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# DESIGN AND ANALYSIS OF RULE-BASED FUZZY LOGIC CONTROLLER FOR PERFORMANCE ENHANCEMENT OF THE SUGARCANE INDUSTRY

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*Research Paper*

***Abstract:*** *In the beginning, Zadeh's 1965 research on fuzzy sets inspired fuzzy logic (FL). FL continues to be comprehended through the estimation, ambiguity, partial reality, and inaccuracy. The integration of system intelligence will be accomplished through soft computing techniques. The study focuses on the widespread FL applications in manufacturing processes and standard computerization approaches. The sugar processing facility with the highest percentage of success in extracting the juice took first place among them. Because of the more significant seasonal component, regularity must be preserved to improve system performance. As a result, the proposed methodology successfully limits the volume or range of the Donnelly channel using the three inputs for the fuzzy controller. However, due to nonlinearities, the amount of cane fibre passing through the sugar mill's carrier fluctuates, which affects the mill's effectiveness. Additionally, the algorithm's use of three fuzzy input controllers to increase cane volume in the Donnelly chute during cane juice extraction results in a critical motor speed for the rake carrier ascribed to the range and quantity of cane on the carrier with the rolling rate. The toolbox function of FL in MATLAB® was used to create the simulation results for the 3-input.*

***Keywords***: *Conventional controller, defuzzification, Donnelly chute, fuzzy controller, fuzzy logic, juice extraction, sugar industry*

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# 1. Introduction

Generally, in India, sugar is produced in states like Maharashtra, Uttar Pradesh, Punjab, Andhra Pradesh, and Telangana (Forbes, 2021). The entire sugar-making process appears in Figure 1. It has three stages stick juice extraction, juice Clarification and crystallization centrifuging. For the extraction of cane juice, two basic procedures followed for removing pulp and juice are the practice of diffusion and milling. Instead ofincreasing the efficacy of the mill through the extraction process, the water undertaken for the inhabitation can be oriented to the prior release of the water fed to the mill. Later, the boiled water can be fed to the mill through the extraction of juice which is re- circulated for the final reach of the mill. By the milling practice, the juice can be squeezed from the cane within the group of mills subjected to more fabulous pressure built-in with the rollers of heavy iron material, which can set up the roller value of 2-6 rolls, at each set value for the tandem or train mill (Baboo, et al., 2002).

Moreover, the extracted juice has undergone a low sugar concentration which further thrust to the, what's more, emptied over cane not long earlier roll that enters for the system. For further development for milling removal execution instead of arrivalof cane at primary aspect stage typically involve blade and shredder as readiness hardware. High temp water is poured over the annihilated stick not long before the delivery diffuser is reflected at the end since the pH value for the sugar stick juice ranges from 4-4.5, highly acidic. Nevertheless, calcium hydroxide, lime or limewater channel is attributed to the variation in the pH to 7.0 for the sugar stick juice (Na, 2009). Further, lime continues to decay with the level of sucrose with fructose and glucose composition. And finally, heats limed juice with the maximum range of temperature under the superheated value of limed juice for permitting the immersed temperature blasted into the suction (Almatheel & Abdelrahman, 2017). within the technique accelerates contaminations stayed for the calcium carbonate valuable pebbles. Later the trades people of flashed juice to enable the solids to settle down. With the supernatant for the capability of the juice extracted for the evaporators being fed to impact the cane syrup for gaining the weight for remaining sucrose levels at 60% (Pitteea, King, & Rughooputh, 2004). Sugar syrup is additionally focused over the vacuum of the boiled pan within the supersaturated theory of the cane material fed with the crystals assigned to the introduction within the seed value of the sucrose for the size altered for the discharged process, which is approximately at 0.04 inch for the sugar crystals grounded at the level of suspension reached with the feasible count of boilers, through which count three is conventional (Michal, Kminek, & Kminek, 1994). Moreover, the procedure for thedifferent boiling stages reaches with the successive feature of the batches such as A-, B- and C-. Conversely, batch A centrifugally separates the sugar content within the liquor region of a mother. Using these centrifuges attributes the capacity to around 2100 kilograms per cycle. Further, with the centrifuges of the sugar stick reaching the shipments based on the package of the bags, the product's insight can be stored in a siloinstead, with the shipment tracked directly (Petridis & Kaburlasos, 2003).

## 1.1. Motivation

Stick juice extraction, juice clarification, and crystallization centrifuging are the three stages of the sugar-making process. However, the batch of A-type region in vacuum pans can be allocated to the crystallization, the aspect of the material feed for the liquor mother, and shift towards the linear motion of the sugar centrifuges. Mother Liquor also crystallized inside the vacuum pans. The excellent case of the molasses obtained at the highest temperature of 45 °C was isolated for the lowest cleanliness acquired for the evaporate crystallization. To reheat the substance in the viscosity of the C batch sugar extraction's centrifugal reach.

Last but not least, the direction toward crushing the juice within the stick beyond the set value of many iron rollers is demonstrated by juice extraction during handling (Liu & Li, 2005). These facilities, also known as plant trains or tandem processing plants, have 3 to 6 steps per set of production lines. It is difficult to monitor processing parameters only at critical stages throughout the sugar manufacturing process. Even if a researcher rejects any substantial obstacles and may find a range of issues throughout the process, it is still important to include the overall process flow in this study because several operations were taking place simultaneously.

