

Chapter 3

3 Modular Fuzzy Logic Control

3.1 Introduction

In this work, a reconfigurable wheelchair is developed based on the two-wheeled inverted pendulum concept and intended for use in narrow and confined domestic environments. The subtle operation involves a transformation from standard four-wheeled wheelchair to two-wheeled mode using a link rotation mechanism in order to lift the whole wheelchair system to the upright position, which is referred to as stabilizing on two-wheeled process. This mechanism also allows the wheelchair to perform stair climbing (ascending and descending), sit-to-stand and stand-to-sit operations using the stabilizing concept. Stabilizing a wheelchair in a two-wheeled mode is not an easy task as it needs to take into account the whole weight of the system and the user. The two-wheeled wheelchair system uses the same concept as an inverted pendulum which has surfaced over the years for balancing control and is known to be an unstable system. At the same time, the seat and the whole wheelchair mechanism have to stay stable at the upright vertical position to ensure that the system does not collapse or slip while carrying a human load of 71kg. Due to the configuration and complexity of the task, the system was incorporated with an intelligent control approach to accomplish the goal.

Tremendous successes have been reported through the implementation of natural and biological intelligence, resulting in ‘Intelligence System’. The intelligent algorithm form part of the field of ‘Artificial Intelligence’ in broad research disciplines, for example, computer science, physiology, philosophy, sociology and biology. Figure 3.1 shows paradigm of computational intelligence (Engelbrechth, 2007).

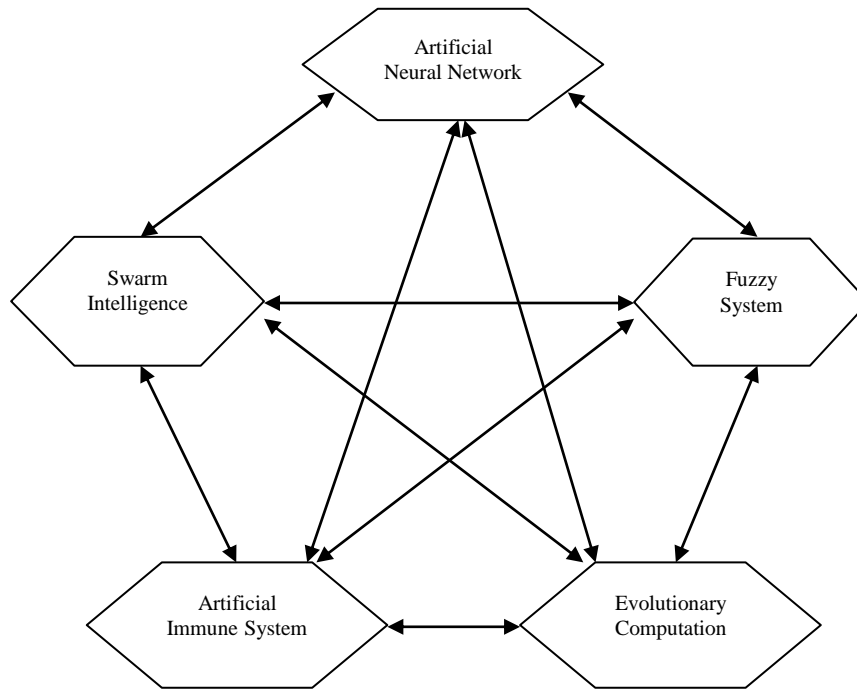


Figure 3.1: Computational Intelligence Paradigm (Engelbrecht, 2007)

Artificial Neural Network (ANN) is originated from nerve cells called neurons which are represented as artificial neurons, ANN and acting like data training machine where as Swarm Intelligence (SI) is adopted from swarm and colonies social organisms such as bird flocks and ant colony behaviours which prompted the design of efficient optimization and clustering algorithms. Natural behaviour and genetic were the main contributing factors to create evolutionary algorithm as one of the approach to evolve behaviour model. Meanwhile, Artificial Immune System (AIS) modelled human immune system to interact with foreign cells known as antigen which enters the body to be able to adapt and memorize the structure of these antigens for faster future response.

Fuzzy logic is with inherent property incorporating uncertainties and nonlinearities of a system (Engelbrecht, 2007). In this sense, fuzzy logic plays a vital role in executing rational decision making process in an uncertainty and imprecision environment by human (Zadeh, 1988). Fuzzy logic has significant advantages because it is one of the computational intelligence approaches which are

close to human reasoning and decision making. Fuzzy logic has found greatest successful in most fields and systems ranging from engineering to social studies due to its ability to construct rule of knowledge which is similar to human expression and thinking. Moreover, fuzzy logic is easy to implement in terms of interpreting the behaviour of environments and real systems. Fuzzy logic control (FLC) has become more favourable due to its significant superiority compared to conventional methods in terms of theory and practicality (Wang, 1993). The stability of fuzzy logic, considered as its disadvantage, is hard to establish and there is no standard approach to analyse its stability. However, the following attributes strongly motivate the adoption of a fuzzy logic approach in this work:

- Suitable for a system which is difficult to model and obtain the mathematical description and need linguistic vague information from human experts.
- The fuzzy control itself does not require mathematical equations as in most conventional controllers, just rely on the rule of knowledge based on the systems' requirement.
- Can be implemented to nonlinear systems due to the nonlinear elements in the fuzzy control in order to perform nonlinear control actions.
- Easy to understand by those who are not control specialists because it emulates human control strategy.
- Simple to implement in both software and hardware and inexpensive to develop.

A basic diagram for fuzzy logic approach is shown in Figure 3.2 which consists of fuzzification, inference mechanism based on the rule construction and defuzzification. Each element is described in detail in next section.