Medical Infobahn for Europe
A. Hasman et al. (Eds.)
IOS Press, 2000

MedIDok - An Intranet Tool for XML-based Data Modelling in Medicine

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Abstract

Integration of administrative, clinical and scientific documentation in medicine is a challenge because of the complexity and dynamics of the underlying data models. At least 50 items per procedure are necessary for clinically adequate documents. Extensive fine tuning is required to achieve acceptance by physicians, thus rapid prototyping is important. The results of this modelling process should be provided independently of specific implementations for reasons of portability.

To address these needs we developed MedIDok (Medical Intranet-based Documentation), a set of intranet tools to generate and maintain specific documentation systems (generated programs, no manual coding) and the associated data models. The data structures are provided in XML format and therefore can be reused with other software architectures.

The feasibility of non-redundant Intranet systems for both clinical and scientific information management is assessed covering the following domains at a major university hospital: hip ultrasound, endoscopic cholecystectomy, ESWL (extracorporeal shock wave lithotripsy) and implantable cardiac defibrillators.

With the programs generated by MedIDok so far more than 10.000 patient contacts have been documented.

1. Background

High-granular documentation, which is suitable for both clinical and scientific data management, is characterized by complex and dynamic data structures. A realistic medical data model requires extensive fine tuning to meet clinical needs, thus rapid prototyping is important. The result of this modelling process should be independent of specific implementations for portability reasons.

Due to insufficient integration at the clinical workstation physicians nowadays are confronted with "triple data entry": the same patient must be documented for administrative, clinical and scientific purposes. These datasets are overlapping, causing redundant data entry with well-known problems (loss of data quality, need for extensive data monitoring etc.).

We developed an intranet tool to generate and maintain high-granular data models which are prerequisites for an integrated documentation workflow. For reasons of portability the description of the data structure is provided in XML format [1,2].

2. Methods

A dedicated software tool (MedIDok = Medical Intranet-based Documentation) has been developed for rapid prototyping of ergonomic, highly adaptive electronic forms and management of data transformations. Clinical data entry is performed with a standard web browser. All applications are server side PERL programs [3]. The dataset is stored by means of a relational SQL database. Open source tools were used for handling of XML structures

[4]. To manage complex and dynamic data models all applications are generated by templates, i.e. no line of code is programmed manually.
Fig. 1 shows the general documentation workflow of MedIDok. After login the patient is selected from a current list of patients provided by the legacy system. The most recent document for this patient is displayed ('view info'). The user can navigate within the documents of one patient , create new ones or edit the current page. The structure of each document is described in XML format.

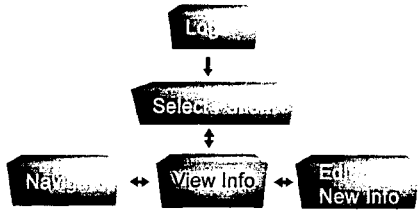


Fig. 1: Documentation workflow of MedIDok. For each patient several documents ('infos') can be stored in the database. The structure of each document is described in XML format.

The models themselves are created and edited with an intranet based modelling tool. For each item a set of attributes is defined: Type of item (text, pulldown menu, checkbox, radio button, textarea, date, time), default values, constraints and layout. Each item has a unique object ID to enable data transformations when the data structure is updated.
The MedIDok tool provides the following functions:

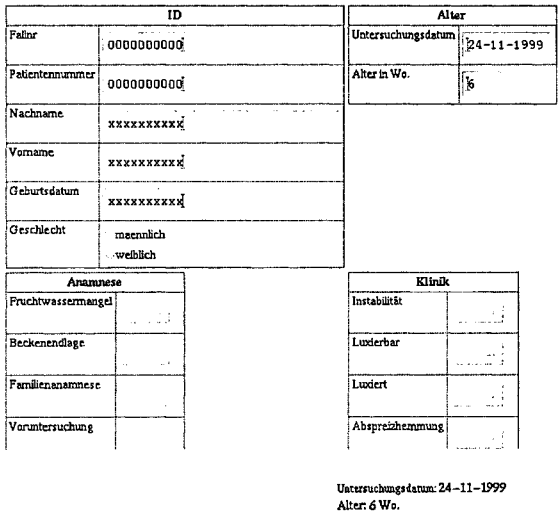
- generation of custom data entry forms
- combination of free text and structured data entry
- individual layout for clinical reports
- data transformations
- interface to relational database
- user authorization and access control
- tools for data export (XML format)

With an HTML form items and their associated attributes can be edited and stored into the database. As soon as a new program version is generated, existing records are transformed according to the new model. The combination of free text and structured data entry is accomplished by intelligent pulldown menus which trigger associated textfields. The selected textelement can be adjusted manually for the clinical report, but the categorical value (e.g. type of operation) is preserved. To protect the confidentiality of patient data individual user accounts with restricted access were implemented.

