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ORIGINAL ARTICLE

Workflow management of content-based image retrieval for CAD support in PACS environments based on IHE

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Abstract
Purpose Content-based image retrieval (CBIR) bears great potential for computer-aided diagnosis (CAD). However, current CBIR systems are not able to integrate with clinical workflow and PACS generally. One essential factor in this setting is scheduling. Applied and proved with modalities and the acquisition of images for a long time, we now establish scheduling with CBIR.
Methods Our workflow is based on the IHE integration profile 'Post-Processing Workflow' (PPW) and the use of a DICOM work list.
Results We configured dcm4chee PACS and its including IHE actors for the application of CBIR. In order to achieve a convenient interface for integrating arbitrary CBIR systems, we realized an adapter between the CBIR system and PACS. Our system architecture constitutes modular components communicating over standard protocols.
Conclusion The proposed workflow management system offers the possibility to embed CBIR conveniently into PACS environments. We achieve a chain of references that fills the information gap between acquisition and post-processing. Our approach takes into account the tight and solid organization of scheduled and performed tasks in clinical settings.

Keywords Content-based image retrieval · Computer-aided diagnosis · Picture archiving and communication systems · Integrating the Healthcare Enterprise · Radiological workflow

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Abbreviations

AET	Application entity title
CAD	Computer-aided diagnosis
CBIR	Content-based image retrieval
CR	Computed radiography
DICOM	Digital imaging and communications in medicine
EC	Evidence creator actor (IHE)
GP-PPS	General purpose performed procedure step
GP-SPS	General purpose scheduled procedure step
GPWL	General purpose worklist
HIS	Hospital information system
HL7	Health level 7
HTML	Hypertext Markup Language
ID	Image display actor (IHE)
IHE	Integrating the Healthcare Enterprise
IM/IA	Image manager/image archive actor (IHE)
IOD	Information object definition
PACS	Picture archiving and communication system
PPM	Post-processing manager actor (IHE)
PWF	Post-processing workflow integration profile
RIS	Radiology information system
SOAP	Simple object access protocol
SOP	Service object pair
XML	Extended markup language
XSL	Extensible stylesheet language

Introduction

Content-based image retrieval (CBIR) is the process of identifying desired images from a large database based on automatically extracted features specifying the images' contents [1]. CBIR's great potential for computer-aided diagnosis (CAD) has been approved and is widely accepted [2]. Applications are manifold, as for example, the retrieval of

similar images from completed examination cases thereby providing the radiologist with a second opinion for diagnosis. However, CBIR is still not an integral part in clinical routine. One crucial point is the concept of embedding CBIR into the radiological workflow. To take full advantage of CBIR applications, a seamless and reliable cooperation with existing clinical systems including hospital information systems (HIS), radiology information systems (RIS) and picture archiving and communication systems (PACS) is indispensable.

Existing approaches of CBIR or CAD integration into clinical workflow have two focuses: Either the CBIR application is incorporated into PACS, e.g., extending the image search by CBIR methods [3] or a workflow including steps for CBIR is prescribed. The first approach depends on the particular PACS manufacturer and hinders the embedding of arbitrary CBIR systems. The second approach includes systems that adjust the application of CBIR step by step on a rather low level thereby complicating a transfer to arbitrary clinical environments [4]. Interesting is a solution named CAD-PACS [5] partly based on the Integrating the Healthcare Enterprise (IHE) [6] integration profiles.

None of these concepts addresses central and standard scheduling. Scheduling is generally employed in conjunction with modalities and their tasks of acquiring examination images, where it has been commonly proved. It simplifies and regulates workflows, leading to improved processes. We consider scheduling also as necessary and reasonable for the application of CBIR systems in clinical environments.

The unscheduled solution lets the physician call the CBIR application from his diagnostic workstation directly. But this is simple and sufficient only at first view. Problems arise at the latest when a CBIR system has to handle different calls at the same time. Concurrently running tasks in separate threads probably lead to a noticeable decrease of performance. The management of a queue maintaining the incoming tasks would imply an extension to each single CBIR system. That is why we aim for utilizing the manifold benefits of central scheduling to advance CAD in radiology.

