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Speed Control of an Autonomous Robot for Improved Output in an Industrial Packing Section Using Fuzzy

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ABSTRACT

The decrease in the quantity of crates conventionally packed in a brewery industry has necessitated to introducing speed control of an autonomous robot for improved output in an industrial packing section using fuzzy. This is done in this manner , characterizing the study environment and study the identified dynamic properties of a robotic system (speed and position), designing a Simulink model for the characterized environment, designing a rule base in the environment, designing a Simulink model for Autonomous robot non-linear system speed control in an industrial packing section for an increased output using fuzzy and validating and justifying the quantity of product packed when conventional and when fuzzy is incorporated in the system. The results obtained are 40 crates which are conventionally packed and 66.61 crates packed when fuzzy is in cooperated in the system. With these results obtained, it shows that using fuzzy increased the quantity of crates packed by 24.96%.

Keywords: *Non-Linear System, Fuzzy, Autonomous Robot, Packing Section, Simulink Model*

Introduction

The conventional approach of packing crates in the brewery industry takes a lot time and energy that is the reason robot is introduced in the system to enhance the efficiency of packing these crates. The speed of DC motor can be greatly adjusted in other to generate high performance and controllability of the system Voldek, (1978), Zhou and LaiL (2000). The controllers of the speed that are conceived for goal to control the speed of DC motor to execute one variety of tasks, is of several conventional and numeric controller types, the controller scan be: PID Controller, Fuzzy Logic Controller; or the combination between them Fuzzy-Genetic Algorithm, Fuzzy-Neural Networks, Fuzzy- Ants Colony, Fuzzy-Swarm (Swarm). Fuzzy theory was first proposed and investigated by Prof. Zadeh Fuzzy logic is expressed by means of if-then rules with the human language. In the design of a fuzzy logic controller, the mathematical model is not necessary. Thus, the fuzzy logic controller owns good robustness. Fuzzy controller has been widely used in industry for its easy realization. However, the rules and the membership functions of a fuzzy logic controller are constructed by expert experience or knowledge database.

2. Methodology

The aim of the research work is to achieve the speed control of an autonomous robot for improved output in an industrial packing section using fuzzy, and this can be achieved using the following procedures: characterize the study environment and evaluate the identified dynamic properties of a robotic system, train the Artificial Neural Network (ANN) in the environment of study, design a model which will use Artificial Neural Network (ANN) to solve the problem, simulate the models in a Simulink environment, obtain fast response of the system to operational demands and demonstrate through extensive simulation the efficiency of the ANN strategy over other nonlinear system control approach like non-linear PID.

Designed Simulink model for the characterized environment, develop membership function for robotic speed control analysis, membership function for robotic motor voltage control analysis, and membership function for robotic production output analysis. Design a rule base in the environment, Simulated rules base in the environment, designed working mechanism of an industrial robot showing overall speed to pack one pallet, Comparing conventional and fuzzy logic industrial crate packing

Characterize the study environment and study the identified dynamic properties of a robotic system (speed and position). The area the robot will carry its operation of packing the crates inside the pallet is taken in to consideration.

Length of the area L = width of the area W = 20m, Area A = L x W

A = 20 x 20, A = 400m^2

The area of the environment is 400 meters square, Conventional speed of packing 40 crates in the pallet is 15.4 rpm. It is first expected to design the mathematical model which can be derived from a schematic diagram of a DC servomotor system shown in Figure 1 below, the mathematical model can be derived from a schematically diagram of a DC servomotor system shown in Figure 1 below. From the diagram, the input is the armature voltage Va in volts being driven by a voltage source. Here the measured variable is the angular velocity of the shaft w measured in rpm and the input voltage V, measured in volts.