3. Results

The medical domains for the prototype systems include hip ultrasound (orthopedics), ESWL (extracorporeal shock-waves lithotripsy, urology), endoscopic cholecystectomy (surgery) and implantable cardiac defibrillators (cardiology).
The hip ultrasound procedure was selected for Intranet based clinical data entry because it is a standardized procedure in orthopedics that is performed frequently. The first step was the definition of a precise data model for this diagnostic procedure. The traditional paper form was used as a first approach. During the system design process the data model was extended

to cover more variables for scientific purposes; altogether 56 items were appropriate. The first prototype was subject to intensive fine tuning. A special focus was set on software ergonomy. From the data definition necessary Intranet programs were generated with MedIDok. Fig. 2 shows entry form and report, Fig. 3 the associated XML structure for this procedure.



ID	
Fallnr	0000000000
Patientennummer	0000000000
Nachname	xxxxxxxxxx
Vorname	xxxxxxxxxx
Geburtsdatum	xxxxxxxxxx
Geschlecht	maennlich weiblich

Alter	
Untersuchungsdatum	24-11-1999
Alter in Wo.	6

Anamnese	
Fruchtwassermangel	
Beckenendlage	
Familienanamnese	
Voruntersuchung	

Klinik	
Instabilität	
Luxierbar	
Luxiert	
Abspreizhemmung	

Untersuchungsdatum: 24-11-1999
Alter: 6 Wo.

Ultraschalluntersuchung der Säuglingshüfte

Sehr geehrte Frau Kollegin, sehr geehrter Herr Kollege,

wir berichten über das Kind [redacted],
das am 24-11-1999 in unserer Klinik untersucht wurde.

Anamnese:	unauffällig
Klinik:	unauffällig
Vorbefund:	Alter bei Voruntersuchung 0 Wo. Hüfte rechts IIa+ Hüfte links IIa+
Befund: (Hüfttyp nach Graf)	Hüfte rechts Ia/b Hüfte links Ia/b
Diagnose:	**physiologische Hüftreife rechts** **physiologische Hüftreife links**
Therapie:	keine Kontrolluntersuchung empfohlen keine

Mit freundlichen Grüßen

Fig. 2: Hip ultrasound documentation (in German): entry form (section) and report.
This report is generated automatically for each record. It can be printed immediately and the same dataset can be used for scientific evaluation: multi-purpose medical record.

```
<?xml version="1.0" ?>
<Hip_Ultrasound version="1.1" author="Dr. Dugas">
  <ID>
    <caseno type="text" position="3" id="70"/>
    <patientno type="text" size="10" position="4" id="1"/>
  </ID>
  <Findings>
    <diagnosis_right type="pulldown" position="65" id="59">
      <e id="1" text="physiological maturity"/>
      <e id="2" text="physiological immaturity""/>
      <e id="3" text="delay of ossification"/>
      <e id="4" text="dysplasia"/>
      <e id="5" text="luxation"/>
    </diagnosis_right>
  </Findings>
  <Therapy>
    <Therapy_type type="pulldown" position="74" id="63"/>
    <Physician type="text" size="30" position="80" id="69"/>
  </Therapy>
</Hip_Ultrasound>
```

Fig. 3: Documentation of Hip ultrasound procedure: data model in XML format (small section, translated to english). 'type' corresponds to the data type of each item, 'position' is a consecutive number for the layout, 'id' is a unique item identifier (invariant to changes of the data model)

The design process of three more XML-based documentation systems (endoscopic cholecystectomy, ESWL, implantable cardiac defibrillators) was analogous: The first approach for the data model was based on pre-existing paper forms. Using the MedIDok tool a prototype was developed, which was subject to intensive fine tuning concerning the data model and layout features. After several iterative design cycles the system was implemented in the clinical setting.