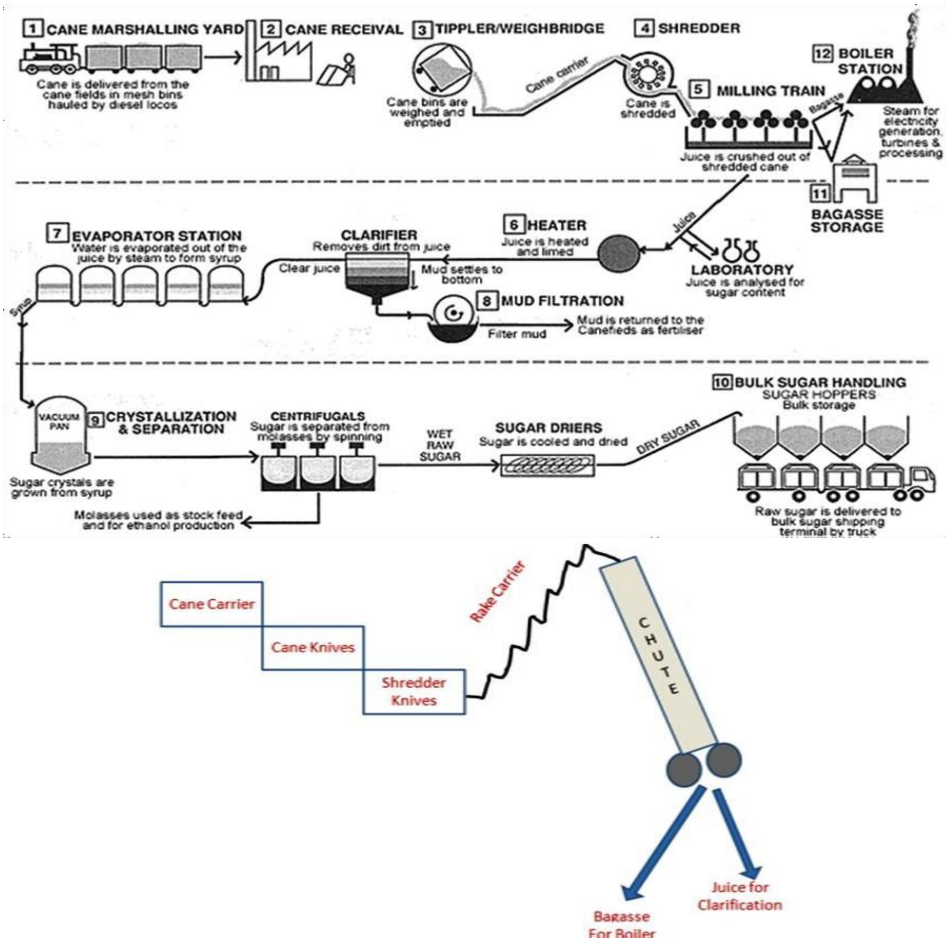


*Figure 1. Schematic Diagram of Sugar Making and Juice Extraction Process*

### 1.2. Contributions:

The primary goal of the proposed study is to improve performance in the sugar cane business by creating an enhanced fuzzy controller using three inputs and a rule-based fuzzy inference system. A methodology designed to enhance the three input controller with fuzzy is utilized to maintain the cane volume (or level) of the Donnelly channel.

### 1.3. Arrangement of the paper:

A brief overview of FL and research related to the current topic is presented in Section 2. Next, Section 3 outlines the whereabouts of the fuzzy controller industry. Theapplications of FL in the sugarcane industry are described in Sectio4 whereas Section 5 presents sugar mill terminology and constraints. Furthermore, Section 6 discusses the proposed fuzzy controller algorithm, which works on 3 inputs. The experimental setup and findings have been highlighted in Section 7. Finally, the concluding remarks are provided in Section 5.

## 2. Fuzzy Logic Overview

A form of reasoning that resembles human thought is fuzzy logic (FL). The FL approach considers choices as made by humans and includes alternative in-between digital yes and no values. A traditional logic circuit is thought of where a computer can comprehend exact input and then generate a clear output as true or false, which is analogous to a human judgment of yes or no. Zadeh (1996) inventor of FL made a few observations on human decision. It includes possible ranges between yes and no such as possibly yes, indeed yes, possibly no, no and cannot say. Membership functions over fuzzy sets of variables allow for the quantification of linguistic terms and the representation of the fuzzy set graphically. The triangular membership function, which is depicted in Figure 2, is the most widely used among Singleton, trapezoidal, and Gaussian membership functions. The 5-level fuzzifier's input ranges from -10 to +10 volts, and as a result, the output also changes.

The structural block of a fuzzy controller is depicted in Figure 3. The input data fromthe real world is called as crisp value. The crisp value from the real world is first converted into fuzzy value, and this process is called fuzzification. The fuzzifier block of fuzzy controller does the fuzzification. The output of fuzzifier is feed to the rule base block. Depending upon the inputs and the developed rule base an output in the form of fuzzy value is generated. The fuzzy value generated by rule base is of no use for real-world; therefore, it must be converted back in crisp form, called defuzzification. The defuzzifier block of fuzzy controller does the defuzzification. Fuzzy controllers' advantages are listed below:

(i) Robust and accurate under the input of disturbance andnoise of various probability functions.
(ii) Easy to implement compared to conventional mode-based technique.
(iii) Customizable and user friendly
(iv) Wide range of application

