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INTEGRATION OF CLINICAL DECISION SUPPORT INTO A HOSPITAL INFORMATION SYSTEM TO PREDICT METASTATIC EVENTS IN PATIENTS WITH MELANOMA

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Abstract

Clinical Decision Support Systems can improve patient care by accelerating diagnostic and therapeutic decisions. As they depend on reliable input data, their integration into different health-care information systems seems very promising. This paper outlines technical and medical aspects of this integration on the basis of a pilot. This project supports computer-aided interpretation of pretest probability and tumour markers in patients with melanoma. Technical feasibility of this integration can be shown, yet user acceptance will need to be verified in further research.

Keywords – CDSS, HIS, i.s.h.med, integration, melanoma

1. Introduction

Over the time, several computer-aided systems for supporting the medical professions in their daily routine have been developed by technical and clinical experts. These include – but are not limited to – Clinical Decision Support Systems (CDSS) which provide diagnostic assistance, reminders and alerts, therapy planning and other services, like image recognition and interpretation [6].

Although these systems are often beneficial even if they are run isolated from other clinical systems as “stand-alone” applications, their integration into health-care information systems (Hospital Information Systems HIS, Laboratory Information Systems LIS, intensive-care patient data management systems PDMS, or other clinical host systems) is even more promising. The resulting workflow integration leads to extended possibilities like ease of use for the clinical physicians, avoiding double entry of data and therefore avoiding errors in using the CDSS. In best case, a “seamless” integration of CDSS services into the therapeutic workflow can improve patient care as it accelerates diagnostic and therapeutic decisions [2].

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This paper is based on software developments and results from the AKIM (AKH information management) project, the aim of which is to renew the HIS of the AKH (Allgemeines Krankenhaus Wien, Vienna General Hospital). This project includes the installation of several additional IT systems for scientific use, among them a CDSS.
Two software packages readily available on the market have been selected and are currently being customized to fulfill the specific technical and clinical needs of the AKH. The technical CDS systems framework used in this project is an Arden Syntax server including an Arden Syntax compiler and a respective engine by Medexter Healthcare GmbH. The HIS used is i.s.h.med by Siemens AG.

As a pilot project and use case during AKIM, the Arden Syntax server is being integrated into i.s.h.med to support computer-aided interpretation of pretest probability and tumour markers in patients with melanoma (S100β, melanoma-inhibitory activity MIA and lactate dehydrogenase LDH), especially to support the prediction of metastatic events. By integrating HIS and CDSS, it will be possible to use a combination of both clinical and laboratory data to evaluate prognostic evidence for melanoma. Timely diagnosis or even prediction of metastasis could improve treatment patterns substantially [9].

2. Methods

2. 1. Technical aspects

2.1. 1. Arden Syntax server (CDSS)

Medical knowledge represented in a CDSS is often written in the standard format Arden Syntax, a special language which is presently maintained by Health Level Seven, Inc. (HL7). To support reuse of knowledge components, knowledge is represented in Medical Logical Modules (MLMs). A typical CDSS consists of at least [5]:

1. *A medical knowledge base*, consisting of one or more MLMs. Knowledge is either derived from interviews with physicians or through automated knowledge mining.
2. *An inference engine* which combines the structured medical knowledge from the knowledge base with the given patient's medical data (e.g. clinical or laboratory data).
3. *A communication mechanism* which allows the system to channel input data to the system and – after data processing by the inference engine – to prepare the results for displaying to the user.

Arden Syntax server by Medexter (and components) represents a service-oriented CDSS. In the context of service orientation it can be seen as a "black box", which means that the communication mechanism provides a public interface and the system ensures the requested functionality (i.e. processing the given patient's medical data and preparing a response to the user), regardless of the internal implementation [5]. The interface uses a web service to communicate with the host system.

This service-oriented approach ensures transferability of medical knowledge (modules), integratability of the CDSS into clinical host systems and it also increases operability (e.g. the CDSS and host system can be run on different physical machines and even networks).

The following *Figure 1* shows a block diagram of the system components used in the production environment of the pilot project. For quality assurance (QA) and operability reasons, most of the components exist at least twice, thus in a design and/or QA environment and in a production environment (the diagram is limited to the design and production instances).

