New Aspects of Image Distribution and Workflow in Radiology

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The progressive use of digital image-generating devices and digital communication technology in clinical and practice environments implies changes in radiological workflow and asks for adequate quality assurance in the whole process of radiology report preparation. This improvement potential has to be rigorously reinvestigated with regard to up-to-date procedures and the full exploitation of supporting technologies like linguistic analysis, help desk and trouble ticket systems, competitive allocation algorithms, time-and-event monitoring, and intelligent agents. These approaches are to be evaluated in combination with business process analysis and shall help to reduce turnaround times for radiology reports while maintaining or even increasing quality-assurance levels.

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IN SPRING 1996, the *Jive* project—development of a Digital Imaging and Communications in Medicine (DICOM) image viewer to be fully implemented in Java—was started at the Institute of Microtherapy (Prof Dr Grönemeyer, Bochum, Germany). The first versions of the DICOM viewer were publicly released for educational purposes and evaluated by the medical personnel of the institute. Later versions could be used as an application, as a bean or an applet, and could be E-mailed together with the order, images, and other patient data.

A first intranet application distributing orders and images for reporting or second opinion via E-mail was set up to be evaluated by the radiologist and physicians involved. Step-by-step critical and constructive comments helped to improve the DICOM viewer, but, quite suddenly, complaints turned towards workflow and image distribution problems, as for example, the allocated job did not match the radiologist's diagnostic focus and consequently the job had to be mailed again.

Some of the radiologists wanted to be notified, literally speaking "tracked down," as there were cases that required special qualification or some were mainly working for the intensive care department and moving around a lot, but did not know there was an order in the E-mail.

It was decided to form a project group—called *TWINNER* (telemedical workflow intelligence in networked radiology)—supposed to collect the most important requests and to map them into scenarios. The project group ended up with five

scenarios, which were later reduced to three by the information technology analysts.

We had underestimated the problems that would arise simply because we were distributing order data and images together with an excellent viewer as E-mail. We experienced the evolution of the medical work environment. New devices, new systems, and often an utterly new infrastructure have to be integrated into an existing environment before requesting the implementation of new procedures. Yet, these new procedures had to interlock with established organizational procedures and devices, which left plenty of room for quality problems.

We intended to cope with higher workloads, aimed at a considerable procedural acceleration, and saw quality standards increasing continually. On one hand, we generated a new freedom of movability—images could be reviewed everywhere—but on the other hand, we caused counterproductive overhead. Under these constraints and quality requirements, we learned that if we rethink basic procedural flows, then we have to relieve and exonerate the medical personnel from overheads and superfluous activities as far as possible by providing adequate information logistics.

This brings us to analyze the radiological service from a business process point of view. Even in apparently simple cases, we come across fairly complex workflow tasks in image distribution, image communication, and time-and-event control. By means of medical use cases and a set of scenarios, the space of conceivable constellations and technical possibilities is to be exhausted to derive atomic tasks which shall be evaluated in this project. The main target remains quality assurance in medical workflow and image distribution, ie, specific allocation, flexible time-and-event control,

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tight documentation, little overhead, and, eventually, good report turnaround times.

SITUATION

Whether in a clinic, a practice, or any cooperating combination clinic-practice, practice-practice, or clinic-clinic, we come across numerous configurations, technical environments, personnel, and organizational structures with different procedures in radiological order processing. The infrastructure with hospital information systems (HIS), radiology information systems (RIS), picture archiving and communication systems (PACS), and image-generating devices has grown into constellations of medical departments, personnel structures, and the existing organizational procedures; if we intend to introduce image workflow in this environment, we have to support new workflow features and exploit some other computer-assistance technologies to avoid quality-assurance deficiencies.^{1,2}

TRENDS AND INFLUENCES

The strongest influences stem from the development of medical devices and communication technology, followed by advances with intelligent agents, workflow, linguistics, help desk, and trouble ticket systems.

Modern imaging equipment natively delivers digital images and digital image viewing outperforms the static film image. Thanks to DICOM, the image communication standard continuously developed during the last decade and widely accepted by device manufacturers and clinic or practice infrastructure systems like HIS, RIS, and PACS may now communicate with each other. With the DICOM presentation states as given in supplement 33, consistency between hard and soft copy can now be achieved, ie, the usage of PC monitors for image viewing is improved.³

The internet plus the worldwide web provide a new networking flexibility on a worldwide accepted consumer standard platform. Secure tunneled transmission (SSL/VPN), the digital signature, and broadband local area network/wide area network (LAN/WAN) communication are being established in E-commerce and enterprise web portals providing the necessary privacy and safety of medical data and accelerating diagnostic procedures.

Help desk systems, as used in call centers, rely on trouble ticket systems, integrate computer trig-

gered phone calls, allow electronic tracking of individuals, deliver tight documentation, and include time-event control, automatic E-mail reminders, and a general monitoring of business processes, ie, help to increase process quality through computer-assisted workflow.

