The intellectual information system of medical aid control in the scope of Russian medical insurance

M A Taranik[1], V A Silich[1], M P Silich[2]

Tomsk Polytechnic University, 30, Lenina ave., Tomsk, 634050, Russia
Tomsk State University of Control Systems and Radioelectronics, 40, Lenina ave., Tomsk, 634050, Russia

E-mail: taranik@tpu.ru

Abstract. The article presents the developed intellectual information system, oriented for healthcare providers. The system solves a problem of medical aid quality control in the Russian medical insurance sphere. The main components are ISO13606, fuzzy logic and a case-based reasoning concept. The system provides medical insurance payments forecasting by the analysis of medical records and generates two evaluations based on medical standards and a set of precedents. The result of the system implementation allowed up to a 10% increase in insurance payments for the healthcare provider.

1. Introduction

Medical insurance companies take one of the major places in the Russian medical insurance system [1]. They provide medical aid quality control of the healthcare provider, based on the expert's accuracy evaluation of electronic health records (EHR). The evaluation significantly effects the medical service's insurance payments [2]. The relevance of the healthcare provider's insurance payments saving by increasing EHR accuracy determines the relevance of special software development for insurance payments forecasting.

A medical expert is the main person, who makes decisions in the process of EHR control in the medical insurance sphere. Therefore, the human factor forms an uncertainty. Early researches allow concluding, that there are differences in medical expert's opinions [1]. Thus, the existence of uncertainty does not allow applying classical medical information systems for health care medical aid quality control. The solution is to use methods of artificial intelligence. We analysed the medical systems, which use these methods to solve such clinical problems as disease diagnostic [7, 9, 11], prediction [8], classification [10], management [12], tutoring [13]. Presented systems are based on the different models: fuzzy logic [11], a support vector machine (SVM) [10], Bayesian networks [9, 13], case-based reasoning (CBR) [12] and data mining methods [8].

The existence of uncertainty and complexity of the subject area formalization defines the relevance of a hybrid inference model for system development. Uncertainty is a result of a human factor – a medical expert's opinion, based on the experience and documents (medical standards). However, medical standards include a fuzzy weight coefficient of presented medical services. Therefore, Fuzzy logic [3] was determined as the basic component. It provides an effective inference based on the expert's knowledge and medical standards in uncertainty conditions for medical aid quality control and insurance payments forecasting. A set of analysed EHR consists of medical expert's knowledge, which can be used as an effective addition to fuzzy logic. So, Case-based reasoning [4, 5] technology was determined as another component of the system's hybrid model. The CBR paradigm in medicine is a comparison of the researched medical case with the most suitable theory in the database concerning the fact that the result of the researched case will be the most identic to the result of a precedent. A clinical precedent was determined as a medical case, which was an object of quality and nonconformity control with formed actual amount of insurance payments.

So, the developed system is based on the two different approaches for insurance payments forecasting: medical standards (explicit knowledge) and precedents (implicit knowledge). It provides a monitoring of the medical aid quality control process in the scope of the Russian medical insurance program. Here the main system components are: fuzzy logic (Mamdani algorithm), a CBR concept and European medical standard ISO 13606 [7], used for storing and transmitting medical data.

2. Materials and methods

In our work, we used a combination of methods of medical data presentation and processing. Medical data were defined in several structured entities such as: a medical standard, a medical case and a clinical presedent. For the entities structure definition, the archetype model of the ISO13606 international standard was used. The physical storing process of medical entities was provided by the SQL database. The medical data processing in the present work was synthesised with a CBR approach and fuzzy inrefence. CBR allows obtaining the closest medical cases from the precedent base using Euclidean metric with 5% restriction of the minimal distance between the analysed medical case and stored clinical precedents. The Euclidean distance calculation is based on the formalized medical case and clinical precedents. The formalization allows presenting these entites in vectors. The final set of the closest clinical precedents are processed by fyzzy logic for medical case quality evaluation and output insurance payments forecasting.