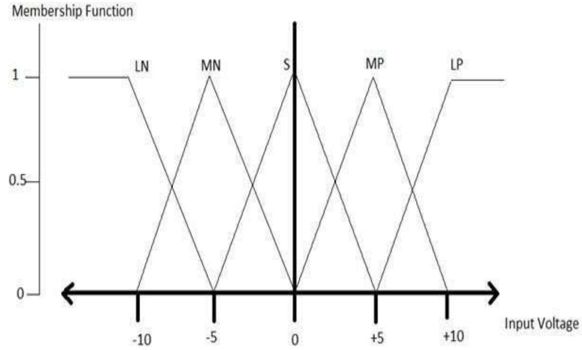


*Figure 2. Membership function*

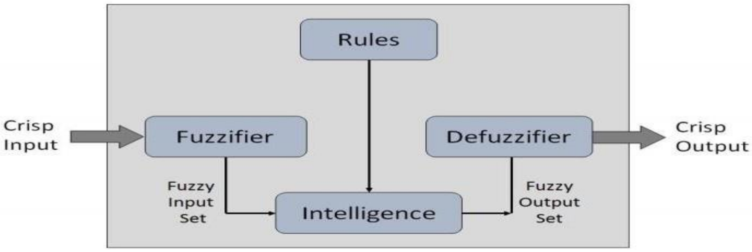


*Figure 3. Fuzzy control system block diagram*

## 3. Fuzzy Controller Industry

We know that practically all modern cycles are nonlinear. Even if only a slight noise is present in the information, the PID's subsidiary term creates a significant shift in process yield. Fuzzy control is an intelligent and easy to design control method which generates fast and accurate result (Cheok et al., 1996). Prior knowledge of model is not necessary. Few instances of unconventional controllers are neuro or neuro-fuzzy, Fuzzy controllers (Hu, Mann, & Gosine, 2001). Initially, FL is invented in the hands of Zadeh (1996), a professor at the University of California at Berkley. He concluded that in the absence of precise input information, it is possible to reach a conclusion by permitting incomplete set participation instead of crisping set enrollment (Guo et al., 2011). A fluffy rationale framework (FLS) can simultaneously deal with mathematical and phonetic information (Zadeh, 1996). It is nonlinear planning of an information vector into a scalar output. Presently FL regulators (FLRs) are as a rule progressively applied in regions where framework intricacies, improvement time and expenses are the significant issues (Mendel, 1995). Japan first started research activities on FL An examination establishment, Laboratory for International Fuzzy Engineering (LIFE) began working in 1993. The Japanese specialists are the innovators in the pragmatic execution of Fuzzy hypothesis and presently have more than 2000 licenses nearby (Sowell, 1997). Prof. E. Mamdani and his understudy, S. Assilian, assembled very first fuzzy regulator in England in 1973 at the University of London. After testing, they inferred that for controlling the speed of a steam motor a fuzzy-based regulator was front proficient when contrasted with regular regulator (Markande, Joshi, & Katti, 2004). Figures 4(a) and 4(b) show a framework reaction with and without a fuzzy regulator. A concrete oven in Denmark in 1975 was the principal modern use of FL Group that fostered a fuzzy-based auto-centering camera. The camera's fuzzy control framework utilizes 12 sources of info and 13 fuzzy guidelines (Kinnaird & Khotanzad, 1999). A fuzzy-based modern climate control system planned by Mitsubishi warms and cools multiple times quicker when contrasted with the past plan, lessens power utilization by 24%, increments temperature soundness by a component of two, and utilizations more miniature sensors (Abdullah et al., 2011).

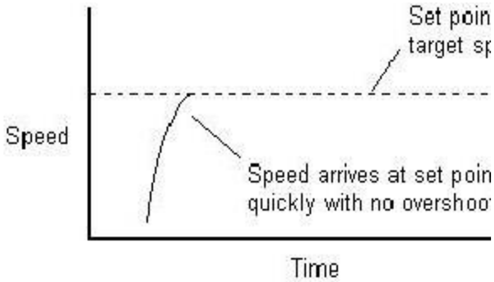


*Figure 4(a). System response with FLC [10]*

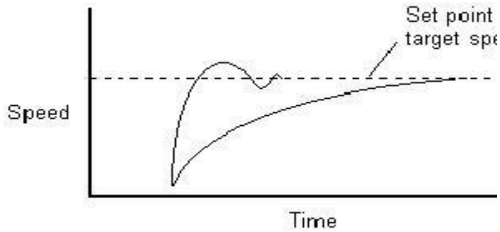

*Figure 4(b). System response without FLC [10]*

Moreover, FLR utilized for temperature control for liquid shower remained planned. It was seen that the reaction with fuzzy regulator remained quicker with the regular PID Controller system. It was likewise inferred that FL controllers (FLCs) are much nearer for the soul to individual reasoning and conclusion-production (El-Saady et al., 1994). Moreover, based on operator experience, FLC was designed to regulate and monitor fortified dimensions for the wear, ball size and shear strength thickness boundaries in holding development. Hence, the fuzzy regulator moves along process control (Yang, 2010). It is difficult for the conventional controller to maintain the pH in metal precipitation and wastewater neutralization processes. An FLC proved efficient in bringing the pH of acidic wastewater to the desired level and maintaining it. An FLC was developed to control the induction motor drive and was more efficient than a conventional controller (Mamat & Ghani, 2009). Regular and fuzzy regulators for controlling the brilliance of a LED light were planned. It was demonstrated tentatively that the P.I. regulator requires minimal time for processing and functioning when compared to FLR (Kovacic & Bogdan, 2018). Further, FLR was created for a computerized vehicle stopping mechanism. Slowing down execution saw in terms of distance and speed to forestall crashes or mishaps for fuzzy, P.I. and P.D. type regulators. Nevertheless, a fuzzy regulator was created to monitor the resultant force of a heartbeat width tweaked inverter utilized in a breeze energy transformation framework. Hence, the fuzzy regulator was proficient at tracking and concentrating the most incredible power from the wind energy transformation framework. However, it is vital to note that an FL can interact with an ordinarycontrol (Hanamane, Attar, & Mudholkar, 2013).

