A Cloud Scalable Platform for DICOM Image Analysis as a Tool for Remote Medical Support

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***Abstract*—Remote diagnosis has become an important research field to provide high quality health care services to larger communities. Even when the importance of providing these services is undisputed, the computational cost of performing such processes is high. In order to deliver this kind of services, we present a scalable platform in the cloud able to process DICOM files with a modular structure. Our platform extracts and processes relevant information from the DICOM file to be used for support in diagnosis in medical applications. The paper presents a discussion about the cloud infrastructures and our choice of storage and HPC processing capabilities on Amazon AWS infrastructure. We also propose an HTML5 and WebGL web based access interface to allow remote access, visualization and manipulation from the user side, but keeping the computational cost on the cloud. The platform offers Cloud processing for computationally expensive tasks (from DICOM image segmentation to data mining in order to extract relevant information from the DICOM file). We present a basic proof of concept and describe the relevant modules of our platform.**

Keywords—DICOM; X3D; WebGL; HTML5; 3D graphics; mobile medical applications; medical cloud DICOM processing; GPU processing on the cloud; Amazon AWS.

I. Introduction

There has been extensive research on using the web for medical image processing, remote support diagnosis and visualization [1][2]. Unfortunately, the large amount of data of DICOM files limits the applicability on mobile devices or require high computational cost to extract relevant information that even desktop computers are limited to do. On the other hand, the adoption of the WebGL [3] and HTML5 standards for the new generation of browsers brings back the interest of web based 3D rendering with WebGL and declarative X3D [5], since it will be supported without plug-ins, allowing the same functionality across platforms. Further, WebGL will make possible to render 3D models in real time with the computational capabilities of the new smartphones and tablets. Some attempts to build WebGL-based medical visualization systems have been reported [4], but these only considered the X3D model creation from DICOM on the server side for visualization in a remote platform. In this work, we propose a cloud based platform where DICOMs are stored but also processed, so a remote (desktop or mobile) computer can access and manipulate visual data and extracted information. Our approach is modular, so different kind of studies and data analysis can be applied to the DICOM file, and 2D or 3D data structures can be visualized by the user, in order to help interpretation and support for diagnosis.

The paper is organized as follows: Section II gives an overview of the cloud infrastructure choice. Section III details the processing architecture, and Section IV the implementation and preliminary results. We give some conclusions and directions in Section V.

II. Cloud Storage and Processing Infrastructure

Many PACS like platforms in the cloud only consider data storage. For general PACS functionality, data must be stored and accessed via HIPAA (Health Insurance Portability and Accountability Act of 1996) compliant procedures [8], for security and integrity reasons.

In our case, we are also interested on data processing in the cloud, so the storage infrastructure must be coupled or connected with a fast link in the cloud with a High Performance Computing (HPC) infrastructure. The Amazon AWS infrastructure provides both solutions in the cloud as separate services.

On one side, the Amazon S3 (Simple Storage Service) allows cloud data storage of large files. It also offers easy solutions to develop HIPAA compliant medical applications. Basically, the Amazon infrastructure offers solutions for: Identification & Authentication, Authorized Privileges & Access Control, Confidentiality, Integrity, Accountability, Security and Protection, Disaster Recovery.

On the other hand, the Amazon EC2 infrastructure provides on demand processing nodes, either multicore processor nodes, or HPC nodes with Nvidia Tesla boards. The later are parallel processing platforms based on CUDA-C, a parallel C version suited for multi thread programming on Nvidia GPUs and HPC boards. Typical acceleration with an Nvidia board goes from 10 to 100 times compared to a traditional CPU node.

There are other cloud solutions but for the architecture we are proposing, Amazon AWS provides a scalable environment for storage and processing suitable for medical image processing and analysis.

III. PROPOSED ARCHITECTURE

The proposed platform is based on a client – server architecture, where the server is in the cloud (Amazon S3 and EC2). Traditional architectures allow physicians/ radiologists to visualize, analyze, and interact with patient information stored in a DICOM repository. This approach has the drawback of requiring large data transfers between the user and the cloud, and limits the amount of processing on the DICOM data in the local computer to basic image enhancement algorithms.

In our case, once the DICOM is stored in the cloud, it can be processed / analyzed on the cloud side, using a large number of nodes (reaching HPC performance), and sending to the final user only relevant information, either data, images or 3D models, as in [7].

