International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

Comparison of Fuzzy Logic Systems and its Applications using Mathematical and Technological Perspective

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Abstract

Human instincts are a difficult concept to grasp. To comprehend this drive, a comprehensive dimensional analysis of discourse knowledge is required. PC frameworks are by and by being prepared to understand how things work in a continuous climate, which will help in the improvement of clever examination. This exertion, albeit groundbreaking, has various downsides too. There is a cognitive gap between humans and machines, which puts humans one step ahead of machines. For a computer to better understand this intelligence gap, the fuzzy logic system may be utilized. Another way of putting it: fuzzy logic is a kind of computational intelligence that enables computers to understand and reason in the same manner that humans do Since it can tackle issues that have never been addressed by joining its capacities with delicate figuring methods, for example, neuro and tumult registering, hereditary calculations, likelihood thinking, and insusceptible organizations, the fluffy rationale framework is drawing in researchers and architects from everywhere the world. It's difficult the fluffy framework that has improved information-based or master framework innovation, yet it has additionally changed the granularity with which knowledge is communicated. Manufacturers of home appliances, for example, are already incorporating intelligence into particular products via the use of the fuzzy logic framework. The utilization of fuzzy logic frameworks has additionally changed mechanical cycle control and opened up new roads for item creation. Regardless of the way that hypothetical progressions in the fluffy rationale framework have for the most part been accomplished in the United States and Europe, Japanese organizations have been at the cutting edge of the innovation's commercialization since its presentation. The motivation behind this examination is twofold: first, to comprehend the fluffy rationale

framework needed for successful dynamic, and second, to exhibit the presence of an insight hole by using true guides to show the presence of a knowledge hole. Singular perusers will profit from the models, which have been chosen with care to delineate and show the fluffy rationale framework's applications.

Keywords: Fuzzy logic, Fuzzy Systems, Applications, Inverted Pendulum Technology

1. INTRODUCTION

In 1965, Lotfi A. Zadeh, a professor of computational science at the University of California at Berkeley, began Fuzzy Logic. In summary, Fuzzy Logic (FL) is a multivalued logic, which defines values such as true/false, yes/no, high/low, etc. Concepts like "tall" or "quick" may be defined mathematically and programmed into computers to emulate human thought in the programming of computers. Fuzzy systems have their roots in ancient Greek philosophy. Many misunderstandings exist regarding fuzzy logic. Fuzzy logic is not fuzzy, to begin with. Fuzzy logic is, in a significant way, exact. The second cause of misunderstanding is the duality of the meaning of fuzzy logic[1,2].

Fuzzy logic, in a limited sense, is a logical system. By and by, in a ruling significance, fluffy rationale, or FL for short, is considerably more than a coherent framework. Fluffy rationale offers a simple strategy to come to an authoritative result dependent on indistinct, questionable, uncertain, loud, or missing information data. The rationale that sees more than essential valid and bogus qualities. With regards to fluffy rationale, thoughts might be communicated utilizing levels of honesty and erroneousness. For instance, an assertion like today is radiant might be valid if there are no mists, 80% valid if there are a couple of mists, half evident if it's hazy, and 0% valid on the off chance that it rains the entire day. The fluffy rationale has become a fundamental apparatus for some, various applications spreading over from designing frameworks to counterfeit intelligence [3].

A short explanation of the fundamental concepts of fuzzy logic and fuzzy reasoning is presented in this quick introduction. The chapter on fuzzy logic control: the design of intelligent control systems that utilize fuzzy if-then rules to mimic human behavior. Math knowledge is maintained simply throughout, with many illustrations to assist with understanding. Thus, everyone interested in fuzzy ideas and their real-world applications will find this a great place to start. An important feature of natural human thinking is the use of natural language [4].

Lotfi A. Zadeh wrote the much-controversial article "Fuzzy Sets" in 1965. Zadeh's articles were referenced over 185,000 times. Later that paper's concepts were used to establish the Fuzzy Logic theory, which has proven to have a wide range of practical applications. We will be discussing Zadeh's pioneering work in Soft Computing and Artificial Intelligence and his early impact on the globe and Romania. Additionally, we shall include a few of FLb's applications. We may now posit FLn as a metatheory of fuzzy mathematics, which provides a model for the fuzziness in many facets. It can also be used as a theoretical tool for the fuzziness in various forms [5].

