, 2000). However, this in-built limitation of the method was addressed by the researcher, by presenting data from different sources, as well as by cross-checking their understandings with the interviewees.

Moreover, someone could argue that another limitation could be the fact that the researcher used a voice-recorder during the interviews. Voice-recording might make interviewees feel uncomfortable revealing specific angles of the case, hence the researcher might not be able to obtain the whole picture. However, at the beginning of each interview, the researcher asked each interviewee whether they would mind them recording the interview as well as letting them know that if at any stage they felt uncomfortable expressing their opinions, they would turn it off. No interviewees expressed any concern with recording the interviews; hence this gave the researcher the confidence to go ahead with the voice-recording process.

Another limitation could be seen to be the fact that SCOT has been criticized for not taking into consideration the social relationships, political biases and power structures, as well as for paying more attention to the social choice and less on the technology (Howcroft et al., 2004). Despite these criticisms, SCOT provides a tool to analyze artifacts in the context of society. As presented

throughout this thesis, the process of developing, implementing and using the MammoGrid was a socio-technical process, influenced by the technological frames of different RSGs, something that SCOT demonstrated well.

The application of Grid technology in medicine is quite recent. Thus, it is exciting to carry out research into this area. It would be interesting to study the actual end-users' reaction towards the final system and make a comparison between the conclusions of the two researches. Additionally, it would be interesting to examine how the conflicting TFs of the RSGs involved in the MammoGrid project will influence the development of the final product.

Furthermore, it would be exciting to observe the deployment of mechanisms for addressing security and confidentiality, which will play a significant role in the users' perception of how secure the system will be and hence to the shaping of their final attitude towards it. Additionally, it would be interesting to examine how the mindsets of clinicians will have to change in order to adopt technologies and accept to use them in their daily work.

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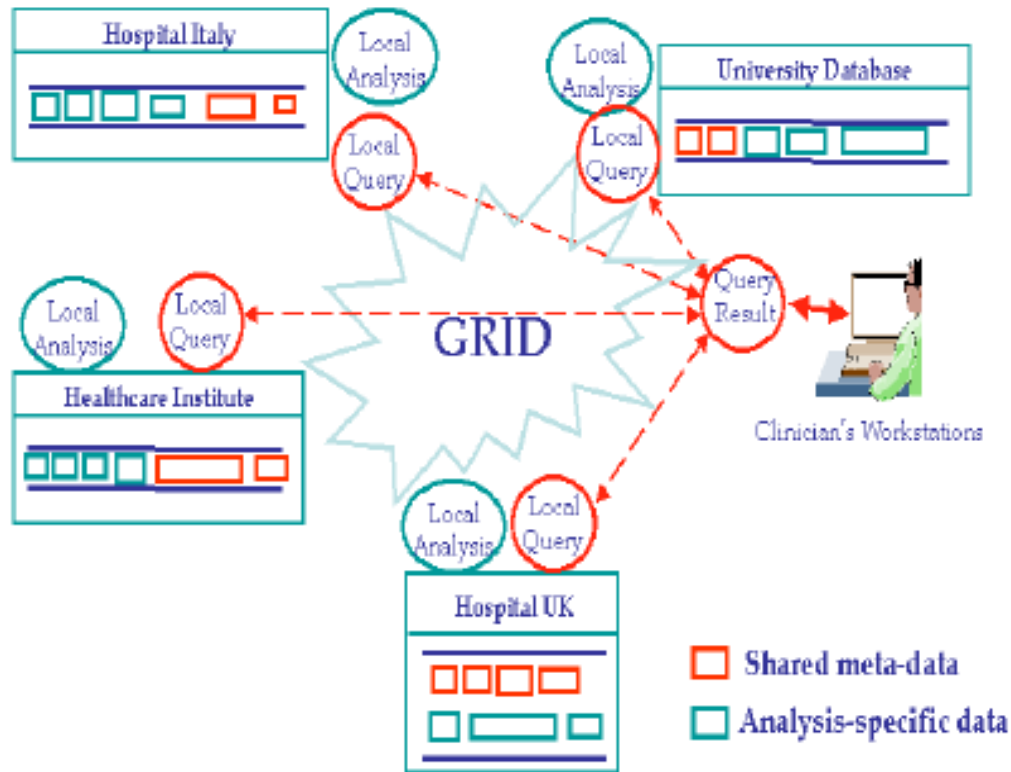
## 10 Appendix One