A. High Performance Computing on the Cloud architecture

Figure 1 depicts the general architecture. On the client side, there is a visualization tool based on a web interface. On the cloud side, there is an S3 server that contains the DICOM repository where the patient data is stored. A file subsystem and HIPAA compliant access is implemented for file upload, storage, management, and traditional DICOM access for visualization through the net. An administration module (m3DicomAdmin) is in charge of authenticating users and initiate task requests. The general steps are:

1. A user is authenticated
2. The user uploads a DICOM file (or is already stored in the S3 server) and a request for a particular image processing task
3. The m3DicomAdmin communicates the file to the EC2 server,
4. The master node in the m3DicomProcessing configures the HPC nodes for the particular image processing task (plug-in).
5. The image analysis/processing is carried out and the result is sent back to the S3 server
6. The user is notified and he/she can download the results of the type of study into the viewer.

The most elaborate and complex processes of DICOM data analysis are based on advanced segmentation algorithms that locate specific organs or tissue in the data. The architecture allows the EC2 unit to allocate several nodes or HPC resources (ie. Nvidia HPC boards) to solve in short time the tasks.

If the cloud processing generates 3D data or 3D models, they can be embedded into a X3D representation that is sent back into the user visualization interface for visual exploration, alleviating the amount of data compared to visualizing only the DICOM file [7].

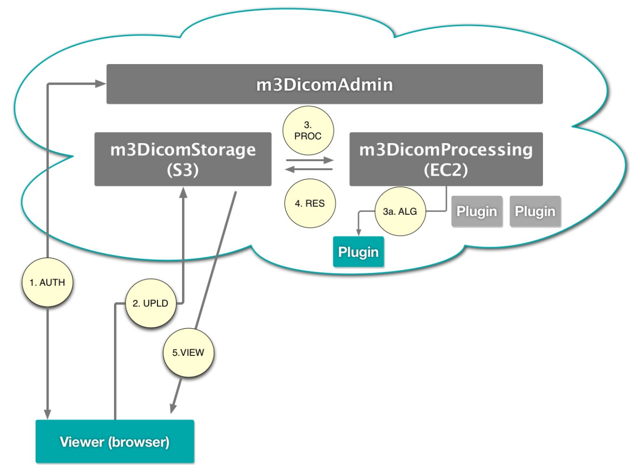

Figure 1. Server-Client architecture of the scalable platform. The S3 service is used for storage and the EC2 infrastructure for cloud processing where several “plug-ins” for each modality can be integrated.

B. Client – web user interface

Figure 2 shows a simplified version of the web interface architecture. On top of figure 2: the cloud processing engine sends X3D files and additional data extracted during the analysis phase and both types of data are integrated into HTML using embedded X3D as a mixed-namespace document (X3DOM implementation [5]). This allows a simple interaction (HTML events) and navigation (zoom, rotate) on resulted 3D objects. The interface is designed to provide cross-browser support (for both desktop and mobiles), using the JQuery Mobile framework [6].

Through the user interface, it is possible to set up algorithm parameters (such as a threshold or other parameters), which are used by the cloud engine to extract and label relevant information from the DICOM file.

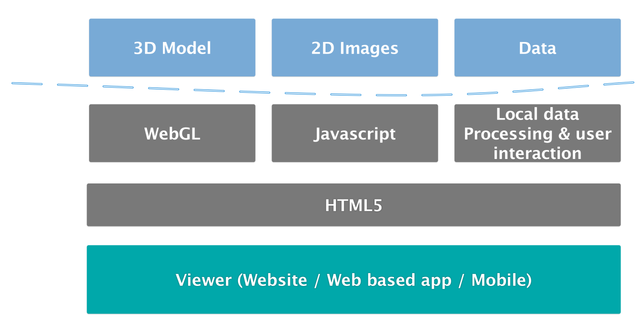

Figure 2. DICOM/X3D data structure from cloud and viewer interpretation for user interaction

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C. The Processing plug-in architecture

Figure 3 presents the HPC platform where the algorithm associated to a particular type of study, is considered at a high level as a plug-in module, but actually it corresponds to a particular software / algorithm configurations for the multi-node HPC part. The platform has a service manager that routes the task requests into a queue, where each task is individually routed to a master node of the HPC. The master node configures the parallel node section of the HPC with a particular algorithm required by the task, i.e. Mammography for a set of DICOMs to be processed in batch.