2. DEVELOPMENT OF FUZZY LOGIC

Fuzzy logic has developed as a useful method for evaluating hydrologic components and making decisions about water resources. Many hydrologic problems include imprecision and ambiguity, which may be easily addressed by fuzzy logic-based models. This article takes a look at several water-related applications of fuzzy logic [6]. To date, fuzzy logic-based hybrid models have been widely used in hydrologic research. A critical role in food acceptability and dietary preferences is played by sensory evaluation. This information helps food-processing companies and food scientists to better assess the sensory quality of food items. Traditional methods only provide qualitative analysis, and cannot provide a precise quantitative analysis [7].

Fuzzy set theory has recently been used for the assessment of sensory qualities of food items produced using fortification and changed processing methods. Framework regulators use fuzzy logic and tumultuous natural product fly control strategies to compute proper damping powers for the front and back bogie outline. The vehicle model has 28 levels of opportunity, and it depends on nonlinear vehicle suspension and a nonlinear heuristic wet blanket. The Modified Dahl model is developed to explain the damper's behavior. Mobile/stationary node positioning and location estimate are crucial, particularly following the amazing advances in wired and/or wireless communications, as well as the widespread use of portable devices [8].

Many end-users, application developers, and service providers all need precise location information. Wireless, multisensory, and autonomous systems have all contributed to an increase in positioning technologies. In each kind of positioning system, the accuracy, communications protocol, algorithm, and technology all vary. Since reliable Fault Detection and Identification rates may significantly reduce costs, a variety of methods have been developed for gas turbine FDI systems [9].

A gas turbine failure detection, which was previously unexplored. Despite the way that fuzzy logic has been broadly utilized in power frameworks, it has regularly been described as "a long way from full" attributable to the absence of a normalized technique for applying it. In this paper [10], we give a deliberate turn of events and execution of a nonexclusive energy stockpiling framework (GESS) coordinated with fuzzy logic for dynamic dependability support in an aggregate force framework. The responsive and genuine force directions of GESS are determined while ensuring a settling execution by lessening a quadratic security record is kept up with all through the reenactment.

3. FUZZY SYSTEMS

In classical logical systems, bivalent logic is often employed. Anything may be either true or false in the bivalent logic system. As a consequence, its ability to depict notions like "wealthy" and "tall" is impeded. Try to grasp the meaning of "tall" with this in mind. In general, the general public believes that someone taller than seven feet is tall, whereas someone who is less than five feet is certainly short. A common method for measuring tallness is to utilize a predefined number (above which everybody is tall and below which everybody is not tall). The height value of 6' would be convenient to utilize for this example. With this default value, people's heights of 7' and 5' are properly classified as tall and short. A and B are both 5'11" and 6'1".

Assumed before, 6' = A is short, B is tall. From the way it seems, it does not appear to be true. Despite having shorter legs, A's height is nearly equal to B's. Regardless matter whether we increase or decrease the preset setting, this issue remains. This issue emerges because we are utilizing a Bivalent sensible framework where esteems like 5'11" and 6'1" are naturally allocated to one of two sets: "tall" or "short." In fuzzy logic, each person's height is given a membership degree, with tall people having a higher membership degree than short people.

To illustrate, a person who is 6'1" in height will be tall to the degree that they are 6'1", while a person who is 5'8" will be tall to a different degree since they are 5'8". The way that people of various statures might be "tall" to changed degrees is clarified in this plan.

In Figure 1, the fuzzy logic system models the uncertainty of "tall" by distributing membership degrees across different heights. This figure shows how the height degree in the group of tall people is proportional to the vertical distance between the plotted points. People who are less than 5 feet tall are considered short; those who are 5 feet or more are considered tall (i.e., definitely tall). A 6'5" individual is short to the degree of 0.7. "Tall" is represented in Figure 1 as a fuzzy set representation. All domain objects must have a membership degree of 0 (not a member of the set) or 1 in a Bivalent logic system (a member of the set). Fuzzy sets include a membership degree, however, this number is between 0 and 1 rather than 0 and 100. The fuzzy logic system's usage with the Bivalent logic system produces similar results.

