OVERVIEW OF AVAILABLE OPEN SOURCE PACS FRAMEWORKS

Summary. The progress of medical services requires the developing of computer science tools that are essential to generate improvement in the existing scientific disciplines within the healthcare field. The article presents an overview of the available open source project for Picture Archiving and Communication Server (PACS) taking into account popular criteria for software evaluation.

Keywords: PACS, open-source

PRZEGŁĄD DOSTĘPNYCH SYSTEMÓW ARCHIWIZACJI OBRAZÓW MEDYCZNYCH KLASY OPEN-SOURCE

Streszczenie. Rozwój usług medycznych rodzi potrzebę doskonalenia narzędzi informatycznych, które są niezbędne do generacji postępu w istniejących dyscyplinach naukowych w zakresie ochrony zdrowia. Artykuł przedstawia przegląd dostępnych systemów archiwizacji obrazów medycznych z otwartym kodem źródłowym, uwzględniając stosowane w praktyce kryteria ewaluacji oprogramowania.

Słowa kluczowe: systemy archiwizacji obrazów medycznych, systemy informatyczne z otwartym kodem źródłowym
1. Introduction

The progress of medical services raises the need to develop information technology tools to support scientific research. Having been given the open source technology advancement, one of the challenges is the research community configuration. A useful step before the start of the compilation of the research is to review the existing solutions. As for the source code availability of the existing solutions, they can be divided into commercial solutions or the open-source. The authors focused on the analysis of open-source solutions for the following reasons:

- the complexity of scientific experiments and the simultaneous need for a rapid change including interdisciplinary aspects requiring a large number of commercial licenses (costs)
- the versatility and the flexibility research environment configuration
- the opportunity to expertise – in contrast to the “out-of-the-box” product
- the opportunity to join its own concept and test the integration with the existing solution.

The study goal is to compare the existing open source Picture Archiving and Communication Systems (PACS) framework, which applies DICOM and Integrating the Healthcare Enterprise (IHE) standard abilities. This is to help users make the choice that best suits their needs from among the existing tools. The designing and the deployment of the cost effective data work-flow is a concern for medical imaging facilities, from small to medium ones, for research environments [1]. An example for research environment new features requirements new may be setup of the anonymized work-flow for orthopedic surgery planning using three-dimensional anatomical structures models.

2. Materials and methods

The differentiation between the existing solutions from the field of open-source software requires the introduction of quantitative analysis which can be based on different criteria. The generally used criteria could be mentioned [2, 3, 4, 5, 6]:

- software downloads,
- mailing list activity,
- production deployment claims,
- conference/PR case studies,
- github activity,
- google trends,
- job board metrics.
The choice of the criteria used in the article requires discussion. The authors resigned from the applying the criterion of popularity (software download) as a criterion considered to be too general. In contrast, it was decided to use:

- functionality (description of the functions),
- the project (COCOMO) [6] complexity,
- community activity related to the project (eg. mailing list activity, etc.),
- new versions of the product.

In this paper we do not consider the analysis of Dicom Viewers because the latest review was published [7]. The catalogue of 26 criteria has been composed concerning requirements for platform, interfaces, support, 2D rendering, and 3D rendering. The interface criteria are based on functionality which has been valued as advantageous regarding our used cases. Focusing on system integration, criteria such as data import and export have been discharged. To avoid subjectivity, all criteria are designed as simple “yes” (+) or “no” (−) categories. The presented article includes important differentiation between three practically used PACS work-flow architecture configurations.

- Central Viewing:
  A patient's DICOM data is viewed on a central client system. For this, the data has to be gathered from the PACS, which requires a broad availability of DICOM interfaces.

- Decentral Viewing:
  A patient’s data is shared between sites. Multi-centered, long distances have to be bridged for a subject’s image data. Hence, an integrated and decentral system provides the optimal work-flow in this used case, which can be satisfied by web-based technologies.

