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SOME METHODS FOR DEVELOPMENT OF ANALYTICAL MODULE IN TELEMEDICINE SYSTEM FOR A CHILD MONITORING

Telemedicine system is system that provides distance medical help and wide application of these systems is started. In the paper two telemedicine systems for pediatrics and specifications of their development are considered. This system will be used for decision different aspects in pediatrics, but both of these systems have similar structure and include special analytical module. The analytical module is used for estimation of initial data and forming of preliminary decision about patient state. Two methods for development of the module are proposed. One of them is based on fuzzy decision trees and second is logistic regression for prediction. These methods are alternative and amplify with one another.

1. Introduction

Like most activities in society today, medical practice as well as research is intimately dependent on Information Technology (IT). One of tendencies of IT application in medicine is development of system to render medical help in distance [1]. There are many rural or sparsely inhabited areas, where access to specialized healthcare is limited or none, e.g. mountains, tundra, under-developed countries. There is a lack of experts, often only nurses in small medical centres, and patients must travel to larger cities, which often may take a lot of time that could prove fatal. For these regions, telemedicine projects could be a solution as they overwhelm distances and provide immediate responses. Another case is an area hit by a disaster, where electricity, network or traffic infrastructure can be damaged [2]. In this situation conditions are even worse than in cases above, making patient treatment a lot harder. Telemedicine applications will play an increasingly important role in health care and provide tools that are indispensable for home health care, remote patient monitoring, and disease management that encompasses not only rural health and battlefield care, but nursing home, assisted living facilities, and maritime and aviation applications.

Most of telemedicine systems include special modules for analysis of obtained data and information. Principal goal of these modules is useful for physicians in assessment of patient state and diagnostics. These modules allow: selecting the most important prognostic factors and their combinations for diagnostic tasks and for prediction of therapy outcome; extraction of knowledge from medical database in the form of interpretable linguistic classifica-

tion rules with interval values of prognostic factors, etc. In particular, the fuzzy logic, neural networks, genetic algorithms, decisions trees and other methods provide the necessary support for developing highly efficient automated diagnostic system for more accurate diagnosis. These methods have different characteristics, properties, and utilities that are dependent on decided problem. But it is very important to use correct methods for decision of specific problem of a telemedicine system. In this paper we consider development of two telemedicine systems that have special analytical modules for assessment of patient state. These systems are intended for application in paediatrics for children monitoring and are designed by the Siberian State Medical University (Tomsk, Russia) [3] and the University of Zilina (Zilina, Slovakia) [4].

2. Telemedicine systems in Paediatrics

Telemedicine systems are systems that provide distance medical help. Depending on a specific application, this service can be information spreading, examination result transfer, sharing medical records, audio/video consultations, surgeries etc. but usually more of them cooperating [5].

Application area of a telemedicine system has an important impact on the process of design and elaboration. Telemedicine systems from different medical domains are distinguished by structure too [2, 6]. Some general recommendations for elaboration of paediatric telemedicine system have been presented in [7]. In particular, next modules can be included in system:

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- *Growth Record*: Some diseases influence the child's height, therefore, it is important to keep track of it. Later, graphs can be generated from these data.
- *Development Milestones*: Some diseases can also influence the child's development, so proper records should be kept.
- *Immunization*: Immunization is one of priorities in paediatric HIV. The records should be stored to provide recommendations later or alert doctors.
- *Social History*: Information about child's life, e.g. people he/she lives with, socio-economic background, education information, details about previous care providers are gathered here.
- *Counselling information*: Evidence-based counselling using patient's socio-economic data and adherence relative information helps in providing healthcare.

Both doctors and patients benefit from telemedicine systems. They represent cost-effective, time-saving and quality enhancing way for providing health care. They may help avoid unscheduled visits or prevent frequent patient transportation. Let us consider some examples of paediatric telemedicine systems that demonstrate advantages of utilising ICT in medicine [8–12]. In paper [8], it is shown that by using telemedicine application real-time diagnosis can be brought to neonatal facilities without in-house paediatric cardiologists. Instead of using courier to deliver videotape, which is time-consuming, videoconferencing is preferred. Furthermore, improved education and monitoring of children with asthma have been shown to be highly effective in controlling symptoms and preventing failure of outpatient therapy. Using Internet-based applications this can be achieved.