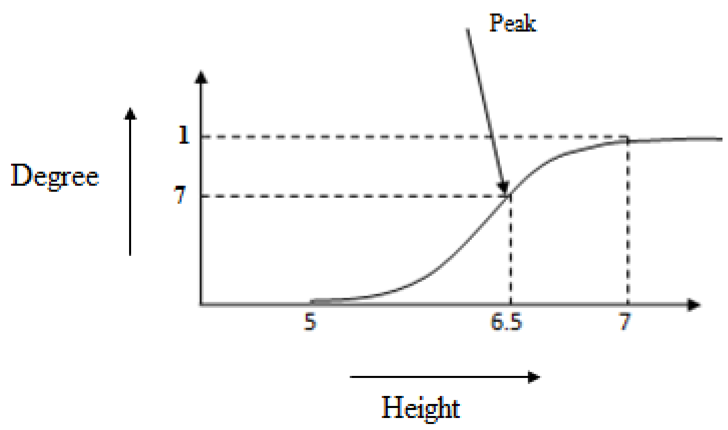

Figure 1: Fuzzy Sets Representation

The union, XUY, of two fuzzy sets X and Y is the probability distribution of the union of those sets. The intersection of two fuzzy sets is represented by the minimal membership degree of each item in the two sets. This results in the probability distribution of the intersection, XY, of the two sets. Just things that are normal to the two gatherings are held in their crossing point. 1 is subtracted from all the components of the domain to get the complementary possibility distribution of a fuzzy set.

In a seminal work on fuzzy sets, Zadeh introduced the min-max operators, which may be used to define fuzzy set-theoretic operations. Many other operators for fuzzy sets have been created by various academics over the years, including the minimum-maximum operators. There will be no discussion of these additional operator types since the scope of this essay does not allow for it. This research revolves around the widely used min-max operators because of their simplicity and appealing characteristics. The fuzzy sets Low, Medium, and High have comparative portrayals for Voltage and Current, as displayed in Figure 2.

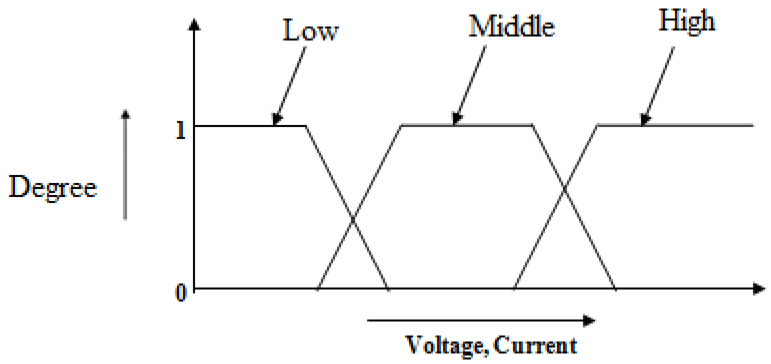

Figure 2: The fuzzy sets Low, Medium, and High

To get the appropriate current value, we shall utilize fuzzy reasoning. In Figure 4, two fuzzy standards and the fluffy info are shown graphically. To accommodate a more clear agreement, the information reality's conveyance is displayed as a marginally specked region across the premises of the two fluffy standards in Figure 3.