Existing communication standards like DICOM and HL7 leave many options for implementation and do not ensure full interoperability. Furthermore, coherent guidelines for communication between CBIR and HIS/RIS/PACS are omitted. We present a concept of workflow management for CBIR systems including scheduling embedded into the radiology workflow in accordance with the IHE framework. Post-processing tasks that are subject to scheduling are addressed by the IHE post-processing workflow (PWF) integration profile [7]. The PWF profile entails several advantages, e.g.:

- Enables scheduling, distribution, and tracking of post-processing tasks using standardized mechanisms;
- Connects post-processing results with corresponding images and their scheduled order thereby filling the information gap between acquisition and post-processing;
- Offers the opportunity to append subsequent workflow steps, e.g. reporting, billing.

In this paper, we propose an approach for scheduling CBIR applications consistent with clinical environments and based on IHE concepts. We aim at the convenient integration of scheduled CBIR applied for CAD into existing radiological workflows. Our system makes use of the dcm4chee [8] PACS and its included IHE components. We establish an adaptation suitable for CBIR in the context of CAD for radiology.

Methods

We adapted concepts from the IHE PWF profile and DICOM to the application of CBIR. The following aspects offer our workflow management for the embedding of CBIR.

CBIR's work list for scheduling

The DICOM standard presents its view of the real world in a model, which identifies objects of the real world as entities related to one another. One or more entities are composed as an information object definition (IOD) used for the implementation of DICOM services (service class), as for example, the storage (service class) of an X-ray angiographic image (IOD). A service class again consists of a set of service object pair (SOP) classes, defining operations on an IOD. The entity that provides a particular service is called service class provider (SCP), whereas the entity that consumes the service is called service class user (SCU).

CBIR scheduling is based on a work list that is realized by means of DICOM general purpose worklist (GPWL) [9]. DICOM GPWL Management Meta SOP Class, which is defined within DICOM's Basic Worklist Management service class, is used to manage scheduling tasks of any kind. Possible fields of application besides CAD are image processing and print. The basic idea is a work list, which holds several items. Each item represents a job that can be executed on dedicated applications.

Three SOP classes form the GPWL Management Meta SOP class:

- General purpose worklist (GPWL): handles the work list,
- General purpose scheduled procedure step (GP-SPS): responsible for work items,
- General purpose performed procedure step (GP-PPS): created for each work item (GP-SPS) in order to

indicate that information delivered in the work item is being processed and to specify the particular execution.

When an item is placed on the work list, its status is set to SCHEDULED. Once a SCU starts processing, it requests the SCP to change status to IN PROGRESS. The changed status denotes that the item is claimed by an application and must be locked for other calling applications. After finishing, status has to be updated to COMPLETED.

IHE-based CBIR workflow

The IHE is a consortium of health care professionals from industry and research that has been founded to establish unified and generally accepted process flows between IT systems for medical applications to improve interoperability. Information exchange is based on established standards like DICOM and health level 7 (HL7). IHE provides a framework that accumulates requirements in use cases and defines guidelines, in IHE terminology called 'Integration Profiles', which represent scenarios and prescribe how well-known standards like DICOM shall be applied. Each scenario involves a set of actors, which represent components or modules that occur in medical information systems and hold a predefined role. Information exchange between actors is defined by transactions, which rely on standard-based communication.

The PWF profile is an extension of the Scheduled Workflow integration profile to support typical post-processing tasks, e.g. image processing, computer-aided detection, 3D view generation. Central point of the PWF profile is the work list holding work items, e.g. requests to a CBIR system. The list is maintained by the post-processing manager (PPM) actor, which manages access to the list and is responsible for the creation of work items. The evidence creator (EC) actor creates evidence objects (images, documents, etc.) intended to serve diagnostic interpretation. In the PWF profile, the EC stands for the particular post-processing or CBIR system. In the introduced scenario, this will be the image retrieval in medical applications (IRMA) framework [10]. We suggest the separation of IRMA from the component that connects it to the clinical workflow. A general EC module that overtakes all tasks necessary to embed an external system simplifies the integration of arbitrary CBIR systems. The image display (ID) actor displays images and evidence objects. The image manager/image archive (IM/IA) actor handles PACS' image data including provision of information and long-term storage. Figure 1 illustrates the principal workflow of the PWF profile, here adapted to IRMA:

1. The EC queries the next work item (GP-SPS) from the post-processing work list regularly and learns about the new work item.

