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Extending PACS Functionality: Towards Facilitating the Conversion of Clinical Necessities into Research-Derived Applications

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Abstract

The Picture Administration and Communications System (PACS) was designed to replace the old film archiving system in hospitals in order to store and move varying medical image modalities. Using the standard Internet transport protocol, PACS creators designed a robust digital signaling platform to optimize media use, availability, and confidentiality. Nowadays PACS has become ubiquitous in medical facilities but lacks imaging analytical capabilities. A myriad of initiatives have been launched in the hope of achieving this goal, but current solutions face issues with security and ease-of-use that have precluded their widespread adoption.

Here, we present a PACS-based image processing tool that safeguards patient confidentiality, is user-friendly and is easy to implement. The final product is platform-independent, has a small degree of intrusiveness and is well suited to clinical and research workflows.

Keywords

PACS; PACS extension; clinical research; 3D imaging; image processing; image analysis

1. INTRODUCTION

While PACS developers have focused primarily on security and availability requirements for data storage, the idea of integrating an image analyzing port into the PACS system has been explored for the last 15 years.[1] The commercial software in PACS platforms is typically proprietary, therefore limiting the potential for third party contributions. These barriers have led some developers to propose different solutions, ranging from building a new application from scratch[2] to a full scheme of back-end and front-end plug-ins, as envisaged by Bellon et al.[3]

The adoption of new systems such as the ones proposed by Mahmoudi et al.[2] is rendered prohibitive by the fact that PACS is currently used in 93% of hospitals.[4] As for plugins

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options,[3] some packages already tackle specific categories of problems such as[5] cardiac-support assessments, empowering team interactivity[6] and traffic alleviation,[7] among others. However, despite tools such as these have the potential to improve medical image analyses, the packages created so far are limited in their clinical usefulness. While data security is at the core of PACS, existing plugins are created following concepts such as everywhere availability, remote javascript-based interactivity, and display on portable devices that may expose the system to confidentiality breaches. Although these tools are launched with free software licenses, politics and legal factors can hinder their adoption.

In this manuscript, we present a low-intrusive and independent solution conceived and implemented at Childrens Hospital Los Angeles. The implementation transparently attaches to the existing PACS at multiple points of the network architecture, creating new secure-lightweight data flows and enables unlimited data processing capabilities without perturbing the actual PACS operation. Our solution creates an open scenario where researchers can test and implement, without delay, their codes and procedures using real clinical data.

2. MATERIALS AND METHODS

The network at CHLA was slightly modified to achieve the desired functionality. Fig. 1 illustrates all the elements present in the network. Additionally, a designated computer, available to clinicians has been assigned as the Processing Application Server (PAS).

The current strategy pivots around the PAS, which is seen by the PACS as any other client in the network. This empowered client generates a new pattern of communications with the PACS and other viewports as well. The automation in the PAS is done using Pythonic gadgets that boost the filtering power of the common Query/Retrieve (Q/R) scheme defined to implement digital imaging and communications in medicine (DICOM) transactions. The PAS solves the problem of coherently transporting the data and having it available for extracting qualitative insights.

Once the PAS-PACS interactivity is established, the following design aspects are considered.

2.1 Query/Retrieve optimized filtering

The Q/R actions in the PACS environment are performed through the Dicom Message Service Element DIMSE-C Services (like C-Find and C-Move), where there is always a Service Class User (SCU) at one end and a Service Class Provider (SCP) at the other. For the querying, the SCU is always a client (local terminal), while in a retrieving function, the SCP is a client, that in turn forces the PACS to act as the SCU. This last operation points to role swapping rarely used in the hospital setting but is highly relevant to this application. Regarding the Q/R functions, the design requirements are:

- The C-Find method to produce only small transactions that are optimized to target specific instances within studies.
- The C-Move method that enables image transportation must be selective and ideally should allow sending information back to PACS.

- Since the analytical information is not required in real-time, the strategy involves the optimization of the best time to transfer.

2.2 Restrictions on produced information and reports

Almost any kind of data can be using the standard internet protocol implementation and the PACS platform exerts this flexibility if the data is wrapped in DICOM headers. In general, DICOM is very inefficient regarding space, but highly efficient when moving large amounts of data in a shared media. This transporting protocol allows flexibility although, the following considerations must be applied to avoid traffic overload issues:

- The PAS must present its results in economic formats.
- The PAS can move reports backward to the PACS, but this will be restricted to only dicomized reports.
- The PAS receives compressed DICOM files, then uncompress these files and then packs them into Nifti format; facilitating the processing and anonymizing the data.
- The PAS may allow enhanced visualization linked to the proper study through the use of permalinks.[8] As the display port in PAS is web-based, economic formats are mandatory.