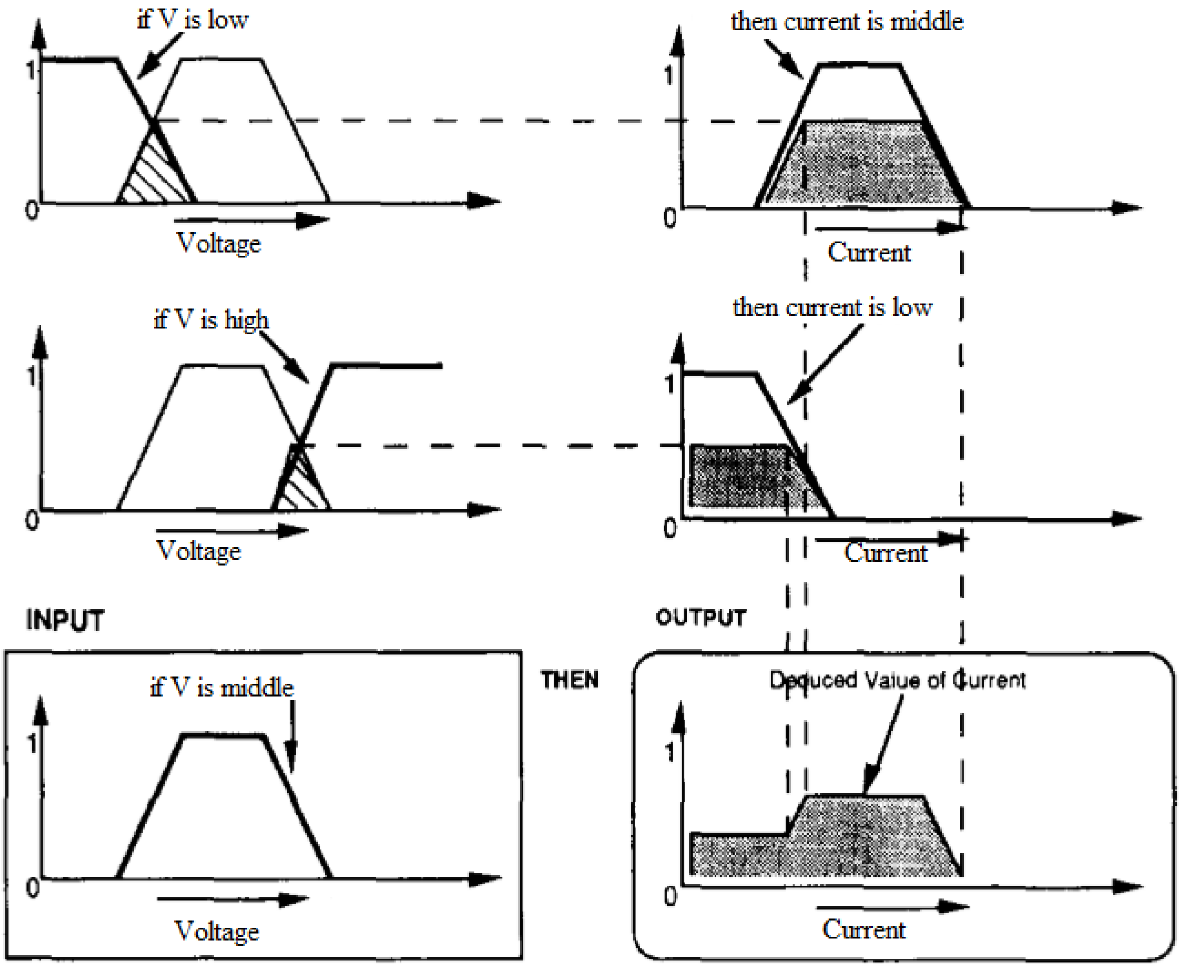

Figure 3: Approximate inference using fuzzy rules (fuzzy point)

Even if the two rules do not have a one-to-one mapping with the input fact, each rule still has a portion of a match. Since this is the case, it is expected that every one of the two guidelines will add to a definitive result. The worth to be acquired is resolved as follows:

For each of the fuzzy premises, the input fact's intersection is computed. Figure 4 illustrates the junction areas on the input premises It is dictated by registering the convergence of the yield fuzzy circulations showed concealed in the finishes of Figure 4, and the commitment of each standard to the yield answer is found by the level of the yield fuzzy conveyances (shown concealed) that is incorporated inside the crossing points. When consolidating the consequences of each standard, the current yield esteem is shaped.

