Knowledge-Based Medical System Integration to Foster Knowledge Transfer and Network Building

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Abstract— This paper describes projects that demonstrate applied knowledge management in medical engineering. It describes Stroke and Alzheimer portal system solutions, designed for patients and their families cope with their problems and help physicians in their treatment. A video conferencing system illustrates how specialists and general practitioners are connected superiorly. A readability test assists to prepare information in a package leaflet for patients. All described projects show that knowledge-based solutions can effectively support people in health matters. The outlook illustrates a comprehensive medical framework which facilitates knowledge transfer and network building between patients, relatives and medical experts.

Keywords— Knowledge-based Medical Applications, Medical Knowledge Integration, Readability Test, Medical Web Portal Solutions, Telemedicine

I. Introduction

Knowledge Management (KM) is the concept of business administration, but it is not limited to this area, it brings interesting ideas which could be useful for other sciences and areas. There are various definitions and discussions on what exactly KM is about [1, 2, 3, 4, 5, 6], the definition of KM and knowledge Based Systems (KBS) depend on the definition of knowledge. In practice, the terms knowledge, information and data are often used interchangeably.

A commonly held view with sundry minor variants is that data is raw numbers and facts, information is processed data, and knowledge is authenticated information. [8, 9, 11] In fact Data is unclassified and unprocessed values, a static set of transactional elements (such as Alice is 21 years old), or structured records of transactions. Information is meaningful collection of data which has been processed and organized. Knowledge is a set of understandings and the state of knowing gained through experience or study to use in decision making activities. It includes facts, opinions, ideas, theories, principles, models, ignorance, awareness, familiarity, understanding, facility, and so on. Knowledge is based on data and Information. Information Technology (IT) can convert data and information to each other, but it is not completely able to convert information to knowledge.

Because of that, we developed for medical scenarios a general technical architecture for patients and medical experts as shown in figure 1. Both user groups can access the health care portal services via the Internet using desktop PCs, laptops, smartphones and so on. Our portals provide a uniform graphical user interface, but users only can see the components they are allowed to. For instance, doctors get access to expert field reports while patients and family member can read progress reports which are penned by patients. Coming down with the same disease, the reporting patients got a lot of experience and knowledge in the course of time to give advice to other patients and family member. In our portals, expert and patient areas are strictly divided, so that unauthorized persons do not get access to patient data. Because of that we designed an access control list to make sure that sensitive patient information are protected.

Patient and family members can also access knowledge information via a call center. Especially the call center uses intelligent search engines and content based filtering to give the caller the information they need as fast as possible. But the call center provides also an emergency detection questionnaire. For example, the Stroke portal provides a questionnaire with ten questions. If one question is answered with yes by the caller, he will be redirected to the official emergency call. The questions are coordinated with our clinical partner. So every emergency detection questionnaire is unique and has to be verified by one of our medical partners.

If patients decide to visit the health care service via web portal, they have the opportunity to use a wiki (e.g. to inform about therapies), forum (e.g. to share experience) etc. All components give patients and family members more information about a disease, help to establish contact to other concerned persons and give them assistance at their everyday life.

Medical experts can be supported by anonymous field reports. In special cases doctors can compare their acute problem with the field reports of their colleagues. Besides that, health personnel have also access to external medical databases like pubmed or medline. So there is no need to visit all these sites in particular.

Our health care portal services give patients, family members and medical experts several opportunities to get information using one uniform user interface.

In the following, it will be shown how knowledge can be represented in medical applications associated to the users (e.g. patients or physicians). In this article, descriptions of a wide range of applications, such as for example a web-based portal system (e.g. StroPoS) or even a video conference system are written down. Not only ongoing projects, but also projects planned for 2012 will be presented.

