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Advanced PACS Applications:

Despite the widespread adoption of the DICOM standard in medical imaging, it can still be challenging to share data across institutions. Too often simple yet inefficient means of sharing data are used due to the lack of fast and secure mechanisms that support interactive access to data resources from outside institutional firewalls.Virtual PACS, a mechanism for standardised, efficient and secure access to geographically distributed resources of imaging data, has been discussed in the literature as a potential solution.

Virtual PACS federates multiple remote data sources including those that do not support DICOM messaging and presents them to a DICOM client as a single virtual resource. It can behave as a virtual DICOM PACS server that allows local DICOM data producers and consumers to interact with multiple image data sources over the internet. These data sources can be native DICOM sources (such as DICOM PACS servers) and non-native DICOM sources (i.e. sources of DICOM objects which do not support DICOM messaging and may store images on disk or in databases). This federation of PACS archives serving cooperative backup archives for one another can be effectively realised utilising GRID technology.

In this design, only a small fraction of the PACS data archive resource is needed from each federated member. Essentially, any federated member can link to this data GRID with minimal cost while benefitting from the continuous availability of image data recovery. GRID computing uses GRIDenabled software so that healthcare enterprises can share geographically dispersed resources, including software, applications, data and computing and storage platforms. GRID computing is not so new within the scientific community but the medical imaging community has only recently begun to explore its possibilities further.

Advanced Image Processing

A vital step in developing image processing applications in medicine is that of evaluation and validation of algorithms, software models and protocols. This requires that the procedure be tested on a sufficiently large set of test cases, i.e. an image database. Generating such an image database, while far from trivial, is only part of the task: Tools are required to access and use data, and in addition to perform something akin to a clinical trial based on which the performance of the procedure can be assessed.

The development and evaluation of effective algorithms requires access to a large number of cases from different geographical locations so that variations in the population are adequately modeled. A traditional approach would involve the collection and transfer of image data to a central location, enabling remote use. While high-speed networks are often necessary for such remote resource use, they are far from sufficient: remote resources are typically owned by others, exist within different administrative domains, run different software and are subject to different security and access control policies. These issues have historically made distributed computing difficult.

Today's technologies do not provide uniform mechanisms for such critical tasks as creating and managing services on remote computers, for supporting "single sign on" to distributed resources, for transferring large datasets at high speeds, or for forming large distributed virtual communities and maintaining information about the existence, state and usage policies of community resources. GRID systems and technologies provide the infrastructure and tools to solve these kinds of issues and make large-scale, secure resource sharing possible and straightforward.

GRID for CAD

There is a growing body of literature supporting the ability of CAD systems to increase diagnostic accuracy when used in combination with human readers. However, the additional time required for use of CAD systems suggests a need for the development of modifications in workflow and in how CAD is used to streamline the interpretation process.

Current CAD systems operate on local data sources and in most practices, a CAD system from a single vendor is used at a specific location. As the diagnostic imaging data obtained with CT and MR imaging increases in spatial and temporal resolutions as well as in overall complexity, the amount of data stored per patient also increases dramatically. Latency in the transfer of data across the healthcare enterprise for remote image review increases with data size, thus adversely affecting the user's ability to dynamically interact with databases. GRID technology could greatly increase the accuracy and speed of image analysis by sharing data as well as computational resources. Indeed GRID computing is suited to complex and computationally demanding applications in medical imaging.

As opposed to current commercially available CAD systems, GRID-CAD integrates different CAD programmes into a GRID framework from multiple vendors, thereby creating an infrastructure that allows invocation of multiple CAD algorithms in parallel on one or more image data sets. For example, especially intriguing is the possibility of using CAD software programmes from different vendors in a cooperative manner to enhance the performance and accuracy of lung nodule detection in a single image data set.

GRID for Efficient Storage

PACS technology remains weak in the area of clinical image data backup. Current solutions are expensive or time consuming and the technology is far from foolproof: many largescale PACS archive systems still encounter downtime for hours or days where it is possible to lose access to pertinent clinical image data.

Current recovery solutions suffer a few limitations. For example the CA archive server has eluded widespread implementation due to confinement of manufacturers by current IT standards. As far as the ASP model backup archive is concerned, image recovery procedures have turned out to be tedious, requiring manual intervention together with the additional complication that the ASP backup server is one site serving potentially multiple hospital sites which could quickly outgrow its cost-effectiveness as more hospital sites are incorporated. To serve enterprise level clinical data recovery, an innovative approach is needed:

- By applying GRID computing architecture to a DICOM environment, a federation of PACS can be created allowing a failed PACS archive to recover image data from others in the federation in a seamless fashion;
- By distributing redundant copies to different storage sites, a GRID implementation would avoid a single-point of failure, thus assuring compliance to FT/CA requirements, and
- GRID technology would enable resource optimisation by matching network availability with the specific task to be performed.

Future Directions

Security, authentication and authorisation are among the most challenging current issues in GRID. Traditional security technologies are concerned primarily with securing clientserver interactions in which a client and server need to mutually authenticate and the server needs to determine whether it wishes to authorise requests issued by the client. Sophisticated technologies have been developed for guarding against and/or detecting various forms of attack. In GRID environments, the situation is more complex: the distinction among client and server tends to disappear (a GRID is a peer-to-peer system) because an individual resource can act as a "server" one moment and a "client" another. It is not so difficult to see how security and privacy could be mined when data treatment requires a geographically widespread resource allocation.

Indeed, a single computation may access many resources at the same time and it is generally unacceptable to require that the user re-authenticate on each occasion. Instead, a user should safely be able to authenticate once and then assign to the computation the right to operate on their behalf. This authentication capability is achieved via the creation of a proxy credential which is a form of delegation, an operation of fundamental importance in GRID environments. A GRID computation that spans many resources creates subcomputations that may themselves generate requests to other resources and services, perhaps creating additional subcomputations. Yet the further these delegated credentials are disseminated, the greater the risk that they will be acquired and misused by an adversary.

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EU R&D Projects Using GRID Technology

Numerous government-funded R&D projects are applying GRID technologies to challenging applications. Industrial interest is growing and the number of radiology-related applications of GRID computing are increasing. Such applications include MammoGrid, a European database that allows access to mammograms by using a GRID-based software, and Connection-5, a project group where GRID-based applications are used for the detection of breast cancer and Alzheimer's disease. One of the most promising GRID computing projects was caBIG, a community initiative sponsored by the National Cancer Institute (NCI) Center for Bioinformatics to create an informatics infrastructures among clinical cancer centres that would facilitate research through the sharing of data, software and expertise. Things keep moving on, even if a long and intensive process is still foreseen in the next future.

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