- Advanced Viewing:
  Advanced viewing functionality such as volumetric analysis and sophisticated 3D image processing is important. Powerful visualization is obtained combining image processing with advanced rendering techniques. The system integration plays a minor role.

The next important factor of PACS evaluation is the opportunity to integrate it into a Hospital Information System. The requested Electronic Data Capture Systems (EDCS) integration could be solved as the PACS or EDCS primary system. Based on [8] EDCS, it is considered as the primary system best supporting the research work-flow. This is in contrast to work [9], which tightly integrates the medical PACS as the primary system, transferring the DICOM identifiers into the Electronic Case Report Forms (eCRF).

As for the scope of the analyzed projects, the review of the existing ones was used (as of 2013 year), which listed the 11 existing projects [10]: MRIdb Medical imaging database, Orthanc, DICoogle, Xebra, Open Source Picture Archiving and Communication System (OSPACS), OpenSourcePACS, ClearCanvas, Conquest DICOM software, CDMEDIC PACS WEB, DCMTK - DICOM Toolkit, dcm4che, Medfloss, mentioned above, is a list of open-
source PACS servers along with a user's ratings. The last update was July 2013. It looked as if DCMTK, Conquest, ClearCanvas were the most popular.

For further detailed analysis, 3 projects were selected: dcm4che, DCMTK, Orthanc due to their greatest utility for configuring the research environment. From 2013 to 2016, these projects have been developing most intensively with the existing billing. In addition, the project Mridb was analyzed [11], characterized by the use of virtualization technology - but it has not been intensively developed in recent years (eg. the lastest version is dated on 2014). Project dcm4che consists of several software components:

- toolkit and utilities: dcm4che2, dcm4che3;
- PACS server (Archive 2, Archive 5): dcm4chee;
- Web Viewers: Weasis, Oviyam, Mayam.

Fig. 1 shows the release timeline DCMTK, Orthanc and two selected components of the project dcm4che (Weasis and dcm4chee).

![Fig. 1. New versions of the software in the timeline](image)

Rys. 1. Nowe wersje oprogramowania w osi czasu
3. Results

Table 1 and Table 2 below show the most important statements of the selected projects functionality and the other criteria measures defined in the Materials and Methods section.

Comparing the value of usability criteria for selected projects

<table>
<thead>
<tr>
<th>Criteria</th>
<th>dcm4chee</th>
<th>Orthanc</th>
<th>DCMTK</th>
</tr>
</thead>
<tbody>
<tr>
<td>The project (COCOMO) complexity [unit: person-years]</td>
<td>64</td>
<td>21</td>
<td>147</td>
</tr>
<tr>
<td>Lines of code</td>
<td>Fig. 2</td>
<td>Fig. 3</td>
<td>Fig. 4</td>
</tr>
<tr>
<td>Community activity related to the project (eg. mailing list activity, etc.)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>The product newest versions</td>
<td>2.18.3</td>
<td>1.1.0</td>
<td>3.6.1</td>
</tr>
<tr>
<td></td>
<td>2016-01-19</td>
<td>2016-06-27</td>
<td>2016-06-30</td>
</tr>
</tbody>
</table>

Fig. 2. dcm4chee – complexity of the project given in the lines of code (data source: openhub.net)

Rys. 2. dcm4chee – złożoność projektu podana w liniach kodu (źródło danych: openhub.net)
Rys. 3. Orthanc – complexity of the project given in the lines of code (data source: openhub.net)

Fig. 3. Orthanc – złożoność projektu podana w liniach kodu (źródło danych: openhub.net)

<table>
<thead>
<tr>
<th>Functionality criteria</th>
<th>dcm4chee</th>
<th>Orthanc</th>
<th>DCMTK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documentation</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Maintainability</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Programming Language</td>
<td>Java, XML</td>
<td>C/C++</td>
<td>C/C++</td>
</tr>
<tr>
<td>Extendibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Systems</td>
<td>Multiplatform</td>
<td>Windows Linux</td>
<td>Windows Linux</td>
</tr>
<tr>
<td>Client/Server PACS Model</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>IHE Integration Profiles</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Dcm4chee fulfills the role of PACS-a. The dcm4che project has survived and prospered to produce a powerful, stable, and feature-rich archive. It is a tool which both PACS administrators and researchers should be familiar with.

