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Current Research on Medical Knowledge-Based Systems in Germany

Results from a Study Conducted in the Framework of MEDWIS

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Abstract. A study of the GSF Research Center performed in 1995, surveys the current state of research concerning the development of knowledge based systems in medicine in Germany on the example of projects promoted by MEDWIS. Furthermore, recent problems in research were found in the development of systems and their successful application in clinical routine. Important future research topics were identified. The focus of research on knowledge based systems has changed from basic methodical research to application-oriented research lately. The study shows, that especially introducing systems into medical environment still provides considerable problems and affords immense further effort.

1. Introduction

In the last years, complexity and volume of medical knowledge have increased continiuously. The availability of current medical knowledge at all levels of medical care is essentially required in order to guarantee high quality of medical care. The objective to reduce costs in Public Health is also related to that. Knowledge Based Systems (KBS) essentially contribute to the solution of these problems.

In the field of research on KBS in medicine (KBSM), a fundamental change has taken place in the last few years. In the process of developing a KBS, the basic methodical problems like knowledge representation and inference mechanisms are no longer holding the spotlight, but problems of introducing the systems in the clinical environment and thus, questions of the application-oriented research (see also [1]).

To differentiate between the two mentioned research fields, and for a better investigation, how far the MEDWIS projects can overcome current research problems like the processing of 'problematic knowledge' on the one hand and 'prominent technological problems' (see [4]) like adequate user intefaces, a satisfactory costs/benefit-ratio and the adaption of system functions to the requests of the clinical environment on the other hand, the questionnaire of the study this paper is based on (see 1.2), the analysis of the results, and the presentation of the results in this paper were subdivided in three different chapters: the aspects of the basic methodical research, the aspects of the application-oriented research and the future main interests of research.

This paper summarizes some of these results of this study on the development of KBS in medicine in Germany, focussing on the projects promoted by MEDWIS ('Medizinische Wissensbasen', i.e. 'Medical Knowledge Bases'. Since it can be assumed, that the basic tasks and the related problems in MEDWIS and other German projects do not differ from each other essentially, the results can be generalized on the current state of KBS research in Germany largely.

1.1. The MEDWIS-Project

MEDWIS (conducted from 1990 to 2000) is promoted by the BMBF (German Federal Ministry of Education, Science, Research, and Technology) with the objective of

supporting the development of KBS in Germany. For a detailed description of goals and structures of MEDWIS, see [2]; recent information about MEDWIS in English is available on the World Wide Web at http://www@gsf.de/MEDWIS/medwis/.
When the study was carried out, 39 projects, covering 8 different medical fields (e.g. neurology, intensive care) were promoted by MEDWIS.

1.2. Objectives and Study Design
The purpose of the study was to survey the current state and to identify problems and future priorities of KBSM research in Germany. Moreover, the results were intended to support the future course of MEDWIS, providing an evaluation accompanying the development. Among other questions, the following were examined:

1. Which are the medical domains of the projects, and which objectives are pursued? Which methods, models, and tools are used for knowledge acquisition, representation, and processing? Which approaches are used for integration and evaluation?
2. Do projects refer to national and international standards or standardisation efforts?
3. To which extent do the projects consider requirements for the clinical application of systems on a large scale?
4. Which are the most important recent problems related to the development of KBSM, and which are the most important topics for further research?

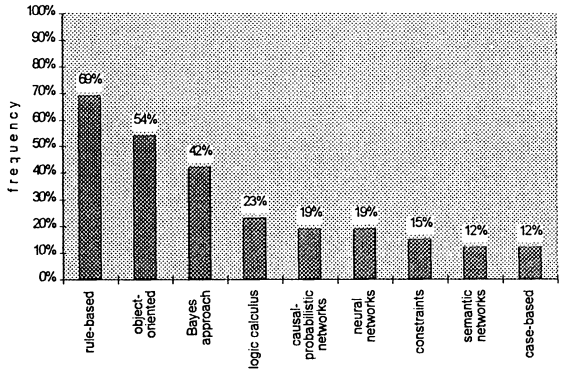
The study was carried out by the medis-institute of the GSF. 36 of 39 MEDWIS-projects returned the questionnaires; since several projects of an association completed the questionnaire together, 26 questionnaires were finally available for analysis.