2.3 Adding interactivity with the produced analytical data

Since PACS prioritizes data security and availability, it remains limited in its display features. Opening 3D capabilities and interactivity with the generated data is just the beginning of an enriched scheme of functionality that is non-existent at present. To this end, the following specifications are highly desired:

- The system to provide client-side interactivity through Javascript language; thus operations are mostly executed in the viewports (local terminals) reducing server interactivity and consequently, traffic overload.
- 3D visualization is also provided by using economic formats such as the stereolithography (STL).[9]

3. RESULTS

When one of the local terminals in the network becomes a PAS, a new set of interactions is enabled. Fig. 2 conceptualizes the associations and new capabilities. The left side corresponds to clients-PAS interactions and the PAS procedures. The horizontal column labeled “Dicom Transfer” defines the set of messages interchanged between the PAS and PACS. Finally, the right side diagram shows the new visualization capabilities that are launched from the PACS viewers and served to the clients by the PAS.

In the proposed architecture, a normal curse of execution requires physicians to associate the imaging studies to the procedures using the configuration interface -see panel A in Fig. 2-. The studies are filtered in a wide range of possibilities yielding from one subject – for example using a PatientID *(0010,0020)* – to several of them – by using the diagnosis

DICOM field *(0008,1080)* –. This studies-procedures association task generates a request to the PAS, that will establish communication with the PACS to retrieve the data. Once the images are in the PAS, it follows a pipeline that expands, decrypts, changes the image format, anonymizes the data and coherently concatenates the images – see frame B in Fig. 2 –. The data is then processed as defined in the procedures box of the configuration interface. At the end of the processing stage, the resulting analytical data is published in a report, which is dicomized and sent back to the PACS –see interaction VII in Fig. 2–. This association enables the one-click concept for clinical applications. Also, a permalink is included in the report which brings to life the PAS visualization interface – see panel C in Fig. 2 –. Therefore, one more click will allow the physician to interact with the analytical data in a javascript empowered web environment.

Table 1 depicts the results of the strategies utilized in this document and reflects the implementation of the design requirements presented in the **Section 2**, Materials and Methods. The numbers correspond to a particular application stated as follows: a neurosurgeon wishes to compare the ventricular volume of a patient before and after the insertion or revision of a cerebrospinal fluid (CSF) diverting shunt. The shunt drains CSF and, as a consequence, the ventricular volume is reduced. The Automatic Ventricular Volume Extraction (AVVE) algorithm, previously selected in the configuration interface, is launched. The AVVE or any other processing procedure, such as the HCE, can be started automatically on new subjects by using the Cron daemon.[10]

The PAS begins by requesting the data using a python code based on the one proposed by,[11] with critical customizations to suit the hospital setup. Then, the PACS responds transferring 12.52 MB of information. This transaction is less resource consuming than typical Q/R ones due to the empowered filtering capabilities of the PAS. Besides, this is done in low network traffic periods that are spotted using the code available in.[12] The PAS processes the information and produces two type of data. A report with 0.81 MB after dicomization -see Fig. 3- which should be moved back to PACS, and a set of volumetric information of 6.03 MB in total, that enables 3D image rendering. An early test of 3D visualization[*] is still available Here.

4. DISCUSSION

According to Huang et al.,[13] during the infancy and puberty of PACS, the objectives were framed by format standardization and modality integration. The same author states that the PACS is currently in its adolescence and highlights the imaging informatics as the developing core for the current state of the system.

Several PACS enhancing proposals have been presented, most of them can be classified as done by Bellon et al.[3] But, as previously mentioned in **Section 1**, those solutions are either too specific or propose to replace a 30 years effort which with clinicians feel very comfortable. OSIRIX deserves a special mention,[14] as it is a well structured plug-in-like desktop application developed for Apple® users, initially similar to any other visualization

[*]Go to http://projects.report and click on the AVVE label if reading a printed format

port such as Synapse® or Ginkgo® but with a growing image processing capability based on collaborative plug-ins strategy of development. This well-structured software is of remarkable quality; however, has not been widely implemented in hospitals due to its intrinsic platform dependence. Our solution has been conceived to utilize the existing PACS implementation. At the same time, we propose a framework that allows researchers to test innovations and validate their models with medical data.

5. CONCLUSIONS

Current PACS systems lack general image analyzing capabilities. Our strategy is not a replacement; instead, it is a solution fully adaptable to the current system. This strategy is conceived inside a hospital and in that sense, considers developmental, operative and legal aspects that add to its feasibility and clinical implementation. The solution is platform independent and respects the strong security policies required in the medical environment. The results are being validated with two simple applications, the AVVE, and the HCE. The instrument presented can allocate an unlimited number of analytical implementations, a flexibility never envisaged before in any other PACS extensibility proposal.