Amazon EC2 allows to configure a set of nodes with a specific software algorithm, but that can be reconfigured on the fly depending on demand, so the Master node could set up more nodes if there is a large demand of task requests.

The result of the processing is routed back to the Amazon S3 repository and associated with the patient in the database, and signaling the end of processing to the remote user.

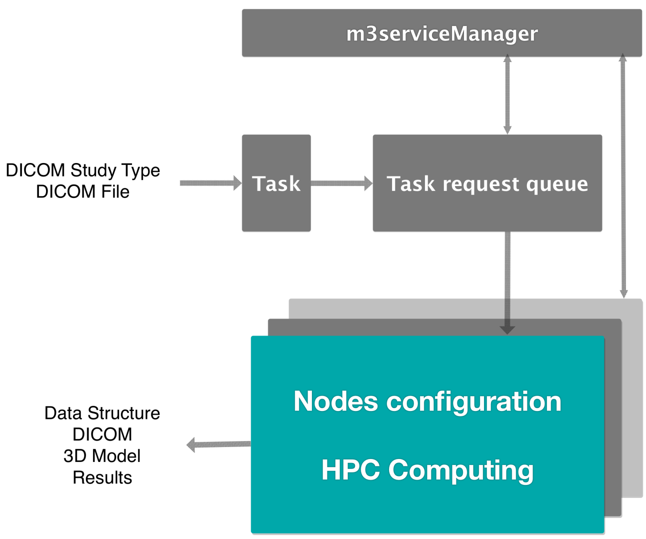

Figure 3. Multi configurable HPC for Image Analysis. Each Node set configuration is treated as a "plug-in" that the m3Dicom Processing node configures on the flight depending on the kind of study to be performed.

IV. PRELIMINARY RESULTS ON CLOUD PROCESSING

An implementation of the platform was carried out. We used the Amazon AWS infrastructure with a basic 4-node server with Nvidia Tesla GPU boards for HPC. For DICOM storage we used Amazon S3. The basic 4-node configuration was chosen to test parallelization and multiple node configuration for the basic test algorithms, but the configuration could be grown to larger setups to reduce processing time. In a multi-user configuration, an additional workload manager is required in order to queue task requests into the server or to dynamically setup more processing nodes.

Some results are discussed below.

A. Mammography analysis in the cloud

Once the user uploads a mammogram DICOM file, it is processed to identify micro-calcifications. This process requires extensive computing in order to segment Regions Of Interest (ROIs), which are possible micro-calcifications, extract features (statistical, texture, and geometric) from the ROIs to be used by a classifier that works on the cloud. The classifier finds the micro-calcifications (eliminating as many false positives as possible) and creates a new mammogram image in which it identifies the micro-calcifications found (adding a mark and id to each possible micro-calcification). This new image is returned to the user to be used as a support tool for medical diagnosis [9, 10, 11].

B. Visualization tool

Figure 4 shows the visualization tool interface. The tool is a web application developed using HTML5 and JavaScript suitable for mobile and desktop browsers. The tool connects to the cloud platform and offers options to select one patient or upload a new DICOM image, to start a processing task and visualize the results, depending on the type of study uploaded. The interface integrates a 3D viewer and a 2D viewer, using X3D objects and HTML5 functionalities to manipulate the 3D objects and images (zoom, brightness/contrast, etc.)