3. Results

The concept of developed intellectual information system is presented in figure 1. Medical standard-based medical insurance forecasting consists of 4 iterations and a precedents-based one – of 6 iterations.

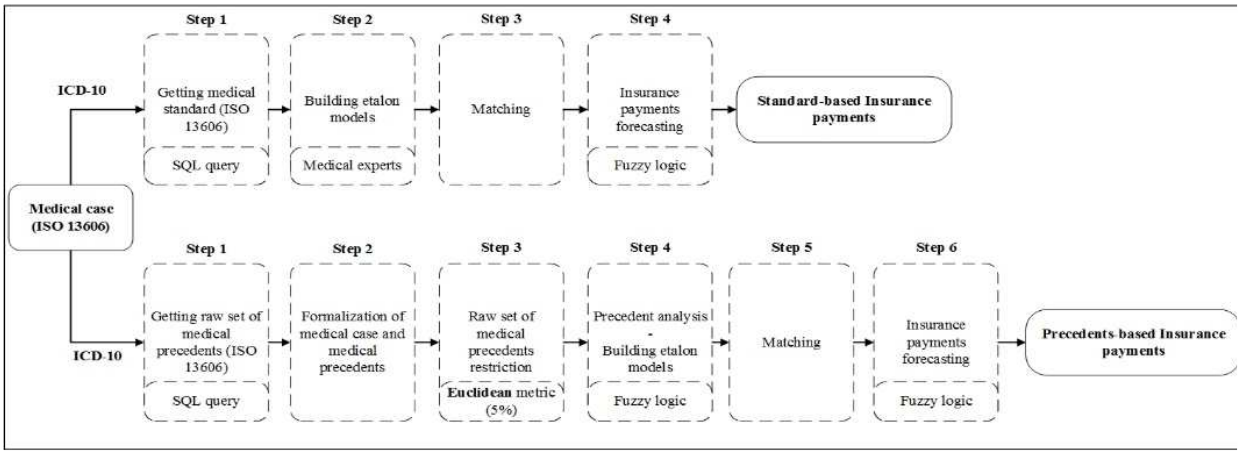

Figure 1. The concept of the intellectual information system of medical aid control in the scope of Russian medical insurance.

The algorithm of clinical precedents analysis restricts the raw set of medical precedents by calculating Euclidean distances between the formalized medical case and clinical precedents. Further analysis defines the most common entities (medical documents, medical services, medical drugs and laboratory tests) which were included in clinical precedents. For each entity, the weight coefficient is formed. A set of entities with coefficients defines an etalon model. A process of matching is a contents verification of the medical case and the etalon model, where deviations characterize nonconformities of the medical case. The fuzzy algorithm forms a value of insurance payments at the last stage. Therefore, the system allows getting two values of insurance payment based on the implicit and explicit medical knowledge.

The developed intellectual information system was implemented in the Institute of Microsurgery (Tomsk, Russia). The Institute provides hundreds of different surgeries each month. At the end of the month, medical insurance companies provide accuracy evaluation of all institute's EHRs. For system implementation, we used the Institute's clinical precedent of 2014. The developed system's algorithm was evaluated on the basis of this training set. The evaluation allowed defining the estimation accuracy by comparison of real results of the medical aid control process and actual amounts of insurance payments. After the series of experiments based on all medical cases of 2014, the following results shown in table 1 were obtained.