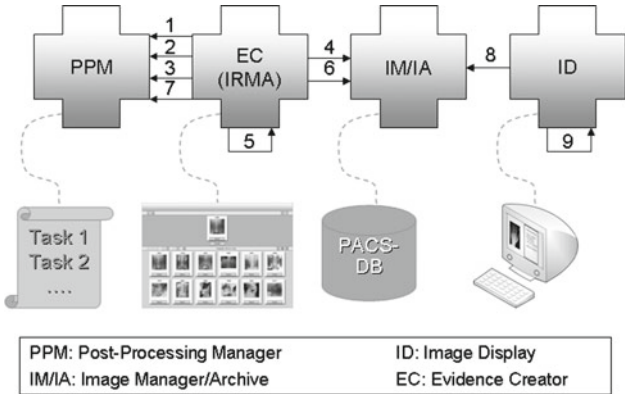

Fig. 1 Overview of CBIR workflow based on IHE post-processing workflow profile

2. The EC claims the work item at the PPM for IRMA. The PPM creates an GP-PPS.
3. The EC notifies the PPM that the work item is in progress. The PPM sets GP-SSP and GP-PPS to IN PROGRESS.
4. The EC retrieves those examination images relevant to the current examination from the IM/IA.
5. The EC starts IRMA and composes a DICOM structured reporting (SR) [11] document from the IRMA results as evidence object.
6. The EC stores the SR document via the IM/IA.
7. The EC notifies the PPM about the completion of the work item. The PPM first sets GP-PPS, then GP-SPS to COMPLETED.
8. ID retrieves the SR document from IM/IA.
9. ID represents the CBIR results to the physician.

Initialization of the CBIR workflow

The PWF profile states that the PPM will have some internal logic to identify newly available images at PACS (IM/IA) that are suitable for the post-processing workflow to begin and will accordingly create a work item. The internal logic might be a set of rules adapted to the particular clinical environment, e.g. to automatically create a CBIR post-processing work item for each newly acquired computed radiography (CR) image of the lung. In this case, the EC has usually already completed the CBIR task before the radiologist starts making a diagnosis. This is the proper initialization in order to support the radiologist in frequent and time-consuming tasks. The background post-processing is also suitable if the response times of the CBIR system are not acceptable to the radiologist. In some settings, the CBIR's results are seldom used by the radiologist and CBIR post-processing would unnecessarily allocate too many resources, e.g. computing time on the CBIR system. Then, a general rule is not appropriate and the CBIR processing should only be performed for selected

cases. We therefore propose two alternatives to initiate the CBIR workflow:

1. Automatic trigger: When new images are available on the IM/IA, the PPM adds a work item to its work list. This is compliant to the PWF profile and suitable for classes of images that generally will be processed by the CBIR system. An example application is bone age assessment based on hand radiographs. CBIR systems are able to identify images of known bone age that show similarities to a given examination image [12].
2. Manual trigger: The physician initiates a new work item on demand to announce that a particular image must be processed. If the physician only requests support by a second opinion in dedicated examination cases, this would be the favored solution.

CBIR's work item query

The EC has to execute a query in order to retrieve work items from the work list. The request is sent via C-FIND command. The PWF profile defines three kinds of queries to retrieve work items from the work list: Patient-oriented, station-oriented and class-oriented query. Patient-oriented queries are not very meaningful in the respective concept since CAD via a CBIR system shall be applied without respect to a particular patient. Class-oriented queries select those work items dedicated for a whole class of workstations. It should be applied if the same CBIR system is installed on several machines and each from this class of workstations can be selected arbitrarily. This will balance the work load. In cases, where different CAD systems are installed, the station-oriented query allows to distinguish the different ECs. Then, the station or EC that requests the CAD analysis and performs a station-oriented query must be noted in the work item in order to retrieve this work item.

Results

To prove the introduced concept, a prototypal system has been implemented. Main focus is on the PPM and the EC since both actors are at the heart of the proposed workflow management system. Communication is achieved through the dcm4che.org project, which provides the dcm4che toolkit that forms an abstraction layer for DICOM messages. Moreover, dcm4chee is a JBoss application server that composes a complete PACS providing also IHE features like support of various actors, e.g. PPM, IM/IA actors. The proof of concept makes use of this already implemented technology but the configuration of work items is adapted to the specific need of IRMA.

Configuration of work items

Work items are created based on information extracted from the DICOM files of the corresponding medical images. The transformation step from image to work item is defined through extensible stylesheet language (XSL). Dcm4chee uses internally an XML representation of DICOM objects, which permits a utilization of XSL to create work items from images.