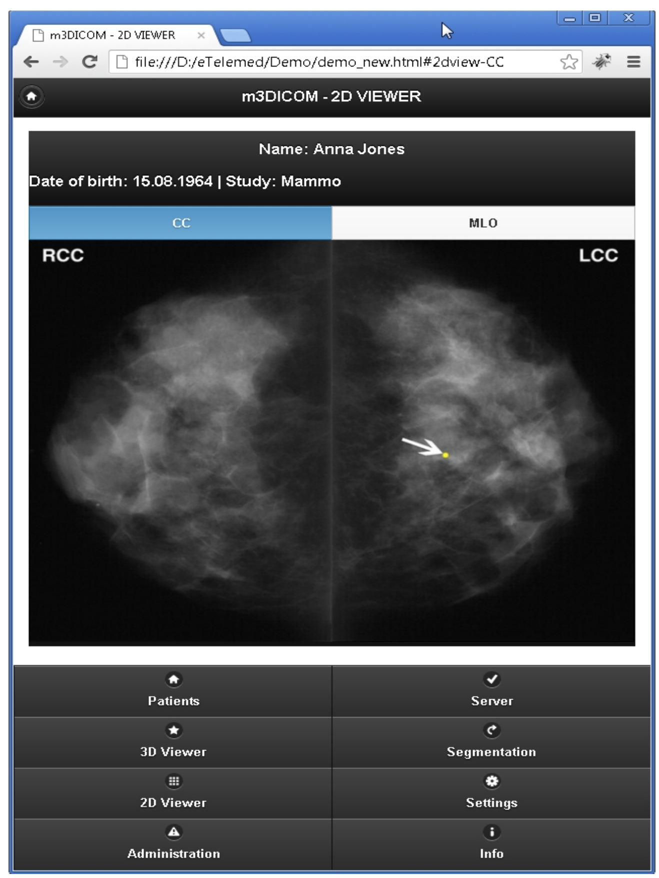

Figure 4. View of the mobile device interface showing a mammography. The detected micro-calcifications are signaled with an arrow.

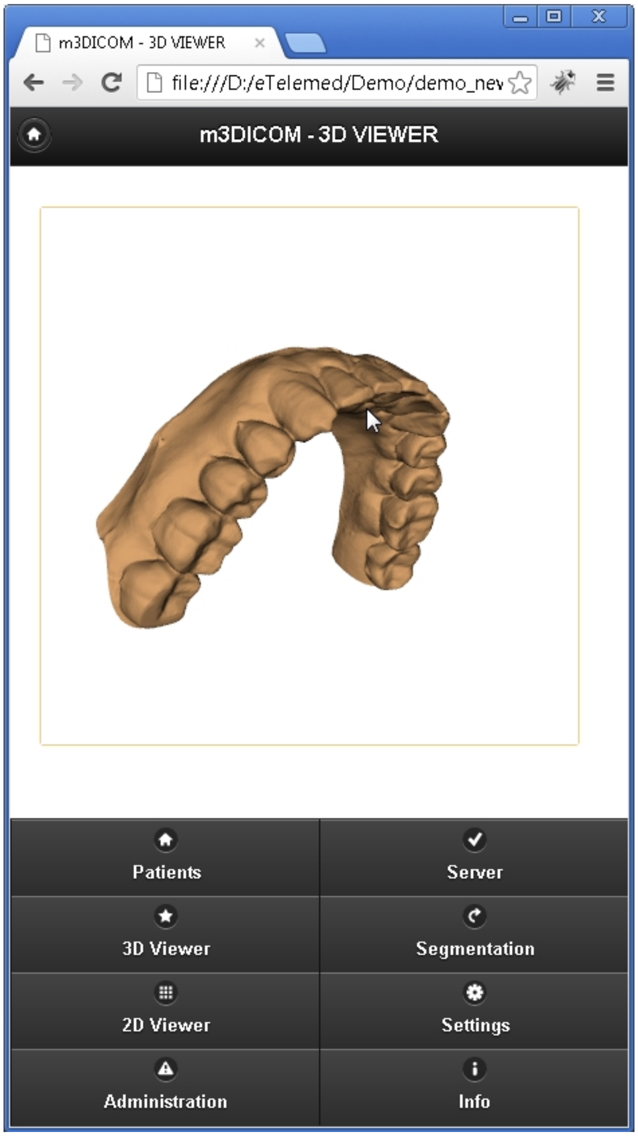

Figure 5. Mobile device interface showing a 3D model extracted in the cloud from a DICOM dental file.

Figure 5 shows the viewer displaying a 3D model from a dental DICOM where the segmentation process was carried in the cloud, following same technique described in [7].

V. CONCLUSION AND FUTURE WORK

We have presented a proof of concept of a cloud platform for DICOM processing. The platform stores DICOM files, processes them on a HPC infrastructure and delivers information to a web client using WebGL and HTML5. The platform is the basis for a larger system where different kind of image data processing will be integrated. A basic proof of concept was implemented with mammography analysis based on data mining algorithms and bone/tissue segmentation for dental applications. Some ideas to be explored are pre-computation of volumetric rendering, a scaled up version of the mammography analysis for batch processing large sets of studies and advanced 3D data segmentation.

On the user side, WebGL and HTML allow flexible visualization. Future work will concentrate on an improved front-end tool that can be used in desktop and mobile devices, and define a standard for plug-in processing/integration that could be used by others to grow functionalities of the system.

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