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Control Systems

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ABSTRACT
Control systems are necessary to prevent problems from arising, foresee on how to address them and provide solutions to manage risks and unnecessary costs. This paper investigates what control systems and fuzzy logic control systems are. These terms may sound very technical and complicated, but their functions are to make things easier to manage problems and even make decision-making process a lot easier.
Keywords*-component; Control system, Fuzzy Control; Modern control system*

I. INTRODUCTION

A Control system is" an arrangement of physical components connected or related in such a manner as to command, direct, or regulate itself or another system." (DistefanoIII, Stubberud and Williams,2013). It entails "a variable quantity or a set of variable quantities made to confirm a prescribed norm." (The Editors of Encyclopaedia Britannica, 2018). Its purpose is to "either hold the values of the controlled quantities constant or causes them to vary in a prescribed way. "There are ways to operate a control system: either by electricity, by mechanical means, by fluid pressure (liquid or gas), or by a combination of means. The computer is often used in the control circuit while it is more convenient to operate it electrically, although a combination may also be a good option.

The development of control systems are related to the concept of automation of feedforward and feedback; this concept can be traced as early as 1801 through Joseph Jacquard of France who invented the use of programmed punched cards woven by the loom. The feedforward control, on the other hand, was incorporated in some machine tools that were created in the 19th century (The Editors of Encyclopaedia Britannica, 2018).

Feedback control even came about earlier in history; it concept involves the processing of information to correct a machine's operation. The Roman engineers were among the first to introduce this control system and were used to maintain water levels for their aqueduct system using the floating valves that opened and closed its valves at appropriate levels. In the 17th century, the Dutch also had its control system using the windmill to keep it facing the wind by the action of an auxiliary vane which moved the entire upper part of the mill. Another example of early version of a control system was the development of a device that regulated the steam flow to a steam engine that maintained the constant engine speed despite the changing load. James Watt developed this technology in 1769 during the Industrial Revolution (The Editors of Encyclopaedia Britannica, 2018).

The control system has continually evolved through the years. In the 19th century, James Clerk Maxwell, the Scottish physicist, came up with his generalized and control theory, which included the automatic steering system of the U. S. battleship "New Mexico," published in 1922; in the 1930s, electrical feedback in long-distance telephone amplifiers and the general theory of the servomechanism were also developed; there were small amount of power controls that made up the automatic corrections; the pneumatic controller used in chemical and petroleum industries were also developed followed by the analogue computer. During World War II, more elaborate developments came about in the control-system theory, and among the examples were the anti-aircraft batteries and fire-control systems (The Editors of Encyclopaedia Britannica, 2018).

The analog- and digital-computing equipment paved the way for more complex control systems; the automatic-control theory or the so-called "modern control" systems have been introduced to distinguish them from the "classical control" which were then a lot simpler control system. The "modern control" systems have two basic principles: "(1) The value of the controlled quantity is varied by a motor (this word being used in a generalized sense), which draws its power from a local source rather than from an incoming signal;" using a motor requires a large amount of power to effect necessary variations of the controlled quantity to ensure accuracy of the control signals; and "(2) The rate at which energy is fed to the motor to effect variations in the value of the controlled quantity as is determined more or less directly by some function of the difference between the actual and desired values of the controlled quantity." (The Editors of Encyclopaedia Britannica, 2018).

II. MODERN CONTROL PRACTICES

The control system can be used in various ways. Modern control practices have been observed for some purposes such as but not limited to the following examples:

1) Industrial control practice. Theoretical automatic control methods are used to predict effects; they are highly interconnected systems that are used in industrial plants; they are used in operations research, using mathematical techniques for evaluating procedures that are of value.

2) Instrumentation or control-system engineer. This is a physical control system used in industrial plants with a wide range of equipment and methods. The control system engineer may use the analog-type of instruments involving a continuous varying physical representation of the signal, just like how a current, a voltage, or an air pressure would do. There are also conventional devices that would receive one input signal and deliver one output correction. Hence they belong to a single-loop system built up of a collection of such tools.

3) Analog-type computers. They are computers that handle several variables with more complex control functions, but their applications are designed for specific purposes.

4) Digital computers. They are computers that are designed to handle popular elements of industrial-plant-control systems that are applied to industrial control problems to optimize control, direct digital control, and hierarchy control. Optimizing control involves computer operations in external or secondary capacity which set points as interventions in the primary plant-control system either directly or manually. The intervention done is aimed to cut down service to lower cost while increasing production, and if the system breaks down, it does not adversely affect the plant.