4. THE INVERTED PENDULUM

The examples of fuzzy logic system applications shown in this section provide real-time examples of how these systems are used. This inverted pendulum system is simple, yet is made up of many components. An inverted pendulum system is a great option for tests and class demonstrations in a laboratory setting.

The upset pendulum is one of the exemplary techniques for investigating control methodologies. The difficult part of balancing an inverted pendulum is applying the proper force. As required, the hand may be moved in one direction or the other to balance the stick on top of it. See Figure 4 where a basic inverted pendulum is balanced by a motor.

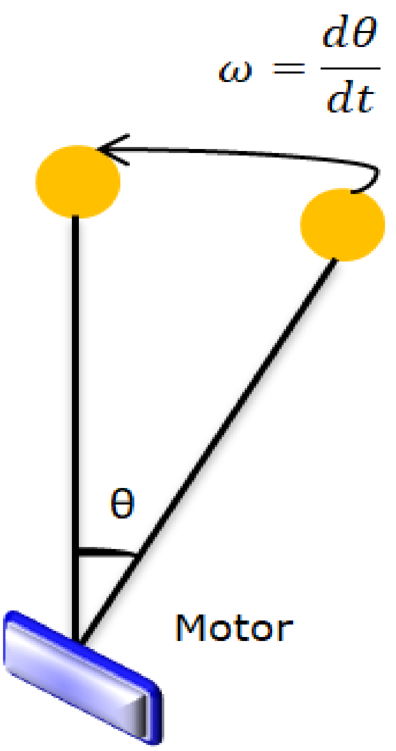

Figure 4: An inverted pendulum.

Despite its effortlessness, the transformed pendulum is a nonlinear framework. Though a system may be correctly stated, it will need to be solved for a second-order differential

International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

equation. Occasionally, such oversimplifications are used to accelerate the solving of a problem, as they should. There are exceptions to every rule, and huge displacements are no exception. for getting the best possible result, several numerical methods are needed (which are computationally intensive). Also, balancing the poles is challenging since the solution point is sensitive to the starting conditions of the system. The arrangements created are influenced by numerous elements, like the heaviness of the sway, the length of the shaft, and the engine's solidarity. The accompanying arrangement of fluffy guidelines might be utilized to oversee such a framework:

IF θ is zero AND ω is zero THEN Force-applied is zero

When clearly defined, Table 1 will demonstrate that a bunch of 12 standards might be used to administer a basic transformed pendulum, for example, the one displayed in the figure to one side. As referenced previously, the precise removal and rakish speed of the pendulum are determined and, separately. Electrical motors will also be utilized to balance the inverted pendulum, as well as to provide the required force.

Table 1: Fuzzy rules implemented to control an inverted pendulum

IF	θ	is negative-	**AN**	ω	is zero	**TH**	Curre	is positive-
IF	θ	is negative-	**AN**	ω	is zero	**TH**	Curre	is positive-small
IF	θ	is zero	**AN**	ω	is zero	**TH**	Curre	is zero
IF	θ	is positive-small	**AN**	ω	is zero	**TH**	Curre	is negative-small
IF	θ	is positive-	**AN**	ω	is zero	**TH**	Curre	is negative-
IF	θ	is zero	**AN**	ω	is negative-	**TH**	Curre	is positive-
IF	θ	is zero	**AN**	ω	is negative-	**TH**	Curre	is positive-small
IF	θ	is zero	**AN**	ω	is zero	**TH**	Curre	is zero
IF	θ	is zero	**AN**	ω	is positive-small	**TH**	Curre	is negative-small
IF	θ	is zero	**AN**	ω	is positive-	**TH**	Curre	is negative-
IF	θ	is positive-small	**AN**	ω	is zero	**TH**	Curre	is zero
IF	θ	is negative-	**AN**	ω	is positive-small	**TH**	Curre	is zero

In Figure 5, you can observe the forms of these fuzzy sets. To illustrate, you should note that the values for and are both precise. Also, the motor has to be supplied with a certain current to maintain the inverted pendulum at its designed amplitude.