The paediatric monitoring systems are used in different aspects of health care. It can be a simple consultation system for parents in the form of website. However, some complex systems allow obtaining a child diagnosis from distance. Systems usually specialize in helping with diagnosing a specific disease. They may be also used to educate both children and parents.

System for blood glucose measurement, developed by Gammon et al. [9], relies on mobile and wireless technologies. A designed device is used to automatically transfer readings from child's blood glucose monitor into his/her parent's mobile phone. This results in reassurance on parents' side and works as an aid in families' self-management of diabetes.

Chan et al. [10] created an Internet-based application for asthmatic children that provide therapeutic and diagnostic monitoring. It includes an asthma symptom diary and video transfer based on store-and-forward technology. Videos capture patients using their controller medication inhaler or peak flow meter use.

Telemonitoring has proved useful in improving care for high-risk infants. Program Baby CareLink was designed to provide enhanced medical, informational, and emotional support to families of very low birth weight infants during and after their neonatal intensive care unit (NICU) stay [11]. Parents have access to virtual visits during an infant's hospitalization or remote monitoring after discharge.

A telemedicine system for HD teleconferences has been used in Chillicothe, Ohio (USA). It allows real-time consultation with neonatologist or paediatric cardiologist resulting in more precise and quicker diagnoses. The project enables specialists in Columbus, Ohio, to view distressed newborns with exceptional clarity, examine detailed x-rays, view lab results and consult with attending physicians in Chillicothe in real-time [12]. The system includes typical workplace of doctor for distant consultation (Fig.1).



Fig. 1 Doctor using teleconsultation, the upper display showing his motions, the lower specialists [12]

3. Development of telemedicine systems for child monitoring

Let us consider another system for child monitoring elaborated for the Neonatal Department of Zilina clinic (Fakultna nemocnica s poliklinikou Zilina) by a team from the University of Zilina. This system is designed to act as an information system concerning newborn healthcare. Healthcare is also about prevention, therefore, systematic education is needed. The main aim was to develop a consulting system with a doctor, by which the patient could get information about health care without need to personally visit a specialist. By using it, it is possible to educate as well as interactively solve the newborn care issues raised.

The basic prototype of the system consists of three parts:

- article section* where a user can obtain information in a passive way in the form of articles published by the administrators
- discussion section* where a user can actively join on-line discussion and get the answers for specific questions from a specialist or other patients
- administration section* where access is limited only to the persons assigned with administration task

The *Articles section* of this system provides a convenient interface for reading, searching filtering and articles. The user has access

to the latest report of published articles, but also to the archive. To facilitate the search a collection of the most frequently entered phrases and a list of the most read posts are available. Group of the chosen articles will still be on hand as reference

The *Discussion section* was added to the system to provide a place for the laymen or the specialists to exchange their knowledge. It was intentionally divided into these groups as there are topics dedicated to either group. If a topic is dedicated to the specialists, this topic is read-only for laymen. The distinction between these types of users is made during a registration process.

The *Administration section* was developed to allow assigned persons to add new content to the system. The interface for creating, editing and deleting articles was provided. Articles can contain images to graphically support the text. In this system part it is also possible to manage the administrators' accounts but only for a super administrator.

This system is currently in the development phase. It was launched temporarily to gather information from the Neonatal Department, e.g. user-friendliness, website design etc, as the system is being developed for it. The foundations for an information system have been laid, which in future may be extended to support other forms of consultation (video/audio), storing health records, etc. in order to increase the quality of healthcare. Another extension will be elaboration and design of the analytical module for child health examination. The basic conceptions and principal methods for this module development were presented in [4, 13]. The *Analytical section* will be elaborated in the system for this module. The principal goal of this section is preliminary examination of child health before visit to clinic.