Table 1 describes an extract of the work item's configuration used in the IRMA scenario. It specifies certain DICOM attributes of a work item and their default values. DICOM attributes are identified by a group and an element tag and are given in the configuration file as a number with 8 digits specified by "attr tag". DICOM tag (0008,0016), the SOP class UID of the work item, has the value "1.2.840.10008.5.1.4.32.2", which denotes the GP-SPS SOP class. The initial status of a work item (DICOM tag (0040,4001)) is "SCHEDULED" and initial priority (DICOM tag (0040,4003))) is "MEDIUM". The reference to the example image is displayed in the third clause, "Input Information Sequence", which copies the UID of the example image into the Input Information Sequence of the work item. The Scheduled Workitem Code Sequence (0040,4018) is configured with content "Computer Aided Diagnosis" to describe the context in which the work item is used.

A rules-based work list maintainer decides if a new work item has to be created. Rules may be configured depending on the image's modality. The dcm4chee PPM server creates a work item as soon as a modality reports the completion of its task.

Evidence creator

The EC is implemented as a standalone application in Java that periodically checks for new work items at the PPM. This is accomplished through the appropriate DICOM C-FIND command, which is implemented by the dcm4che command "dcmgpwl". The EC is fully configurable via a configuration file that specifies DICOM application entity title (AET), period between successive queries etc. It sends outputs to log files or the system logger. Logging is achieved through the log4j framework developed by the Apache Foundation. The communication between EC and PPM and work item status handling is solely DICOM driven, which is implemented by the utilization of the dcm4che toolkit.

The communication to IRMA is realized by means of the simple object access protocol (SOAP). This interface can be adapted to any CBIR system. Evidence documents are encoded as DICOM SR documents [13]. This ensures that the CBIR results can be stored and retrieved using the already existing DICOM infrastructure of a PACS environment.

Table 1 Extract from the IRMA work item configuration in dcm4chee

```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform" version="1.0 ">
<xsl:output method="xml" indent="yes"/>
<xsl:param name="date">20091214</xsl:param>
<xsl:param name="time">093000.000</xsl:param>
<xsl:template name="workitem">
<item>
        <!– Specific Character Set –>
        <xsl:copy-of select="attr[@tag='00080005']"/>
        <!– SOP Class UID –>
        <attr tag="00080016" vr="UI">1.2.840.10008.5.1.4.32.2</attr>
        <!– SOP Instance UID (0008,0018) will be created by the application –>
        <!– General Purpose Scheduled Procedure Step Status –>
        <attr tag="00404001" vr="CS">SCHEDULED</attr>
        <!– General Purpose Scheduled Procedure Step Priority –>
        <attr tag="00404003" vr="CS">MEDIUM</attr>
</item>
<!- Scheduled Workitem Code Sequence –>
<attr tag="00404018" vr="SQ">
      <item>
            <!– Code Value –>
            <attr tag="00080100" vr="SH">110003</attr>
            <!– Coding Scheme Designator –>
            <attr tag="00080102" vr="SH">DCM</attr>
            <!– Code Meaning –>
            <attr tag="00080104" vr="LO">Computer Aided Diagnosis</attr>
        </item>
</attr>
<!- Input Information Sequence –>
<xsl:template match="item" mode="refsop">
            <item>
                  <!– Referenced SOP Class UID –>
                  <xsl:copy-of select="attr[@tag='00081150']"/>
                  <!– Referenced SOP Instance UID –>
                  <xsl:copy-of select="attr[@tag='00081155']"/>
                  </item>
</xsl:template>
</xsl:stylesheet>
```

System architecture

We realized the proposed CBIR workflow using a modular system architecture, which clearly maps the IHE actors and involved components to functional units (Fig. 2). The PACS unit hosts its database (DB) and the actors IM/IA and PPM together with the work list. Modalities store their acquired images to the PACS DB. We separated IRMA from the workflow integration part incorporated in the EC actor. The EC actor has an interface that has to be adapted to the particular CBIR system. Changes to the CBIR system are usually not necessary as long as it already provides a non-interactive way of invocation and exchange of results. The general part of the EC responsible for the creation of SR results document and the communication with PACS is independent on the actual CBIR system. This design of the EC allows a convenient linking of arbitrary CBIR systems to PACS environments. The separation results in the units CBIR_IHE hosting the

