Empowering Clinicians by eHealth Technologies in Decision-Making Tasks

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Abstract. We present three types of eHealth applications that can enhance quality of clinical decision-making. Formalized electronic medical guidelines are bringing medical knowledge close to clinicians. eHealth tools for evaluation knowledge and competency in a given clinical decision-making problem are demonstrated by systems ExaMe and TECOM. The TECOM system supports training of clinical competence in a given decision-making problems using real clinical cases. The TECOM system estimates the decision-maker abilities using a coefficient of prediction or a classical error rate. Transfer of data and knowledge important for clinical decision-making without language barriers is demonstrated on features of the European Journal for Biomedical Informatics.

Keywords. clinical decision-making, eHealth, medical guidelines, education, evaluation

1. Introduction

Medical decision-making is the “core” of clinicians’ working activities. Clinicians not only use their medical knowledge to make diagnostic, therapeutic and prognostic decisions, but they also coordinate patient care over time and among multiple providers and settings. Attempts to evaluate medical decision-making processes and the effort to get insight in their nature have recently become very up-to-date due to the penetration of ehealth technologies in medical practice. Formalization of existing medical knowledge and new results in medical research make it more and more easier to assimilate all the information, which might be useful in making medical decisions. The role of biomedical ontologies in medical decision support and diagnostic processes were described in many different ways, see [1], as well as new approaches to medical education and formalization of medical knowledge were discussed in [2, 3]. Moreover, new methods for evaluating clinical decision abilities that contribute to measuring of clinical competence were published [4, 5].

Further we will mention three types of eHealth applications and their realizations in the Czech environment that can enhance quality of clinical decision-making.

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2. Formalized Electronic Medical Guidelines

Medical guidelines are used for clinician decision support. They are intended to improve the quality of patient care and reduce costs. Unfortunately, finding information contained in conventional (free text form) guidelines may be difficult. A prerequisite for developing decision support systems that use guidelines is creating formalized electronic medical guidelines. A number of groups are actively developing computer interpretable guideline representation languages for this purpose. The Arden Syntax [6] is perhaps the best known representing language, but there are many other related languages successfully introduced for representing medical knowledge, such as Asbru [7], EON [8], GUIDE [9], PRODIGY [10], PROforma [11], GLIF [12], etc. We designed knowledge representation model [13] based on the GLIF3.5 specification. It is the universal tool for the formalization of knowledge stored in a free text form (e.g., medical guidelines). The XML representation of the graphic model and the creation of the data interface in a paramodel form make it possible to use it in different types of applications and to connect to real data from different sources (e.g., XML or CSV files). There is a big potential of formalized electronic clinical guidelines to enhance quality of clinical decision-making, decrease the number of medical errors and save human and financial resources. However the use of formalized electronic clinical guidelines is also highly dependent on factors of legal, social and ethical environment.


Although clinicians learn to cope with uncertainty, they seldom master it. In this case eHealth applications that support learning processes for a given decision-making task can rapidly increase quality of clinical decision-making. We have developed two applications that can be used in this area: ExaMe system and system TECOM.

3.1. ExaMe System

Since 1998 the ExaMe system for evaluation of a targeted knowledge has been developing [14]. The idea of the system is based on generalized multiple-choice questions, with no prior restrictions on the number of given answers. The only restriction is that at least one answer is correct and at least one wrong. This new idea has led to new concepts of standardization of test results and also to new research problems in statistics.

Evaluation by the ExaMe system is performed using fixed or automated test. A fixed test is appropriate for evaluation of the group of students in computer classroom connected to Internet. An automated test is appropriate for self-evaluation on remote places. Students can pass evaluations by automated tests by themselves and the final results of the tests are displayed immediately. The displayed results also give explanation to students why some answers were not correct. The ubiquity of the Internet and its World Wide Web applications made it possible to realize the new educational goals in an innovative and creative way.

New features of the ExaMe evaluation system and statistical issues of evaluation were described in [15]. During the last decades the reliability of didactical tests has often been examined. It is easy to show (see for example [16]) that equivalently the
reliability can be expressed as the squared value of the correlation between the observed score X and the true score T, \( \text{corr}^2(X,T) \). It means that the reliability of a didactical test can be understood as the strength of the relationship between the score reached by a student and his true knowledge. The ExaMe system covers also knowledge on decision-support systems, expert systems and medical guidelines and can be used for evaluation of students’ knowledge in the field.

Higher education programme on Biomedical Informatics for Ph.D. studies was presented in [17]. Nowadays, topics of biomedical informatics are covered by five different types of courses in the Czech language. The courses are focusing on health information systems and electronic health records, telemedicine, bioinformatics and biostatistics, knowledge discovery and decision support systems, standards, interoperability, safety and security, evidence-based medicine and other topics. The total number of participants in these courses in the years 2006–2007 was 132, the number of successful graduates was 109. Target groups in these courses were postgraduate doctoral students of medical faculties, clinicians and general practitioners, health managers and other healthcare workers. Participants in these courses were coming from more than 60 workplaces. These courses highly used e-learning tools, e.g., electronic books, ExaME program, multimedia presentations of lectures and different software tools.