4. System for monitoring and Assistant for paediatrician (ASSPED)

The system ASSPED is a complex paediatric decision support system that is developed and used in Tomsk region (Russia) [3]. This region covers an area over 300 000 km², with the most of it inaccessible due to taiga and swamps. The combination of these factors opens an opportunity for the use of telemedicine. A lot of the residences possess only small medical centres. For more difficult cases an advice or intervention from a specialist is needed. Transportation is a burden; both financial and physical, therefore, if possible it should be avoided. The system mentioned above could be a solution as its main function will be to assess the seriousness of a case. Therefore, the monitoring telemedicine system is the principal component of the ASSPED. This component is meant for the monitoring of children health for early detection of disease and include a special analytical module for definition of a patient state. Results of preliminary medical checkup are used for analysis. Temperature, pulse, coverlet and similar data form initial information for analysis. X - ray investigation, blood test and urine analysis are included in preliminary examination too if these results were implemented as a preliminary. Based on the analysis of initial

information the analytical module detects the state of a child health by four levels:

Normal (green): The patient can receive health care in a basic medical centre or does not need medical help.

Intermediate (yellow): The patient needs some medical observation and this patient state requires control in a basic medical centre or by telemedicine centre in some time.

Monitoring (blue): The patient needs a treatment and will be monitored by the telemedicine system continually.

Hospitalisation (red): The patient needs hospitalisation immediately.

This information is obtained and analysed by a physician-analyst that has possibility to confirm or to change a derived patient state. After this control the decision about the child's health is sent to the basic medical centre.

Therefore, the analytical module for detection of the patient's health state is important for correct functioning of the ASSPED system.

5. Methods for development of analytical module of the telemedicine system

Two principal methods were used in the development of analytical modules in the ASSPED system and in the developed telemedicine system presented above in section 2. The first of these methods is a logistic regression [3]. The second method is Fuzzy decision tree (FDT) [14]. The decision about a patient's health state is implemented by these methods independently (Fig. 2). But results of both methods are analyzed and definitive decision is determined by the special weight algorithm that will be elaborated in step of the module testing.

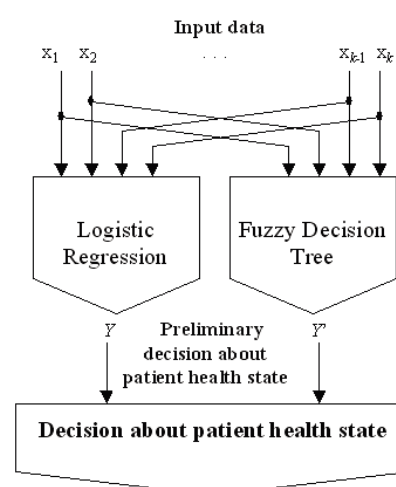


Fig. 2 Structure of the analytical module of the telemedicine system

Logistic regression is a mathematical technique used to make prediction. It is used in medical and social sciences, but also in marketing applications. The main principle of logistic regression is a logistic function. The input, z , of the logistic function is a set of independent variables. There is a coefficient associated with each independent variable that expresses contribution of this factor to the overall result, called *regression coefficient*. The output, Y , of the logistic function is a binary variable expressed by probability, meaning an interval $(0, 1)$.

$$Y = \frac{1}{1 + e^{-z}}, \quad (1)$$

where $z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \dots + \beta_k x_k$; k is the number of input variables; β_0 is a value of z when all independent variables are zero.

Variables x for the developed modules were indicated as results of a preliminary medical check-up and their values were defined along with doctors. The Y is the level of a patient's health state and has four values.

The application of the logistic regression in the ASSPED system allows improving the detection of a patient's health state in comparison to the heuristic methods [3]. But the next step of this module development can be the combination of two methods for decision support. The FDT can be used as additional approach for this module. The FDT was used as a basic method in the development of nomogram for prostate cancer detection [4, 14] and now is used for analytical decision in the produced telemedicine system (section 3).