Progress in linguistic data processing, mainly triggered by search engine development, has given us morphological analyzers, relevance and semantic cluster analysis, plus the necessary semantic matching. The extraction of relevant terms from any kind of text combined with semantic matching is supported by excellent tools available on the market. These are used with the identification of experts and the allocation of orders.⁴

Intelligent and learning agents can learn from routine, ad hoc, and emergency decisions once they are fed with the necessary event data and find out about logistics and process problems.

The programming language Java provides us with hitherto unknown platform independence, covers communication standards and functionality to a very high degree, and offers a continually growing set of standard libraries that guarantee unmatched implementation efficiency.

PROJECT PLOT

The Basic Model

The model in Fig 1 schematically shows the potential of process paths of a radiological order issued by the order placer. In this model, framework for workflow and image distribution, we consider the following process steps: identification of order filler, order allocation, document compilation, order transmission with image distribution and communication, notification of order filler, scheduling, progress monitoring and individual tracking, escalation, getting a second opinion, compilation of data after finalization of findings, and transmission to and notification of order placer (referring physician).

From a medical workflow point of view, we differentiated between three attribute cases: *normal*, *emergency*, and *special*. The normal case is supposed to be a straight walk through scheduling, acquisition, and report preparation, and receives "normal" priority, event control, and monitor settings. For the emergency, these settings are extremely tight or set manually. The special case implies the request of a second opinion. This case may appear in combination with the other attribute

cases. The priority scale and the event-control settings may be used for other purposes as required.

WORKFLOW USE CASES

The model in Fig 1 is applied to discuss the following medical workflow situations:

Linking the Order Placer

The order placer compiles the order with patient data, patient history, etc, and transmits it electronically to a radiology department or practice of his choice. After release of the findings, the material is returned to the order placer. The order placer updates the patient record at his discretion and may review the images with the windowing and annotations of the radiologist.

Second Opinion

The radiologist sends an order together with patient data, text documents, and images electronically to an expert colleague. The expert colleague prepares his report with windowing, annotations, etc, and sends them back to the order placer.

Clinical Radiology Department

The order placement is effected by medical personnel or through the system with a possible break down of the order into suborders for distributed devices. Each radiologist involved has access to the electronic patient record. All results including images are available after link insertion into the electronic patient record. The order placer is notified.⁵

THE CORE COMPONENT

The *Jive* proxy, originally a server for Java-based DICOM imaging, is supposed to host all the tools and technological services to be evaluated:

linguistic and learning agents, trouble ticket system, time-event control, tracking, etc. Furthermore, the *Jive* proxy communicates with the existing HIS, RIS, and PACS, the modalities installed and other servers for external communication (Fig 2).

SCENARIOS

Scenario 1

Environment. The radiological department avails of the modality; reports are prepared by a single radiologist; expert opinion is requested optionally; the radiologist can be reached via phone or pager and avails the workstation with internet/intranet access; the radiology runs a *Jive* proxy server and has Integrated Services Digital Network (ISDN) and Asymmetric Digital Subscriber Line (ADSL) equipment and ISDN telephony.

Takeover and receipt confirmation. The *Jive* server registers the series data sent by the modality and checks for order data. If not delivered, those order data are requested from modality, RIS, or HIS. The radiologist has the case already on his worklist through the RIS. After taking over the series, the *Jive* server notifies the radiologist by E-mail that the series is available and ready for

Fig 2. Jive proxy server.

processing. The radiologist confirms receipt of the E-mail; the *Jive* server sets the notify-confirm timer according to the case priority, eg, 1 hour for normal, 3 minutes for emergency. A second commit timer is set when the report is supposed to be finalized (the latest) and a trouble ticket is generated.

Tracking and escalation. If the notify-confirm interval elapses without confirmation, the *Jive* server initiates a tracking procedure, ie, tries to find the radiologist (urgent cases and emergencies)

1. Automatic phone call: play audio file after receiver pick-up and refer to the urgent/emergency case and request confirmation by certain phone dial button.
2. If after ringing n times, no pick-up occurs, a pager message (Short Message Service [SMS]) is sent. If the notify interval elapses again the radiology help desk number is dialed and the audio file is played again.
3. If all escalation/notification attempts fail, a physical alarm is triggered. Reallocation may have to take place.

Time-event monitoring. The *Jive* server monitors the timely report finalization by the commit timer set to default values or set by the radiologist. When the timer elapses, a trouble ticket E-mail is generated and the timer is set again. If the second interval elapses, escalation starts. The timer may be reset by the radiologist at any time according to medical priority.