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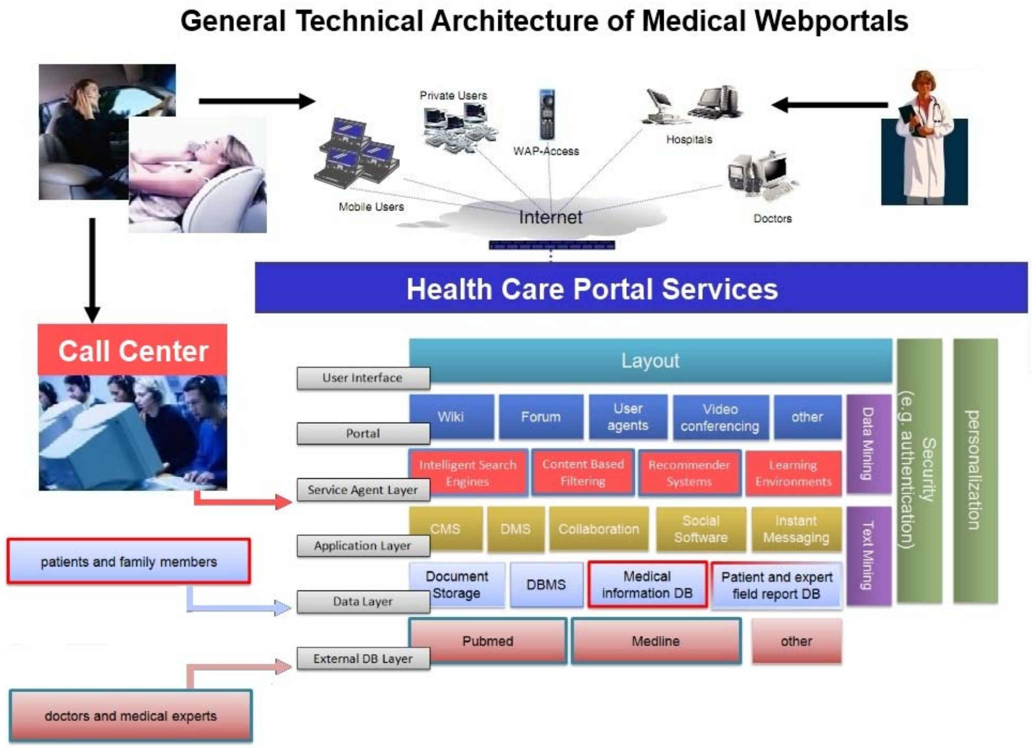

Figure 1. General technical architecture of medical portal services

II. KNOWLEDGE MANAGEMENT IN MEDICAL APPLICATIONS

Various fields of application, huge amounts of data and experts with specific know-how are the main reasons why medical research area can be seen as a precursor for other branches in applied KM. Evolutionary algorithms, fuzzy logic or neural networks have potentials in discovering new knowledge and can help medical practitioners in creating diagnosis for different diseases. For instance "integration of knowledge-based methods such as atlas-based approaches with Bayesian methods increases segmentation accuracy" [29] of diagnosis and treatment image evaluation of multiple sclerosis (MS) lesions, recorded by Magnetic Resonance Imaging (MRI) scans of the brain. [29]

Determining specific experts in a healthcare organization who have the knowledge on a certain issue (e.g. disease or therapy) is necessary to conduct a knowledge audit. This process is called “Knowledge Identification and Capture” and it is one of the important steps in Medical KM (MKM).

In the healthcare setting, knowledge creation can take place in terms of improved organizational processes and systems in hospitals, advances in medical methods and therapies, better patient relationship management practices, and improved ways of working within the healthcare organization.

A healthcare organization is a collection of professional specialists who contribute to the delivery of patient care, but also often act competitively inside the organization, without being willing to transfer knowledge because of associated status and power within the organization and the society. Effective knowledge management in Medical Application area, as well as in other branches, requires a “knowledge sharing” culture to be successful.

Knowledge application refers to taking the shared knowledge and internalizing it within one’s perspective and world-views. Knowledge-enabling technologies which can effectively be applied to healthcare organizations are: Groupware, Intranet, Collaborative tools and Knowledge Portals.

