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Development of a modular IT-Framework supporting the oncological Patient Treatment in ENT Surgery

Jens Meier[1], Andreas Boehm[2], Erik Schreiber[1], Sebastian Lippert[1], Thomas Neumuth[1], Stefan Bohn[1]

[1]Innovation Center Computer Assisted Surgery (ICCAS), Universität Leipzig, Germany
[2]Department of ENT Surgery, University Medical Center Leipzig, Germany

{j.meier, firstname.lastname @ medizin.uni-leipzig.de}

1 Abstract

The oncological workflows in most hospitals are supported by heterogeneous IT-systems and paper records where different kinds of patient specific information are stored. Information, which is important for the patient treatment, clinical evaluations or quality management have to be gathered and integrated manually by the clinical personnel, thus leading to less-than-ideal processes and error-prone data handling. This paper presents a modular IT-Framework, which retrieves information automatically from existing hospital information systems and provides an integrated platform to support the entire oncological workflow.

2 Introduction

2.1 Motivation

The overall oncological patient treatment process consists of diagnostic, therapy and after-care phase. Within these phases the patient goes through multiple care units where diagnostic and treatment procedures are applied such as radiological imaging, tumor board, surgery, chemotherapy or repeated after-care meetings. In each of these steps new information about the patient is generated and stored in clinical information systems such as Hospital Information System (HIS), Picture Archiving and Communication System (PACS), department-internal systems such as the Tumor Therapy Manager (TTM) [1], or as new entry in the paper-based patient record.
The central clinical information systems are powerful instruments offering the physician numerous functionalities and are available at many computer workstations in the hospital. Unfortunately these systems often suffer from an inefficient design and inappropriate integration into the workflow so the physician does not find the relevant information at a glance (see Figure 1). Many documents have to be browsed before the appropriate information is found.

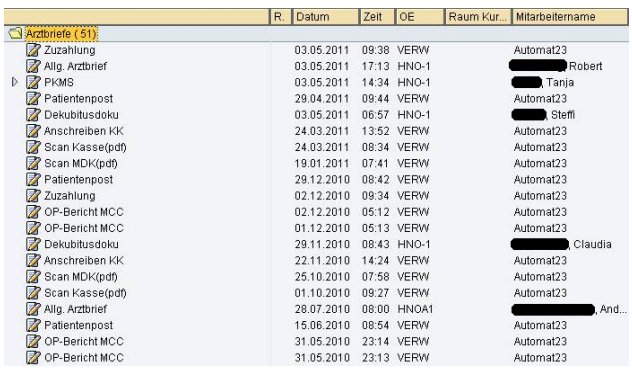

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Figure 1: The actual HIS (i.s.h.med) shows patient-related information in an unstructured way.

The department-internal information systems are only accessible by a small group of physicians so relevant patient information can only be obtained if a privileged person is present.
A paper-based patient record contains plenty of information but can only be used at one specific place per time. Thus, the information is not instantly accessible where it is needed.
This work aims to provide an information system that is clinical-wide accessible, stores information at a central place, allows a convenient and structured information retrieval and supports physicians during the entire oncological treatment process.

2.2 Current Situation

In this section the current situation including the clinical workflow and the involved documentation systems in the department for ENT surgery at the University Medical Center Leipzig will be briefly described.
In Figure 2 the oncological workflow and relevant information systems are depicted. At the oncological ambulance a patient record in the HIS (i.s.h.med) and paper-based records are created. During panendoscopy samples of potential tumor tissue are taken and sent to the pathology department for histopathological examination.

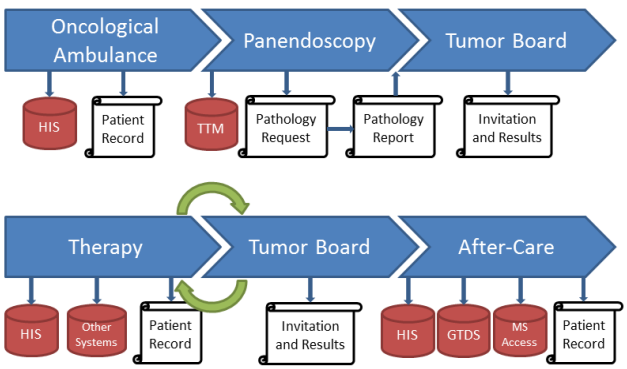

Figure 2: Chronological steps of the oncological workflow in ENT surgery with relevant information systems and paper forms.