### 10.1 MammoGrid's information infrastructure

The MammoGrid project shares many of the requirements of high energy physics, and that is why its information infrastructure was based on the philosophies of two already existing technologies developed by CERN (McClatchey *et al.*, 2003). Alice Environment – AliEn- is the Grid framework developed to satisfy the needs of the Alice experiment at CERN LHC (Large Hadron Collider) for large scale distributed computing for physical analysis. It allows transparent access to distributed datasets and provides top to bottom implementation of a lightweight Grid applicable for cases which handle large amounts of data. CRISTAL is a distributed database system used in the development and operation phases of HEP experiments at CERN (Amendolia *et al.*, 2003). The MammoGrid's middleware is based on the CRISTAL software which enables the location of data sets and the decomposition of complex queries into their constituent parts.

In addition, the MammoGrid project has adopted the standard mammogram form (SMF) as a common standard for mammogram analysis and storage across Europe. SMF is important because it allows you to make all the images uniform. It is also the key to quantitative assessment of breast images (*ibid*). By combining the two above technologies, researchers have created new approaches to management of virtual organizations, provided an insight into the mediation of queries across a geographically distributed database and furthered the development of the next-generation of “Grid-resident” information systems (McClatchey *et al.*, 2003).

Figure 10.1.1 below illustrates the MammoGrid information infrastructure.



**Figure 10.1.1 MammoGrid information infrastructure (McClatchey et al., 2003)**

The MammoGrid virtual organization (MGVO) is composed of three mammography centers: the Addenbrookes Hospital (Cambridge/UK), Udine Hospital (Italy) and Oxford University. These sites are independent with respect to their local data management and ownership. As a part of the virtual organization, registered clinicians have access to mammograms, diagnosis, results and imaging software from other centers. The MGVO central node at CERN is coordinating the access (Rogulin *et al.*, 2005).

The CERN AliEn software has been installed and configured on a set of novel GridBoxes – secure hardware units. Each site/hospital workstation in the MGVO has direct and secure access to a GridBox through the local area network. The GridBoxes are seen as the gates to the MammoGrid and are in charge of storing new patient images automatically, updating the file catalogue and broadcasting the changes. The data transferred through this network is anonymous and encrypted, something that is important for security and confidentiality. The aim of the

GridBoxes was to ensure that each hospital can view the data on its GridBox as well as on the others GridBoxes and that the databases' view at each hospital is up-to-date.

Figure 10.1.2 below presents the GridBoxes' placement in the different sites.