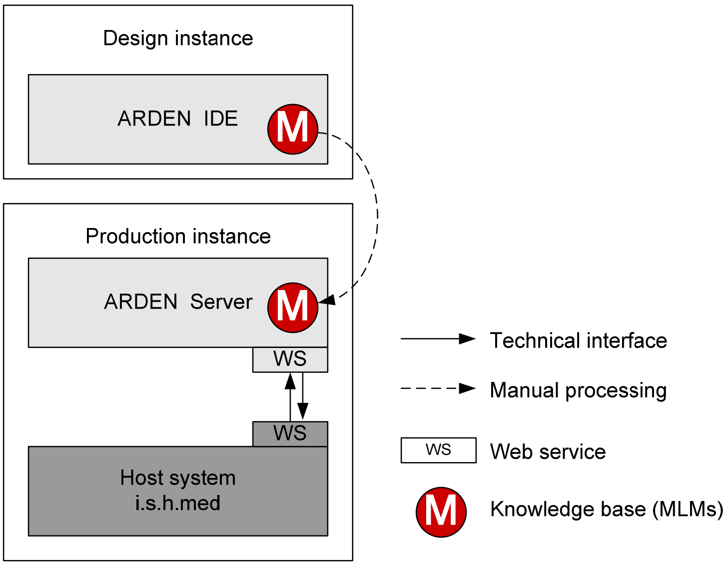

Figure 1: Block diagram of system components used in pilot project. Light grey= CDSS, dark grey= HIS

On the design instance, development of MLMs in Arden Syntax is done using the Arden Syntax IDE, an integrated development environment providing features for source code processing and testing. The finished MLMs are compiled using the Arden Syntax compiler (not shown in the figure, but being part of Arden Syntax IDE) and transferred manually onto the production instance. There, the Arden Syntax server with its reasoning and analysis component [2] processes the respective patient's data, which is received from the host system i.s.h.med via web service. After processing, the results are prepared to be displayed to the user. The Arden Syntax server does not act as a user interface, which means that data entry and result display is done by the host system (see section 2.1. 2).

2.1. 2. i.s.h.med (HIS)

Hospital information systems provide patient-oriented workflow support for medical professionals and administrative personnel. The functions include patient administration (admission/ discharge/ transfer), medical data recording and processing (e.g. physician letter writing, documentation of patient history and status praesens, electronic medication record), data integration (collecting and processing data received from specialized systems such as LIS and PDMS) and reporting features (e.g. for accounting, statistics, QA and scientific purposes) (compare [1]).

i.s.h.med represents a full-featured HIS. Some of its features are used in the pilot project as follows:

1. *Clinical workplace*: It provides a work environment for the medical users (including patient and ward lists, access to scheduled appointments, etc.). Information received from the CDSS, e.g. alerts or reminders, can be displayed in the respective list(s) on the clinical workplace.
2. *PMD* (parametric medical documentation): It provides a framework for medical documentation (e.g. documentation created in out-patient departments) which can be customized to the special medical needs of the respective clinical department. PMD is used in the pilot project as user interface for the CDSS. It generates forms for entry of clinical data (e.g. Breslow, ulceration and sentinel node status) and displays results of the CDSS to the user. With respect to data and results, the i.s.h.med documents also ensure storage and archiving.

3. *Web Service*: It has two basic communication functions: First, it provides laboratory (e.g. tumour markers) and clinical data (see above) for sending to the Arden Syntax server in XML format. Second, it receives results (and explanation, if applicable) from Arden Syntax server and saves them into the i.s.h.med document. By programming, the medical document can – on receiving results – trigger certain "events" in the software, e.g. put alerts or reminders on a patient list on the clinical workplace.

2.1. 3. Technical aspects of integration

Two important criteria need to be fulfilled by CDSS/ HIS integration. The first criterion is security. Therefore, the CDSS is not enabled to retrieve data from the host system. All necessary data is sent from the HIS to the Arden Syntax server without including base data (e.g. patient names). The connection between the data sent by the HIS and the results received from the CDSS is established via the HIS document ID (which is a unique identifier). So the relation between clinical and laboratory data, results and patient base data is well secured inside the PMD, which can rely on the sophisticated user rights management of i.s.h.med.

A second criterion relevant for integration is operability. From this point of view an asynchronous call of the CDSS is preferable. During asynchronous communication, the HIS need not wait for results being sent back by the CDSS. So the user can continue with his work immediately. As soon as the results arrive, the HIS web interface receives and stores them in the PMD. Upon next refresh of the list(s) on the clinical workplace, the CDSS reply status is also updated. This process can be compared with clinical users' practice to order a test or examination and receive the results later.

2. 2. Medical background

The malignant melanoma, which mainly affects Caucasian people, is a malignant tumour of the skin with an incidence in Central Europe of 15/100,000 per year [4]. To achieve early detection, medical assessment of skin lesions and an examination with a reflected-light microscope is applied [8]. The presence of a potential malignant melanoma calls for several follow-up examinations. This includes dermatoscopy of the suspicious skin lesion and palpation of the body (primary tumour, lymph nodes and abdomen). Furthermore, blood serological tests and clinical imaging procedures are common [7].

To support the early detection of metastasis of malignant melanoma, prognostic parameters are a crucial factor. Balch et al. [3] published the revised TNM classification of malignant tumours in 2009 which is used to classify the stages of the tumour based on thickness, ulceration, node status and number of distant metastasis. As a further prognostic parameter tumour markers can be used to detect a relapse of the tumour [10].