III. KNOWLEDGE BASED MEDICAL WEB-PORTAL SYSTEMS

By incorporating applied KM and medical science many fields of application can be discovered. Modern medicine generates almost daily, huge amounts of heterogeneous data [14]. Researchers and medical practitioners have to deal with data on one hand and with personnel know-how on the other hand. Knowledge discovery as an early step in the KM process transforms data into knowledge [14], and helps medical practitioners in that way to decrease information overload. Knowledge Management and Medical Engineering center (KMME) in corporation with some medical experts and clinical centers discovered a wide gap between raw data and concluded knowledge. Disparity of data collection and data comprehension makes computerized techniques necessary to help humans to address this problem [14]. In the following section the three projects of the KMME and another MKM project will be described shortly with their aims and benefits.

A. *StroPoS*

Stroke Portal System for emergency risk patients, which is called StroPoS, was implemented based on the concept of a corresponding portal solution [21]. The need for a portal like StroPoS results from serious influences strokes have on the society. Strokes are the fifth common cause of death in Germany in 2008 [25] and they are often affiliated with heavy disablements. Early diagnosis supported by a Stroke Portal System could decrease the costs of therapy and aftercare immensely. The architecture of StroPoS System has been illustrated in figure 2. Furthermore, a Stroke Portal System should offer a service which recognizes warnings. Concerning recognizing warnings, a Medical Call Center (MCC) with agents can help as well. The KMME developed several methods of KM within this portal which will be integrated and realized in the next steps of the project.

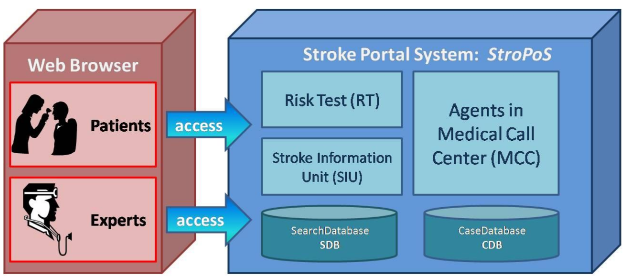

Figure 2. Architecture of the Stroke Portal StroPoS

Patients and experts can access StroPoS via Web browser. Some other components like the Risk Test (RT) and Stroke Information Unit (SIU) can be accessed by the MCC. The system is divided into two parts: Patient section and expert section. While patients have free access to information like definition and descriptions about the stroke disease, experts have to log in to get access to the expert area on the portal. After this authentication procedure they can use the case database (CDB), which includes patient case studies, as well as the search database (SDB) for DB queries. In the database experts can find special stroke cases. They can set up several parameters to localize a case. After making a case file anonymous experts also can upload their special case file to share these with other experts. The challenge was to implement a program structure by abstracting the anonymous example health records for entering, saving and comparing different courses of disease [20]. With the RT, users can test their stroke risk. The test contains ten questions which are easy to understand and to be proved by clinical partners of KBS group.

Users have also the opportunity to search for special stroke clinics. To find the nearest clinic, users only need to type their post code, therefore the system will find nearest stroke clinic.

Besides these aspects, APIs were developed as the basis for a video conference system. These APIs provide access to the CDB and SDB. The aim was to provide experts access to these components via the video conference system.

B. *DiProS*

Discus Prolapse System (DiProS) is another knowledge-based medical application implemented with KMME at the University of Siegen. The major goal of the project is to achieve a modular and structural portal in the field of disc herniation disease. DiProS focuses on allocation of reliable and authentic information supplemented by additional knowledge for experts and individuals, regardless if they are just interested or affected by spinal disc herniation. The offered information in the portal is extended by interactive services, which allow instantaneous contact to medical practitioners and make tele-medical consultation possible. Beside this methods for estimation of individual patients are offered in the portal.

The reuse of components like the case database or the forums saved a lot of time, but it also shows that the components can be reused in other projects.

Beside the well-proven components, new components have been developed. One of these new components is the navigation assistant which helps users to navigate through the system and find the information they need.

C. *AlWiP*

This project is another implemented project with KMME. The major goal of 'Alzheimer Wissens Portal' (AlWiP) project is early detection of Alzheimer disease indicators. Reasons, symptoms and factors of risk have to be evaluated through data and picture material (i.e. brain MRT's, course of brain alteration) in terms of correlation and integrated into the Knowledge portal as a decision support component.