2. Results

2.1. Basic research: Knowledge modelling, representation, and processing
Concerning knowledge modelling, only 35% of the projects developed a conceptual knowledge model, independent of certain knowledge representation models. Figure 1 surveys the methods of knowledge representation and shows the frequencies of their application. Both, programming languages and Expert System Tools are used for knowledge representation and processing. The programming languages most frequently used are C++ (54%)[1], PROLOG (38%), C (31%), LISP (15%), and Smalltalk/Visual Works (15%), Occam, and Excel (both 8%)[2]. Well-known Expert System Tools applied are ProMD (31%), HUGIN (19%), NEXPERT (12%), KAPPA (8%), and ClassicaD3 (8%).

92% of the projects indicate, that their relevant knowledge includes 'problematic knowledge' like uncertain (96%) and temporal (92%) knowledge. Throughout their work and among other things, 73% of the projects process temporal knowledge; tasks to solve are the analysis of time series (58%), the recognition of trends (47%), planning (e.g. of therapies; 47%), predicition (37%), and completing temporal order relations (37%). The processing methods most frequently used are database queries (73%), logic based methods (67%), and

Figure 1: Methods for Knowledge Representation



[1] For reasons of perspicuity, the values are shown in percent.
[2] A sum of more than 100 for added percentages indicates a question allowing multiple entries.

statistical methods (47%). 77% of the projects are occupied with processing uncertain knowledge. The methods most frequently used are the Bayes approach (58%), causal-probabilistic networks (47%), and neural networks (21%).

2.2. Aspects of application and application-oriented research

2.2.1. Medical topics and roles of the systems

The following medical fields are covered by MEDWIS so far: surgery (acute abdominal pain), microbiology (borreliosis), radiology (thoracic diseases), pharmacology, neurosurgery (meningitis), anesthetics and intensive care, pediatrics (metabolic diseases), neurology (cerebrovascular diseases), laboratory medicine (diseases of the thyroid gland, borreliosis, nephrology), and internal medicine (rheumatology, diabetes mellitus, nephrology, hepatology).

Goals for the purpose of patient care are pursued by 90% of the promoted projects, further 8% try to improve patient care indirectly by supplying knowledge. Only 2% of all projects pursue goals exclusively associated with medical informatics. 85% of the developed systems include a component for decision support based on patient data, 65% include a knowledge based encyclopaedia, and 31% a tutoring component.

In addition, 54% of the projects provide 'added values' (e.g. statistics about performance or reports) to improve the costs/benefit-ratio.

2.2.2. Knowledge maintenance

The knowledge bases are maintained by experts (54% of the projects) or by knowledge engineers (31%). 15% did not comment this question. However, only 85% of the projects provide a version of the knowledge base which can be read by medical experts. In 46% of the projects a single expert and in 42% an expert-panel is responsible for the contents of the knowledge base. 46% of the projects coordinate the contents of their knowledge base with respective medical associations.

2.2.3. Places of application and user groups

69% of the developed systems are planned to be installed in a clinical environment, 27% in doctors' offices, and 12% in student education facilities. 4% will be used for the development of KBS in computer laboratories.

69% of the projects are planning to design an international version (mainly English) of their system or are already working on it.

Future user groups are expected to be physicians with little experience (96%), experienced physicians (81%), students (69%), medical/technical assistants (23%), care staff (15%), patients, and developer of KBS (both 4%).

2.2.4. Integration

60% of the systems will be integrated in other information systems: 40% in laboratory information systems, 27% in hospital information systems, and 13% in ward information systems. Figures 2a) and b) show the consultation time of the systems estimated by the projects and subdivided in integrated and stand-alone systems.

2.2.5. Human computer interface

Future users participated in the specification of the human computer interface in 92% of the projects. Privileged input devices are keyboard (96%) and mouse (85%).

2.2.6. Evaluation

Evaluations within the term of MEDWIS are planned in 88% of the projects. They will be carried out in hospitals (91%), in computer laboratories (65%), in lectures (13%) and workshops (4%).

Fig. 2.a.: Consultation time in integrated systems

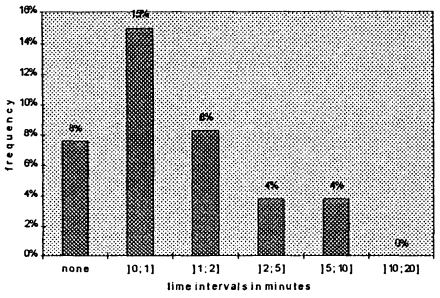
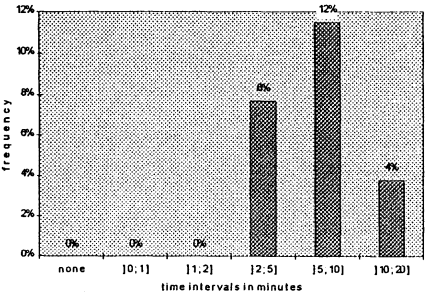


Fig. 2.b.: Consultation times in stand-alone systems



2.2.7. Standardisation

48% of the projects use standards for knowledge representation (83% of these use the ARDEN Syntax and 50% KIF), and 85% use standards for terminology (mainly ICD 68%, ICPM and 'Rote Liste' both 50%, and SNOMED 14% only). The only document standard used is HTML. For data exchange no project uses any of the current standards like HL7 or EDIFACT.

