Managing Uncertainty with Fuzzy-Automata and Control in an Intensive Care Environment

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Abstract. Medical informatics has changed tremendously over the past few decades, and changes in the approach to uncertainty are probably the most important advances in this field. The envisioned role of computer programs in health care is perhaps the most important. Uncertainty is the central, critical fact about medical reasoning. Particularly in an intensive care environment, where decisions must often be made quickly, or that physicians will follow it rather than openly or surreptitiously limiting care on their own.

This paper surveys the utilization of fuzzy logic on the basis of two medical applications. The first, an intelligent on-line monitoring program for the intensive care data of patients with Acute Respiratory Distress Syndrome (ARDS), so called FuzzyARDS which is using the concept of fuzzy automata, and the second is a fuzzy knowledge-based control system, FuzzyKBWean, which was established as a real-time application based on the use of a Patient Data Management System (PDMS) in an intensive care unit (ICU). These complex systems confirm that fuzzy logic is quite suitable for medical application in a per definition uncertainty environment as an ICU, because of its tolerance to some imprecision.

Keywords: Uncertainty, fuzzy logic, fuzzy automation, medical fuzzy applications, decision making.

1 Introduction

Medicine is one field in which the applicability of fuzzy set theory was recognized in the end-1970s. Within this field it is the uncertainty found in the process of diagnosis of disease that has most frequently been the focus of applications of fuzzy set theory. In other words real world knowledge is characterized by uncertainty, incompleteness and inconsistency. Fuzzy set theory, which was developed by Zadeh [1], makes it possible to define inexact medical entities as fuzzy sets. It provides an excellent approach for approximating medical text. Furthermore, fuzzy logic provides reasoning methods for approximate inference.

2 Intensive Care Environment Applications

Two medical applications, FuzzyARDS and FuzzyKBWean are presented in this paper, representing these concepts. FuzzyARDS is an intelligent on-line monitoring
program of data from patients with acute respiratory distress syndrome (ARDS) at an intensive care unit (ICU). It employs fuzzy trend detection and fuzzy automata. FuzzyKBWean is an open-loop fuzzy control program for optimization and quality control of the ventilation and weaning process of patients after cardiac surgery at the ICU. The above-mentioned computer systems have reached the state of extensive clinical integration and testing at the Medical University of Vienna’s General Hospital. The obtained results show the applicability and usefulness of these systems.

2.1 FuzzyARDS

FuzzyARDS is an intelligent on-line monitoring program for the intensive care data of patients with Acute Respiratory Distress Syndrome (ARDS) [4].

ARDS is a vaguely defined nosological entity therefore a crisp definition of ARDS seems therefore not adequate. In particular, the commitment to crisp limits of findings is problematic. Fig. 1 shows the thresholds of PaO2 and FiO2 for patients suffering from ARDS.

![Fig. 1. ARDS threshold of PaO2 and FiO2](image)

It's clinical aim is to detect ARDS in patients as early as possible and to give appropriate therapy advice. ARDS is an ill-defined medical entity and is modeled using the concept of fuzzy automata. States in these automata are considered to be a patient's pathophysiological state or entry criteria for different forms of ARDS therapies (Fig. 2). Patients may be partially assigned to one or several states in such an automaton at the same point in time. Transitions in the automata carry fuzzy conditions that have to be true or partially true to transit from one state to another. Fuzzy conditions are usually high level medical concepts such as low, normal, or high FiO2, hypoxemia, or linguistically expressed trend information, e.g., rapidly improving oxygenation. These high-level concepts are permanently evaluated in a data-to-symbol conversion step according to an adjustable time granularity. An extended description of these formal concepts can be found in [5, 8, 29].