The biopsy locations are reported in the TTM. Finally when histopathological results are available from pathology the patient is scheduled for the next tumor board for final therapy decision discussion. The tumor board invitation and result documentation are performed with MS Word documents that are sent via email to all participating physicians.
The therapy phase of the care process may include surgical interventions, radiotherapy or chemotherapy depending on the patient specific diagnosis and the tumor board decision. Information generated in this phase is stored in the HIS as well as department internal databases or paper-based patient records. A post-therapeutic tumor board clarifies if further therapies are necessary or if the patient can be released into after-care.
During the five year after-care phase the patient joins regular meetings. In each meeting notes about the patients constitution, problems and possible tumor recidivisms are taken into the paper-based patient record. Afterwards the information is manually reentered into HIS, Gießener Tumordokumentationssystem (GTDS) and a department internal Microsoft Access database.

2.3 Goals

This work presents an information system "*oncoFlow*", which aims to overcome the previously described shortcomings. The system is designed to support the oncological workflow in ENT surgery. Automatic import of patient specific information from existing clinical information systems should prevent manual reentering of patient details and save valuable time. Systematically categorized and structured information should be available for further processing. Data and functionalities should be available as web based rich-internet application that allows instant access from each workstation within the hospital. A key design requirement is to present the user only with functionalities that are needed within a certain context.
The first step towards the management and support of the entire oncological workflow in ENT surgery is the seamless integration from existing patient information, panendoscopy results and management of team meetings. This includes automatic creation of paper forms for requesting pathological examinations of biopsy tissue or semi-automatic composition of physician letters, preparation of tumor board meetings and mailings for inviting physicians to the board and providing results after the meeting took place.
The Surgical Planning Unit (SPU) provides an IT and room concept to support decision making in tumor boards. It will be interconnected with *oncoFlow* for seamless data storage, retrieval and visualization within the digital meeting room SPU [2].
In daily clinical usage the system will provide a large information basis containing patient, diagnosis and therapy specific data in a structured manner. This information is very valuable for further scientific research. Hence, the *oncoFlow* system will serve as a basis for the development of a Digital Patient Model (DPM) for ENT surgery. The DPM aims to provide an individualized patient treatment based on patient-specific knowledge management [3]. An integration of the available information into probabilistic mathematical models will serve as medical decision support system and help the surgeon to improve patient treatment.

2.4 Related Work

The fields of patient management and team meeting assistance are already addressed in the scientific literature. M. Eisner describes the integration of workflow and tumor board support into the HIS of the Steiermärkische Krankenanstaltengesellschaft [4]. A tool was implemented into i.s.h.med that suits the requirements of their tumor boards and optimally integrates into the daily clinical routine. Bumm et al. developed a web-based oncological patient documentation and conference software [5]. This software provides a paperless planning and execution of tumor boards, decision documentation and a database including oncological clinical studies. Li et al. also developed a web-based information system supporting tumor conferences [6]. Their focus was on supporting tumor conferences held in multiple locations via videoconferencing.
All the aforementioned research activities are primarily focused on tumor board assistance, whereas the framework presented in this paper aims to support the entire oncological workflow.

3 Methods

3.1 Proceeding

The development of *oncoFlow* has been realized in three steps. Firstly, requirements and information entities were assessed and a hierarchical information model has been created. Subsequently the database has been designed based on the information model. The second step covers the requirements analysis and design of the three-tier system architecture. Finally the system has been implemented as Java web application.

3.2 Information Model

An extensible, flexible and hierarchical information model based on commonly accepted standards such as Union Internationale Contre le Cancer (UICC) [7, 8] and the variables from the local oncological treatment process (see Section 2.2) has been developed.
The required information entities were identified and grouped into different classes whereby each class represents a step in the clinical workflow. A detailed class and entity description is depicted in Table 1. The information model development was performed in close cooperation with clinical partners.
The information model allows an instantiation of a temporal view of the patient history through a time stamped acquisition of diagnosis and therapy steps as well as an instantiation of a causal representation of stored information based on the logical sequence of activities in the care process (see Figure 4).

