

Chapter 3

Fuzzy Logic: Concepts, System Design, and Applications to Industrial Informatics

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ABSTRACT

The field of industrial informatics has emerged as one of the key disciplines for the purpose of intelligent management and dissemination of information in today's world. With the advent of newer technical know-how, the subject of informative intelligence has assumed increasing importance in the industrial arena, thanks to the evolution of data intensive industry. Real world data exhibit varied amount of unquantifiable uncertainty in the information content. Conventional logic is often unable to explain the associated uncertainty and imprecision therein due to the principles of finiteness of observations and quantifying propositions employed. Fuzzy sets and fuzzy logic provide a logical framework for description of the varied amount of ambiguity, uncertainty and imprecision exhibited in real world data under consideration. The resultant fuzzy inference engine and the fuzzy logic control theory supplement the power of the framework in design of robust failsafe real life systems.

INTRODUCTION

Industrial informatics (Acciani, 2011; Gomperts, 2011) has assumed importance of late thanks to intelligent management and dissemination of information. With the rapid advancement of

technology, there has been a stupendous increase in the exchange of data based information leading to data explosion. As a result, for keeping pace with this ever-increasing data and knowledge base, new subjects like informative intelligence and intelligent informatics have come to the fore.

Information is manifested in several different forms. It may be either in the form of raw data,

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images, video content, speech signals or in any other electronic form. Any form of consumed real world data contains a varied amount of ambiguity and imprecision, which cannot always be measured in practice. As such, classical computing systems seldom account for the associated uncertainty and imprecision in the principles of finiteness of observations and quantifying propositions employed.

Fuzzy sets (Zadeh, 1965; Cox, 1994; Dubois 1980; Kosko, 1997; Ross, 2003; Ross, 2004; Berkan, 2000) evolved by Professor Lotfi Zadeh of the University of California at Berkley are capable of describing the vagueness and ambiguity inherent in real world data. Professor Zadeh reasoned on the intelligence in human reasoning to pave the way for foundation of fuzzy sets and fuzzy logic. He was motivated by the fact that human beings more often communicate via natural language terms or linguistic expressions, which cannot be always quantified by numeric values (Zadeh65, Zadeh73, Cox94, Dubois80, Zadeh78, Zadeh94). Typical human expressions include either one or several linguistic phrases, viz., *very*, *very tall* boy, *very fast* car, *quite a few* people, etc. These phrases, though aptly describe human feelings, cannot be numerically quantified in the strict sense of the term. Thus, even in the absence of any precise, numerical input information, human beings are capable of highly adaptive control. Moreover, as the complexity of a system increases, it becomes more difficult and eventually impossible to make a precise statement about its behavior, culminating in a point of complexity, which cannot be adjudged by means of a value. Zadeh coined the term “fuzzy” (standing for something which is vague, obscure and imprecise) to replicate the notion of non-measurable human understanding and logic. Thus, fuzzy sets form the backbone of more efficient and robust systems, which are immune to all sorts of uncertainties and imprecisions prevalent in the real world. Hence, fuzzy systems operate in a linguistic framework and their strength lies in their capability to handle linguistic information and perform approximate reasoning

(Ross2003, Ross2004) through the assignment of non-measurable logical qualities.

This chapter is devoted to develop an understanding of the essence of fuzzy set theoretic concepts, the embodied logic and their application to fuzzy system design as it applies to different fields of science, engineering, finance and industry. One of the important tenets of fuzzy system design is proper appraisal of fuzzy based inference system design and fuzzy control theory, which lead to the development of robust and failsafe systems. A part of the chapter would deal with the intricacies of fuzzy control with reference to its application to industrial system design. Case studies of the applications of fuzzy sets, fuzzy logic and fuzzy inference system to information management are also highlighted in this chapter. Due to the ability of handling uncertainties in real world data, fuzzy sets and fuzzy logic have made a huge impact on virtually every sphere of science, engineering and finance. The application perspectives of fuzzy sets and fuzzy logic is also touched upon with special emphasis on the fields of industrial informatics and resource management (Chaudhari2010), machine intelligence (Kyoomarsi2009), process modeling and quality control (Berkan2000), robotics, image processing and pattern recognition in industry (Simpson92), financial engineering domains (Shipley2009, Meng2008), to name a few.

The chapter is organized as follows. The limitations of the conventional crisp sets and crisp logic are highlighted in the section titled FUZZYSETTHEORY: CONCEPTS AND TERMINOLOGIES with three real life observations. The foundations and efficacy of fuzzy set theory in dealing with the stated problems are discussed. The concept of partial membership assignment in fuzzy sets is also presented in this section. The section titled TYPES OF MEMBERSHIP FUNCTIONS introduces some of the standard membership functions used to model fuzzy sets. Any fuzzy system operates on linguistic inputs.

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