Figure 5 depicts a visual representation of the inference process for crisp input values. In Figure 8, two fuzzy rules from Table 1 are shown. Two premise clauses are now included in the regulations. This statement is known as "The Inputs Have Arbitrary Values". The following numbers show the greatest degree of correspondence between the info upsides of and the premises of rule 1: r11 (which is 1) and r12 (which is 2). and in Figure 9 (about 0.5 as indicated). The value of r11 is 1 may be considered a fuzzy set with a membership degree of 0, where 0 is the single element making up the set. This section of the output, from r11 to r12, is attributable to the conclusion of the rule.

International Journal of Aquatic Science
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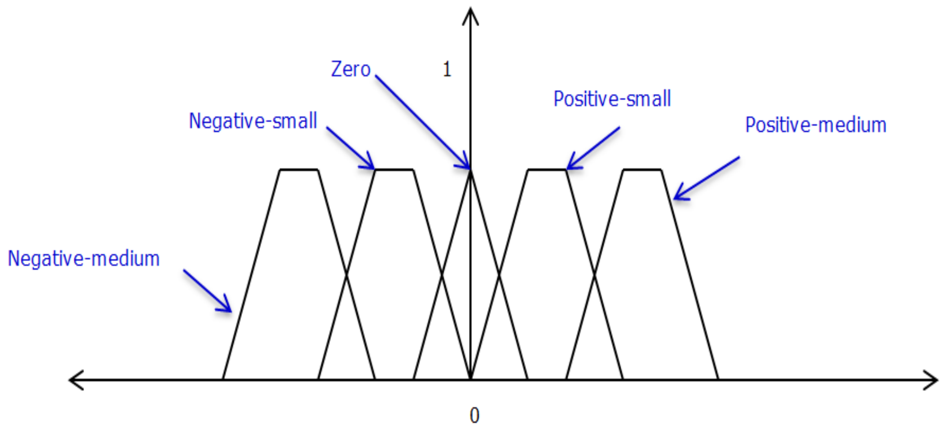
Rule 2 does not affect the outcome in Figure 5, since r21 is equal to zero. The zero minimum of r21 and r22 is always achieved. Next is the inference phase where you follow the same stages as in Figure 4. In Figure 5, the crisp numbers used as inputs are represented by the fuzzy rules that constitute the final output. However, the fuzzy output must be defuzzified, meaning it must be made crisp enough that it may be stated as the current value that is essential.

The final output crisp number in Figure 5 is almost equal to ω' (which is close to zero). Instead of measuring the location and velocity of the bob, these rules utilize the current angle and orientation of the mechanism to regulate the pendulum. The very 11 rules that might be utilized to adjust the upset pendulum paying little mind to the mass of the sway or the engine strength can be applied regardless of whether the mass of the weave or the engine strength is evolving progressively. Rather than customary control frameworks, which are delicate to changes in these boundaries, our strategy is unaffected by them.

To need more knowledge and technical talents to discover correct fuzzy rules than you'll need to solve difficult arithmetic problems. Although the particular distributions have been proven to have minimal effect on the system's performance, the fuzzy distributions, in general, have not. This greatly simplifies the procedure from an engineering perspective. Likely just as noise and breakdowns are very resistive to the system, so too are glitches in the system.

The inverted pendulum will be regulated, although not as reliably as before, even if at least one of the active fuzzy rules in Figure 5 is deactivated (for example, owing to a hardware failure). In a fuzzy logic system, mild degradation is one of the smart characteristics. These principles are specified by linguistic variables, which are established on the domains of input and output. These fuzzy rules are modeled after other fuzzy logic systems, whose rules are functionally equivalent to these fuzzy rules.