The whole project is aiming for creating a knowledge management portal for the medical application of the Alzheimer disease. An image analysis of the brain, combined with information about the general state of health of patients can indicate the danger of coming down with Alzheimer.

The cooperation partners of the KMME were the Alzheimer and dementia specialists of the University of Cologne. With their help an Alzheimer knowledge database for users like family members of patients and experts was built, in which different forms of dementia were shown.

In the discussion area, family members are able to share their experience with other concerned persons. In this way, people can share their knowledge and find solutions for their special problems.

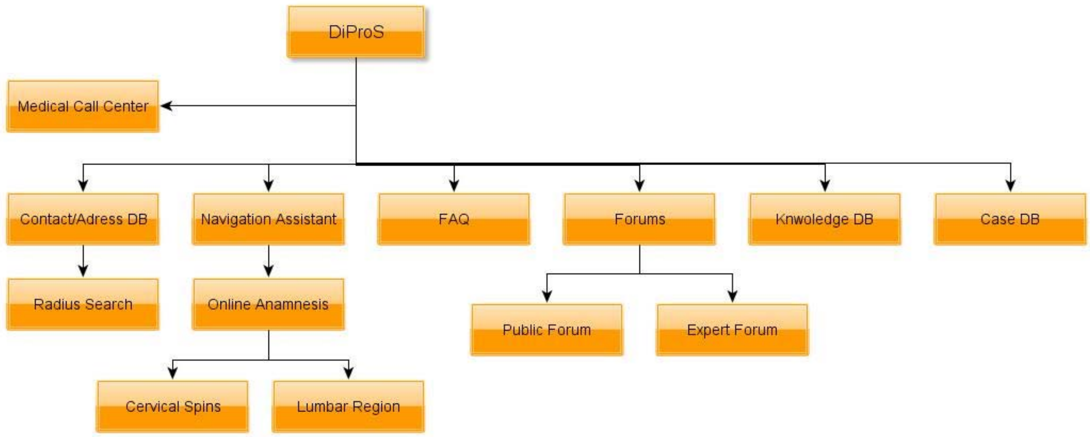

Figure 3. Diagram of the DiProS project

The portal should not replace other information sources like health personnel, expert's guides [16] or caregiver's guides [7]. In fact, the portal is planned as a knowledge platform which completes these traditional resources. Beside this, AlWiP is a quick and easy opportunity to get Alzheimer information on demand.

For best possible user support an intelligent assistant is implemented in the portal. It can be accessed via a web interface from every page of the portal. The program core consists of an AIML-based Chatbot which stands for 'Artificial Intelligence Markup Language'-based Chatbot. [30] The AIML-Chatbot has been modified to work in the portal environment. It enables the user to ask questions to the system in natural language, like "What is dementia?". By using pattern matching methods, the assistant returns an appropriate answer to the user input.

The already implemented features include an integrated spellchecker based on a performance-optimized Levenshtein-Algorithm. This enables the system to detect incorrectly spelled user inputs and offer a correction. Another feature is the ability to search the whole portal and external sources for articles related to the input terms. Currently supported external sources are Google and PubMed.

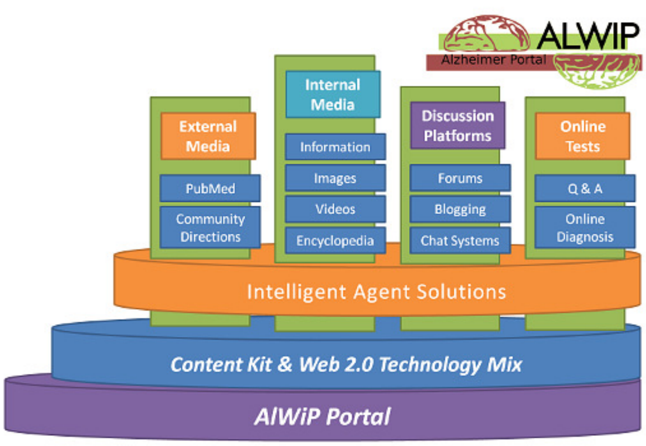

Figure 4. Alzheimer Knowledge Portal

The next feature planned is an integration of speech recognition and a text-to-speech engine to allow a mouse and keyboard independent use of the assistant. This step allows even better support especially for visually impaired users.