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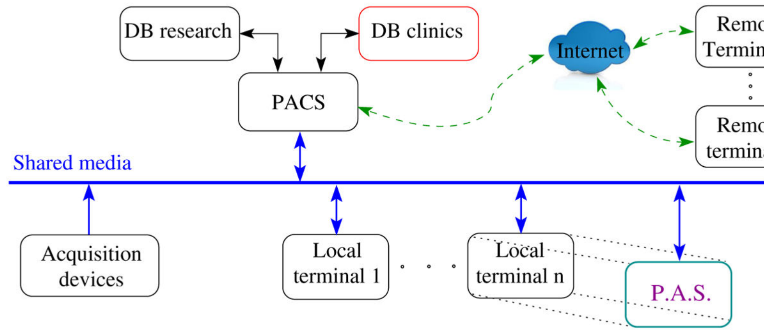

Figure 1.
Default PACS network and abstraction of PAS concept. The abreviations DB stands for Database.

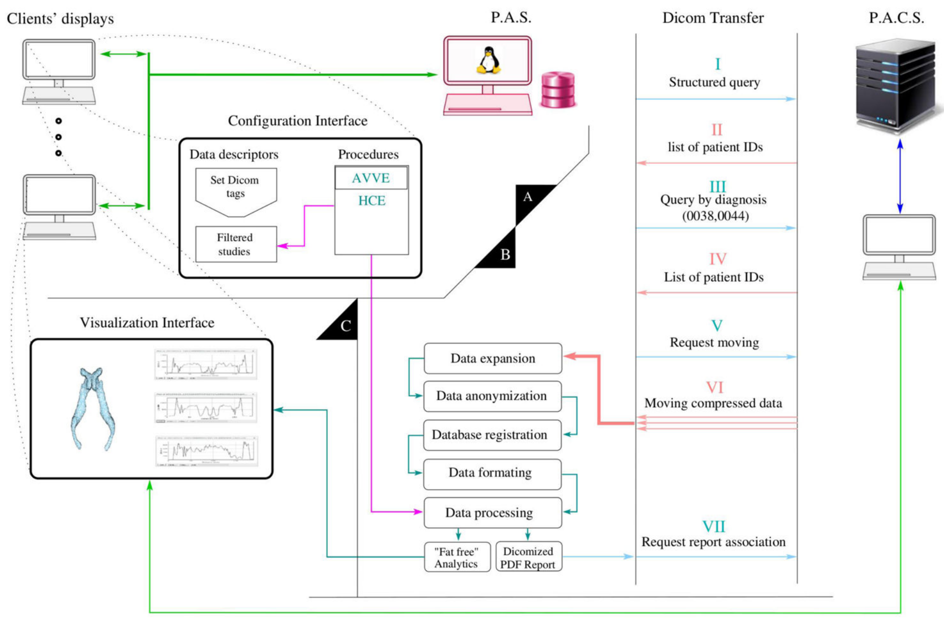

Figure 2.

PAS interactions and workflow in the enhanced PACS system. The automatic ventricular volume estimator (AVVE) and head circumference extractor (HCE) are proof of concept mechanisms used to test the feasibility of the strategies proposed in this manuscript. Some AVVE results are shown in **Fig.**

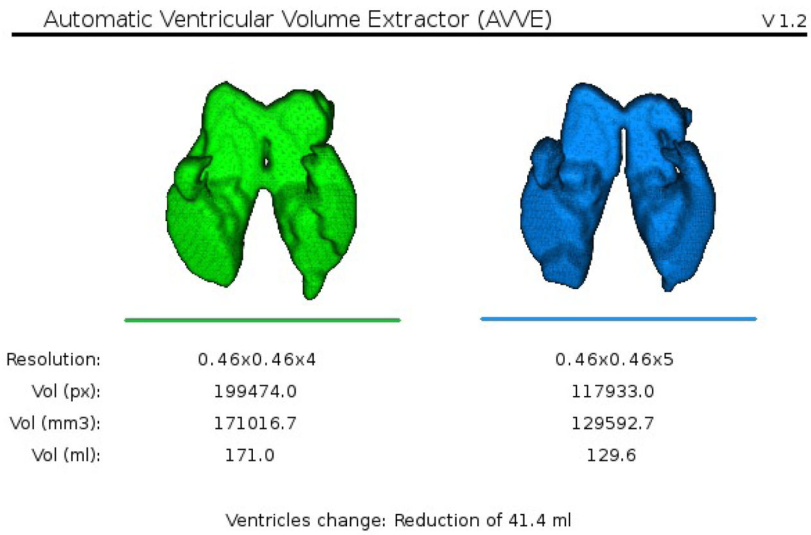

Figure 3.

AVVE report of a before and after shunt procedure.

Table 1

Record of files' sizes and transactions executed by the AVVE algorithm for an in-house ventricular volume estimation. All file sizes in MegaBytes (MB)

	Dicom		Nifti (gz)	STL (bin)	Pdf	
	Compressed	Expanded			Original	Dicomized
Before shunt	5.49	14.23	5.33	1.81	-	-
After shunt	7.03	16.81	8.56	1.44	-	-
Report	-	-	-	-	1.00	1.01
Total traffic	12.52	-	-	3.25	-	1.01