Table 1: Detailed description of the information entities in the *oncoFlow* information model

Information Class	*Information Entities*
Patient	Name, Address, Date of Birth Referring Physician Circumstances of Death
Anamnesis	Nicotine, Alcohol, Risk Factors Weight (at different Times) Karnofsky Index, Pain, Teeth Status
Diagnosis	Case Number, Date, ICD Code
Tumor	Type (Primary, Secondary, Recidivism) Localization, clinical TNM Grading, pathological TNM Histopathological Examination
Panendoscopy	Endoscopy Images, Biopsy Location
Surgery	Personnel (Operateur, Assistants, Staff) Detailed Intervention Description Neck-Dissection Levels
Chemotherapy	Drugs, Dose, Cycles
Radiotherapy	Type, Target Areas, Dose, Mucositis
After Care	Complications, Recidivisms
Laboratory Results	Blood Count
Team Meeting	Type, Time, Location, Participants, Patients Attended Participants, Therapy Decision
User	Name, Group, Specialty, Mailadress

3.3 System Architecture

The *oncoFlow* framework is designed as a modular system to support the extension with new functionalities and an easy integration with multiple external systems such as clinical information systems, databases or workflow management systems. The core framework consists of a three-tier-architecture (see Figure 3). The presentation layer consists of a rich internet application within web browser. The application layer contains the main program logic and is implemented by different modules. Each module works independently, but may use the services that other modules provide. The data layer provides access to database systems and is responsible for data transformation and exchange between the system internal database (*oncoFlow* DB) and other information sources.

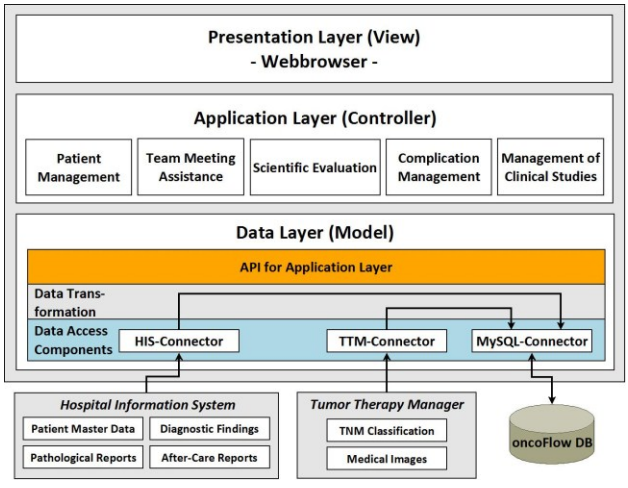

Figure 3: Three-tier system architecture of the *oncoFlow* framework

3.4 Implementation

The system is exclusively implemented with **free software** products depicted in detail in Table 2.

Table 2: Software components used for the development of *oncoFlow*

Component	*Software*	*Version*
Operating System	Debian Linux 6	Kernel 2.6.32
Database	MySQL	5.1
Application Server	Apache Tomcat	7.0.27
Webserver	Lighttpd	1.4.28
Java	Oracle Java SE	7.0.3
SSL Encryption	OpenSSL	0.9.8
Web Framework	Vaadin	6.7.7
Charts	Invient Charts	0.8.6
Development Environment	Eclipse Indigo	3.7.2

The system architecture was implemented by using well-known **software design patterns**. The application is separated into different modules working independently from each other. New modules can be developed and easily integrated into the core framework. Each module implements the Model-View-Controller (MVC) pattern [9]. Hereby the controller is responsible for creating the view and establishing the connection to the model. Afterwards the main application includes the module into the main navigation bar.

The **persistent storage** of information into database systems has been realized with Object-Relational-Mapping (ORM). The database access has been implemented in a generic fashion using Java Database Connectivity (JDBC). Therefore each object that should be stored inside the database must inherit from a common super class. Afterwards the object is passed to the model determining the appropriate object type and performing necessary transactions with the database.

The system deals with high sensitive patient information. Therefore **system security** is crucial to protect information from illegal access and eavesdropping. A fine-grained user authentication secures the patient information from illegal access. There are multiple user groups with separate access rights supported. Different user groups allow system administration, full privileges to create, edit and delete patient information or only view patient information as anonymous datasets. The anonymization hides sensitive information such as patient name, address, date of birth or patient ID. The communication between web server and browser is secured using Secure Socket Layer (SSL) encryption, hence, usernames, passwords and transmitted patient specific information is end-to-end protected from eavesdropping.