Another feature is that the assistant can read out articles and every text file on the portal. If there is reason why a user cannot read articles, it is possible for him to receive needed information by using the assistant.

D. *OncoDoc*

Developed and implemented in the Service d'Oncologie Medicale Pitie-Salpetriere (Paris, France) [12], OncoDoc is a decision support system designed to provide best therapeutic recommendations for breast cancer patients. While clinical trials offer cancer patients the optimum treatment, historical accrual of such patients has not been very successful. Developed as a browsing tool of a knowledge base structured as a decision tree, OncoDoc allows physicians to control the contextual instantiation of patient characteristics to build the best formal equivalent of an actual patient [26].

Originally published as textual documents, clinical practice guidelines have poorly penetrated medical practice because their editorial properties do not allow the reader to easily solve a given medical problem at the point of care [15]. OncoDoc has been developed as a guideline-based decision support system to provide best treatment recommendations [15]. It is non-automated and allows flexibility in guideline interpretation to obtain best patient-specific recommendations at the point of care [24]. Rather than providing automated decision support, OncoDoc allows medical practitioners to control the operationalization of guideline knowledge through his hyper-textual reading of a knowledge base encoded as a decision tree. In this way, physicians have the opportunity to interpret the information provided in the context of the patient, therefore, controlling the categorisation to the closest matching formal patient [15].

Within the tree (fig5) different parameters describe the actual state of a patient. The complete expansion of the decision tree can be seen as a patient centerd repository of all theoretical clinical situations that could be met within breast cancer pathology [26]. Recommendations based on the clinical state of the patient are displayed at the lower side of the decision tree (fig5) and the path through it represents the clinical profile of the patient.

The System has been tested at the Institut Gustave Roussy (IGR) with a before-after study in which treatment decisions for breast cancer patients were measured before and after using the system in order to evaluate its impact upon physicians' prescribing behaviour [24]. To assess how the system could be reused in another institution which was not involved in the development process, a new experimentation at IGR was conducted. Minor site-specific customisations of the knowledge base have been performed. After four months, 127 cases were recorded. Results showed that there was no significant difference of physician compliance with OncoDoc (85%) when site-specific recommendations were, or not, available, although local recommendations were chosen preferably (55%), thus legitimating the adaptation [12].

Summing up the system uses patient characteristics to disseminate between different treatments alternatives and furthermore offers matching clinical trials for the actual case. Physicians can be supported in that way to disseminate between next therapy steps.

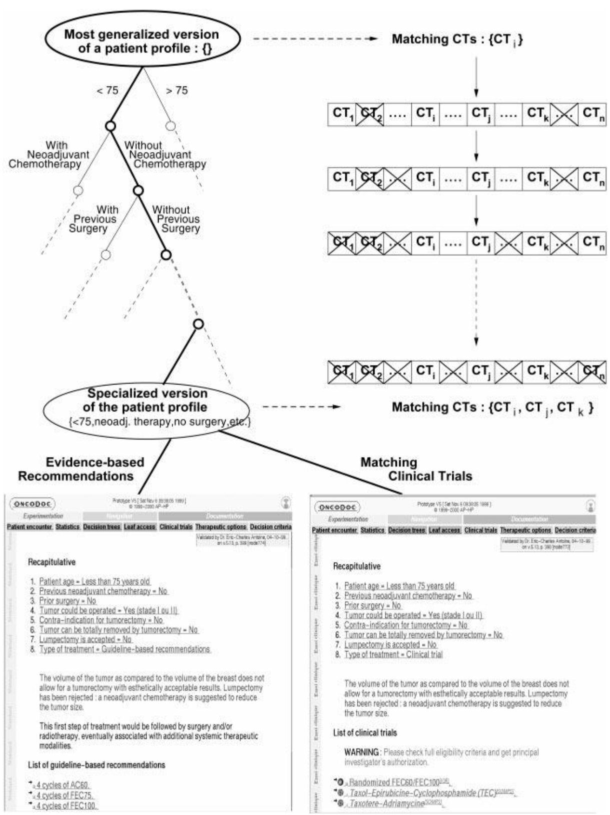

Figure 5. Representation of the process underlying eligibility criteria screening [26]