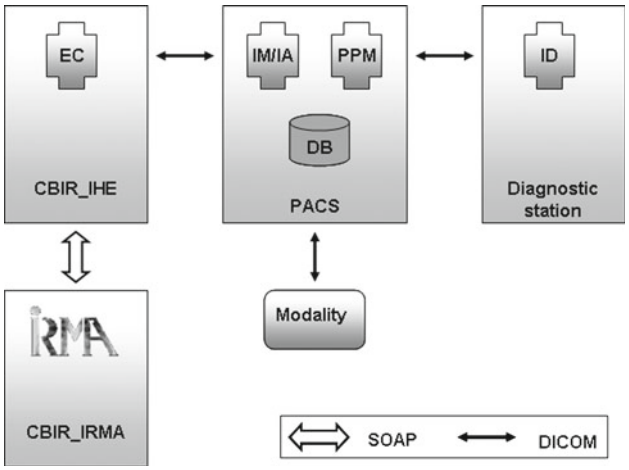

Fig. 2 System architecture connecting involved IHE actors and IRMA

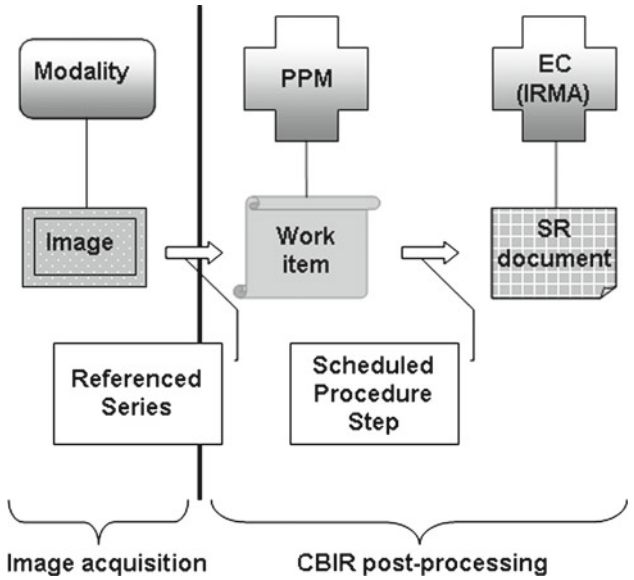

Fig. 3 Information chain between image and corresponding CBIR SR document

EC and CBIR_IRMA with the installed IRMA system. The actor ID resides at the diagnostic station, able to fulfill its task of displaying the CBIR results to the physician.

Communication is established using standard protocols. DICOM is utilized for the linkage of the IHE actors because it is the prior standard in clinical environments. IRMA is connected to the EC using SOAP, a widespread and reliable communication protocol. The transfer protocol used for sending SOAP messages is HTTPS. This implies the implementation of a SOAP interface at the EC and a web server running on CBIR_IRMA capable of processing SOAP messages. IRMA already provided a SOAP interface. The realization of the corresponding interface of the EC comprised a new module for the creation and sending of the query SOAP message, as well as the processing of the reply SOAP message.

Bridge from acquisition to post-processing

We established a chain of references in order to create a link from the examination image to the corresponding CBIR results. As shown in Fig. 3, there usually is a separation between the image acquisition and the CBIR post-processing. The presented workflow management system specifies the image created by a modality as "Referenced Series" in the work item of the PPM. The EC produces a SR document from the CBIR results that uses the referenced Scheduled Procedure Step information in the analyzed image as the referenced SPS. This keeps the workflow consistent by connecting the CBIR results with the order of the underlying query image.

Handling of concurrency

Scheduling provides features for handling concurrency. The work list collects all incoming CBIR requests and manages the corresponding work items. Concurrency is addressed in several ways:

- Concurrency of CBIR requests: The EC claims work items either in sequence or several at a time. Thus, the EC decides how many CBIR post-processing tasks it performs in parallel. Usually, each CBIR request is processed with separately. This ensures that there is no bottle neck of resources because of too many coexistent CBIR processes on the same machine. Therefore, our implementation of the EC only treats work items successively. If the EC processes several jobs at a time it is also responsible for handling concurrency.
- Concurrency of CBIR systems: The work list holds jobs for arbitrary many ECs or CBIR systems. Each EC requests work items scheduled for the respective EC. The PPM ensures that no CBIR request is processed multiple times because work items can only be claimed once. Usually each CBIR system resides on a separate machine and the parallel execution of other CBIR systems does not have any influence.