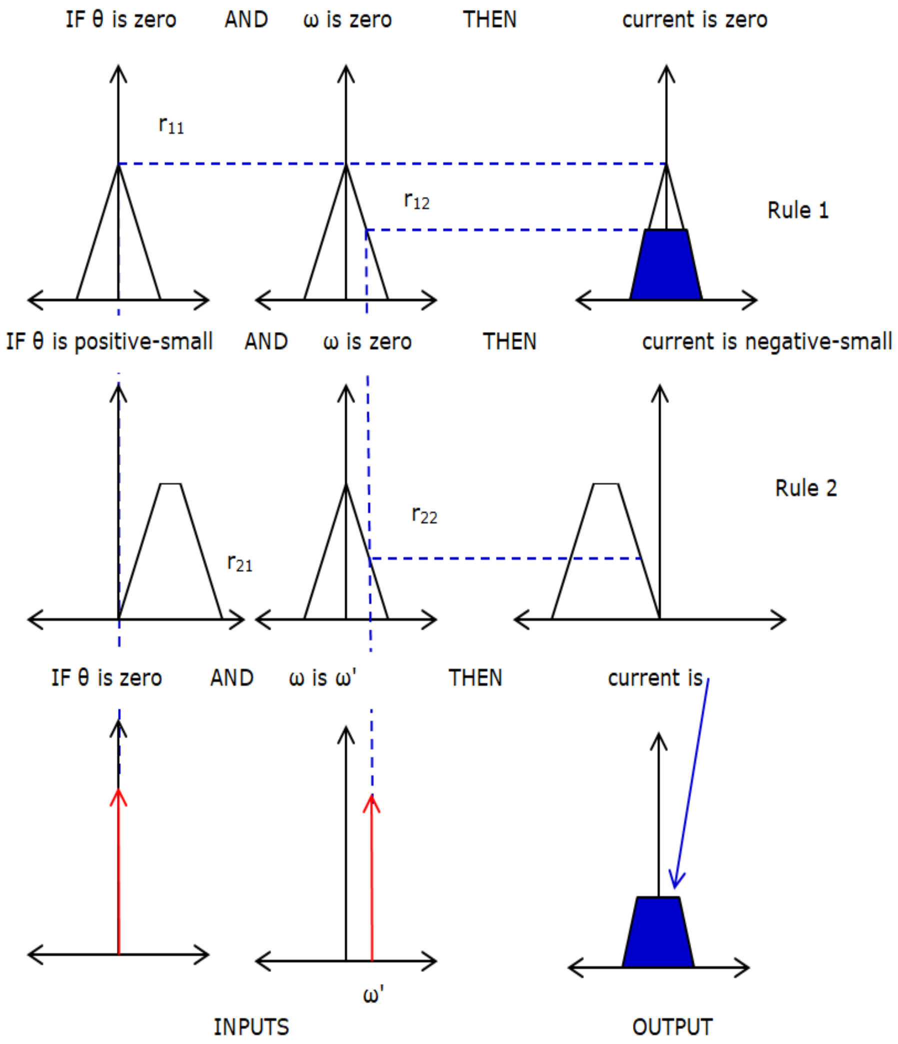


Figure 5: Fuzzy inference in the inverted pendulum

Fig. 5 shows many variations on the basic inverted pendulum. This is a sampling of them:
A flexible, pendulum-style connecting rod is assumed in Figure 7. However, even though the issue is more difficult to describe and solve if the assumption of a rigid rod is removed, we must do so if we want to get a full understanding of the problem.

Two or three joints in the (inflexible) rod supporting the pendulum bob, hence a two- or three-phased pendulum. While such a system may be described correctly, the subsequent control equations are too complicated to be solved in real-time with regular computers. Although building a real-time controller to regulate the many inverted pendulum "complex" states is challenging, According to researchers from Aptronix (China/USA), but other Japanese companies as well, certain inverted pendulum systems have been effectively managed using a fuzzy logic system. Fuzzy logic has impressed engineers who view it as a highly smart tool for directing complicated operations.

5. CONCLUSION

Air quality systems, vacuum cleaners, antiskid braking systems, washing machines, subway control, models for new product pricing, and project readiness Fuzzy logic has effectively been used in industries such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics, and optimization. Mathematics has brought formerly stagnant areas of science back to life. According to most indications, the fuzzy logic system's business impact is only starting to be appreciated. In the long term, industry and business remain to acquire an incredible arrangement. While fuzzy logic can't fix everything, it does offer some benefits that have been shown. Creative products are now far more reliant on a company's ability to sell them in a cost-effective and timely way, particularly in the global market.

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