IV. KNOWLEDGE BASED MEDICAL VIDEO CONFERENCING SYSTEM

The video conference system is an extension of the 'StroPoS' project. Discussions with our cooperation partner Prof. Reul of the 'beta Klinik' (Bonn, Germany) showed unequivocally that it is desirable for hospitals that do not have a stroke center to provide the opportunity to contact a specialist for consultation in difficult cases very fast. Thus was born the idea of an audio-visual, medical conferencing system able to support with the help of doctors from medical stroke centers in other hospitals in the diagnosis and further treatment steps. For example, can thus be determined whether a patient will initially be examined with CT or MRI should be curtailed to the diagnosis. "This allows about 90% of all patients with a clinical picture of stroke in the anterior cerebral circulation primarily and study only with the MRI, without having to enter into a relevant time delay until the indication of thrombolytic therapy compared with CT." [22] An additional CT examination in this case would not be necessary. A wrong decision at an early stage not only costs valuable time, but worsened the long term prognosis.

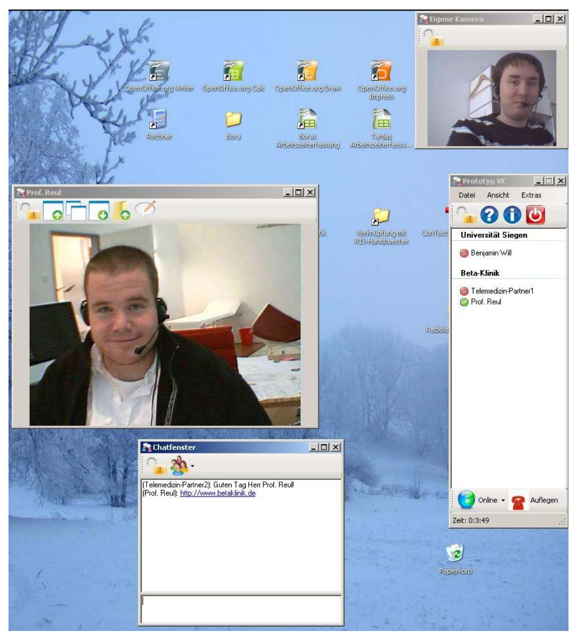

Figure 6. Videoconferencing-system in action while testing the installation before starting the testing phase in "Beta Klinik", Bonn (Germany)

"Because stroke symptoms can be well detected by video analysis and the data of the key imaging techniques (CT and MRI) can be transmitted digitally, stroke appears to be the ideal disease for a telemedicine application. [...] Also, stroke mimics' can be seen via telemedicine by experienced neurologists." [27]

Because a connection between the video conferencing system and the StroPoS database exists, a doctor can draw on the knowledge provided by the StroPoS database. Thus, the video conference system fits almost seamlessly into the project 'StroPoS' field. So it provides a targeted source of information for a doctor. The video conferencing system in combination with the stroke portal is a knowledge base for physicians.

The video conference system is currently in the testing phase and is well tested in beta clinic in Bonn (Germany). It is planned in the future to involve more hospitals and thus to build up a larger network.

V. Knowledge based readability test for package leaflets

Information for Patients must not only be made accessible, as seen in the medical portals like StroPoS, but also processed linguistically. The initial point for extending the general technical architecture will be an electronic readability test for package inserts. The techniques will later be found in our further medical Web service applications and architecture.