3. Results

3. 1. Technical view: integration of the Arden Syntax server and i.s.h.med

From the technical point of view, the aim of the pilot project is to show the advantages of integrating a CDSS into HIS compared to a stand-alone decision support system. The interface approach as outlined in 2.1. 1 and 2.1. 2 supports the workflow integration as postulated in section 1. The reason is that the CDSS makes complete use of the HIS user interface components, such as its medical

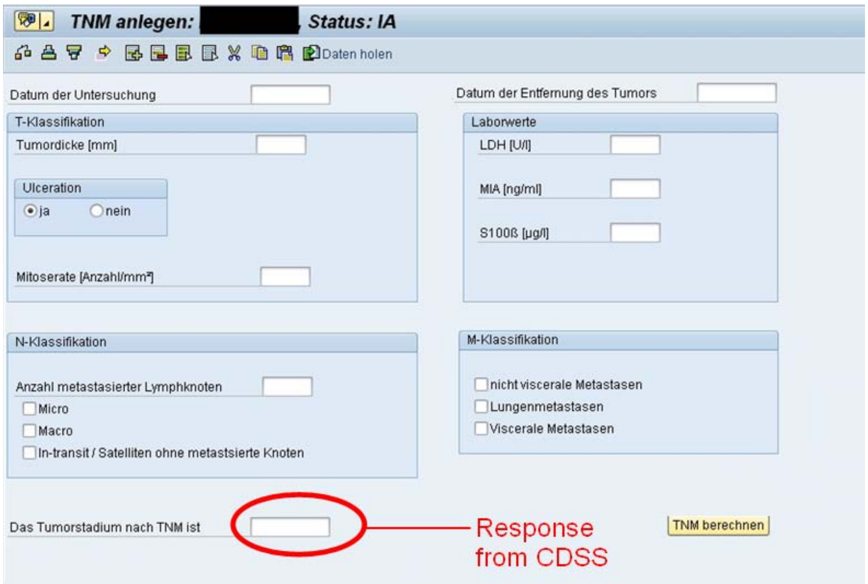

Figure 2: An i.s.h.med document (PMD) acting as user interface for Arden Syntax server (simplified screenshot)

documents, so that the clinical users do not notice a difference between the two systems, even though they are not similar from a technical perspective.

The screenshot in *Figure 2* above shows integration from the user's view. By clicking the button in the lower right corner of the PMD, the user can trigger sending data from HIS to CDSS. As soon as results are received via the web interface, they are shown in the field left to the button (see red circle in *Figure 2*). Except from these two items in the PMD, the shown document has exactly the same look-and-feel as other medical documents well-known by the users.
PMD structure and elements, e.g. the document status network (current status "IA" displayed in header row means "in work"), can be modified to restrict visibility of results to certain users. This allows unbiased data collection during the evaluation of a new medical knowledge base.

Besides extending integration possibilities on the front-end, the service-oriented architecture has also helped to solve operability issues, e.g. the problem that for security and stability reasons, CDSS components need to run on machines different from HIS in the production environment.

3. 2. Use case: prediction of metastatic events

The aim of the project at the Department of Dermatology (see also [9]) is to join the interpretation of the pretest probability for malignant melanoma and the interpretation of the tumour markers S100β, MIA and LDH using logistic regression or an artificial neural network (ANN). The calculations for the logistic regression and the ANN were done with Matlab R2009b. SPSS Statistics 17 used the results obtained from Matlab to calculate receiver operating characteristic curves (ROC curves).The pretest probability classification, represented by the TNM staging system by Balch et al., has already been modelled in Arden Syntax using the Arden Syntax IDE as described in section 2.1. 1.
The designated target of the dermatological project is the implementation of the joint results (pretest probability and tumour markers) as a CDSS into the HIS with a preceding reliability study of the system.

4. Discussion and outlook

The technical feasibility of CDSS integration into HIS can be shown in the pilot project (see section 2. 1.). The service-oriented approach chosen for this integration will make it easier to integrate further CDSS, thus supporting a joint approach as outlined in 3. 2.

From the medical point of view, a risk assessment CDSS might offer substantial benefit for patients and physicians. Tedious routine classifications are automatically calculated and interpreted by rule-based programming language. Regarding our special case, the system integrates pre-test probabilities for metastasis combined with actual lab values. Thus the system is simulating clinical decision making. The deployment under routine conditions might reduce unnecessary examinations such as CT-, MRI- or PET-scans. However, it has to be noted that the final decision will be up to the physicians' discretion.
Nevertheless, "real-life" user acceptance of the system is to be verified in further research. This acceptance will not only depend on system reliability and quality of the achieved results, but also on a reasonable workflow provided by the HIS.

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