Second opinion. To identify second opinion experts, the *Jive* server offers a profile list of experts or automatically matches profiles with relevant terms extracted from the cases text material if available. The *Jive* server displays text and image material available, supports the compilation of a second opinion container, and mails it instantly. A trouble ticket with the desired finalization time is generated for event-monitoring. The radiologist determines the reminder E-mail addressee: self or colleague.

Web conference. Multimedia conferences between primary and secondary radiologists are to be supported by net meeting sessions with dual—own and remote—cursors on the same image material and using internet telephony.

Scenario 2

Environment. The radiology department is equipped with a set of modalities; report writing is

done by a number of radiologists with different or overlapping diagnostic foci; the main order refers to more than one modality and more than one radiologist is to be involved. There may be a set of different *Jive* servers.

Image takeover, text analysis, matching, allocation, and distribution. The *Jive* server registers series and orders pertaining to the same patient from different modalities; text data are subject to the extraction of relevant terms, which are relevance-matched with diagnostic focus profiles. Autoallocation considers the best profile match first and the current worklist load with second priority.

Automatic and manual delegation. The addressee decides to delegate a case to a colleague. Substitute regulation is deactivated. Task and data are rerouted automatically to the addressee. Automatic delegation works like automatic allocation and takes place if primary escalation fails during allocation.

Coordination. With two or more modalities, there may be more than one *Jive* server involved. Depending on the topology, a complete subtask may be delegated for time-event control to another *Jive* server, which operates as *Jive* proxy. In this case, one *Jive* server works as coordinating master-server.

Scenario 3

Environment. Like scenario 2, but locally distributed modalities and radiologists.

Operation. The *Jive* server receives orders and carries out automatic allocation in a distributed environment. History data and images are collected from identifiable network sources.

ATOMIC TASKS

Collect-Complete

Collecting additional patient data through contacting the HIS, RIS, and PACS: in a medical practice this means to support the compilation of data to be transmitted electronically.

Allocate-Route

Allocation is carried out after linguistic analysis of related text material, ie, relevant terms are extracted and compared with expert profiles using semantic cluster matching; emergencies and workloads are taken into account.

Notification, Forwarding, and Event Control

The radiologist is notified about the order considering order priority. TWINNER expects a receipt confirmation of the order, triggers automatic telephone or pager calls, and initiates escalation, the addressee cannot be reached in time.

Reminders

Reminders for submittal are generated automatically. The physician may set the case priority and the reminder timer. Time-critical emergencies work with tighter timer settings. All workflow relevant events are subject to time-event control. Override event data are forwarded to intelligent agents to learn about override decisions.

Expert Identification

TWINNER integrates an expert identification service. Relevant terms are extracted from all available text data sources and matched with an expert profile database.

Teleconference

Jive proxy coordinates the experts involved, automatically triggers phone calls, and collects and submits the data required for the conference.

Delegation, Forwarding, and Reallocation

For medical or other reasons, the responsible physician may want to pass on a case to a col-

league. The case is subsequently reallocated and a routing of the data material, including the corresponding notification, takes place plus submittal of all event data to the learning agents.

Release, Digital Signature, Logging, and Archival

On release of the report, *Jive* proxy notifies the order placer and requests a confirmation of receipt. Data involved are optionally transferred to the PACS for archiving or archived locally. *Jive* proxy TWINNER monitors the entry of the digital signatures and logs events like notification, distribution, reminders, reallocations, etc on request.

CONCLUSION

As stated earlier, we underestimated the consequences that image distribution and reviewing on an intranet/internet station brings about. So far we have only implemented 10% to 15% of the whole set of features planned. We still realize that what we planned regarding allocation, tracking, reminders, etc has to be much more configurable than initially designed. Some radiologist would like to turn off certain features, others would like to make use of them. Too much manual input is considered as overhead and we have been requested to look for speech command support. The project will run for another 2 years depending on European Research and Development funding.

REFERENCES

1. DeJarnette WT, Csipo D, Orth A, et al: A standards based distributed PACS architecture. DeJarnette Research Systems, Inc. SCAR 99, 16th Symposium for Computer Applications in Radiology, Houston, TX, May 1999
2. Schmidt J: Workflow management systems—A powerful means to integrate radiological processes and application systems. Philips Research Laboratories. SCAR 99, 16th Symposium for Computer Applications in Radiology, Houston, TX, May 1999
3. Eichelberg M, Riesmeier J, Kleber K, et al: Consistency of softcopy and hardcopy: Preliminary experiences with the new DICOM extensions for image display. Medical Imaging 2000, Spie's International Symposium, San Diego, CA, July 2000
4. Bollen J, Heylighen F: Cluster analysis of word associations. Principia Cybernetica, Jan 22, 1997; <http://pespmc1.vub.ac.be/CLUSTERW.html>
5. Erickson BJ, Ryan WJ, Gebring DG, et al: Image display for clinicians on medical record workstations. J Digit Imaging 10:38-40, 1997 (suppl 1)