## 4. Fuzzy logic applications in sugar cane juice productions

However, there exist various impact evaporator (MEE) for the sugar stick juicefixation (brix) from an ostensible worth of 20 wt% these centrifuges attributing the capacity around 2100 kilograms per cycle. Further, with the centrifuges of the sugar stick reaching the shipments based for the package of the bags in the insight of the product can be stored in a silo instead with the shipment tracked directly. The entire sugar making process has three stages stick juice extraction, juice Clarification and crystallization centrifuging. Nevertheless, the crystallization aspect of the material fed for the liquor mother can be assigned to the batch of A type region in vacuum pans along with shift towards the linear motion of the sugar centrifuges MEE happens A-, B- and C-. Conversely, the batch A centrifugally separates the sugar content within the liquor region of mother. Using these centrifuges attributing the capacity around 2100 kilograms per cycle. Further, with the centrifuges of the sugar stick reaching the shipments based on the package of the bags, the product's insight can be stored in a siloinstead with the shipment tracked directly (Misra & Kamath, 2015).

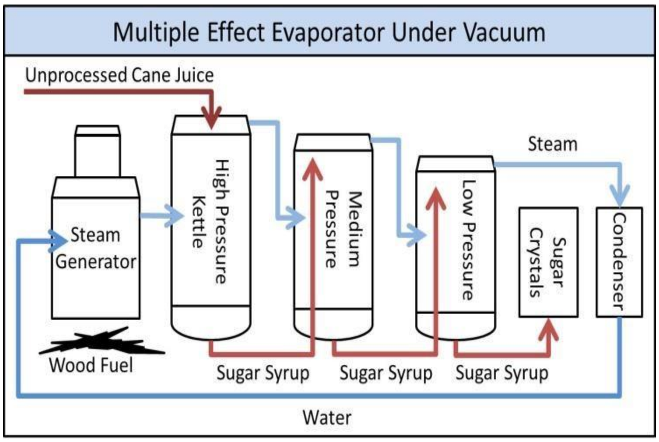


*Figure 5. Multiple-Effect Evaporator Station*

With the raise in sugar cane industry economy for fabricating relies firmly upon the MEE on account of the tremendous measure of nuclear power (steam) expected during the cycle. The clump idea of the vacuum skillet activity implies that the interest of steam as shown in Figure 5. Different Effect Evaporator (MEE) Station from the MEE station is irregular, along these lines upsetting firmly the MEE developed a microprocessor-based system for the control of pH during juice clarification process. The simulation has been performed for a Fuzzy-PI Hybrid controller to control pH during juice FL is used in the environmental performance evaluation of beet sugar plants (Misra & Kamath, 2014). A fuzzy regulator was produced for working on the presentation of bagasse evaporator in sugar factory. The multipurpose evaporator requires fuel as well as air clarification using feasible count of boilers, through which count 3 is conventional. Moreover, the procedure for the different stage of boilingreaches with the successive feature of the batches such as A-, B- and C-. Conversely, the batch A centrifugally separates the sugar content within the liquor region of mother. Using these centrifuges attributing the capacity around 2100 kilograms per cycle.

Further, with the centrifuges of the sugar stick reaching the shipments based on the package of the bags, the product's insight can be stored in a silo instead, with the shipment tracked directly. The entire sugar-making process has three stages stick juice extraction, juice Clarification and crystallization centrifuging. Nevertheless, the crystallization aspect of the material fed for the liquor mother can be assigned to the batch of A-type region in vacuum pans along with a shift towards the linear motion of the sugar centrifuges in Simulink and fuzzy toolbox. The subsequent vacillations like this cause skillet unsettling influences.

Researchers have proposed further trial and error to survey the effect of G.A. boundaries, for example, the number of ages on the wellness esteem. They have likewise recommended dealing with the impact of tuning of M.F.s of a few FLCs simultaneously on the outcomes. Cane juice clarification is an essential chemical process applied in a sugar mill after the raw juice is extracted within the cane process system. Narayan et al. (1986) at CEERI Pillani, India, developed a microprocessor-based system to control pH during juice clarification. The simulation has been performed for a Fuzzy-PI Hybrid controller to control pH during juice clarification using Simulink and the fuzzy toolbox of MATLAB. It was successfully proved during simulation that the Fuzzy-PI Hybrid controller was more efficient than the conventional P.I. controller (Misra & Kamath, 2014). With the development of the controller based on fuzzy, the continuous monitoring of the temperature takes place with the sugar-based plant soaking into the region of the plant procedures held for increasing the system efficiency. It was proved that FL improves the control performances.

The sugarcane juice process in sugar making is highly energy-consuming. An FL scheme was proposed to control the operation of a multiple-effect evaporator during the sugar-making process. The genetic algorithm was used for tuning the membership functions of the proposed fuzzy controller. The proposed intelligent controller proved efficient compared to manual control must be able to grow sugar crystals at a fast rate and with the lowest energy consumption. The expert controller based on the Bayesian probabilistic inference to control the crystallization process was tested and implemented in a sugar factory in the Czech Republic in 1993. The expert system exhibited significant improvement (George & Kyatanavar, 2014). FL was utilized to foster an instrument for further developing the forecast of sugar creation for the Hellenic sugar industry, Greece. FL is used in the environmental performanceevaluation of beet sugar plants. A fuzzy regulator was produced for working on the presentation of the bagasse evaporator in sugar factory. The multipurpose evaporator requires fuel as well as air for producing the steam. It was seen that wind stream control ended up being smooth when contrasted with non-fuzzy control.

