С Е К Ц І Я 1
ІНФОРМАЦІЙНІ СИСТЕМИ

INFORMATION SYSTEMS
S E S S I O N 1

Модель розумного медичного простору, що виконує автоматичне інтерв'ювання пацієнта

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У статті представлена архітектура і результати впровадження програм для розумного медичного простору (Повсюдний домашній лікарський кабінет - Ubiquitous Domestic Doctor's Office (UbiDoDo). Основною метою програми є моніторинг біомедичних параметрів пацієнта в його домашніх умовах в режимі реального часу. Це дозволяє негайно реагувати на симптоми і забезпечує засоби для автоматичного опитування пацієнта і доставку його результатів до лікаря. Ідея розумного медичного простору виникла в обширній сфері дослідження сфери охорони здоров'я і завдяки відмінним прикладам повсюдного використання компютерних технологій для охорони здоров'я

Основними функціями простору UbiDoDo є прозорий моніторинг і опитування пацієнта через природну розмову (що вимагає синтезу і розпізнавання мовлення). Модуль експертної системи програми адаптується в ході інтерв'ю згідно з історією біомедичних параметрів пацієнта і його відповідей. Після цього програма надсилає резюме лікарю, який вже має дані пацієнта, протокол інтерв'ю і набір пропонованих попередніх діагнозів.

У статті вивчаються питання вимог до персоналу і пацієнтів, модель програми і її інтеграція з роззосередженим серодовища, сформованого інтелектуальними просторами, лікарський кабінет і KASKADA (польська абревіатура для: контекстуальний аналіз потоків даних з відеокмер для додаткі негайного визначення) платформи на суперкомп'ютері Галера у Гданському університеті.

Велика увага приділяється дереву знань експертної системи, котре описує сценарій інтерв'ю і алгоритм рекомендацій щодо діагнозів. Були також запропоновані подальші удосконалення алгоритму, які базуються на аналізі статистичних даних.

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The design of an intelligent medical space supporting automated patient interviewing[1]

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The article presents the architecture and results of implementing an application for the intelligent medical space UbiDoDo (Ubiquitous Domestic Doctor's Office). The main purpose of the application is real-time monitoring of the biomedical parameters of a patient in his domestic environment. It allows an immediate reaction to appearing symptoms and provides means to automatically interview the patient and deliver his results to a medical doctor. The main functionalities of the UbiDoDo space include transparent monitoring, interviewing the patient through natural conversation and cooperation with the MedEye application that allows the doctor to access his patients' data, refer them for examinations and order automatic analysis of examination results on a multimedia processing supercomputer platform.

Much emphasis has been put on the construction of the expert system's knowledge tree which describes the scenario of the interview and the diagnosis recommendation algorithm. Further improvements to the algorithm based on the analysis of statistical data have been proposed.

Keywords – intelligent medical space, pervasive health, ubiquitous computing, supercomputer, medical interview

I. Introduction

Regardless of ongoing campaigns, promoted screening programs and simple common sense, people tend to neglect the regular examination of their health. Some programs, like the Polish National Program for Early Colorectal Cancer Detection have been unpopular mostly due to the discomfort caused by the colonoscopy. In addition, people often ignore minor or less bothersome symptoms or are not able to recognize them (e.g. slightly increased body temperature, fecal occult blood).

For representatives of the most typical high-risk groups, mainly – elderly people, potential risk factors are growing in number. It seems to be necessary to provide means for automatically measuring their biomedical parameters in order to speed up the diagnosis and detection of

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developing diseases. Computer-aided solutions, collecting and analyzing data from various kinds of sensors, can not only supply doctors with the most recent medical history, but also support them in making the diagnosis. The immediate access to the medical history and the most recent measurements of biomedical parameters turns out to be especially valuable as empirical data [1] connects the time spent on preliminary examination with the accuracy of the decision about the severity of the illness and the decision to hospitalize or not.