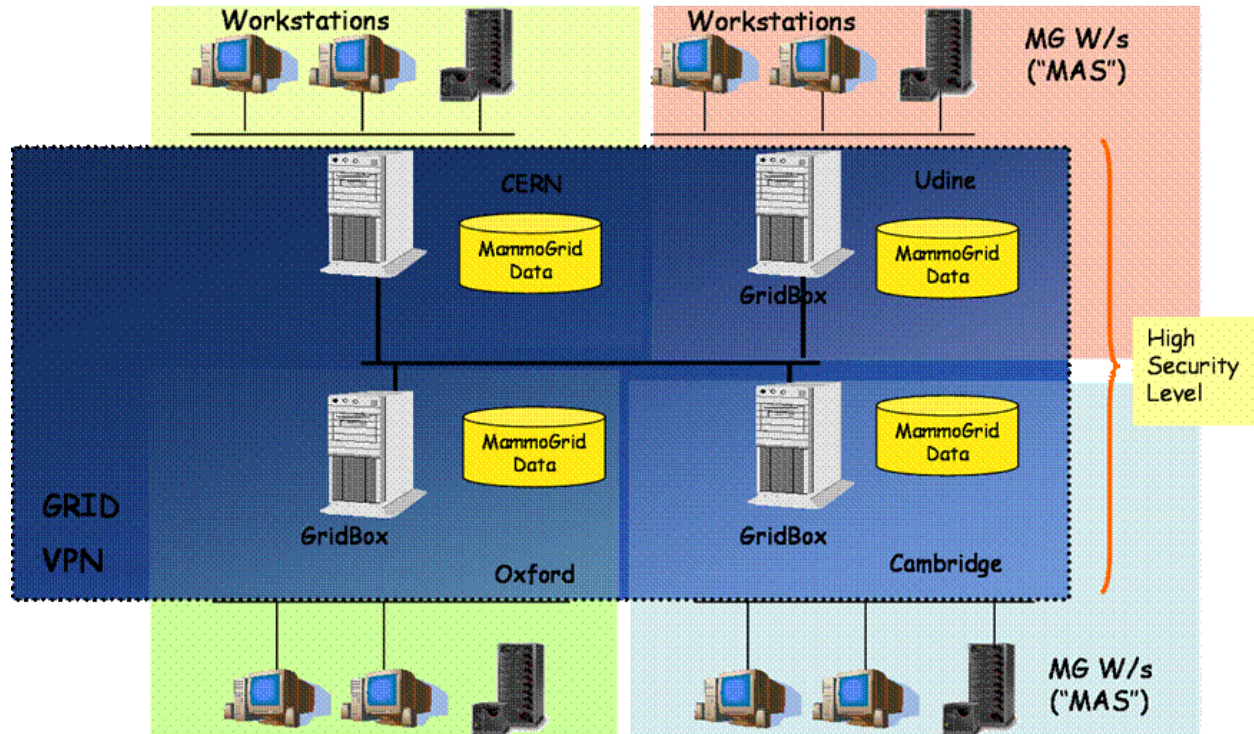


Figure 10.1.2 GridBoxes placement (Source: <http://mammogrid.vitamib.com/>)

## 11 Appendix Two

### 11.1 Table of interviews

(In no particular order)

Name	Position in the MammoGrid	Institution
Professor Roberto Amendolia	Project Leader	CERN
Professor Tony Solomonides	Research Dissemination Coordinator	UWE, Bristol
Jerome Declerk	Chief Scientist of Mirada Solutions	Mirada Solutions, Oxford
Bruno Ancelin	Promote Standardization technology (SMF)	Mirada Solutions, Oxford
Iqbal Warsi	Research Associate (Working closely with clinicians)	Addenbrookes Hospital, Cambridge
Jane Ding	Research Associate (PhD Student)	Addenbrookes Hospital, Cambridge

### 11.2 List of interview questions

1. Personal details - position in the MammoGrid project
2. How was the idea of the MammoGrid project conceived?
3. The aim/vision of the MammoGrid project. What is the final output?
4. Are the doctors using the final output of the project? Do they find it effective, useful, user-friendly and easy to use? Does it provide all the functionalities they expected?
5. Was a formal training plan followed before the implementation of the prototype?
6. What is CERN's part in the project?
7. What is UWE's part in the project?
8. What is Mirada Solution's part in the project?
9. What is the clinician's part in the project?
10. The reasons and goals behind its creation (for particle physicists, academics, commercial people, clinicians). What do they seek from the project? Why are they involved in the first place?
11. What is your understanding about its likely value in healthcare?
12. Did you have any previous experience of using the Grid technology?

13. What are your understandings about the capabilities and functionalities of the MammoGrid?
14. What are your understandings concerning how the MammoGrid will be used on a day-to-day basis and the likely or actual consequences associated with such a use?
15. What are your expectations and assumptions concerning the final output of the project? (E.g. what do you want and need from this project?)
16. How do you see the MammoGrid evolving?
17. What are the problems and difficulties encountered in the development of the MammoGrid
18. When confronted by a problem, what is the standard strategy followed in order to solve it?
19. What is the relationship of your group with the other collaborators of the MammoGrid project?
20. What is the influence you have on them? Do you believe you have a strong influence concerning specific decisions about the project?
21. What are the reasons for disagreement on a particular issue?
22. Are there cases where you had difficulties in reaching an agreement? Why?
23. How do you reach an agreement for a specific decision? (E.g. majority, strong actor or mutual agreement?)
24. Do you feel that there is a good environment among the team?
25. In your opinion, who is the stronger actor/group and who plays the most important role in the MammoGrid project?
26. Do you believe clinicians will eventually use the MammoGrid on a daily basis?
27. Do you believe clinicians have any worries concerning losing their image and prestige as good doctors by collaborating and asking advice from other doctors through the Grid?