The direct-digital control replaces a group of single-loop analog controllers since it can compute and make substitution possible. It can also handle more complex advanced-control techniques that the analog type of computers cannot do (The Editors of Encyclopaedia Britannica, 2018).

Hierarchy control is applied in computers to handle all the plant-control situations simultaneously. It is considered the most advanced and the most sophisticated-control devices that would assist the overall plant operation (The Editors of Encyclopaedia Britannica, 2018).

Digital computers are cost effective as they can be programmed to carry out different tasks separately; their applications are flexible, and the process can change without the need to change the physical equipment of the control system. There are some physical hardware apparatus of the control system that can achieve or implement new functions (The Editors of Encyclopaedia Britannica, 2018).

III. FUZZY CONTROL SYSTEMS

This paper shall tackle in particular about fuzzy control systems. They are forms of intelligent control system "using expert knowledge on the control strategy and the behavior of the controlled plant" (Jakel et al.). They make use of the If-Then rules and linguistic variables; they are related to fuzzy sets.

The fuzzy set theory is the theoretical basis that backs up the information processing in fuzzy control systems. Its system is a "static nonlinear transfer element incorporate into a control loop" used as methods for analysis and system design" (Jakel et al., No date). They perform different structural schemes, namely: in many technical or non-technical fields; in support of numerous hardware and software solutions. They are designed to meet the challenges of increasing number of complex processes to solve problems using automatic control systems. They are control systems either for an alternative or conventional control techniques that work for one's best advantage. They meet the necessary requisites: controlled exhibits pronounce non-linear behavior; there are no mathematical models of the process; expert knowledge is treated as the controlling process acquired for automatic control; since they are multi-dimensional and nonlinear and they are represented in ways that they can be understood and modified easily. By the term itself, fuzzy control system can further be described as a nonlinear controller rather than differential equations; it implements the control strategy of a human expert; its information process takes place within a fuzzy control system; it interacts with the plant and other components of the automatic control system using fuzzy logic, and control theory (Jakel et al.).

The Essentials of Fuzzy Modeling and Control.Fuzzy Modeling and Control provides for all concepts, tools, and techniques that follow a logical, pedagogically consistent format for readers or those who make use of them. The arrangement offers a wide range of fuzzy concepts, tools, and modeling techniques that will allow users, researchers to use them and in the development of the controllers, now better known as the next generation of intelligent systems. They are also used in most relevant engineering and application aspects to justify overall judgment when it comes to motivating and illuminating natural background from the conceptual level. Other inherent considerations are those that include a broad spectrum of methods of successful modeling reality using Fuzzy Set Theory (FST) (Yager and Filev).

The basic definition and concepts from FST are focused on the area of building fuzzy models with different kinds of linguistic models. It also includes basic ideas of FST like fuzzy relations, the extension principle, linguistic variables, and possibility distributions.

The Aggregation Operations on Fuzzy Sets, on the other hand, presents in considerable detail a broad class of aggregation operations for fuzzy sets, which generalize many of the well-known and commonly used operators.

The Theory of Approximate Reasoning is one that presents the necessary machinery for the development of fuzzy-set based linguistic models; its propositions set are values to variables.

Introduction to Fuzzy Logic Control (FLC) takes into consideration the fundamental concepts and paradigms that introduces the Mandani FLC and the PI-like, PD-like, and PID-like FLC.

IV. FUZZY SYSTEM MODELS

It is involving classes of fuzzy system models and different types of the fuzzy system models.

A. Basic categories classes of fuzzy system models:

1) Linguistic Models (LMs), and example of which is the Mamdani type FLC.

2) The Takagi-Sugeno-Kang (TSK) Fuzzy Models where their first group are composed of a qualitative description of the system behavior, while the other second group is one that combines that linguistic rule antecedents with numerical consequent parts.

B. Types of Fuzzy System Models

1) Developing Fuzzy Models are those that involve the process of building models of fuzzy control; it has major identification techniques that identify common steps to solving problems; they also provide constructing fuzzy models as "direct" approaches by authors using their expertise as described in linguistic terms; they also tackle methods of developing fuzzy models based on the use of input-output data, based on the process of "system identification."

