Chapter 7
Fuzzy Fusion for Multimodal Biometric

ABSTRACT

Fuzzy logic is a mathematical tool that can provide a simple way to derive a conclusion with the presence of noisy input information. It is a powerful intelligent tool and used heavily in many cognitive and decision-making systems. In this chapter, fuzzy logic-based fusion approach for multimodal biometric system is discussed. After discussing the basics of fuzzy logic, the fuzzy fusion mechanism in the context of a multimodal biometric system is illustrated. A brief discussion on the research conducted for fuzzy logic-based fusion in different application domains is also presented. The biggest advantage of the system is that instead of binary “Yes”/“No” decision, the probability of a match and confidence level can be obtained. A fuzzy fusion-based biometric system can be easily adjusted by controlling weight assignment and fuzzy rules to fit changing conditions. Some results of experimentations conducted in a recent research investigation on two virtual multimodal databases are presented. The discussion on the effect of incorporating soft biometric information with the fuzzy fusion method to make the system more accurate and robust is also included.

1. INTRODUCTION

In chapter six, the Markov chain based rank level fusion method has been introduced. The basics of Markov chain have been discussed and its construction mechanism in the context of multimodal biometric rank fusion has been shown. This method demonstrates a number of advantages over other rank fusion approaches in terms of recognition performance. Furthermore, this method satisfies the Condorcet criterion, which is essential in any fair rank information fusion process. In this chap-
ter, another new biometric fusion approach based on fuzzy logic is discussed and hence named as fuzzy fusion for multibiometrics.

Fuzzy fusion method is one of sub-branches of information fusion, which has recently emerged as information consolidation tool. Most fuzzy fusion methods reported in the literature are developed for areas such as automatic target recognition, biomedical image fusion and segmentation, gas turbine power plants fusion, weather forecasting, aerial image retrieval and classification, vehicle detection and classification, and path planning. In the context of biometric authentication, fuzzy logic based fusion approach has recently been used for quality based biometric information consolidation process. In Monwar, Gavrilova, and Wang (2011), the fuzzy fusion method is utilized in multimodal biometric system. The advantage of fuzzy fusion method is that it utilizes both match score and rank information from unimodal biometrics. Also, unlike with traditional systems returning only binary (Yes/No) decision, the level of confidence in recognition outcomes of the multimodal system can be obtained using this method.

2. FUZZY LOGIC BASICS

Fuzzy logic refers to the theories and technologies that employ fuzzy sets, which are classes with un-sharp boundaries (Pedrycz & Gomide, 1998). The idea of fuzzy sets was introduced in 1965 by Professor Lotfi A. Zadeh from the University of California, Berkeley (Zadeh, 1965). The core technique of fuzzy logic is based on following four basic concepts (Wang, 2009):

- **Fuzzy Sets**: A fuzzy set is a set with a smooth boundary. Fuzzy set theory generalizes the classical set theory to allow partial membership (Harb & Al-Smadi, 2006).
- **Linguistic Variable**: A linguistic variable in one which allows its value to be described both qualitatively by a linguistic term and quantitatively by a corresponding membership function (which represents the meaning of the fuzzy set) (Harb & Al-Smadi, 2006).
- **Possibility Distributions**: Assigning a fuzzy set to a linguistic variable constrains the value of the variable: it generalizes the difference between possible and impossible to a degree called the possibility (Pedrycz & Gomide, 1998).
- **Fuzzy Rules**: Fuzzy rule (or the fuzzy if-then rule) is the most widely used technique developed using fuzzy sets and has been applied to many disciplines. Some of the applications of fuzzy rules include control (robotics, automation, tracking, consumer electronics), information systems (DBMS, information retrieval), pattern recognition (image processing, machine vision), decision support (adaptive HMI, sensor fusion), and cognitive informatics (Pedrycz & Gomide, 1998).

The development of fuzzy rule-based inference consists of three steps – fuzzification, inference and defuzzification (Figure 1) (Zadeh, 1965). In the fuzzification step, fuzzy variables and their membership functions are defined, i.e., the degree to which the input data match the condition of the fuzzy rules have been calculated. In the inference step, fuzzy rules have been developed and those rules outcome based on their matching degree has been calculated. In the defuzzification step, the fuzzy conclusion is converted into a discrete one (Zadeh, 1965).

3. RESEARCH ON FUZZY LOGIC-BASED FUSION

Fuzzy logic is indeed one of the fascinating areas on the edge between cognitive science and decision making. Utilizing principles of fuzzy logic for information fusion allows to emulate
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