International Journal of Cyber-Physical Systems
Volume 2 • Issue 2 • July-December 2020

Fuzzy Control in Cyber-Physical Systems

Michael Gr. Voskoglou, Graduate Technological Educational Institute of Western Greece, Greece
https://orcid.org/0000-0002-4727-0089

ABSTRACT

Controllers are devices regulating the operation of other devices or systems. Fuzzy controllers analyze the input data in terms of variables which take on continuous values in the interval [0, 1]. Since fuzzy logic has the advantage of expressing the solution of the problems in the natural language, the use of fuzzy instead of traditional controllers makes easier the mechanization of tasks that have been already successfully performed by humans. In the present paper a theoretical fuzzy control model is developed for the braking system of autonomous vehicles, which are included among the most characteristic examples of Cyber-Physical Systems. For this, a simple geometric approach is followed using triangular fuzzy numbers as the basic tools.

KEYWORDS

Autonomous Vehicles, Center of Gravity (COG), Defuzzification Technique, Fuzzy Approximation Theorem (FAT), Fuzzy Associative Memory (FAM), Fuzzy Controller (FC), Triangular Fuzzy Number (TFN)

DOI: 10.4018/IJCPS.2020070103

INTRODUCTION

Famous social thinkers of our times (Rifkin 2011, 2014, Schwab, 2016, etc.) argue that we are already in the beginning of the era of a new industrial revolution in which an advanced *Internet of Things (IoT)* will be created, providing energy at the right time and place, and goods and services anytime at any place. This new revolution is characterized by the emergence of the *Cyber-Physical Systems (CPS)*, which are controlled through the Internet by computer programs. CPS are in intensive connection with the surrounding physical world and its on-going processes, providing and using data-accessing and data-processing services available on the Internet. Common applications of CPS typically fall under sensor-based communication-enabled autonomous systems. Examples are autonomous vehicles, distance medicine, robotic systems, industrial control systems, smart grids, environmental monitoring, etc.

It becomes evident that the *control* mechanism of a CPS plays an essential role for its general function and performance. Controllers are devices regulating the operation of other devices or systems. The operation of a traditional controller is regulated by a set of *IF-THEN logical rules*. A rule connects a process or event A to another process or event B. For example, in case of the central heating boiler of a building, IF the temperature of the building is lower than a prefixed bound, e.g. 18^0 C, (A), then the thermostat sends a signal, which, with the help of one or more mechanical valves, turns on the boiler (B). On the contrary, if the building's temperature exceeds a prefixed upper bound, e.g. 27^0 C, (A), then the thermostat sends a signal to the controller to turn off the boiler (B).

Controllers are used to achieve, through automatic operation, increased productivity, high quality products and improved performance of a device or another system. Control theory dates from 1868, when J. C. Maxwell described the theoretical basis for the operation of the governors, i.e. mechanical devices for regulating the operation of industrial engines. The traditional controllers are described by mathematical models using one or more differential equations that define the controller's response to its inputs. Such type of controllers, initiated by N. Minorsky in 1922, are usually referred as *PID (proportional – integral – derivative) controllers.*

In many cases, however, the mathematical model of a classical controller may not exist, or may be too "expensive" in terms of computer processing power and memory. The classical expert systems of Artificial Intelligence (Voskoglou & Salem, 2020), for example, work by using 100 – 1000 bivalent IF-THEN rules. It has been estimated, however, that the human intelligence could be approached by a machine using at least 10^5 such rules! In such cases, therefore, a system based on empirical rules could be more effective.

Zadeh, who introduced the concept of *fuzzy set (FS)* (Zadeh, 1965), realized that FSs are connected to words (adjectives and adverbs) of the natural language; e.g. the adjective "tall" indicates the FS of the tall people, since "how tall is everyone" is a matter of degree. A grammatical sentence may contain many adjectives and/or adverbs, therefore it correlates a number of FSs. A synthesis of grammatical sentences,