A MODEL TO OPTIMIZE THE USE OF IMAGING EQUIPMENT AND HUMAN SKILLS SCATTERED IN VERY LARGE GEOGRAPHICAL AREAS

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Abstract: Recent studies have shown that the good geographical coverage of Imagiologic Information Systems and equipment such as Picture Archiving and Communication Systems (PACS) is not matched by similar coverage levels of radiologists, especially in rural and academic health institutions. In this paper, we address this problem proposing a solution that is twofold, with the first one being process based, through the optimization of work assignment within pools of human resources according to Service Providers availability, and the second part being technology based, through the interconnection of all the health institutions PACS equipment and radiologists geographically dispersed. After describing the high level solution, we present some of the results of the implementation of this concept and some of the technical challenges still to overcome. Finally, the conclusion chapter presents the impact of the system in the involved institutions.

1 INTRODUCTION

During the last 10 years, the use of digital medical imaging systems increased tremendously inside healthcare institutions (Reiner, Siegel et al. 2003), representing today one the most valuable tools supporting the medical decision process and treatment procedures.

Initially, the benefits of digital technology were confined to the equipment machines and to the relatively few examples of image data migration into a centralized shared archive, for posterior utilization. The medical imaging digitalization and the implementation of PACS, Picture Archiving and Communication Systems, enabled practitioner's satisfaction through improved, faster and ubiquitous access to image data (Costa, Oliveira et al. 2005). Moreover, it reduced the costs associated to the storage and management of image data and it increased the intra and inter-institutional data portability (Costa, Silva et al. 2004). In fact, one the most important benefits of digital medical imaging is to allow widespread sharing and remote access to medical data outside institutions. This type of system presents an opportunity to improve cooperative work among groups, taking place within or across healthcare institutions. With PACS a new saying emerged: "Any Image, Anywhere and at Any Time".

2 MATERIALS AND METHODS

The most important contribute to the exchange of structured medical image was the establishment of DICOM, Digital Imaging and Communications in Medicine, standard in 1992. Medical images in electronic format opened doors to numerous post-processing techniques that allow extraction of more and better information from the acquired data.

However, modelling and quantitative imaging analysis tools are especially expensive regarding software packages and computational power requirements, thus becoming a very scarce goods, that, although are available 24 hours a day, are only used for a few hours (Reiner, Salkever et al. 2005).

Most statistical data and productivity studies show us that medical image data can be generated in practically any healthcare institution, even with limited human or financial resources (Reiner, Siegel et al. 2002). However, the expensive computational tools and the human skills are usually concentrated in a reduced number of specialized medical centres, and there is no direct relationship between the

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existence of digital imaging equipment and the existence of sophisticated software and highly skilled technicians and examiners (Reiner, Siegel et al. 2005).

Our research question was centred in the following *motto*: Is there a way to optimize the even distribution of equipment across the country and the uneven distribution of software analysis packages and skilled examiners using technology and processes for trans-institutional use of resources from the equipment and human point of view?

2.1 "As is" Scenario

As shown previously, most studies show us that there is a good distribution of hospitals and radiological equipment across the country in which it is not matched by the distribution of resources (physicians and radiologists) nor by the productivity of the equipment (number of exams made by that equipment).

In the Portuguese case, the National Health Service shows, in its statistical data (Saúde 2004), that most of its secondary care institutions possess PACS equipment and a radiology technician. However, if we measure the productivity ratio of each of this equipment we reach the conclusion that most of the equipment is under utilized, either by lack of appropriate human and technical resources to perform a quick follow up on the patient situation, and either by lack of external clients that acquire services to the institution, thus maximizing equipment productivity.

Most of the institutions are properly equipped with PACS software acquisition modules, including digital image modalities interfaces, also known as "dicomizers", that run over appropriate internal institutional LAN infrastructures and that are connected among themselves through a private governmental network infrastructure, the RIS, acronym for *Rede de Informação da Saúde*, (Saúde 2006) that interconnects to the Internet. Also, staff that operates this equipment is considerably skilled in managing and operating its basic features, through multiple periodic training actions made by equipment vendors.

However, these institutions have difficulties in recruiting and/or economically supporting specialists (full time or partially) like, for instance, a physician radiologist. So, these hospitals engage external services to third party service providers, in the form of institutions or singular persons, to perform detailed examinations and provide feedback to the institution physician.

These entities have remote access to the institution PACS and the communication is established in a "peer-to-peer" architecture, supported by a VPN channel that connects to the institution LAN.

The system requires a high speed internet connection (or private dialup link) and a specific client PACS application installed on remote PCs. Many times, these external specialists are physically distant more than 300 kilometres away.

2.2 Proposed "to be" Model

First of all, the proposed model assumed that all equipment that joins the system uses the technical norm DICOM v3 as support format for archiving and transmitting medical imaging among the different partners (DICOM).

In our model, we have a twofold approach to optimize the use of computational resources and human skills scattered in very large geographical areas. The first is a process-based approach where, from analysing the human resources and software infra-structure available, a process optimization method is developed. The second approach is a technical one where the required technological infrastructure is described, demonstrating the information workflow and the way it is possible to optimize the existing systems.

