The Fuzzy Set and Rule Editor KBWEdit of the Medical Expert System KBWean

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Background

Mechanical ventilation, which is a standard therapeutic treatment of modern intensive care medicine, is applied if the patient's spontaneous breathing is disturbed or completely broken down. Nevertheless it cannot be kept up indefinitely, since, as time progresses, more and more negative (and even dangerous) side effects arise [1,2]. Therefore the patient should be weaned from mechanical ventilation as soon as possible. But alas, the process of weaning is not an easy one. Controlling it requires expert knowledge and practical experience. A study [3] has shown that medical assistance personnel, using protocol guidance, has been able to wean patients "safely and more quickly than the team following the traditional practice of physician-directed weaning". The important issue in this context is: Can such protocols be implemented and applied via a medical expert system [4-6]?

Objective

The goal of the KBWean project is to control the process of weaning ICU patients from mechanical ventilation by a rule based expert system [7,8]. In the first stage of development, its task is to compute proposals for an efficient weaning strategy, whereas the final decisions are left to the physician. After extensive testing and further development, the ultimate goal is a closed loop system, that weans patients autonomously, where the physician only has to intervene in cases of emergency.
This work focuses on three key components of KBWean:

- knowledge acquisition component,
- inference engine applying fuzzy control including fuzzy logic,
- database model.

Material and Methods

Knowledge Acquisition Component

This component is implemented as an editor application (KBWEdit) that can be used to generate KBWean knowledge bases (Fig. 1,2). KBWean knowledge bases consist of *variables* (physiological parameters and respirator settings), *values* (fuzzy sets and linguistic terms), and *rules*. From the knowledge base's source code, the editor generates a compiled, e.g., directly executable version, which is used by KBWean.
The editor enforces a certain pre-structuring of the knowledge base's components (Fig. 3). Therefore many of the syntactic and other errors common in software development are avoided from the start.

Inference engine

The entire set of rules is run through once a minute and the calculated results are displayed as well as stored in a database. The rules' conclusions also contain a blocking

mechanism, that can disable a subset of rules for a limited period of time or until they are explicitly enabled again. By doing this, the knowledge base programmer can design various subsets of rules according to different stages or situations within the weaning process. Due to the fact that medical statements are often characterized by a certain vagueness, e.g., ”body temperature *slightly* increased”—what is meant by ”slightly”?, the inference machine of KBWean includes a fuzzy logic component that enables an adequate interpretation of vague statements in the rules’ premises as well as faulty or incomplete data.

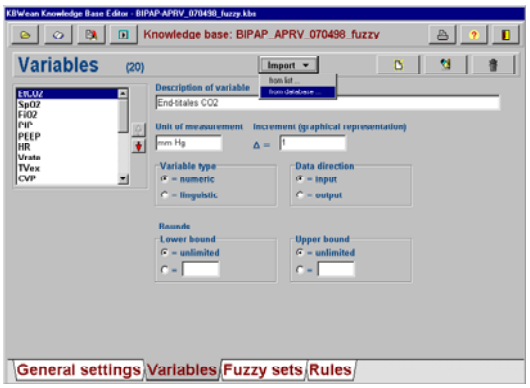

Fig. 1: Variable Editor

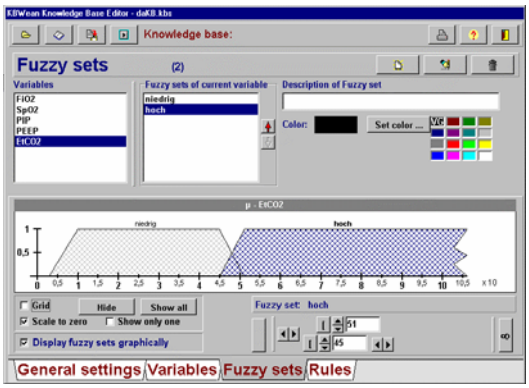

Fig. 2: Fuzzy Set Editor

Database model

The raw data provided by the Patient Data Managment System PICIS is not suitable for immediate use by KBWean. Therefore the values of interest are extracted and then, provided with a time stamp, stored in a central database. The fired rules for each data record, the proposed and the effective changes of the respirator settings, patient data, etc. are also included in the database. The database model provides efficient access to all required data via database queries in structured query language (SQL), easy analysis of results and comparative test runs with different settings of KBWean.

Results

KBWean is currently running off-line at the ICU of the Department of Cardiothoracic Anesthesia and Intensive Care Medicine at the Vienna General Hospital. It interprets streams of patient data and proposes weaning strategies by calculating adequate respirator settings and verbal instructions. According to physicians’ opinions, KBWean produces ”quite clever” outputs. Evidently, the knowledge base generally works well. On the other hand there are still many situations the human expert has no problems dealing with, whereas the expert system fails, e.g., noisy data. Future research has to focus on how these situations can be identified by the expert system, e.g., by applying pattern recognition methods. Furthermore, we have to develop appropriate therapeutic schemes for the different stages of the weaning process.

Technical Specification

Operating System Windows-NT® 4.0, PDMS PICIS CHART+ (Paris-Barcelona), Delphi® 2.0 Client/Server Suite. The KBWean program is a 32 bit application, and uses an Interbase® database for data storage and retrieval.
8 bedside PCs, Pentium 166 with 32 MB Ram, Intelligent Digiboard, and Light-Pen. All PCs are connected to a server, using the hospital’s tokenring network.

Ventilator Draeger Evita: fraction of Inspired oxygen (FiO_2), airway pressures (PIP, PEEP), tidal volume, minute volume, respiratory rate. Oximeter Capnometer Datex Oscar: Pulsoximetry (SpO_2) endtidal CO_2 ($EtCO_2$), respiratory rate. Monitor Mennen Horizon: Heartrate, blood pressures, cardiac output, body temperature, respiratory rate.

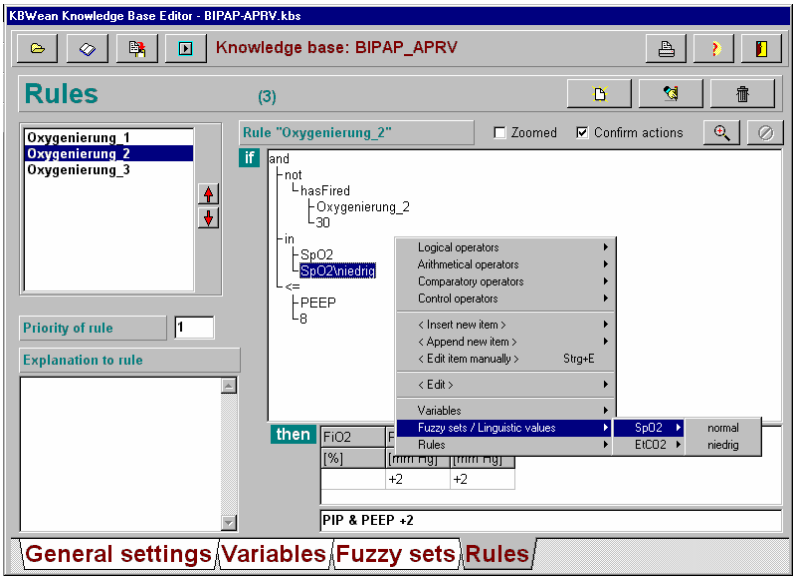

Fig. 3: Rule Editor

Conclusion

Controlling a weaning process through an expert system definitely seems possible. Nevertheless there are still many obstacles ahead that we have to tackle.

Acknowledgement

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