An "one click" **data visualization** has been realized with the InvientCharts java script framework. Often recurring database queries for statistical analysis of patient data or quality management can be easily performed by physicians without a complex data export to MS Excel and creation of appropriate diagrams (see Figure 5).

The framework is actually connected to the HIS and the TTM for **data import**. The HIS exports patient master data and diagnoses into semicolon separated ASCII files.

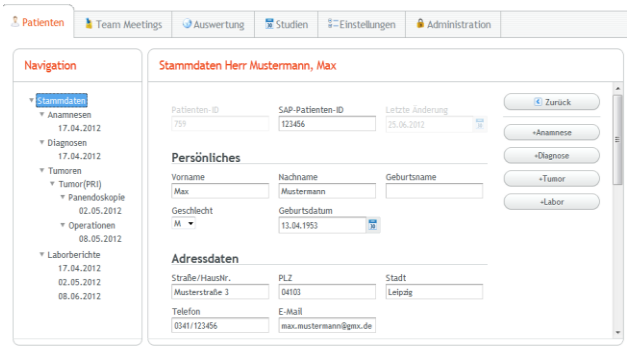

Figure 4: The structured and well-designed view of patient-related information in *oncoFlow*

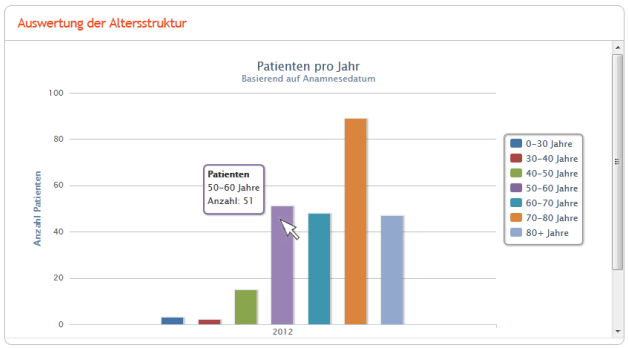

Figure 5: Age distribution of all patients in the year 2012, the diagram is based on test data

The TTM interface handles HTTP request-response messages. A zip file containing relevant medical images from panendoscopy and a tumor classification (TNM) in a XML file are delivered from the TTM system and imported into the database.

4 Results

A modular IT-Framework that supports the oncological workflow in ENT surgery has been developed. The well-designed web-based user interface facilitates the access to relevant patient-specific information via web browser. In comparison to Figure 1, the data presentation in the HIS, and Figure 4, the data presentation in *oncoFlow*, a considerable gain in clarity in the presentation of the information is visible.

An automatic import of patient relevant information from other clinical information systems has been established and facilitates data management for clinical staff by replacing error-prone manual data import.

A team-meeting module provides management of regular meetings such as tumor boards. The patients that are to be discussed within the meeting are automatically proposed based on their status “after panendoscopy” and assigned to a tumor board. The relevant information about the patient is automatically retrieved. The surgeons who should participate the meeting are chosen from the user list and assigned to the meeting. After the planning is finished the invitations are sent to all participants via email.

The scientific evaluation module, which is still in development, actually provides an instant statistical analysis of recurring clinical questions with one click (see Figure 5).

5 Conclusion

The current version of *oncoFlow* has been presented to surgeons and clinical staff. The feedback to the new concept was completely positive. The automatic data import from clinical information systems and the well-designed user interface were the most desired and accepted features. This positive feedback forms the basis for the acceptance of the system in clinical routine.

The modules for patient and tumor board management have been finalized. Current research aims at the integration of the system into the daily routine. This means the automatic creation of clinical forms such as order requests to pathology or physician letters based on already available information and the connection to the SPU to provide support while the tumor board takes place.

An integration of additional instantly available analysis functions as well as a data export to IBM SPSS Statistics in the scientific research module is planned.

Future work is focused on the implementation of two modules supporting clinical trial studies and complication management. The studies module includes the management of clinical studies and their parameters. A search function uses the study parameters and performs a regular search inside the patient database to determine appropriate patients. The complication management module will consist of a structured acquisition and evaluation of intraoperative and after-care complications.

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