Induction of FDT is a useful technique to find patterns in data in the presence of imprecision, either because data are fuzzy in nature or because we must improve their semantics. We proposed the algorithm to induction of new types of FDT: unordered, ordered or stable FDT [15]. The use of our cumulative information estimations allows to precisely estimate mutual influence of attributes [14, 15]. We introduced also the cost of diagnostics into classification algorithms. Our algorithm has a minimum cost of decision process based on different criteria of optimality.

In the FDT, each non-leaf node is associated with an initial attribute A_i . When A_i is associated with a non-leaf node, the node has m_i outgoing branches (m_i is number of possible values of attribute A_i). The j -th branch of the node is associated with value $A_{i,j}$. The class attribute B has m_b possible values $B_1, \dots, B_{j_b}, \dots, B_{m_b}$. Let the FDT have R leaves $L = \{l_1, \dots, l_r, \dots, l_R\}$. There is also a vector of values $F_r = [F_1^r, \dots, F_{j_b}^r, \dots, F_{m_b}^r]$ for each r -th leaf l and each j_b -th class B_{j_b} . Each value $F_{j_b}^r$ means the certainty degree of the class B_{j_b} attached to the leaf node l_r .

In fuzzy cases, a new instance e may be classified into different classes with different degrees. Then, each leaf $l_r \in L$ corresponds to one (r -th) classification rule. The condition part of the classification rule is a group of conditions presented in the form "attribute is attribute's value" and those conditions are connected with an operator.

These attributes are associated with the nodes in the path from the root to the leaf l_r . The attribute's values are the values associated with the respective outgoing branches of the nodes in the path. The conclusions of the r -th rule are the values of the class attribute B with their truthfulness vector F_r values.

For example, the path $Pr(e) = \{[A_{i_1,j_1}(e)]^r, \dots, [A_{i_{s,j_s}}(e)]^r, \dots, [A_{i_{S,j_S}}(e)]^r\}$ from the root to the r -th leaf. This path $Pr(e)$ consists of S nodes which are associated with attributes $A_{i_1}, \dots, A_{i_s}, \dots, A_{i_S}$ and respectively their S outgoing branches associated with the values $A_{i_1,j_1}, \dots, A_{i_s,j_s}, \dots, A_{i_S,j_S}$. Then the r -th rule has the following form:

IF (A_{i_1} is A_{i_1,j_1}) & ... & (A_{i_s} is A_{i_s,j_s}) THEN B (with truthfulness F^r).

Our approach uses several classification rules for classification of a new instance e . That's why there may be several paths whose all outgoing node's branches are associated with values $A_{i_{s,j_s}}(e)$ greater than 0. Each path $Pr(e)$ brings about leaf node l_r and corresponds to one r -th classification rule. In this case each r -th classification rule should be included in the final classification with a certain weight $W_r(e)$. The weight is for instance e and the r -th rule is given by the

rule $W_r(e) = \prod_{s=1}^S [A_{i_{s,j_s}}(e)]^r$, where $[A_{i_{s,j_s}}(e)]^r$ is the value of the attribute A_{i_s} for the new instance e . The weight $W_r(e)$ is equal 0 if there is an attribute's value $A_{i_{s,j_s}}$ whose membership function equals 0. Values of class attribute B for the new instance e are: $\mu_B(e) = \prod_{r=1}^R W_r(e) \times F^r$, where F^r is the truthfulness of the r -th rule.

Therefore, two methods for elaboration of analytical module for telemedicine system are considered in this paper and will be used in real application. The output of these methods will determine if a patient should be treated locally, be monitored or immediate transportation is required. Using this information, medical staff can decide on the next stage of treatment more responsibly and greater attention can be paid to a patient's health.

6. Conclusion

We induced telemedicine and telemedicine systems as a possible tool for remote diagnosis and rendering a medical help on distance. We presented a web-based paediatric telemedicine system that allows consultation as well as educates. Web-based applications are widely spread therefore they can be reached by majority of population and this approach can contribute to higher quality of health.

The system ASSPED is a complex system that offers recommendation about child's health. This information about patient's state is based on analysis of results of a preliminary medical check up. A physician can confirm or change a derived patient state and this decision is stored at the basic medical centre.