Table 1. The results of system implementation

Month	Insurance payment	Fact insurance payment	Precedent-based insurance payments forecasting	Standard-based insurance payments forecasting
January	1453078.95	1426719.097	1426719.097	1412451.906
February	1243769.37	1232996.397	1214501.451	1202356.437
March	1416603.47	1400698.491	135877.536	1317917.21
April	1840312.09	1815457.909	1815457.909	1815457.909
May	2073797.2	2064890.412	2064890.412	2064890.412
June	1574380.83	1555655.37	1555655.37	1540098.816
July	968507.14	840821.974	815597.3148	815597.3148
August	861201.62	853895.934	853895.934	853895.934
September	1293392.96	1279205.718	1260017.632	1247417.456
October	1214080.05	1204261.377	1168133.536	1156452.2
November	1402607.06	1388928.78	1347260.917	1306843.089
December	1408544.94	1385058.59	1385058.59	1371208.004

As a result, we can conclude that there is an insignificant divergence between insurance payments computations using clinical precedent analysis and medical standards. In the way of using clinical precedents, the forecast is more precise. All medical cases received insurance payments values are conformed to the real values from the training set of 2014. The results are presented in figure 2.

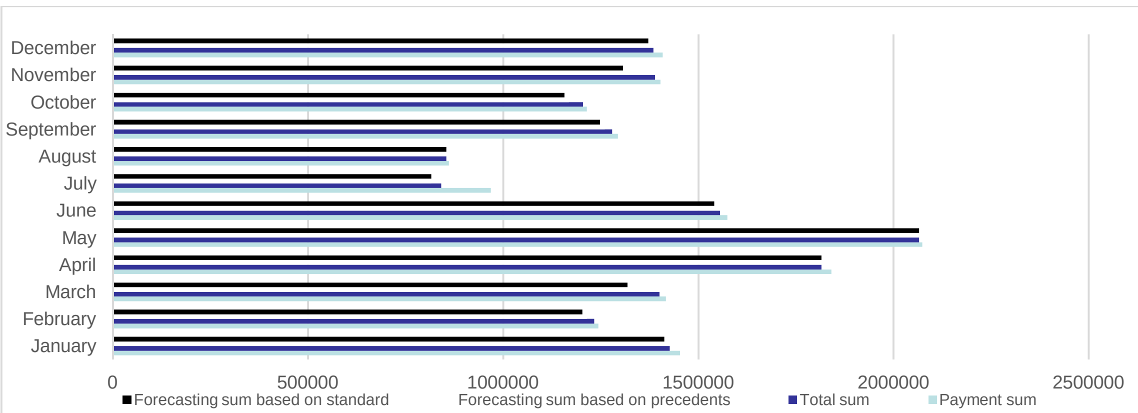

Figure 2. Graphical results of system implementation.

Insurance payments forecasting of the developed system is based on the differences recognition between the etalon model and the formal model of the researched medical case. The conclusion of the end of the first stage of implementation is that the results of the inference engine comply with the fact. This confirms the accuracy of the developed algorithm.

The system implementation in the Institute of Microsurgery’s cure process in the beginning of 2014 would allow a significant decrease of the total sum of deduction from insurance payments. The data are described in table 2, where the graph «fine sum after implementation» (figure 3) shows a value of insurance deductions in case of timely correction of medical cases EHR.

Table 2. Comparative analysis of the results before and after implementation

Month	Fine sum before implementation	Fine sum after implementation
January	26359.853	10016.74
February	10772.973	7002.43
March	15904.979	8111.54
April	24854.181	10190.21
Mai	8906.788	1068.81
June	18725.46	0.00
July	2990.136	508.32
August	7305.686	3068.39
September	14187.242	7093.62
October	9818.673	0.00
November	13678.28	6018.44
December	23486.35	6106.45