How much stick fiber conveyed by stick transporter shifts because of non- consistency under stick source? Further the ceaseless variety for stick with the Donnelychute throughout stick to extract the juice contrarily influences stick extracted juice productivity under factory. A two-input fuzzy controller was developed to optimize the cane juice extraction process in 2014. The fuzzy controller with two-input showed improved outcome when contrasted with regular regulator in keeping up with the cane level in Donnely chute. However, simulation result of two input fuzzy controller for fourdifferent cases are shown in Table 1. It demonstrates the different range of cane volumes with respect to the motor speed of rake carrier. The fuzzy controller was developed to control the motor rapidity for the carrier rake ranging with units of rpm that was contingent to the stick level of the Donnelly chute within the stick-on rake quantified to transporter with speed of roll. A three-input fuzzy controller algorithm was developed as shown in Figure. 6. The detailed 3 input fuzzy controller algorithm is depicted in Figure 7. The three sources of info fuzzy regulator were created and reproduced by utilizing FL tool kit of 'MATLAB® variant 7.11.0.584 (R2020b). It was inferred that assuming the roll speed is more lopsided than fuzzy regulator execution is improved.

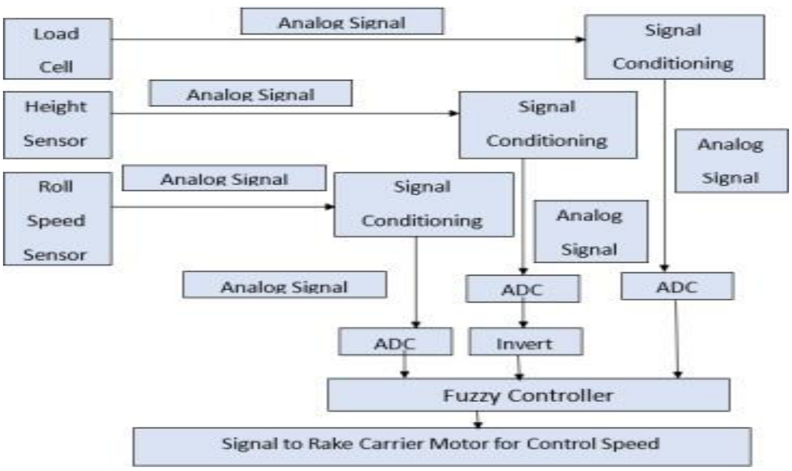


*Figure 6. Cane volume conservation with three inputs Fuzzy Controller*

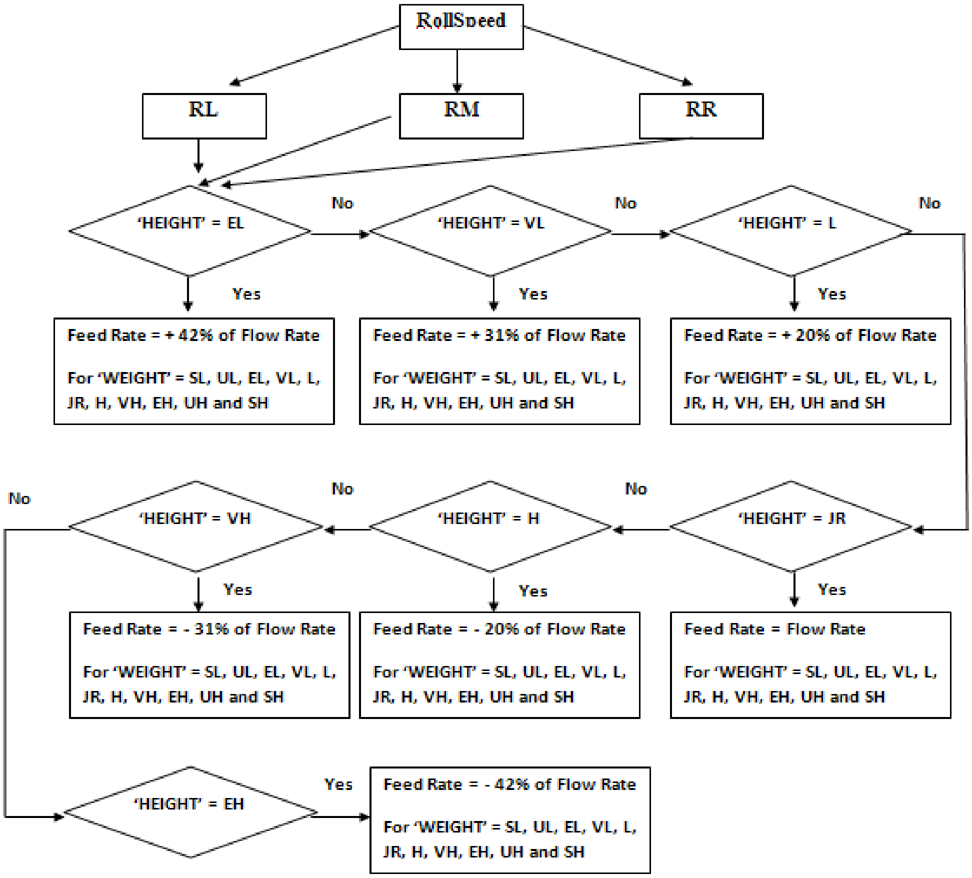


*Figure 7. Three Inputs Fuzzy Controller Algorithm (Misra, Y., & Kamath, H. R).*

## 5. Sugar Mill Terminology and Constraints

Implementing the juicing procedure produced over the cane rails can be arranged by executing the crushing cane into two rolling fields. It necessitates the various component metrics that are important for the system performance enhancement, i.e., Roll width ($Bc$) and Roll length ($Lr$) subjected to the change in the optimum level of angle (α) under roll speed at the fastest movement has been measured. In which the mean volume or diameter of the roll is expressed as,

$$D = D_0 - D_g \tag{1}$$

Where $Dg$= Depth of Groove, $Do$ means exterior roll diameter. Moreover, the volume under escribed range describes the cane level set-up given over for the work done for the mill's inlet.