Workflow of scheduled IRMA

As a result, the approach is exemplarily applied to IRMA. IRMA offers a SOAP interface. The implemented EC already provides a SOAP interface. The initial configuration then only requires the adoption of certain parameters in the configuration file, e.g. AET of the IA/IM managing the PACS DB and AET of the PPM.

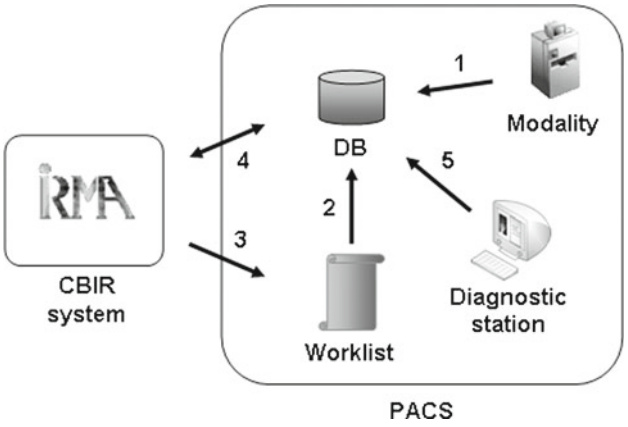

Fig. 4 Overview of scheduled IRMA workflow

The following exemplary workflow (Fig. 4) depicts the automatic initialization triggered by the acquisition of a hand radiograph used for bone age assessment. A commonly applied method is to examine the skeletal maturation of the hand bones.

1. The modality generates a new hand radiograph and stores it at the PACS DB, managed by the IA/IM.
2. The next time the PPM checks for new images at the PACS DB (IM/IA), it notices the new hand radiograph and adds a new item to its worklist.
3. The EC providing the interface to IRMA requests and claims the work item and executes the CBIR run at IRMA. The result list contains hand radiographs from finished examinations with known bone age determinations.
4. After completion of IRMA, the EC creates an SR document from the IRMA results and stores it at the PACS DB (IM/IA).
5. The radiologist uses the viewer (ID) at the diagnostic workstation and requests the SR document from PACS DB (IM/IA). The IRMA results are displayed, and the radiologist then makes his bone age assessment based on his comparison of the identified similar hand radiographs by IRMA.

Figure 5 shows an extract of an exemplary SR document in DICOMscope [14], a common SR viewer that is capable of creating general HTML output of SR documents. On the left side, the query image of the current medical case is shown. On the right side, information on the SR document is specified with the succeeding list of all identified similar cases.

Conclusion

We provide a paradigm for the workflow integration of a CBIR system into PACS environments. The introduced proposal is based on the IHE framework and therefore, it is able to establish a standardized procedure. Up to now, integration solutions do not address scheduling and for that reason do not deliver a broad and comprehensive integration scheme. We take into account that clinical processes require solid structure and organization. Scheduled and performed tasks need to be traced and created results need to be linked to their original data. The proposed approach quits with isolated applications running unobserved. It achieves a true embedding of CBIR into clinical workflows. We hope this will foster CBIR for CAD in patient care.

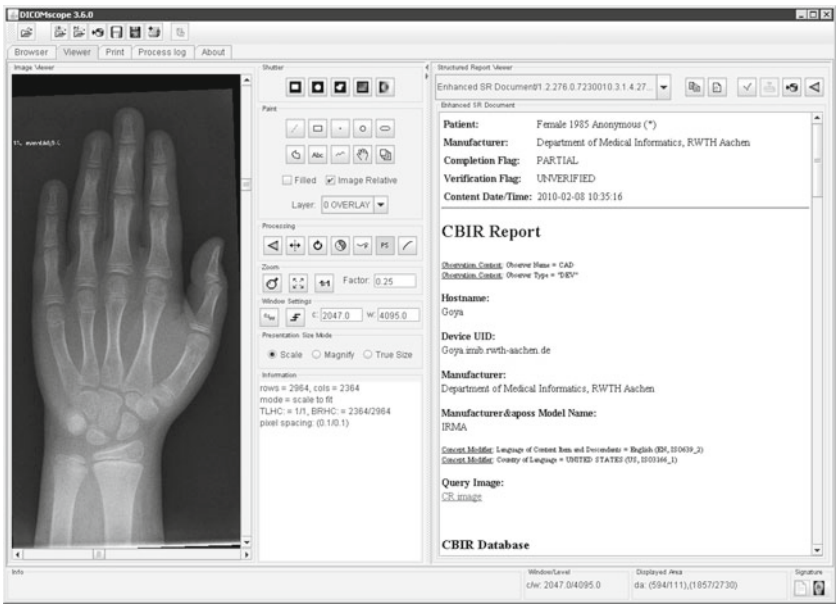

Fig. 5 Extract of exemplary IRMA output in DICOMscope [14]

