Representational Hierarchy of Fuzzy Logic Concepts in the OBOA Model

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Abstract. This paper describes hierarchical modeling of fuzzy logic concepts that has been used within the recently developed model of intelligent systems, called OBOA. The model is based on a multilevel, hierarchical, general object-oriented approach. Current methods and software design and development tools for intelligent systems are usually difficult extend, and it is not easy to reuse their components in developing intelligent systems. The OBOA model tries to reduce these deficiencies. The model starts with a well-founded software engineering principle, making clear distinction between generic, low-level intelligent software components, and domain-dependent, high-level components of an intelligent system. This paper concentrates on modeling and implementation of fuzzy logic concepts within the hierarchical levels of the OBOA model. The fuzzy components described are extensible and adjustable. As an illustration of how these components are used in practice, a practical design example is shown. The paper also suggests some steps towards future design of fuzzy components and tools for intelligent systems.

1. Introduction

In the general domain of object-oriented software engineering, hierarchical modeling refers to layered software architectures [Batory and O'Malley, 1992], in which:

- each component in a system belongs at a certain conceptual layer (layers are sets of classes on the same level of abstraction);
- more complex components are designed starting from simpler components from the same layer or from the lower layers;
- A hierarchically organized tree of components that spans across multiple layers can be drawn to represent the architecture of the system.

One particularly important extension of the concept of layered software architecture is the orthogonal architecture [Rajlich and Silva, 1996]. In the orthogonal architecture, classes (objects) are organized into layers and threads. Threads consist of classes implementing the same functionality, related to each other by the using relationship [Booch, 1994]. Threads are "vertical", in the sense that their classes belong to different layers. Layers are "horizontal", and there is no using relationship among the classes in the same layer. Hence modifications within a thread do not affect other threads. Layers and threads together form a grid. By the position of a class in the architecture, it is easy to understand what level of abstraction and what functionality it implements. The
The architecture itself is highly reusable, since it is shared by all programs in a certain domain which have the same layers, but may have different threads.

These general concepts have been recently applied to modeling intelligent software systems in the object-oriented way. As a result, a hierarchical model of intelligent systems, called OBOA (Object-Oriented Abstraction) has been developed [Devedzic and Radovic, 1999]. The model encompasses a wide range of knowledge representation methods and inference techniques commonly used today in designing intelligent systems. The purpose of this paper is to describe how the main concepts of fuzzy logic and fuzzy systems, being important modeling techniques and tools in intelligent systems, are supported in the OBOA model.

The paper is organized as follows. Section 2 is an explicit problem statement. In Section 3, the essence of the OBOA model is described. Section 4 is the central section of the paper. It shows how fuzzy concepts fit into the OBOA model, and presents some design examples. Section 5 shows examples of current implementation of software components for designing fuzzy systems based on the OBOA model. In Section 6, some informal performance analysis is presented. Finally, Section 7 shows the benefits of this kind of modeling fuzzy systems and directions for future research.

2. Problem Statement

The purpose of this paper is threefold:

- it shows how the concepts of fuzzy logic and fuzzy systems fit into a more general, object-oriented, hierarchical model of intelligent systems (the OBOA model);
- it explains how design of fuzzy intelligent systems can be facilitated by imposing some hierarchical structure onto the concepts and tools used in the design process;
- It presents an example of how development of practical fuzzy systems can be alleviated using this approach.

3. Previous Work

This section illustrates how hierarchical modeling has been included into the OBOA model in order to facilitate design and development of intelligent systems. It also briefly shows how some well-known concepts from the domain of intelligent systems the model supports.

3.1. Levels of Abstraction and Dimensions in the OBOA Model

The OBOA model defines five levels of abstraction for designing intelligent systems, Figure 1a. If necessary, it is also possible to define fine-grained sublevels at each level of abstraction. Each level has associated concepts, operations, knowledge representation techniques, inference methods, knowledge acquisition tools and techniques, and development tools. They are all considered as dimensions along which the levels can be analyzed, Figure 1b. The concepts of the levels of abstraction and dimensions have been derived starting from the orthogonal architecture.