In addition to doctor and pharmacist, package leaflets serve patients as the main source of information. [10] This source of information appears to many patients like a closed book. Surveys of patient information leaflets revealed the technical terms as the main point of criticism, because they are not understandable to most end users. Therefore, patients' associations demand a German translation of technical terms in German package inserts. [18]

Despite the focus on the user, package inserts should be understandable for experts as well. Technical terms provide physicians and other health care professional information a colloquial equivalent cannot provide.

From July 2011, the Institute for Knowledge Based Systems from the University of Siegen will develop with the pharmaceutical partner 'MTW Gesundheit GmbH', a method for an electronic readability test. The test will be based on German language with the opportunity to expand the test for other languages or scenarios.

In the first phase, a list of criteria will be made. Although the elaboration of the pending list of criteria has not been started. But by now it can be roughly divided into two sections. The first is the formal and technical printing criteria to be mentioned. Among these target values for example, font and size are related. Properties of the information medium paper can be found among them as well. On the other hand, structural set of criteria can be incorporated in the section, Linguistic criteria'.

The criteria will be the basis for a software-based method. The software-based method will not only consider the latest scientific findings, but also the legal framework. Also regulations of public authorities are to be considered. [19] The now dominant cycle of trial and error in the transformation of package leaflet optimization would be broken and a targeted adjustment of leaflets would be feasible.

VI. Conclusions and Outlook

The projects, which were described in this paper, show that two groups of users exist in the medical field. On one hand doctors and on the other hand patients with their relatives. In each group, different aspects are considered. To ensure data protection, special protection mechanisms are required because physicians are working with sensitive patient data. For patients and family members information need to be processed so that they are understandable. At the readability test project, both groups use the same medium and the same information, so that a compromise has to be found between the different needs: simplicity for the patient, but still enough information for doctors.

It also shows that there are different ways to transfer knowledge. For example, through forums and wiki to patients or through the video conferencing system from one doctor to another. In combination with a knowledge portal as StroPoS a doctor receives new possibilities to get actual data for the treatment of a patient; therefore most of medical centers and doctors want to be real time and to be able to control their patients remotely and immediately (for instance using the videoconferencing system).

Our general technical architecture of medical webportals is the fundament to design other medical portals to help more patients with other diseases like 'Amyotrophic lateral sclerosis' (abbreviated ALS). It will also deal as fundament of an medical service framework to build up medical service networks e.g. a clinical diagnosis stroke network. The idea is that clinic administrators can choose which components their users need. By clicking on a check box they can choose to install for instance a forum or a wiki. Administrators can then decide to install a template structure or to build up their own structure for e.g. the wiki. In the future the framework should also give the opportunity to connect patient record databases of medical facilities. The goal is to connect as much clinics and as easily as possible. This increases the probability of documenting more cases which are outside the norm.

As medical reports showed, first minutes of the most medical attacks are very important for the consequences of disease. As an example, stroke treatment can be mentioned. The faster the treatment, the lower the risk of permanent damage ("time is brain"). When patients are living in their private areas, direct support of patient at the first minutes of attacks is not possible for the medical and support team, therefore having urgent remote controlling and guidance system could be more helpful to decrease consequences of disease. That is the basic idea of assisted living projects which is common in the most research institutes nowadays. It was also our initial point of idea to connect clinics as easily and effective as possible.

Since some disease need full time controlling and that is not possible for everybody to employ full time nurse, the importance of remote and intelligent controlling systems are clear for everybody. One example for these applications could be knowledge-based portals. They are able to share the knowledge of experts for individuals, exchange the professional knowledge between experts, find the best fit and nearest medical centers to patients, find and introduce special cases of diseases for experts, establish panel discussion between experts and individuals and so many other facilities. All of these services are using different categories and techniques of KM like content based filtering.

As a result the Institute of Knowledge-Based Systems of the University of Siegen summarized the characteristics of the different medical projects [21,28] around to a common architecture model as shown in figure 1. The goal for the next two years will be to focus all knowledge which the institute acquired about medical services for patients, family members and experts to develop an medical framework for medical services like expert field databases with content based filtering algorithms.

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