The principles of our approach are not limited to CBIR but are applicable to any non-interactive post-processing task, e.g. 3D reconstruction. In this paper, we concentrated on the application of CBIR as a concrete post-processing task. To proof the general concept of integration, other applications should be investigated.

The DICOM standard will probably shortly be extended by Supplement 96, the Unified Worklist and Procedure Step (UWPS) [15], which is open for ballot by the DICOM commission at the moment. The UWPS entails the advantage that a task may also be pushed to the component responsible for it. In our CBIR workflow, the EC has to query the PPM regularly to learn when a new work item has been created. This could be simplified when the PPM sends a new item queued in the worklist to the EC.

Our workflow system demonstrates how scheduling can be applied for CBIR integration. In order to provide a general solution, it needs to be independent of the particular PACS. We make use of the already included PPM of the dcm4chee PACS. A separation of the PPM module as a stand-alone application similar to our EC would accomplish a generic workflow integration platform.

References

1. Eakins JP, Graham ME (1999) Content-based image retrieval—a report to the JISC technology applications programme. Technical Report, Institute for Image Data Research, University of Northumbria at Newcastle. http://www.jisc.ac.uk/uploaded_documents/jtap-039.doc. Accessed 17 March 2010
2. Müller H, Michoux N, Bandon D, Geissbuhler A (2004) A review of content-based image retrieval systems in medical applications—clinical benefits and future directions. Int J Med Inform 73(1):1–23
3. Traina C Jr, Traina AJ, Araujo MR et al (2005) Using an image-extended relational database to support content-based image retrieval in a PACS. Comput Methods Programs Biomed 80(1):71–83
4. Fischer B, Deserno TM, Ott B, Günther RW (2008) Integration of a research CBIR system with RIS and PACS for radiological routine. Proc SPIE Med Imaging 6919:691914.1–691914.10
5. Le A, Mai L, Liu B, Huang HK (2008) The workflow and procedures for automatic integration of a computer-aided diagnosis workstation with a clinical PACS with real world examples. Proc SPIE Med Imaging 6919, doi:10.1117/12.772990
6. Integrating the Healthcare Enterprise (2010) http://www.ihe.net. Accessed 17 March 2010
7. IHE (2008) IHE technical framework, vol I: Integration profile. http://www.ihe.net/Technical_Framework/upload/ihe_tf_rev9-0ft_vol1_2008-06-27.pdf. Accessed 17 March 2010
8. dcm4che.org (2010) Open source clinical image and object management. http://www.dcm4che.org. Accessed 17 March 2010
9. National Electrical Manufacturers Association (2001) DICOM supplement 52: general purpose worklist. ftp://medical.nema.org/medical/dicom/final/sup52_ft.pdf. Accessed 17 March 2010
10. Lehmann TM, Güld MO, Thies C, Fischer B, Spitzer K, Keysers D, Ney H, Kohnen M, Schubert H, Wein BB (2004) Content-based image retrieval in medical applications. Methods Inf Med 43(4):354–361
11. National Electrical Manufacturers Association (2000) DICOM supplement 23: structured reporting storage SOP classes. ftp://medical.nema.org/medical/dicom/final/sup23_ft.pdf. Accessed 17 March 2010
12. Fischer B, Brosig A, Welter P, Grouls C, Günther RW, Deserno TM (2010) Content-based image retrieval applied to bone age assessment. Proc SPIE Med Imaging 7624
13. Welter P, Deserno TM, Gülpers R, Wein BB, Grouls C, Günther RW (2010) Exemplary design of a DICOM structured report template for CBIR integration into radiological routine. Proc SPIE Med Imaging 7628
14. OFFIS (2010) DICOMscope DICOM viewer. http://dicom.offis.de. Accessed 17 March 2010
15. National Electrical Manufacturers Association (2007) DICOM supplement 96: unified worklist and procedure step. ftp://medical.nema.org/medical/dicom/supps/sup96_lb.pdf. Accessed 17 March 2010