The Orthanc software allows them to archive and retrieve images, offering scalability and flexibility at the same time. This is a robust tool that brings technological independence to clinical departments and allows users to automate their own, very specific imaging-flow, including proprietary systems connected across and via the Internet.
This DICOM ToolKit (DCMTK) package consists of the source code, documentation and installation instructions for a set of software libraries and applications implementing the part of the DICOM/MEDICOM Standard.

The MRIdb system is composed of two components: a pre-configured instance of the open-source dcm4chee DICOM server and a bespoke web application, henceforth referred to as MRIdb, which provides a user-friendly interface for searching and viewing imported images. Both are written in Java, though MRIdb depends on some native tools and libraries in order to perform the image format conversion. MRIdb was developed at Imperial College London by Mark Woodbridge (Bioinformatics Support Service). The project was commissioned by Declan O’Regan (Robert Steiner MR Unit) and technical oversight was provided by Gianlorenzo Faggio-lo (MRC Clinical Sciences Centre).

Another author's view and the most important element of the PACS solutions evaluation was launching and testing application environments of selected projects slated in the previously described evaluation process.

For this purpose, we defined three different fields of application:

1. Application one: The system archives and allows the remote access to the data as an extension of the existing hospital circulation system of radiological examinations.
3. Application three: The preoperative planning system based on spatial printouts.
We can say that the proposed application corresponds to the classification presented earlier: 1-Central View, 2-MultiView, 3-Advanced View. The conclusions resulting from the testing period are as follows:

- according to the authors the best system for implementing the "application one" is dcm4chee. During the lifetime which approx. lasts one year the system dcm4chee has not suspended even once. The Reliability of the software dcm4chee was greater than the problems arising from administrating of the compound architecture comprising the plurality of software components and the maintenance of its components and all these services. The problems usually, stemmed from the fact that not all the services were active and running, or outright failure of other components. For example, PACS work, but due to deficiencies such as power and restart of the network NFS file server, there was no access to the image data stored in the DICOM Storage.

- for "application two" a very good integration with browsers that use DICOM Web Access to DICOM Objects (WADO) protocol is needed. The project dcm4che.org has two solutions, which develops and which are very well integrated with the server. One is a cross-platform browser written in Java called Weasis. The second solution is a simpler client for DICOM Browser based on HTML5 called Oviyam.

- for "application three" using the project Orthanc as the middleware/communication interface was very important and useful. In this way it was possible to define individual flow imaging data between multiple PACS servers. In particular, the project Orthanc is easier to manage the workflow image data by:
  - individual data flow,
  - intervention and modification workflow,
  - anonymized data,
  - select and selective transfer, eg. the relevant sequence.

4. Conclusions

- After the analysis, four of the existing solutions should be mentioned.

- Even after 20 years of intense research in this field, not every useful case is covered, e. g. perfusion imaging still remains a research tool without a broad clinical usage. One problem is the lack of standardization in technical aspects which has to be considered for successful quantitative evaluation; the second problem is the lack of tools that would allow direct integration into the diagnostic workflow in radiology [12]. We noticed also an im-
important and unsolved problem that is the joint management of the data in DICOM with other data, e.g. for spatial format prints (*.stl).

- More generally, the Open Source PACS systems allow easier integration of the existing project into new image modalities and challenges in a rapidly developing healthcare field. The integration of medical informatics and e-learning systems could provide many advanced applications including training, knowledge management, telemedicine, etc. The Open Source PACS systems could be applied in several cases such as: a multi-center view, an advanced view and research.

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Omówienie


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