An analytical module for child monitoring was proposed that utilises two methods: logistic regression and Fuzzy decision tree. Logistic regression is a technique used for prediction. Fuzzy decision trees are able to deal with imprecise real life data and are based

on fuzzy classification rules. These methods work independently. However, their results are analyzed together and the final decision is made.

References

- [1] ACKERMAN M. J., BURGESS L. P. et al. *Developing next generation telehealth tools and technologies: Patients, systems, and data perspectives*. *Telemedicine and e-Health*, 16(1), 2010, pp. 93–95
- [2] BASHSHUR R.L., SHANNON G.W. *History of Telemedicine*. Evolution, Context, and Transformation. 2009, 466p.
- [3] KOLOMEJCOV A.O., SIZOV E.E. *Implementation of logistic regression statistical method for definition of children groups with high risk of disease*. In *Proc. of the 16th Int. Conf. on Modern Technique and Technologies*, Vol. 2, pp. 40–42 (in Russian).
- [4] ZAITSEVA E., MATIASKO K., DOBROTA D., *A Decision Support System for Early Diagnostics in Oncology*. In *Proc. of the 2nd Int. Conf. on Advanced Information and Telemedicine Technologies for Health (AITTH-2008)*, 1–3 October, Minsk, Belarus, 2008, pp.117–121.
- [5] GRASCHEW G., ROELOFS T.A., et.al. *2020 - New Technologies for the workplace of the physician of the future*. In *Proc. of the 5th Int. workshop on Digital Technologies*, 20–21 November, Zilina, Slovakia. 2008.
- [6] TULU B., et al. *A Taxonomy of Telemedicine Efforts with respect to Applications, Infrastructure, Delivery Tools, Type of Setting and Purpose*. In: *Proc. of the 38th Hawaii International Conference on System Sciences*, 2005
- [7] PAUL, S.; BHATTACHARYA, S.D et al. *A web-based electronic health care system for the treatment of paediatric HIV*. In *Proc. of the 11th International Conference on e-Health Networking, Applications and Services*, 16–18 Dec., 2009, pp.175–180.
- [8] SABLE C., CUMMINGS S., et al. *Impact of Telemedicine on the Practice of Paediatric Cardiology in Community Hospitals*, *Paediatrics*, Vol. 109, No. 1, 2002, pp.e3.
- [9] GAMMON D., ÅRSAND E., et al. *Parent-Child Interaction Using a Mobile and Wireless System for Blood Glucose Monitoring*, *Journal of Medical Internet Research*, Vol. 7, No 5, 2005, pp. e57.
- [10] CHAN D., CALLAHAN C., et al. *An Internet-Based Store-and-Forward Video Home Telehealth System for Improving Asthma Outcomes in Children*. *American Journal of Health-System Pharmacy*, Vol. 60, No. 19, 2003, pp. 1976–1981.
- [11] GRAY J., SAFRAN C., et al. *Baby CareLink: Using the Internet and Telemedicine to Improve Care for High-Risk Infants*. *Paediatrics*, Vol. 106, No. 6, 2000, pp. 1318–1324.
- [12] BARBER P., DOVYAK J., MANTEY S. *HD videoconferencing links critical care newborns from rural hospitals to tertiary care facilities, specialists*, 2008. Available on internet <<http://www.telehealthvrc.org/news/2008/telemedicine.shtml>>
- [13] LEVASHENKO V., ZAITSEVA E., et al. *Nomogram for assistance in treatment of prostate cancer*. In *5th International workshop on Digital Technologies (DT 2008)*, 20–21 November, Zilina, Slovakia, 2008.
- [14] LEVASHENKO V., ZAITSEVA E., *Usage of New Information Estimations for Induction of Fuzzy Decision Trees*. In *Proc. of the 3rd IEEE Int. Conf. on Intelligent Data Engineering and Automated Learning*, Kluwer Publisher, pp. 493–499, 2002.
- [15] LEVASHENKO V., ZAITSEVA E., PUURONEN S. *Fuzzy Classified Based on Fuzzy Decision Tree*. In *Proc. of the IEEE International Conference on Computer as a Tool*, pp. 823–827.