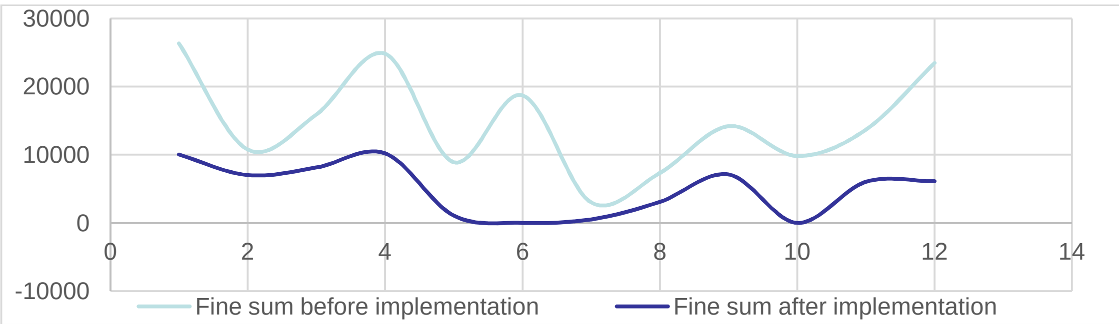

Figure 3. Graphical results of comparative analysis before and after implementation.

The key results of intellectual system implementation in the Institute of Microsurgery:

- The possibility of the fact insurance payments forecasting was realized locally by EHR accuracy evaluation;
- The percent of insurance payments for medical aid was increased by timely correction of medical cases EHR;
- The implementation on the intellectual information system of medical aid control in the scope of the Russian medical insurance allowed a decision-making process on different administrative levels.

4. Discussion and Conclusion

The hybrid inference engine of the developed medical intellectual system can be also applied to other solutions in public health. Thus, the using of the ISO13606 standard allows describing any objects of any area, and the process of formalization will be similar. So, the hybrid inference method based on fuzzy logic, CBR and the ISO13606 standard can be used for different relevant problems which require a decision-making process. The method, described in this research, has demonstrated an effectiveness of insurance payments forecasting by the example of the scoped medical data set. For further work, the method functional can be widened for the decision-making process of a higher level.

References

[1] Taranik M.A., Kopanitsa G.D. 2015 Analysis of the process of control quality of medical service in the scope of compulsory health insurance program, *Journal of control and computer science* **3 (32)** 75–85
[2] Kopanitsa G., Yampolsky V. 2015 Approach to extract billing data from medical documentation in Russia – lessons learned. *Studies in health technology and informatics* **2010** 349–353
[3] Zadeh L.A. 1965 Fuzzy Sets. *Information and Control* **8** 338–353
[4] Haghighi P, Burstein F, Zaslavsky A, Arbon P. 2013 Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings. *Decision Support Systems* **54** 1192–1204
[5] Gonzalez C, Lopez DM, Blobel B. 2013 Case-based reasoning in intelligent Health Decision Support Systems. *pHealth: Studies in Health Technology and Informatics* **189** 44–49
[6] Kopanitsa G., Taranik M. 2015 Application of ISO 13606 archetypes for an integration of hospital and laboratory information systems. *Information and software technologies* 29-36
[7] Sengur A. 2008 An expert system based on principal component analysis, artificial immune system and fuzzy k-NN for diagnosis of valvular heart diseases *Computers in Biology and Medicine* **38** 329–338
[8] Yeh J, Wu T, Tsao C. 2011 Using data mining techniques to predict hospitalization of hemodialysis patients *Decision Support System* **50** 439–448
[9] Arsene O, Dumitrache I, Mihu I. 2011 Medicine expert system dynamic Bayesian Network and ontology based *Expert Systems with Applications* **38** 15253–15261
[10] Chao P, Wang C, Chan H. 2012 An intelligent classifier for prognosis of cardiac resynchronization therapy based on speckle-tracking echocardiograms *Artificial Intelligence in Medicine* **54** 181–188
[11] Pal D, Mandana K, Pal S. [etc.]. 2012 Fuzzy expert system approach for coronary artery disease screening using clinical parameters *Knowledge-Based Systems* **36** 162–174
[12] Haghighi P, Burstein F, Zaslavsky A, Arbon P. 2013 Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings *Decision Support Systems* **54** 1192–1204
[13] Suebnukarn S, Haddawy P. A 2006 Bayesian approach to generating tutorial hints in a collaborative medical problem-based learning *Artificial intelligence in Medicine* **38** 5–24