Development of decision support algorithms for intensive care medicine: A hybrid system of time series analysis and a knowledge base system

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Abstract

Traditional expert systems rely on a tedious, labor-intensive and time-consuming approach in their development while they do not effectively exploit existing medical databases. We applied a new concept of combining time series analysis and a knowledge base system with learning and revision capabilities (MOBAL) for rapid development of decision support algorithms for hemodynamic management of the critically ill. This approach could be successfully implemented in an existing intensive care database handling time-oriented data to validate and refine the intervention rules.

Introduction

In critical care an abundance of information is generated during the process of care. The multitude of variables presented at the bedside precludes medical judgement by humans. Electronic decision support systems (DSS) help to solve these problems. But all currently known medical DSS are based on manually acquired expert knowledge which is refined in an iterative process of prospective trials. With the advances of artificial intelligence and statistical time series methods, consistency of rules and (patient) data can be checked automatically. Therefore, knowledge can be formalized and validated against highly multivariate data structures. Our new approach combines modeling of expert knowledge with data-driven methods. The knowledge base is validated against existing patient data. This approach is meant to be significantly more effective than the tedious, time-consuming, and costly process of traditional DSS development.

Methods

The knowledge discovery and validation process consisted of five steps:

- Data abstraction from the numerical and time series data.
- State-action rules, describing the appropriate intervention toward a specific clinical state.
- Action-effect rules, describing the expected effect of a certain intervention.
- Conflict detection, detecting contradictions between established rules and observed data.
- Conflict explanation, resolving the detected contradictions and refining the knowledge base.

The following tools were used during this process:

- CIS (Eclipsys SCD 1.2) for point-of-care data acquisition.
- Medical expert knowledge for representing a traditional knowledge base.
- Time series analysis (phase space models) for data abstraction of on-line monitoring data.
- Support vector machine (SVM) for the detection of state-action rules in the CIS database.
- MOBAL, a knowledge base system with learning and revision capabilities for validation of the knowledge against actual patient data.

The goal was to develop a knowledge base for a restricted set of drug interventions to the cardio-vascular system in critically ill surgical patients. This knowledge base should then serve as the rule engine for a clinical decision support system.

Results and Conclusion

The entire database comprises about 2000 independent variables. On-line monitoring data was acquired from 148 consecutive critically ill patients who had pulmonary artery catheters for extended hemodynamic monitoring, in one minute intervals from the CIS amounting to 679,817 sets of observations.

The rules derived with the SVM from 1,319 training examples correctly predicted actual medication interventions to the cardio-vascular system with an average accuracy of 85% (473 test examples), which was comparable to a senior intensivist.

The hybrid system of time series analysis and MOBAL allowed to validate the rules derived from both the SVM analysis and the medical expert knowledge base against the historic CIS database. In 27,400 intervention-effect-relations 4,070 contradictions between knowledge base and actual data were detected, providing information for refining the knowledge base.

The entire development and validation of the knowledge base required less than one manyear. This is significantly less than with a traditional expert system approach. The rules learned and validated with this approach are explicit, executable and exportable, so that they can be used in a clinical decision support system.

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