$$V_e = L_r \times B_C \times S\cos(\alpha) \tag{2}$$

where S = roll surface speed

$$S = (\omega \times D)/2 \tag{3}$$

And contact angle among two centric rolls has been assigned to cos(α).

$$\cos(\alpha) = (D + W - B_C)/D \tag{4}$$

The beginning of work (W) is

$W = W_S + D_g$ (5)

Also, the flow rate quantity or the rate of crushing the sugar in (Kg/s),

$Q_C = V_e \times q_C$ (6)

$qc$ = Density of bulk cane located at entry plane. Combined with rake carrier speed,the speed is expressed as follows,

$S_C = F_r \times 1/\mathrm{M}$ (7)

where Sc is carrier speed in cm/s, Fr is Feed rate and M = 1 cm from Mass of cane in the carrier.

Further,

$S_m = 1.91 \times S_{rake}$ (8)

Where Sm is a dynamic change in motor speed measured in rev/min, and $Srake$ is rake carrier speed in cm/s. Thus, those mentioned above are the parameters employed in the sugar-making process and its extraction, majorly with the contact angle, roll means diameter, and work opening.

## 6. Inputs Terminology for Fuzzy Controller Algorithm

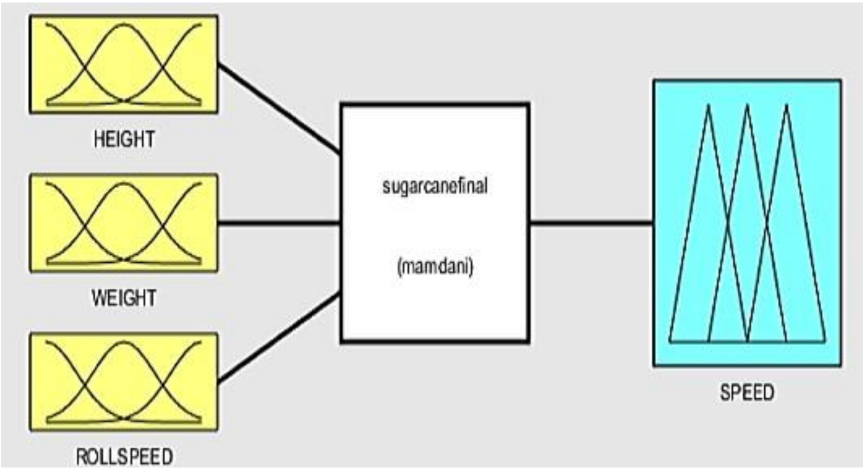


*Figure 8. Objects of Fuzzy Inference System (FIS) with I/O blocks*

To undergo the Fuzzy Controller, the essential functioning components areFuzzifier, Rule base, Inference engine, and Defuzzifier. Through the membership functions, the Fuzzy Inference System (FIS) is constructed, indeed formed throughconsideration of 3 inputs and the outcome is received with the membership function. In this process, the triangular membership function is considered. The triangular membership function has the I/O parameters of overlapping of 50% regarding adjacentmembership function.

Here, the 3 I/O parameters are HEIGHT, WEIGHT, and ROLL SPEED and SPEED correspondingly. And every membership function in I/O parameters employed in the algorithm implementation is triangular, as shown in Figure 8. Very low (VL), Extremely low (EL), Low-medium (LM), Low (L), Medium-high (MH), Medium (M), High (H), Extremely high (EH), and Very High (VH) are the different levels of lowness (EH). Consistent, each is maintained homogeneous with the equivalence of upstream and downstream realities for reasoning.

*Table 1. Numerous Circumstances under the concept of Fuzzy Controller to conserve Cane Level in Donnely Chute [25]*