It is important to state that all of the presented solutions are only means of supporting medical doctors, not substituting them with a machine. Therefore, any automated reasoning performed by a machine still needs being verified by a specialist, who is personally responsible for the entire medical process of diagnosis and treatment. All computer based innovations are nothing but tools which allow a medical doctor to perform his work at the highest level possible.

The article presents an intelligent medical space [2][3] designed as a part of the Mayday Euro 2012 [4] project at the Gdańsk University of Technology. The medical system has reached an early prototype stage. It is able to identify a patient's presence, gather his data and interview him. In the meantime the medical doctor has access to all the data and interviews. The first results and issues are discussed below.

The following section introduces the intelligent medical space – UbiDoDo. Sections III and IV give a perspective on the architecture of the medical space and it's place in a broader medical system. Section V discusses all the aspects considered while designing a structure for describing interview scenarios, its final form and implementation. The last two sections present the results of implementing an application for performing medical interviews and present directions for further work and research.

II. Intelligent medical space

The intelligent medical space UbiDoDo (Ubiquitous Domestic Doctor's Office) is being developed to meet all the needs presented above on behalf of the groups at the greatest risk. It consists of set of sensors and dedicated applications that discreetly changes the living-space of the patient into a sophisticated environment which constantly and transparently monitors his health and stores all the observed biomedical parameters. This course of action is a part of the pervasive health field of research, which has developed intensively in recent years [5][6][7]. A similar approach was taken by other researchers designing projects like the Shimmer Wireless Sensors [8] from the Intel Corporation or the Healthy Aims project's Body Sensors networks [9]. The first one's main purpose is to provide various transparently working sensors for different applications – including medical ones. The second one is far more sophisticated and involves the use of medical implants.

An important property of UbiDoDo, is the sense of security that it creates for a patient. At any moment he can report his observed symptoms by starting an interview that will be performed by a virtual doctor. The assistant converses with the patient in a natural manner, by talking with a human voice and processing the spoken answers. Afterwards, the interview is saved and reported to the medical doctor responsible for the patient.

The work on the description of the interview scenario is one of the major parts of the efforts put into the current version of the intelligent medical space UbiDoDo. Normally, if a patient experiences some troubling symptoms, he eventually goes to a physician's office for a consultation. The main goal of the intelligent medical space UbiDoDo is to speed up that process by making it as easy and convenient as possible for the patient.

At the same time, the proposed procedure does not increase the effort of the doctor, allowing him to maintain the quality of his service. The doctor has access to his patients' data at all times through the MedEye application developed as part of the Mayday Euro 2012 project. It enables the doctor to browse through lists of patients, analyze their data, order examinations and their further analysis by the supercomputer Galera.

III. Architecture of the intelligent space

In the design phase of the project much consideration has been given to the distributed architecture of the system. The complete medical history of the patient is stored in his local database, on a dedicated computer. At the same time, there are applications and services being run locally and providing access to the local system to the doctor, assuring connectivity to the central part of the system, interviewing the patient and sending notifications about changes in his state. Fig. 1 presents the designed architecture of the system. The layer responsible for communication with the outside is especially worth noticing – it is implemented as a set of web services, hence providing the best possible versatility of the solution. Any major changes either at the side of the intelligent space or the doctor's office will be compensated by adapting this middle layer if possible.

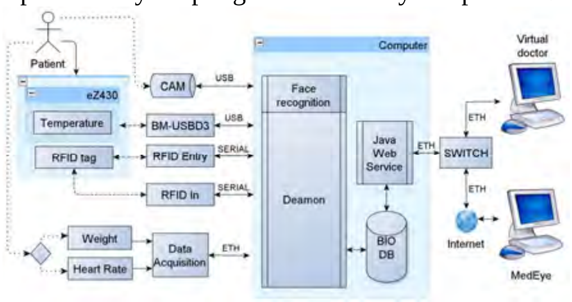

Fig. 1 Architecture of the medical space

The intelligent medical space UbiDoDo consists of a set of devices and sensors:

- an industrial computer (Advantech PCM 9584),
- a digital weighting scale (adapted SilverCrest scale),
- an internet camera (Logitech QuickCam 9000Pro)
- a RFID reader (CAEN A928EU),
- a wristwatch (Texas Chronos eZ430) containing:
  - a heart rate monitor (manually assembled),
  - a thermometer (A927Z Tag),
  - the patient's unique RFID tag (EPC C1G2 label).

