Teaching of Electrocardiogram Interpretation Guided by a Tutorial Expert

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Abstract

This article describes an approach to an Intelligent Tutorial System – CARDIOLOG, specially developed to help in teaching electrocardiogram (ECG) interpretation to medical students. Although the system can be used as a self-learning tool, one of its main characteristics is the adequacy to classroom environment – a Professor module and many Student's modules.

Medical students and professors, physicians and people interested on the subject will be able to form a solid knowledge base or complement their studies with CARDIOLOG. The activities rely on user-friendly interfaces, based on the questions/answers model, with the possibility of consulting reference (if enabled by the professor). Analysis of students' performance, reports and knowledge base maintenance tools are also available in CARDIOLOG.

CARDIOLOG was implemented using Artificial Intelligence technologies, development using object methodology, Client/Server structure, 32-bit Windows platform.

Keywords:
Expert Systems; Tutor; Cardiology; Learning Systems; Object Oriented Modelling.

1. Introduction

Presently, universities are developing researches on alternative ways of improving the learning process. These alternative ways' objective is to maximize the quality of the students formation and reduce costs and wastes of time. Particularly in Medicine, its objective and the complexity inherent to the subjects involved show up the importance of a solid formation of future professionals.

Another point of concern for universities is the necessity of keeping a group of qualified professors, since expert professionals may not be available to teach or may not have directed their abilities to knowledge transmission. Students also search for tools that can help in learning: supporting the process, as a reference or as a complement to classes.

Even though many parts of the professionals' formation require a personal relationship between the professor and the student, there are some which can be assisted and/or managed by

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a computing system. Tutorial systems are computing tools that can be used in universities to achieve improvement in teaching/learning process through the simulation or presentation of real cases, interpretation and explanation of each case.

- **Tutorial systems** - Tutorial systems may be classified into conventional and with knowledge representation.
- **Conventional systems** - Systems of case simulation are becoming more popular in medical teaching. These systems implement known cases naturally. The use of tools for automatic generation of tutorial systems eliminate any major requirement of programming, allowing the production of tutorial cases to start promptly. The difficulty comes in the inclusion of new cases. Conventional systems are usually restricted to predefined cases and all interaction with the students is coded explicitly. A more generic approach is necessary [1].
- **Tutorial systems based on knowledge** - A differential feature of tutorial systems based on knowledge is their theoretical ability of supporting clinical problems resolution[2,3]. In these systems, the knowledge of experts is stored in a knowledge base, making codification of the system independent of the domain. This technique allows a fast production of new cases, with not much additional effort, since the necessary changes are made in the knowledge base only.

Intelligent tutors present problem cases to the students which try to solve them while the interactive system compares the students choices and decisions with its own and then provides an appropriate feedback (explanations, comments, critics).

Opposite to the development of a conventional system, the developer of a tutor based on knowledge does not have to explicitly specify beforehand each reaction of the system to each possible response of the student. The feedback is derived automatically from the knowledge base of the system. Depending on the congruency level between the knowledge base and the student, the student's answer is considered correct[1,4]. Therefore, the basic premise of the intelligent tutorial procedure is that the knowledge base knows the correct answers to all questions concerning the context of the case resolution in its domain.

The development of a tutor based on knowledge requires an initial investment in the construction of the knowledge base. After its completion, new tutorial cases can be produced with a minimal additional effort, since the knowledge base solves the cases correctly[1].

The general architecture of tutors based on knowledge is presented as the following: in addition to the expert systems' basic components – for problem resolution, knowledge acquisition and representation, explanation, interview/dialogue – an specific tutorial component is necessary to case presentation and feedback[5]. All these modules influence the operation and it is important to evaluate empirically how exactly their particular specifications and features affect the systems performance and the students motivation.

The teaching quality of the conventional systems is in inverse proportion to the amount of developed systems. In intelligent tutorial systems, the tendency is on the contrary: a large quantity of teaching cases can be produced, but the teaching quality tends to be limited due to the automatic generation of all tutorial feedback. At this point, improvements in quality cannot be obtained directly, but through the development of the knowledge base and of the tutorial system. This way, the progress tends to be small and slow, but when achieved, it affects positively a multitude of cases[6].

- **Knowledge representation for intelligent tutors** - Decision support systems must provide correct suggestions to the user, independently of the way these suggestions are computed. For that reason, they explore a variety of problem solving methods, including Bayes statistics, probability networks, neural networks, case comparison and heuristic rules. Nevertheless, not all of them are used in tutorial systems. In this case, one of main requirements is to provide

feedback in a way that improves students' learning and understanding. The explanations given by tutorial systems concerning whether the student's choice is correct or not must be clear and of easy memorization.

Among the most adequate knowledge representation forms to develop teaching support systems are the heuristic approaches. In contrast to many other representations, they are formulated by people and they are understandable to other people. In opposition to functional causal methods, heuristic representations have proved their efficiency in large knowledge base constructions, and there is also the empirical evidence that human experts highly trust in heuristic knowledge for problem solving[7].

2. Materials and Methods

The use of tutorial systems that implement a knowledge base for teaching and for diagnosis support has become quite common in the medical field. A research on the existing tutorial systems had shown that there was a lack of a system that helped in classroom activities. The objective of CARDIOLOG is to supply this lack. CARDIOLOG is a tutorial expert system directed to electrocardiogram interpretation, to be used as a support in classroom (computer local network), although it is possible to use the system as a standalone practice tool (standalone personal computer).

Artificial Intelligence resources are applied in CARDIOLOG to guide the learning process, having its kernel based on knowledge representation.