19% of the projects are working on a standardisation of the knowledge of their medical field regarding terminology or quality assurance aspects, e.g. an international standardisation of reports of laboratory findings.

2.3. Current research problems and future main interests

Current research problems were divided into those problems resulting from medical tasks, those appearing during development, and occuring during application in clinical routine. Concerning the first problems, the most important are, that medical knowledge cannot be differentiated clearly (54%), and that experts have different opinions (46%). Research problems showing up during development were thought to result from processing uncertain and incomplete knowledge (62%) or temporal knowledge (54%), the availability of appropriate tools (46%), insufficient methodology for the development of KBSM (42%), and the cooperation between physicians and computer scientists (31%). The most significant problems occuring when the systems are introduced in the medical environment are the integration of the systems into available information systems (65%), user acceptance (58%), and integration of systems into the working processes (50%).

The most important future interests of research in the field of KBSM mentioned are: processing of uncertain and temporal knowledge (54%), aspects of integration (35%), standardisation of knowledge representation formalisms and corresponding inference mechanisms, as well as terminology and development methodologies (e.g. KADS) (31%) and aspects of knowledge acquisition and maintenance (27%).

A summary and a discussion of all study results as well as the used questionnaires and a list of addresses of all involved projects is found in [3].

3. Discussion

Related to basic research topics, the most serious deficits seem to consist in the existing models for representation and processing of temporal and uncertain knowledge. For this reason, MEDWIS established a working group 'Temporal and uncertain knowledge'.

Concerning knowledge representation and processing, the majority of the projects applies well-known models and methods. The goal pursued by the projects is an adaption, refinement and evaluation of existing approaches more than the development of new approaches. The high heterogenity of the methods and tools used is conspicuous and cannot only be derived from specific conditions of the projects, since their tasks are comparable to some extent. Hence, it has to be explained by missing methodologies for a problem-dependent selection of adequate methods and tools and by missing adequate methods and tools. The lack of these tools is also confirmed by the frequent use of universal programming languages. In the future, the attention must be turned to the development of conceptual knowledge models, since they play a central role in solving problems in fields like knowledge acquisition, explanation capability, and multiplication, which are all topics of great importance to practical use (e.g. see [4]).

The application-oriented nature of research in MEDWIS is reflected in the study results in many places, one example being the goal described in 2.1.: Nearly all projects pursue goals serving for patient care directly.

MEDWIS tries to overcome 'prominent technological problems' [5] of the diffusion of KBSM: the disposition of adequate user interfaces can be achieved by including a large number of future users in the development process (92% of the projects). To improve the costs/benefit-ratio 54% of the projects provide 'added values'. Adapting the system functions to requests of the medical environment is accomplished by evaluation. Evaluation steps are provided from 88% of the projects.

Also, integration of KBS in information systems is an essential prerequisite for applicability (e.g. see fig. 2.a and 2.b, the influence of integration on the consultation durations), but so far only 60% of the projects strive for it. This means, that there still is an immense necessity to act, as well as in the field of standardisation: apart from few exceptions, neither at the models and methods nor at the tools standards got their way. Standardisation is an essential prerequisite for aspects like communication, data and knowledge exchange, and integration (see [1]). By developing standards for medical fields (19% of the projects), medical care will become more transparent and controllable, resulting in an increase of the quality of care [5].

A further deficit for the application is that not all projects provide knowledge bases which are transparent for medical experts, aggravating the process of maintenance.

By increasing the cooperation with industrial partners and research and development activities of the EC (e.g. with the 'Telematic Application Programme'), MEDWIS stresses the application-oriented aspect of its research and, at the same time, tries to achieve a stronger alignment to international standardisation efforts (e.g. CEN TC 251).

To survey the further course of MEDWIS, its future research, and the application of its systems in clinical routine, the study will be repeated in a later phase of the MEDWIS project.

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