### 3.2. TECOM System

An important part of teaching medical decision-making is the method of measuring the increase in the decision-maker’s ability to make correct decisions. The new TECOM system (TEsting COMpetency) can evaluate decision-making ability of decision-makers for any decision-making task. Simultaneously, clinical competence expressed by the prediction coefficient is calculated. The use of the TECOM program is demonstrated by an example from cardiology using real cases from the Municipal hospital in Caslav.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Sex</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac infarction</td>
<td>male</td>
<td>53</td>
<td>181</td>
<td>86</td>
<td>26.3</td>
<td>yes</td>
</tr>
<tr>
<td>Cardiac infarction</td>
<td>female</td>
<td>59</td>
<td>*</td>
<td>76</td>
<td>*</td>
<td>no</td>
</tr>
<tr>
<td>Cardiac infarction</td>
<td>female</td>
<td>71</td>
<td>155</td>
<td>69</td>
<td>28.7</td>
<td>no</td>
</tr>
<tr>
<td>Cardiac infarction</td>
<td>male</td>
<td>72</td>
<td>175</td>
<td>94</td>
<td>30.7</td>
<td>yes</td>
</tr>
<tr>
<td>Cardiac infarction</td>
<td>female</td>
<td>80</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>yes</td>
</tr>
<tr>
<td>Cardiac infarction</td>
<td>male</td>
<td>78</td>
<td>*</td>
<td>72</td>
<td>*</td>
<td>yes</td>
</tr>
<tr>
<td>Cardiac infarction</td>
<td>female</td>
<td>47</td>
<td>159</td>
<td>100</td>
<td>39.6</td>
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</tr>
<tr>
<td>Pulmonary embolism</td>
<td>male</td>
<td>42</td>
<td>*</td>
<td>89</td>
<td>*</td>
<td>no</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>female</td>
<td>63</td>
<td>165</td>
<td>68</td>
<td>25</td>
<td>no</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>male</td>
<td>71</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>yes</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>female</td>
<td>81</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>yes</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>male</td>
<td>83</td>
<td>*</td>
<td>72</td>
<td>*</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The TECOM system was created in C++ Builder. In essence, it is capable to test competency of decision makers in any area. The system acquires information for a decision-making task from a data matrix that can contain any type of data. The data matrix contains information on cases (e.g., patients) in the rows and correct decisions as headings of rows. Correct decisions in the data matrix (e.g., correct diagnosis, optimal therapy, validated prediction of a patient health state) should be carefully validated by experts (e.g., physicians). Table 1 shows an example as a part of the data.
matrix for a decision-making task from cardiology translated to English. We use the TECOM system for evaluating competencies of Czech clinicians and medical students, therefore we developed the Czech version of the TECOM system. However, the TECOM system can be translated to other languages if necessary.

The data matrix, partly displayed in Table 1, is based on real cases described in medical reports generated in the Municipal hospital in Caslav. 76 patients (cases) were included in the data matrix and the data model contains 75 features describing each patient. The headers in the first row are used by the TECOM system for the questions to be asked. A generator of random numbers selects one row (i.e., data about an examination of one patient and the final correct diagnosis, which of course the tested student cannot see). The student can ask about values of symptoms, signs and laboratory tests for the selected patient. The student can stop the process of asking about these values any time. After that a new window appears with a list of possible decisions (e.g., diagnoses). Then a student can distribute 100 points among possible decisions. If the student is quite sure about the correctness of his/her final decision, he/she gives 100 points to this decision. If he/she is not quite sure about the final decision he/she divides points among more decisions, where one decision has a maximal number of points. The decision with the highest number of points (highest subjective probability) is the final decision made by the student. In case that the final decision of the student is the same as the correct decision in the data matrix we classify the final decision of the student as the correct one.

Then decision-making results of a student are evaluated by the traditional error rate technique (percentage of false and correct decisions) and by the prediction coefficient $Q$,

$$Q = \frac{1}{n} \sum_{i=1}^{n} \log_2 (p_i + 1),$$

where $n$ is the number of cases and $p_i$ is the probability of the correct outcome at the $i$-th case (i.e., $p_i$ states how much the student’s final decision coincides with the correct decision described in the data matrix, e.g., diagnosis given by an experienced cardiologist). The prediction coefficient was proposed in [4] and it seems to reflect well the competence of a student (decision-maker) in the given decision-making problem.

The TECOM system can help clinicians reveal more explicitly their decision-making competencies and enhance their medical knowledge from cases and correct decisions stored in the data matrix.

4. European Journal for Biomedical Informatics

In the year 2005 we came with a new initiative to publish the European Journal for Biomedical Informatics (EJBI) on Internet (http://www.ejbi.eu/). The journal gives the possibility to publish papers in original English versions with translations to other European languages simultaneously. The multilingual versions of papers help to solve problems with terminology and support semantic interoperability. Methods of Information in Medicine (Methods) is a journal stressing the basic methodology and scientific fundamentals of data, information and knowledge in medicine and health care. As an official journal of IMIA, it has an international focus and readership. The editors of Methods and EJBI agreed on future more close collaboration with the aim to better meet future demands of timely and high-quality, peer-reviewed publications for a broad readership, including possibilities for multilingual publications. Therefore EJBI is
bringing new knowledge to clinicians in their own language that avoids misunderstandings of notions or procedures.

5. Conclusion

We demonstrated several eHealth applications that can help clinicians to cope better with uncertainty in decision-making tasks and increase their knowledge and skills. We stressed the role of education and training in the field as well as the knowledge transfer in the most understandable native language of clinicians.

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References