With this approach by now (January 2000) more than 10.000 patient contacts with approximately 50 items each have been documented (hip ultrasound n=2879, implantable cardiac defibrillators n=8430, urology n=1194).

More databases for internal medicine and surgery are now under development.

4. Discussion

Currently scientific information management is mostly performed on paper despite the progress of information technology in the last years. This problem of efficient data acquisition in the clinical setting has been well-known for more than 20 years [5]. One of the main issues is the lack of well-customized, high-granular and portable clinical data models. A lot of work has been wasted because most data structures nowadays are bound to specific implementations. Our approach provides XML data models which can be reused on different software architectures.

The clinical impact of decision support based on patient-specific data has been shown recently [6]. A close cooperation between clinicians, medical statisticians and informatics professionals is required to bridge the gap and to develop new IT instruments to collect both clinical and scientific data in a comprehensive manner. From our experience - as shown by several medical applications -, intranet technology provides a universal technical platform for clinical data entry with the potential for inter-institutional cooperation. Cimino [7] even described a concept for web based data entry by the patient himself.

Many information services and computer based training can be implemented with web technology [8,9]. Meanwhile - caused by the success of the Internet - web browsers have become well-known standard programs even to non-technicians, so the level of acceptance for web based systems in general is very high.

The major technical advantages of our approach are easy administration, rapid prototyping and a consistent user interface. The main disadvantage consists of a high server workload. Client side JAVA was inappropriate in our setting because of limited technical resources of our clinical workstations. To minimize redundant data entry an interface to the legacy system has been integrated (Remote Function Calls to IS-H from SAP Inc.). This improves data quality and supports patient identification during followup visits.
By XML-based clinical data entry paper forms - and the associated "paper work" - can be reduced. Our next step will be an in-depth analysis of the impact of this methodology on data quality (by now, more than 10.000 patient contacts with approx. 50 items each are documented). From a technical point of view the web server and Intranet programs have proven reliability and performance in clinical routine.
Non-redundant, Intranet based systems for both clinical and scientific information management are feasible, but require a significant amount of data modeling and fine tuning to gain clinical acceptance. Typically 40 to 120 items with a total of 30 to 200 textelements are required for a single procedure [10]. Given the large number of medical procedures (our department of surgery performs more than 100 different procedures and there are about 20 different departments), a full featured Hospital Information System can have in the range of 100.000 items (50 items per procedure, 100 procedures per department, 20 departments: 50x100x20 = 100.000 items).
A single company or scientific workgroup can't maintain a data structure of this complexity; thus over-institutional cooperation is required. XML data models should be shared among the medical informatics community to prevent "re-inventing the wheel" and to support the evolution of standardized medical data structures.

5. References

[1] World Wide Web Consortium, http://www.w3.org/XML/ (visited February 14th 2000)
[2] R. Sokolowski and J. Dudeck, XML and its Impact on Content and Structure in Electronic Health Care Documents, Proc AMIA Annu Fall Symp 1999: 147-151
[3] L. Wall, R. Schwartz, Programming PERL. O'Reilly & Associates Inc., Sebastopol, CA, USA 1992.
[4] XML Modules for PERL, http://www.perl.com/CPAN-local/modules/by-module/XML/ (visited February 14th 2000)
[5] C. McDonald, W. Tierney, J. Overhage, D. Martin and G. Wilson, The Regenstrief Medical Record System: 20 years of experience in hospitals, clinics and neighborhood health centers, MD Comput 9 (1992) 206-17
[6] K. Shojania et al., Reducing vancomycin use utilizing a computer guideline: results of a randomized controlled trial, JAMIA 1998; 5(6):554-562
[7] J. Cimino, S. Socratous and P. Clayton, Internet as Clinical Information System: Application Development Using the World Wide Web, JAMIA 1995;2:273-284
[8] M. Dugas, Clinical applications of Intranet-Technology. in: New Technologies in Hospital Information Systems (ed. Dudeck J. et al.), Amsterdam 1997: IOS Press, 115-118
[9] M. Dugas, An intranet-based information system for nurses, MD Computing 15 (1998),158-161
[10] M. Dugas, J. Scheichenzuber and H. Hornung, An Intranet-Based System for Quality Assurance in Surgery, J Med Systems 1999 23(1), 13-19