The development under a Client/Server Architecture implements an environment suitable for classroom (a professor module as the server and the students modules as clients). CARDIOLOG also includes facilities for activity configuration, classroom administration and students' performance monitoring.

Professor Module

The Professor Module was developed to provide the following features:

- Automatic and on-line generation reports of the students' individual history of all steps during the development of each activity;
- Option for making the personal student's report available, allowing each student to follow one's own performance;
- Maintenance of a record of all students that apply the discipline;
- Students' access to the same support references and professors' ability to edit them;
- Configuration of the kind of activity to be developed in classroom: exercise or evaluation. In case the activity is of evaluation type, no reference will be available and messages of correct/wrong answers will be disabled;
- Maintenance of the knowledge base and possibility of making it immediately available to the students. This way the whole system will work on the new edited knowledge rules;
- Inclusion of new ECG cases and data correction for the already registered ECGs – the interface for this type of maintenance is similar to the one for the students' activity.

Student Module

The Student Module provides:

- Execution of the activity configured by the professor;
- Personal report request.

3. Discussion and results

CARDIOLOG is to be used in classroom, with personal microcomputers (IBM/PC, Pentium like), using Windows 9x, Windows NT 4.0 operating system or superior, communicating on network protocol TCP/IP, and using Interbase 4.2 as database manager system.

Modeling of the system was made on object-oriented methodology, supported by Visual UML tool. Interface with the users and the database manager system was implemented in Delphi 3.0 Client/Server environment. Artificial Intelligence modules of CARDIOLOG were developed in the Shell Expert Sinta (version for 32-bit operating systems) and making use of Sinta's visual components for Delphi, developed by "Laboratório de Inteligência Artificial da Universidade do Ceará".

The system uses a traditional methodology of teaching, where activities developed in classroom may be classified into "exercise" or "evaluation" type and consist of practical exercises of ECG interpretation. To give support to the student, references (texts and images selected by cardiology experts) for each item analyzed are available.

The "intelligent" module of CARDIOLOG is a production rules based system, founded on backward chaining to conduct the activities of ECG analysis. The knowledge base construction was made through interviews with Cardiology experts, so that the system can follow the same steps of analysis of ECG waves.

CARDIOLOG's module interfaces are represented in Figure 1 and the way these modules work and interact are then described. The Client/Server Interface helps the professor to follow the performance of the group and to edit the reference texts simultaneously to all students; allows the students to know one's own performance; feeds the inference machine with the students answers. The expert system conducts the learning activities. The expert shell allows the professor to edit the knowledge base, personalizing it to the subject program.

Additionally, the system allows learning activities to be executed over registered ECGs or any other ECG available to the user. In the first case (registered ECG), the measurements read by the student are compared to the registered ones – and the student is informed of the correctness or not of the readings. Then, the student will be requested to come to conclusions based on the correct measurements which will be compared to the results of the inference machine of CARDIOLOG. This way, all the student's answers are evaluated, practicing information extraction form the ECG and interpretation of these information. In the second case (other ECG), the student's measurements are not verified – they are taken as correct. From the measurements entered, the system computes the conclusions, requests for the student's and makes the comparison.

The conclusions reached by the expert system correspond to the cardiac conditions included in the knowledge base. To come to a conclusion, the system verifies the heads of the knowledge rules against the answers selected by the student. As many questions as necessary to prove the occurrence of one of the existing cardiac conditions will be made.

When a cardiac condition is concluded, the system presents to the student a list of all measurements/values analyzed, the cardiac condition category and the possible conclusions. Then, the student is requested to choose the most adequate option base on the information previously provided. CARDIOLOG analyses the student's option and provides a corresponding feedback. When the activity is finished, the system calculates a final performance score, based on the number of correct answers. Another important feature is the automatic generation of reports of the activities developed, where all the questions, answers and results are registered.

Through the whole process described, CARDIOLOG is able to present precise, justifiable and correct inferences:

- using artificial intelligence techniques to infer the clinical state of the patient's heart whose ECG is being analysed;
- the exact reproduction of the steps that cardiology experts (the ones who helped in the project development) would make.

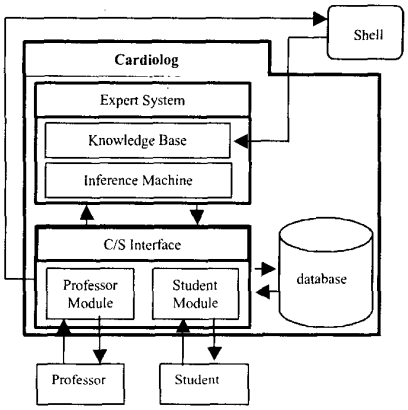

Figure 1 – CARDIOLOG: schematic diagram.

4. Conclusions

This work has presented an approach of a system development integrating computing technologies to improve the quality of medical training in electrocardiogram interpretation.

The methodology described was applied to a medical system, but it could be used in the development of hybrid intelligent environments of many other areas of knowledge.

Limitations of the system were as follows:

- the production rules model used in the knowledge representation is understandable by the experts, but requires logic reasoning to edit the rules;
- the knowledge domain of the system was restricted to basic cardiac conditions (general heart diseases) – further expansion of the knowledge base was left for future researches due to the Cardiology complexity.

The application of CARDIOLOG on classroom for training medical doctor students are being available and these results will be acquire on the last of academic year.

It's necessary to expand the CARDIOLOG for accept more rules. For instance the user's interface and acceptability are testing. Normally, the medical doctors agree with the systems, but, for instance, there is only informal evaluations. When the finish the evaluation process, new and more confidence results can be obtained.

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