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An Open Distributed Medical Image and Signal Data Server Network with World Wide Web Front-End

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Abstract. In modern patient care and medical research diagnostic imaging from multiple modalities plays an essential role. In general these digital image data are acquired at different locations. An efficient access to the data via network is often not provided due to technical, organisational and political reasons. This article presents an approach to solve the problem by means of an open distributed data server network with Web-based front-ends and describes the prototype DACHS that has been developed at the University Hospital of the Technical University of Munich.

1. Introduction

Modern medicine is a huge domain with a high degree of specialisation. Both patient care and medical research depend on the acquisition of data from many different sources at different locations. An example for this dependency in medical research are the neurological sciences that in many cases depend on the fusion of complementary imaging modalities like MRI, PET and EEG [7]. In patient care the whole field of specialised diagnostics performed by dedicated providers is an example for this dependency. Up to now the obstacles of the distributed generation of data have not been overcome [6]. Slow and incomplete supply of data on conventional media (paper, photographic film) and loss of data (which is normality, not an exception) cause tremendous additional costs in health care and medical research. Although many sources are digital and integrated in local computer systems, the access or transfer of these data is not performed due to technical, organisational and political reasons. Providers want to keep their data and make a very careful access policy. The rapidly increasing use of images with increase rates of up to 20% per year [2] should be paid special attention in this context.

This article gives an approach to a distributed data provision network. Firstly the requirements to such a network are defined with respect to the different roles of actors on the information. Secondly a prototypical realisation is presented, the open distributed medical image and signal data server network DSNet (DACHS Server Network) of the pilot project DACHS (Database And Communication in Health System) that meets most of these requirements.

2. Objectives and requirements

The objective of the project was to implement a Medical Collaboration Network (MCN) satisfying certain requirements with respect to the four types of actors in an MCN: 1) Providers: Institutions generating data and providing it to users. 2) Administrators: Persons implementing the access policies of the providers. 3) Users: Clinicians and scientists retrieving data for their work. 4) Privileged users: Users who have the right (and duty) to import new data into the providers' data collections.

According to legal constraints and a careful access policy that shall avoid unauthorised data access providers have two global requirements: G1) Local data storage. The data is to be stored on media located at the provider's institution. This can be a commercial archiving or documentation system as well as a special data server. G2) Controlled access to this data for clinical and research partners. Partners that perform a further treatment of a patient of the provider or research partners of the provider within running projects shall be given exactly defined access rights to all those data that are required to fulfil the task. In order to meet the global requirements the following operative requirements must be stated with respect to the administration of a MCN: A1) Dedicated grant / revoke of search rights on the local data to other providers. A2) Selection / de-selection of providers as search space for user queries. A3) Dedicated grant / revoke of access rights to users. A4) Dedicated grant /revoke of the import right to privileged users. A5) Logging of all queries (user), imports (privileged user) and administrative actions (administrator). A6) Simple intuitive graphical user interface. User requirements are: U1) Transparent access to the data in the network from every workstation. U2) Simple intuitive usage by a graphical user interface. U3) Image and signal data processing tools: a) domain specific (e. g. object recognition), b) universal (e. g. filters for visualisation), c) hybrid (e. g. registration / matching). In addition to the user requirements privileged users need to have: P1) Simple facilities to import data into the system. P2) Same user interface as users.

3. Concept

Within the pilot project DACHS a prototype of a distributed application has been developed to support neurological research with image and signal data with patient identification in the corporate network of the University Hospital of the Technical University of Munich. The overall concept of the DACHS application is shown in figure 1. The providers store the data they want to make accessible for some partner on a dedicated DACHS Server (DS) located at the provider's institution. The DS's are all connected to a network, for example some corporate network or the Internet. Every DS has the DACHS server software installed that provides the communication modules for a loosely coupled DACHS Server Network (DSNet) which is our MCN. The network is loosely coupled in the sense that any DS can operate also locally without a connection to the network. On the other hand the network can further operate if a DS goes down; the only effect is that the data of this DS is no longer available to the DSNet.

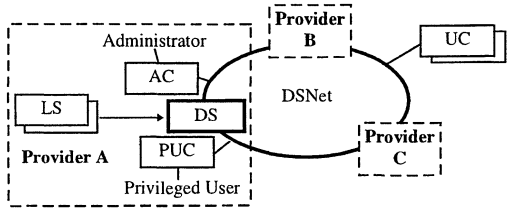

Fig. 1: The DSNet Concept

Every provider has an administrator responsible for the implementation of the access policy. By means of an Administration Client (AC) he configures the access rights of other DS providers of the DSNet to his DS and defines the remote DS's his DS has to search through when performing a user query. He also defines the access rights of users and privileged users of the DSNet on his DS.

The data is imported into the DS by a privileged user of the respective provider. To perform this task the application provides the functionality of a Privileged User Client (PUC). Usually but not necessarily a PUC is located at the provider's institution. The data originally come from Local Sources (LS) of the provider like medical imaging systems.

A user of DSNet can use the network for acquisition of data he got access to by means of queries. For this purpose the system provides User Clients (UC). The user needs not to know on which DS's this data are actually located. UC's can differ in the number of data formats they support. The user can view acquired data if his UC supports the respective data format, i. e. if there is a viewer for the format on the UC.