2) Theoretical Analysis of FLCs another fuzzy logic control that provides a general view of the FLC as a fuzzy system; it also investigates its relationship to classical models of control and the sliding controllers.
3) Defuzzification Problem is another fuzzy model that deals with the selection of some singleton value as a representative of the fuzzy set that one can get as the system output in a fuzzy model; this is used in general setting when making decisions based on fuzzy sets.
4) The Flexible Structure of Fuzzy Systems provides a flexible-structured fuzzy model where they provide a parameterization of all their components; they can adjust according to fuzzy models, antecedent aggregation, fuzzy implication, and rule aggregation with the help of some parameterizable operations.

V. FUZZY LOGIC CONTROL APPLICATIONS

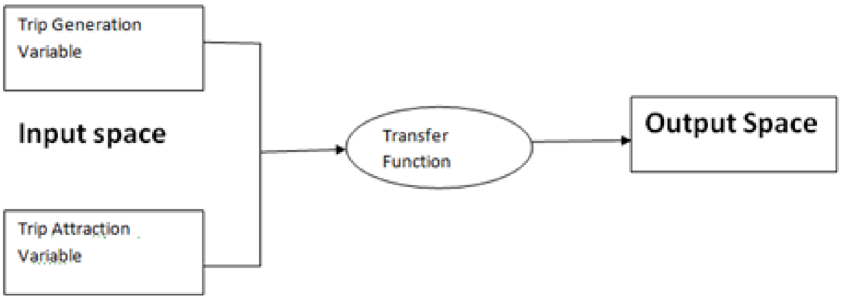
The following are cited examples of Fuzzy Logic Control applications:

1) Fuzzy logic applications are seen in addressing transportation problem.

In transportation system services, it is observed that costs, infrastructure, vehicles, and control systems are subjects of quantitative evaluation to determine their characteristics and performances. Problems involving these services may vary from transport decisions that are under imprecision, uncertainty, and partial truth. There are also constraints in measuring objectivity as well as values hence the need to find useful techniques to solve real-life transportation problems. Pappis and Mamdani (1977) applied fuzzy logic to control intersection of two-way streets; Gianluca (2012) and Brito et al. (2012) used it in developing decision-making system (Gupta, 2017).

The fuzzy logic is commonly applied in generating transportation planning trip by taking into consideration the number of people who want to go out of their homes and determine what their purposes are. The data are used to address non-congestion trip generation models to predict better and adapt well. Kalic and Teodorovic (1997) used fuzzy logic to solve trip generation problem through learning from numerical examples. Wang and Mendel (1992) used fuzzy logic to generate transportation procedure using the available set data to make the fuzzy rule base and to control data subset. By creating the fuzzy rule base, a fuzzy system is obtained to test on both subsets of data. The fuzzy logic approach established shall be tested, and its result shall provide the closest estimate of the actual number of trips that is a generation in a given area.

The fuzzy logic is also used in trip distribution, which forms the second stage in the traditional transportation planning process. Trip distribution models determine the number of trips generated between pairs of zones; the same is produced when particular zones are also known. Traffic flows and trip distribution may vary depending on human choices, which are affected by some variables that are social and personal to commuters. To map social and demographic variables, Jassbi et al., (2011) developed a fuzzy inference system (FIS) to generate a total number of trips between origin-destination (OD) pairs (Gupta, 2017). A conceptual model has been created to forecast trip input-output space.



(Source: Gupta, 2017)

The modal split is the third phase of transport planning which determines which mode of transportation is used and by how many fractions of people (Gupta, 2017). Teodorovic and Kalic (1996) came up with their fuzzy logic to solve what mode to choose to solve problems; they were able to generate numerical data on difference between the travel and travel costs of competitive modes (Gupta, 2017).

2) The traffic signal controls a product of fuzzy logic.

It is designed to help control traffic signal situation and provides multiple solution and vehicle's movements. Mathematical modeling in traffic signal control is used by an experienced human to conduct the process, mainly when addressing complex issues with multi-objective problems. To cite some works, Pappis and Mamdani (1977), Chiu and Chand (1993) used this knowledge in distributed architecture by designing cycle time, phase split, and offset using local traffic data collected at the intersection; Jarkko and Esko (2003) came up with their version of fuzzy logic using the performance of a signalized intersection, where the time value, environmental effect, and traffic safety are controlled at signalized isolated pedestrian crossing in a minimum waiting time, thus providing a minimum risk of rear-end collisions while managing multiphase vehicle control (Gupta, 2017).