2.2.1 Process Based Approach

From the process side (including economic, human and computational perspectives), first of all, it is be necessary to make an inventory of all the interested parties in participating in the process, either as **Client Institution** (the one that performs the **Service Requests** and feeds the system with data to be serviced), either as **Service Provider** (the one that gathers the data to be serviced, downloads it, performs the requested service and uploads it again to the Client Institution).

The **Client Institution** is identified according to the type of institution ,i.e., clinical practice, hospital, etc.; the **Users** allowed to access, the type of **Modalities** that are attached to the PACS system and a **Track Record** of the requested services, including the number of providers requested for each service and their experience level. Each Client Institution has the ability to, optionally and according to the status of the user which performs the request, includes the specific type of expertise required by the provider and if any specific type of equipment is necessary, thus maximizing the existing equipment and computational power available by the pool of Service Providers. Also as an option, a priority level for the Service Request can be attached, thus defining minimum and maximum response time.

According to the complexity level required for each Service Request, a given number of tokens is automatically assigned by the **Client Institution Interface Engine** (Figure 1), based on the number of examiners, experience level, expertise required, equipment required and priority level. These tokens determine the “virtual value” to be paid by the Client Institution to the Service Provider for the service requested (Prinz 1999).

The Service Provider is identified according to the type of institution that it belongs to (free lancer, clinical practice, hospital, etc.), the experience level that possesses, the type of expertise that it has and the equipment available. It also has attached information concerning service level agreements such as minimum and maximum response time to a request that it must contractually meet.

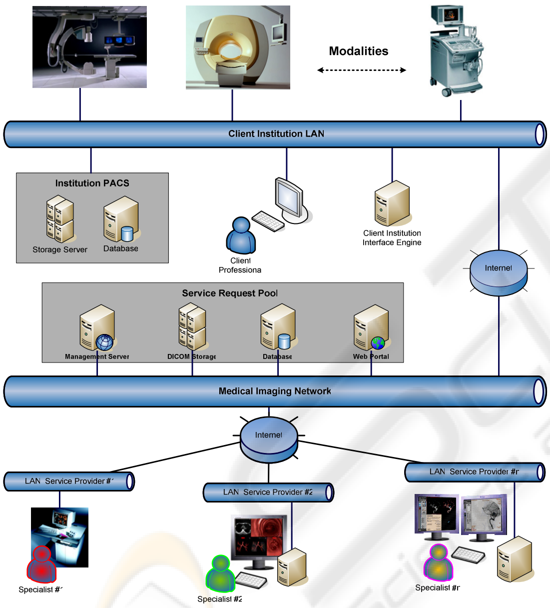

Figure 1: PACS based Service Request Pool.

Providing a use case, we have the following:

Once the exam is performed in an Image Modality of the Client Institution (Figure 1), it is placed in the Institution PACS and the **Client Professional**, examines it, determining that it needs a service to be provided by a number of specialists in the field, with a certain priority level and, eventually, requiring the use of specific equipment.

The Service Request is then placed in **Client Institution Interface Engine** where its clinical information is anonymized. It is also attached some information concerning clinical data, inserted as a DICOM structured report file (Noumeir 2003).

The Service Request is then sent through the Internet (or a Virtual Private Network) to a Medical Imaging Network that has attached to it a **Service Request Pool**, where the exam is placed.

The **Service Request Pool Web Portal** (Figure 1) shows a personalized view to each **Service Provider**, where the Service Request that is most likely to fit its profile comes on top, followed by a series of all the other it can execute according to its profile.

Once a Service Provider selects a Service Request, it counts down the number of reviewers for that Service Request. If the number reaches zero, it will disappear from the “pending” list in the web portal. A Service Provider can only select simultaneously up to a predetermined number of service requests, thus preventing a Service Provider from gathering the most interesting (or profitable) Service Requests.

Another feature included is to increase the number of tokens associated with a Service Request at a given rate as time passes by, thus guaranteeing that, at a given point, all exams are sufficiently attractive to receive a response from the Service Provider.

After performing the service requested, and according to a Service Level Agreement to be negotiated the moment the Service Provider joins the system, based on the number of tokens associated and the time that it took to perform the service, a number of credits will be assigned to its “virtual purse”, coming out from the Client Institution “virtual purse”.

Once the service is concluded, data not only is returned to the **Client Institution Interface Engine** to be “de-anonymized” and sent the requiring clinician, but it can also be kept, under its anonymized form, in the **Service Request Pool Database** so that an optional random Quality Control review (Treitl, Wirth et al. 2005) can be made *a posteriori* by a panel of reviewers that can, based on these controls, change the Service Provider experience level and/or type of expertise.

The same system that filters the data in the Service Request Pool for Quality Control can also have other utilizations like, for instance, keep data to be used in epidemiological and scientific studies (Krug, Bottge et al. 2003) where researchers can gather anonymised data to be inserted into clinical and/or research studies and where Service Providers can reference previous cases to fundament their decisions.