4. Material and Methods

The DACHS system has been developed on a Silicon Graphics workstation SGI Indy with the operating system IRIX 5.3 in a TCP/IP network. The application uses the features of a HTTP (HyperText Transfer Protocol) server (Apache 1.03) and a WAIS package (freeWAIS-sf 2.0). It consists of several CGI (Common Gateway Interface) scripts which are realised with the interpreter language Perl 5.0. The password cryptography has been written in C. For data transfer the FTP (File Transfer Protocol) functionality is used. Therefore on the LS of the provider a FTP server is required for the DACHS application [4]. The client must have running a HTML (HyperText Markup Language) browser which understands the HTTP authorisation features. Therefore the Netscape Navigator 2.01 and higher (Netscape Communications Corporation, Mountain View CA, USA) is used in the project. The DACHS Viewer can be used only if the client supports IDL 4.01 (Interactive Data Language, Research Systems, Inc., Boulder CO, USA).

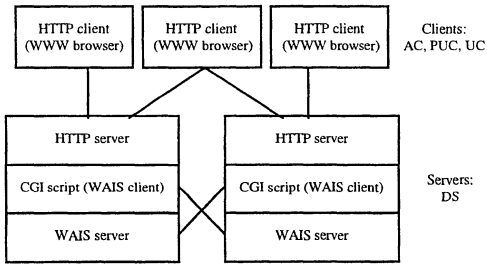

Fig. 2: DACHS architecture

5. Application Prototype

Figure 2 shows the software architecture of the DACHS application. On every DS an independent WAIS server is implemented. The access to this WAIS server is done by means of a CGI script. In this role the CGI script becomes a client of the WAIS database. The CGI script knows all existing DSs from a configuration file. It starts a retrieval not only on the own DS but also on all other DSs in the DSNet. The CGI script is triggered by a HTTP server which is started by a WWW browser using a HTML form. Image and signal access is performed by means of hyperlinks to the data files. The front-end uses a HTML browser for the user interaction. For each server a Uniform Resource Locator (URL) address is avail-

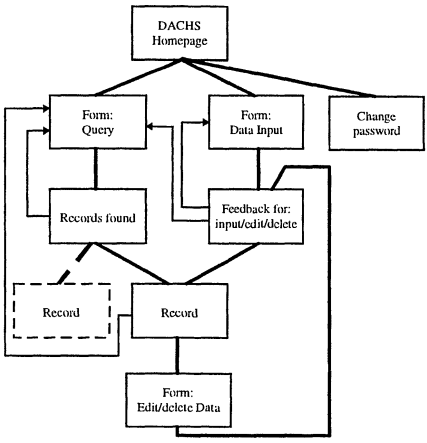

Fig. 3: Interface structure for privileged users

able to get to the homepage of the DACHS application. This homepage refers to HTML forms for query, the data import and administration.

Data Import

To import information into a DS, the privileged user fills in the data import form for the DS. The finishing of this form triggers, by the HTTP server, a further CGI script which generates the new database record, transfers via FTP the required data from the LS to the DS and finally updates the database. Finally a confirmation message informs the privileged user that all went right. Figure 3 shows the menu structure for the privileged user. With the import form the privileged user can edit and delete entries directly. The DS allows to decide whether an imported file shall be treated as special DACHS file. For such files the DACHS Viewer, an IDL application, is available. Import and modification are logged in the DACHS input log file.

Data Retrieval

After the formulation of the query by filling in the query form the user gets a list of all records in the DSNet (i. e. on any server in the DSNet) that fit the search criteria. Each list entry refers via hyperlink to the URL of the corresponding record. When an entry has been selected by an authorised user the full record is displayed by the browser as a HTML page. The page contains the links to the referred data which can be loaded into the appropriate viewer by a mouse click. If the viewer is missing the file is transferred to the UC. These actions are logged into the DACHS query log file.

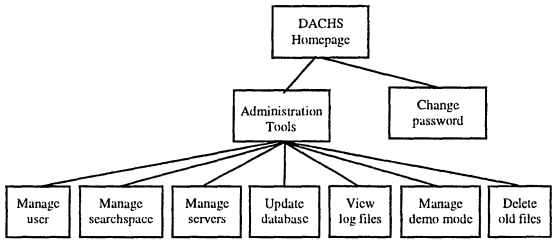

Fig. 4: Interface structure for administrators

Access Control

The access control by means of password check, machine authentication and domain restrictions is provided by the HTTP server functionality. For both query and import of data the access mechanisms are equal. The users and the privileged users are able to change their own passwords they have got from the administrator by use of a separate form via the HTML browser.

Administration

The administrator has a special account on the DS. With this account he has all facilities to control the access of and on the DS (see figure 4). He can add or delete new servers of the DSNet which are allowed to search on his DS, and defines the servers on which his DS will search. He adds or deletes users or privileged users giving them an account with password.

6. Discussion

The DACHS application meets nearly all the requirements stated above. An exception is the requirement (U3), where only part b) is covered to some extent (visualisation features) by means of the DACHS viewer. All other requirements are fulfilled.

The open architecture of the application with external data viewers and WWW front-end provides a very flexible framework for extension, for example the integration of further modalities. The application can easily be ported to other medical as well as non-medical domains that need distributed data provision and wish access via WWW. The prototype solution with WAIS, HTTP server and WWW browser is nearly free of charge and can be considered as 'all-round solution' for different application fields. WWW browsers are very well known and used by more and more people, so the acceptance of the interface is very good. Within the ongoing evaluation of the prototype the practicability and acceptance is tested with radiologists.

The application has not yet been implemented on the Internet. At the moment the implementation of security modules is work in progress. The aim is to further develop the application to make it a secure DACHS.

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