| CASE I – At 600 kg of cane in a rake carrier and 10 cm of cane in a chute | | | | | | | |
|---|---|---|---|---|---|---|---|
| Factors | At 0.0s | At 10.0s | At 20.0s | At 30.0s | At 40.0s | At 50.0s | At 60.0s |
| Level of Cane (cm) | 10.0 | 38 | 57 | 73 | 83 | 87 | 90 |
| Weight of Cane (Kg) | 599 | 599 | 599 | 599 | 599 | 599 | 599 |
| Motor Speed (rpm) | 89 | 80 | 80 | 73.8 | 70.7 | 68.8 | 68.0 |
| Carrier Speed (cm/s) | 47 | 43 | 43 | 39 | 36 | 37 | 36 |
| Carrier with cane(Kg/cm) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Feed Rate (Kg/s) | 35 | 32 | 32 | 30 | 28 | 26 | 27 |
| Data for next sampling | +82Kg, +30cm | +50, +18cm | +50, +18cm | +23Kg, +8cm | +11Kg, +5.0cm | +6Kg, +1.5cm | +1.1Kg, +0.5cm |
| Next sample's canelevel (cm) | 40 | 57 | 73 | 83 | 87 | 89 | 89 |
| CASE II - 10cm Cane with Differing Cane in Rake Carrier | | | | | | | |
| Factors | At 0.0s | At 10.0s | At 20.0s | At 30.0s | At 40.0s | At 50.0s | At 60.0s |
| Level of Cane (cm) | 11 | 40 | 57 | 77 | 81 | 80 | 83 |
| Weight of Cane (Kg) | 600 | 800 | 1000 | 800 | 1000 | 700 | 800 |
| Motor Speed (rpm) | 89 | 5 | 54 | 48 | 48 | 49 | 47 |
| Carrier Speed (cm/s) | 47 | 29 | 25 | 28 | 26 | 27 | 25 |
| Carrier with cane(Kg/cm) | 0.8 | 2 | 2 | 2 | 2 | 2 | 2 |
| Feed Rate (Kg/s) | 35 | 32 | 31 | 32 | 29 | 27 | 28 |
| Data for next sampling | +81Kg, +29cm | +50Kg, +19cm | +51Kg, +19cm | +11Kg, +5.2cm | +3Kg, +1.0cm | +2Kg, +0.5cm | 0 |
| Next sample's canelevel (cm) | 39 | 58 | 74 | 35 | 34 | 28 | 29 |
| CASE III At 50 cm, the cane is different sizes in the rake carrier. | | | | | | | |
| Factors | At 0.0s | At 10.0s | At 20.0s | At 30.0s | At 40.0s | At 50.0s | At 60.0s |
| Level of Cane (cm) | 50 | 50 | 68 | 75 | 58 | 69 | 39 |
| Cane Weight (Kg) | 900 | 500 | 70 | 600 | 800 | 500 | 400 |
| Motor Speed (rpm) | 59 | 68 | 61 | 57 | 59 | 57 | 56 |
| Carrier Speed (cm/s) | 45 | 58 | 54 | 27 | 25 | 26 | 27 |
| Cane In Carrier(Kg/cm) | 1 | 2 | 1.01 | 1.071 | 2 | 2 | 2.13 |
| Feed Rate (Kg/s) | 31 | 30 | 27 | 28 | 28 | 24 | 25 |
| Data for next sampling | +41Kg, +14.6cm | +38Kg, +4cm | +5.5Kg, +3cm | +17Kg, +6cm | +2.6Kg, +2cm | +2Kg, +0.6cm | 0 |
| Next sample's canelevel (cm) | 67 | 68 | 59 | 57 | 53 | 49 | 48 |
| CASE IV At 90 cm, the cane is different sizes in the rake carrier. | | | | | | | |
| Factors | At 0.0s | At 10.0s | At 20.0s | At 30.0s | At 40.0s | At 50.0s | At 60.0s |
| Cane Level (cm) | 90 | 85 | 87 | 79 | 81 | 80 | 87 |
| Cane Weight (Kg) | 750 | 800 | 560 | 600 | 700 | 900 | 800 |
| Motor Speed (rpm) | 56 | 45 | 57 | 57 | 56 | 48 | 49 |
| Carrier Speed (cm/s) | 29 | 23 | 22 | 48 | 49 | 26 | 34 |
| Carrier with cane(Kg/cm) | 0.9 | 0.8 | 0.6 | 1.1 | 2.13 | 0.98 | 0.887 |
| Feed Rate (Kg/s) | 27 | 29 | 24 | 26 | 21 | 26 | 27 |
| Data for next sampling | -1.2Kg, -0.5cm | - 23.5Kg, -7.9cm | +15Kg, +4.9cm | +3Kg, +1.0cm | +20Kg, +7cm | +11Kg,+4cm | -17Kg, -7cm |
| Next sample's canelevel (cm) | 90 | 87 | 85 | 84 | 89 | 91 | 90 |

## 7. Results and Discussion

The three inputs fuzzy controller has been industrialized and simulated with the MATLAB software and FL toolbox function. Further, the controller produces essential implementation with three fuzzy input controllers for the enhancement of cane volume in Donnelly chute during cane juice extraction, which indeed produces an essential motor speed of rake carrier attributed to the volume range and quantity upon the carrier with the rolling speed. In addition, the sampling period is considered 10.0 seconds, and the entire simulation extent is 210.0 seconds. For every iteration, the fuzzy inference system (FIS) is built with several changes in parameters in the system model. Created FIS varies with the input level of cane as 0cm, 15 cm, 30cm, 35cm,45cm, 50 cm, 60cm, 90cm, 120cm, and 150cm, in which the initial set-up value surveyed through feeding rate for the cane cumulative to the quantity being improved with the range of 45%, 39%, 23%, 8%, 1% correspondingly.

Moreover, the bounds are calculated within the range of cane to the motor speed and rake carrier movement. The study also analyses the variables under lower range with respect to input and output parameters for the applied FIS and controller membership functions differentiated for the outcomes achieved for the nonlinearities of the system. Altogether distinguished outcomes are depicted with the membership functions associated with the controller in figure 9.