2.2.2 Technology based Approach

The technological approach, consists in implementing an information gatherer in every institution that adheres to the system, which interconnects the institution PACS, that by itself interconnects the existing modalities, (Figure 2 – step 1). Thus it is able, through the Client Institution Interface Engine, to receive the data from the institution PACS in DICOM format, anonymize the patient identification data in the DICOM headers, label them with an internal ID number, ID request, as well as service priority and service code intended from the structure.

It should be noticed that the ability of radiology technicians to operate modality equipment, to use the PACS system and to perform basic imaging adjustment such as brightness or contrast adjustment is not jeopardized by the introduction of this engine.

Since PACS systems have the ability to configure external DICOM servers to export imaging procedures, in this case it is added a new export unit to the local PACS system designated “PACS POOL”. In order to use this functionality, the radiology technician only has to select the intended information and “Send to PACS POOL” (Figure 2 – step 2), just like when a DICOM image is sent to another server or institution nowadays.

Whenever it is necessary to add extra clinical data to support the intended service code (patient history, lab analysis, etc.), this information can be given as a DICOM file of the type Structured Report. In this DICOM file it can also be included the specification of the intended service, represented, for instance, as an ICD10 or as ontology. The specification can also be placed in a “DICOM Private Tag” especially inserted.

Once the service request is inserted in the POOL (Figure 2– step 3), i.e.: the medical images are stored to the “DICOM Storage” and the “Database” is updated with a new request in “pending” status, the Service Request Pool Web Portal informs all suitable Service Providers that there is a pending request for that specific type of clinical service. Once a Service Provider shows interest in analysing that request, it passes from the state of “pending” to the state of “lock” and it is automatically sent to the service provider PACS system (Figure 2– step 4).

The Service Provider then processes the request according to the request made earlier (Figure 2 – steps 5 and 6) and sends back to the Service Request Pool the complete process (Figure 2 – step 7). The service results (images and reports) are, once again, supported and transferred using DICOM standard (Storage Syntax and Communications Protocol).

In the Service Request Pool, the Service Request is passed from “lock” to “complete” in the “Web Portal” and the results are sent back to the requesting Client institution (Figure 2– step 8) i.e.: to the Interface Engine of the Client institution.

Once arrived here, the patient identification data is reset to all DICOM headers and the information sent to the “Local PACS” (Figure 2– step 9) where the results and the requested service are available for the clinician that requested the service (Figure 2– step 10).

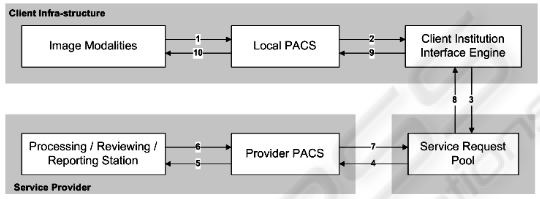

Figure 2: A PACS based management of resources.

3 RESULTS

With the conceptual model previously proposed, we point to a solution to several problems that now impairs the optimal provision of radiological services, such as the imbalance in the distribution of equipment and specialists over wide geographical areas, reducing the response time and establishing a virtual market for the provision of radiological services.

This virtual market has a set of features such as the ability to set up an Engine that acts as a broker that guarantees functionalities such as:

- Double blind review of the exam if desired (the Client Institution may not know the identity of the Service Provider and the Service Provider may not know the identity of the Client Institution and the Patient that it is reviewing, with the broker being able to reverse this situation at any time),
- Quality of service in terms of time and expertise (every request gets serviced through an embedded priority management system),
- Review of the quality of service provided (every service request processed can, randomly, go to a database where an expert committee samples them in order to grade the Service Providers),
- Build up of an anonymized studies database for epidemiological and scientific reference analysis and fundament decisions,
- Set up a virtual market where only the most appropriate service request are presented to the Service Providers, performing a previous

filtering of all the requests not suitable, and listing them according a list of preferences set by the Service Provider, and
- Perform administrative and financial management of the system, guaranteeing payment of the Service Providers by the Clients through a token-based system that prices the service according to its complexity, response time and expertise of the service provider required.

4 DISCUSSION

The implementation of such a network will be of utmost interest for well implemented nationwide networks of PACS infra-structures, usually owned by National Health Service and/or by large insurance companies in order to optimize turn-around times of detailed diagnosis by external specialists and will also be of interest for insurance companies that have insurance policies options that enable the extension of the quality of service provided to the speed of response time, quality of the service provider and/or the number of service provisioners.

The use of ontologies in the processing the request in (Figure 2 – steps 5 and 6) will enable the possibility of extending the network at a pan European and/or at a worldwide level (admitting that there are no ethical and legal problems with the mutual recognition of service providers), in extraordinary cases such as rare malformations or in cases that require a specific expertise and/or software only available outside the network.

From the purely economical point of view, and abstracting the legal and ethical problems associated, a global market could be established, thus transforming a purely local market onto global network of service providers, thus making available a set of expertise and software anywhere and at any time.

5 CONCLUSION

This entire model is designed so that there is no need in changing the existing institutional PACS structure of the entities involved, with no need for additional hardware or applicational software and with a quick learning curve for the clinical staff involved. Furthermore, the underlying economic rationale allows an optimization in the use of resources, creating mutual benefits for the parties involved in the service provisioning.

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