The patient's biomedical parameters are measured after the RFID From this moment on, all the readings of weight and pictures are assigned to the recognized patient. At the same time, the system reads the body temperature and pulse measurements taken by the sensors in the watch. To ensure the transparency of the measures, the target plan includes installing the weighting scale in an unobtrusive place, e.g. as a tile in the flooring of a bathroom. The application acquiring the images of the patient for the skin color analysis is designed with similar transparency in mind. After being signaled about the patient's presence in the intelligent space, it starts the camera and runs a face recognition algorithm. After it determines the patient's presence in the frame it automatically acquires a picture of him.

IV. Integration with the KASKADA platform

The medical doctor has constant access to his patients' database through the MedEye application. He can refer a patient for further examination to acquire more data, e.g. a video of the patient's gastrointestinal tract from an endoscopic examination. The examination can be performed by traditional means (an endoscope) as well as using the innovative Wireless Capsule Endoscopy [10]. A capsule, swallowed by the patient, traverses his gastrointestinal tract filming its insights. The length of a single recording can be up to 8 hours. Its detailed analysis requires the medical doctor to spend up to 3 hours of work.

The MedEye application allows the doctor to submit a video for an automatic analysis by the KASKADA platform on the Galera [4] supercomputer. It is one of the crucial parts of the whole system, that consists also of the intelligent medical space hardware and the user's applications. Streaming of the data, advanced image processing and artificial intelligence algorithms allow fast processing of the acquired video. Therefore, the amount of work the doctor has to put into one examination is reduced significantly, down to a few minutes. The implemented algorithms allow the distinction of any lesion types introduced to the system. The first tests performed involved the recognition of polyps, ulcers, cancers and bleedings using well-known algorithms [11][12][13] for endoscopic video analysis.

V. Tree representation of the interview scenario

In the design stage a data structure had to be chosen for describing the interview scenario. It not only has to count in the natural means of interacting with the patient but also adapt the course of the interview to the answers given. No less important are incorporating all the collected history of the patient and taking into consideration a vast amount of diseases while limiting the number of questions asked. The assumption is that a healthy patient should not have to answer more than 15 questions from the main list (skipping all the additional questions detailing particular symptoms). The interview should take him 5-10 minutes – sufficiently short to ensure staying focused. The potentially ill patient would have to answer more questions to describe his condition in detail. Though, the awareness of a possible progressing illness should make him capable of focusing longer.

Various medical publications (e.g. [14]) contain sets of decision trees arranged by patient and ailment types. While they can be a solid basis for an interview scenario for the virtual doctor, they have to be adapted to the lack of possibilities to perform even basic examinations. Furthermore, the limited communication with the patient introduces a need to introduce a broad set of possible diagnoses into the final recommendation. Meanwhile, the available interview scenarios mostly lead to a single diagnosis.

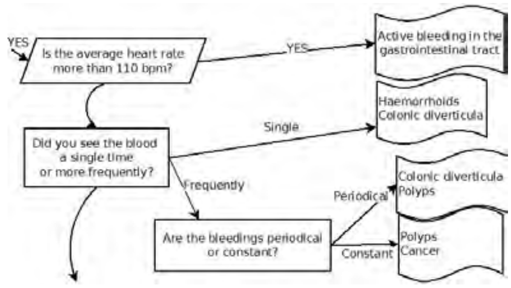

Fig. 2 Part of an interview scenario tree

Taking into account all the limitations stated above, a simple tree representation of the interview scenarios has been designed. Fig. 2 presents a piece of an exemplary interview tree. It contains all the elements an interview scenario tree consists of:

- A regular question (rectangular box) – a question asked to the patient. The outgoing straight arrows indicate the possible answers.
- An automatic question (inclined box) – it is not shown to the user, but the answer for it is acquired from the patient's data. It may have influence on the further course of the interview and/or on the final recommendation.
- A list of questions (question boxes connected with curved arrows) – after reaching a list the application traverses through all of its questions, one subtree at a time.
- The leaves of the tree – these vertices build up the final diagnosis recommendation. Each leaf contains a list of possible diseases. After the interview has been completed, all the diseases in the leaves reached are counted and the diagnosis recommendation is formulated.

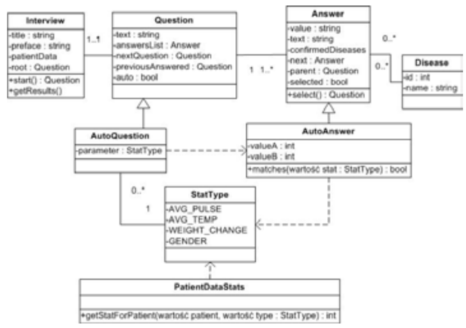

Fig. 3 Simplified UML diagram of the tree structure

That simple structure of the tree describing the interview scenario is described as an XML bean configuration of the Spring platform. Fig. 3 shows a simplistic UML diagram of the classes forming the structure of the interview. The helping class PatientDataStats is responsible for computing statistics for the automatic questions.

VI. Results

So far, the first prototype version of the intelligent medical space UbiDoDo has been created. In cooperation with a gastroenterologist an exemplary interview scenario for gastrointestinal problems has been produced. The main list consists of 11 questions, some of which may lead to a subtree to acquire more details. The average time of performing an interview is ca. 5 minutes. Possible mistakes made by the patient or the voice recognition have been taken into consideration, although the accuracy of the recognition is maintained at a relatively high level (above 90% after a short training). Nevertheless, the fairly simple language model used in the prototype version needs to be replaced by a more advanced one, as the target users will need almost perfect effectiveness. The limited set of commands used in the interview scenarios allows this future goal to be realizable.

The application MedEye has been supplemented with a component allowing accessing the basic data and medical history of the patient. The application also allows to analyze the video from endoscopic examinations – by oneself or by ordering an automatic analysis by the supercomputer platform KASKADA.

The complete system distinguishes itself with its convenience for the patient, who is not required to be accustomed to computer usage at all. Similarly, the interface of the MedEye application doesn’t call for any special computer abilities from the doctor. Therefore, the goal of providing a user-friendly and effective solution for performing automatic medical interviews and monitoring the state of a patient in his domestic environment has been achieved.

VII. Further work

Further efforts will be concentrated on improving the algorithm of creating a diagnosis recommendation. Currently, it considers solely the quantity of the indications. Therefore, qualitative aspects remain to be introduced. Every indication can be connected with appropriate statistical data, including the incidence and prevalence of particular diseases and the probability of the reported symptoms being related to them. Therefore, designing and implementing the algorithm for a weighted assignment of symptoms to diseases is one of the primary goals for further work. To conclude this goal the increase of accuracy of the recommendation will be researched afterwards.

The second direction of our research is going to be monitoring the state of the patient and detecting any aberrations from an established norm. This field introduces the possibility to incorporate the means of data mining and other artificial intelligence methods. Furthermore, to increase the usability of the system in real-life applications, implementing the HL7 specification for medical information exchange [15] is taken into account to introduce communication with dedicated diagnostic modules.

The algorithms on the KASKADA platform that are detecting lesions are showing a satisfying level of accuracy. Therefore, work in this area, rather than improving the existing algorithms, is going to be focused on extending the list of recognized diseases and the parallelization of the components of the system.

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