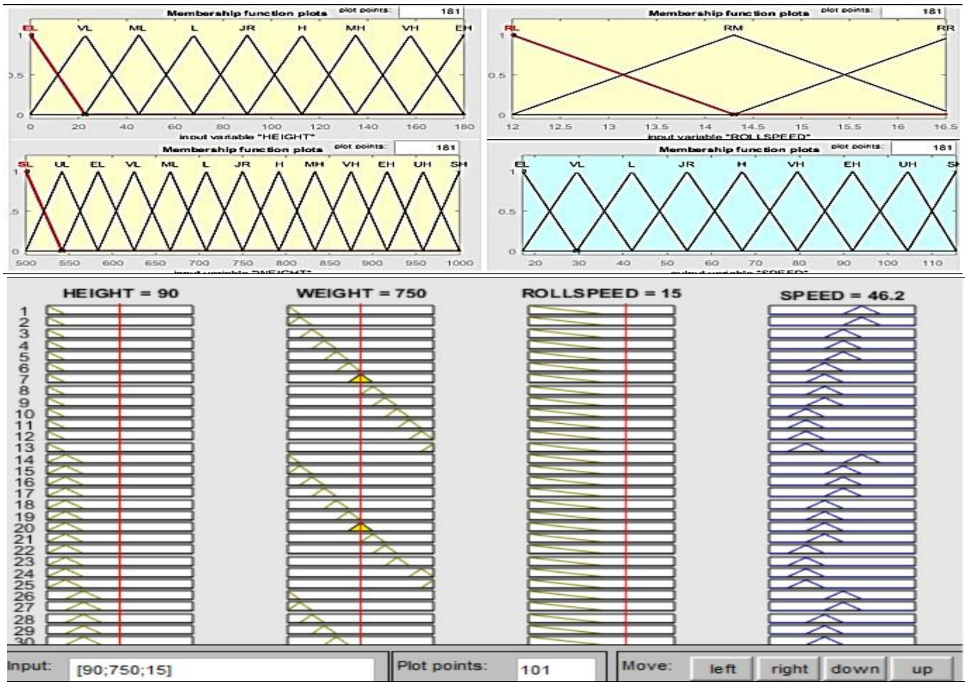


*Figure 9. Upon the following shows the sequential outcome for the simulation done: Input 1 HEIGHT attributed with nine factors are E.L., V.L., ML, L, J.R., H, MH, V.H., E.H. Input 2 - WEIGHT attributed with 13.0 factors are S.L., U.L., E.L., V.L., ML, L, J.R., H, MH, V.H., E.H., U.H., S.H. Input 3 - ROLL SPEED attributed with three factors are R.L., R.M., R.R. and Output - SPEED attributed with 11 factors E.L., V.L., ML, L, J.R., H, V.H., V.L., E.H., U.H., S.H.*

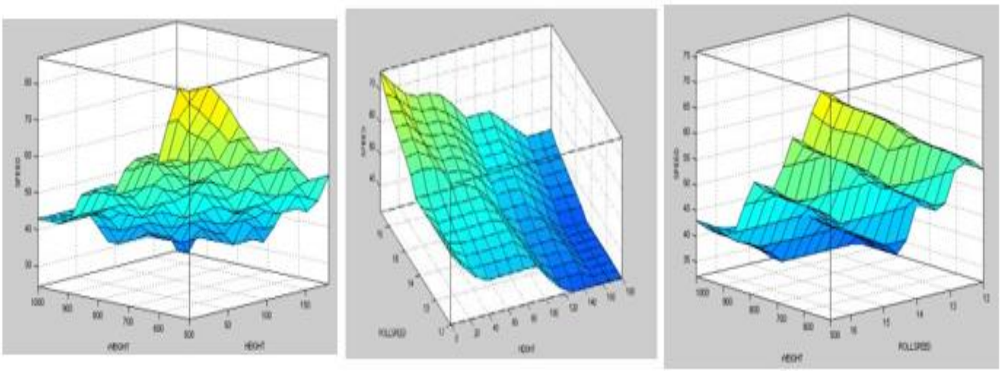

*Figure 10. Surface Viewer among (a) 'HEIGHT', 'WEIGHT' and 'SPEED', (b) 'ROLLSPEED', 'HEIGHT' and 'SPEED', (c) Surface Viewer between 'WEIGHT', 'ROLLSPEED', 'HEIGHT' and 'SPEED'.*

Figure 10 demonstrates the surface viewer within the parameters grouped for threefuzzy input systems that associate with height, weight, and speed concerning input and output parameters for the applied FIS and controller membership functions differentiated for the outcomes achieved for the nonlinearities of the system. In this process, the triangular membership function is considered. The triangular membership function has the I/O parameters of overlapping of 50% regarding adjacent membershipfunctions.

## 8. Conclusion

The operator's experience and field tests are the foundation for the fuzzy control algorithm. A conditional statement between an undefined input variable and a fuzzy output variable is the core of fuzzy control systems. It's also vital to remember that FL can obstruct traditional control. The authors of this study compared several FL uses in industrial processes with conventional automation techniques. The provided methodology successfully limits the volume or range of the Donnelly channel using the three inputs for the fuzzy controller. Additionally, the algorithm's use of three fuzzy input controllers to increase cane volume in the Donnelly chute during cane juice extraction results in a critical motor speed for the rake carrier related to the quantity and range of volume on the carrier with the rolling rate.

The toolbox function of FL in MATLAB® was used to create the simulation results for the 3-input fuzzy controller. In these systems, fuzzy logic can be used flexibly and effectively. Additionally, the scaling factors (SFs) and membership functions of the FLCsare improved using genetic algorithms (MFs). Probabilistic fuzzy logic has been developed as a theoretical framework for merging fuzzy logic with nonlinear dynamics to analyze and control physical systems with potentially disastrous effects. Probabilistic fuzzy logic has been created to combine fuzzy logic with nonlinear dynamics and enablethe analysis and control of physical systems with potentially devastating consequences. In future, we would like to work on decision-making approaches (Senapati & Yager, 2019a, 2019b, 2020) using the rule-based fuzzy logic controller.

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