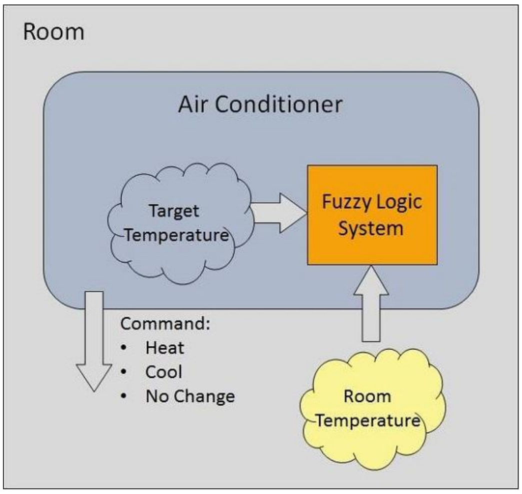
The transportation decision and investment is another area where the fuzzy logic control use in traffic management. The decision process entails a synthetic evaluation to justify highway alignment with impact in the environment. Its fuzzy logic explore innovative technology in integrating infrastructure and land use in planning for transportation corridors (Gianluca Dell'Acqua, 2012); the same fuzzy logic is also used as a method to minimize the total product and transportation costs and whole delivery time by taking into consideration the budget constraint and limited supply of resources (Gupta, 2017).

3) The fuzzy logic in washing machine.

It has a process control system used in household appliances; it has a precise mathematical relationship between inputs and output which cannot be defined and so the washing machine is designed to have automatic washing time with two subsystems: 1) the sensor system, which collects data from outer environment to controller; and 2) the controller system, which sets the washing time based on the information received from the sensor system, where the fuzzy logic controllers are installed or used. The washing machine will have its linguistic inputs, such as type of dirt, type of clothes, mass of clothes, and the like; there are also controls for the linguistic output such as wash time, spin time and rinse time; the fuzzy logic controller functions in three blocks: fuzzifier, fuzzy inference engine and defuzzifier (Gupta, 2017).

4) The room air cooler.

It has a control system using fuzzy systems that have computational intelligence where it manages commands that regulate the behavior or other systems. The fuzzy logic control systems for room air cooler are designed to manage temperature and humidity; they have two input (linguistic) variables, temperature and humidity, and three output variables, cooler fan speed, water pump speed and exhaust fan speed (Gupta, 2017).



(Source: www.tutorialspoint.com)

5) Fuzzy logic is applied in medical science.

Especially in the development of medical domain application. It is used for research studies, such as in developing a detection system for heart disease. It is used for clinical decision purposes which support the knowledge-based CDSS and the non-knowledge based CDSS. The knowledge-based clinical decision support system is associated with rules, such as generating a warning in determining pain intensity at a certain level. It can generate adaptive guidelines for more effective chest pain management. The decision support systems support artificial intelligence as it can provide computer-aided support systems/expert systems in congregating information for the process of decision-making (Gupta, 2017).

The natural way to describe patterns is to use vague terms. However, teaching vague terms could mean letting the computer provide a precise definition, but the computers cannot understand vague concepts, so there is a need to conclude. Computers require data to be expressed in the simple logic described by a binary code, but the natural way to describe patterns is to use vague terms such as 'round' or ‘dark.' The mathematical way to look at vagueness using the computer is done through the ‘fuzzy logic’; this approach has become a common household term in Japan; even Japanese companies understood what the mean by the fuzzy logic as this terms is used to improve efficiency of automatic transmission not only in cars but also in plants, for example in chemical plants are as they control the injection of chemicals to simulate the shutdown of a nuclear reactor on a computer. Japan’s fuzzy logic is now used in appliances, especially consumer goods, such as washing machines and rice cooker, where they are easy to operate using fuzzy logic (Sangalli, 1992).

VI. CONCLUSION

Fuzzy control systems are applied in various ways to solve problems because they are capable of solving these problems using the traditional analytical approaches or techniques or hard computing models. They are beneficial tools applied in power system fault diagnosis, determining decision-making behavior, and conducting crime investigation. In today's very complex environment with challenging problems to solve, the fuzzy logic control is just about the right ingredient to manage them.

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