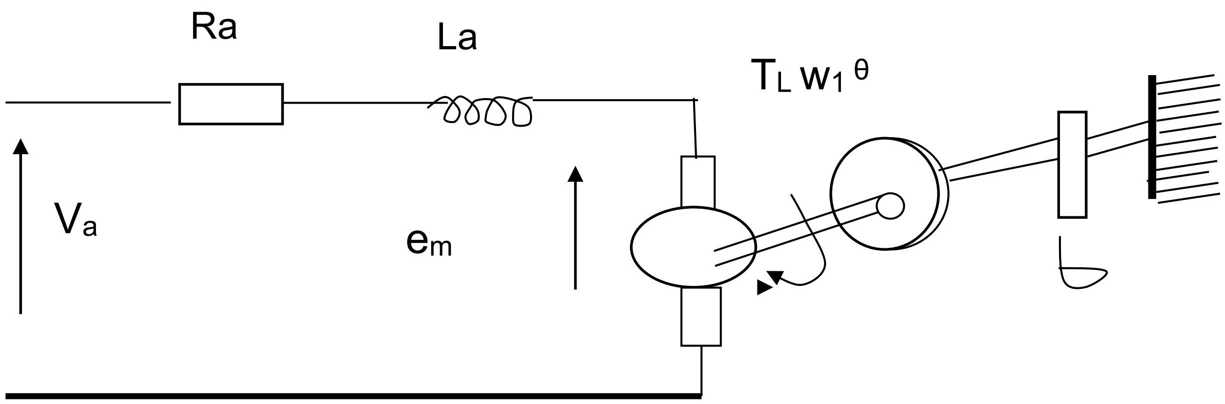

Figure 1: Servo motor circuit diagram

Analyzing the circuit to get the mathematical model, the following equations are generated

$V_a = R_a I_a + L_a \frac{dIa}{dt} + e_m$ -- (1)

$e_m = K_e W_m$ -- (2)

$T_m = K_i I_a$ -- (3)

$T_m = I_m W_m + bw_m + T_i$ -- (4)

Where R - equivalent motor resistance

La - equivalent motor inductance

Va - applied voltage

e_m - Motor back emf

Ki - motor torque constant

Jm - equivalent moment of inertia reflected

Bm - equivalent viscous coefficient reflected at the motor shaft

Ia - The armarture constant

Ke - motor voltage constant

Tm - Torque generated by the motor

Wm - The motor speed

T_L - the load torque

Motor torque, T is related to the armature current I by a constant factor ki

T = K_i -- (6)

The back electromotive force (emf), Vb is related to the angular velocity by

$V_b = K_w = K\frac{d^{\theta}}{dt}$ --- (7)

Applying Norton's laws and kirchoff's laws, the following equations are generated from Figure 1

$J\frac{d2\emptyset}{dt2} + b\frac{d\emptyset}{dt} = K_i$ --- (8)

$L\frac{di}{dt} + R_i = V - K\frac{d\emptyset}{dt}$ -- (9)

Applying Laplace transform to equation (8) and (9) result in equation (10) and (11) below

$Js^2\emptyset (s) + bs\emptyset (s) = KI (s)$ --- (10)

$LsI (s) + RI(s) = V(s) - Ks \emptyset (s)$ -- (11)

Where s denotes the Laplace operator, from equation (11)

$I_{(s)} = \frac{V(s) - k s \emptyset s}{R + L s}$ --- (12)

Then substituting this in equation (10) result in

Js^2 + bs $\emptyset b_s$ = K$\frac{Vs-Ks\,\emptyset\,(s)}{R+L\,s}$ -- (13)

Expanding and re- arranging of equation 13 yields the transfer function from input voltage, V(s) to the output angle $\emptyset$ *in equation* 14 *below*

Ga (s) = $\frac{\emptyset(s)}{dx}$ = $\frac{1}{s[(R+Ls)(Js+b)+K^2}$ --- (14)

Since Wn = Ø -- (15)

Also w(s) = sØ(s) -- (16)

Substituting Ø (s) in equation (14) yields the transfer function of input voltage, V(s) to the output angular velocity, w as G (s) = $\frac{W(s)}{V(s)}$ = $\frac{k}{(R+Ls)(Js+b)+K^2}$ -----------------------(17)

These derived equations are shown in the block diagram of Figure 2 below

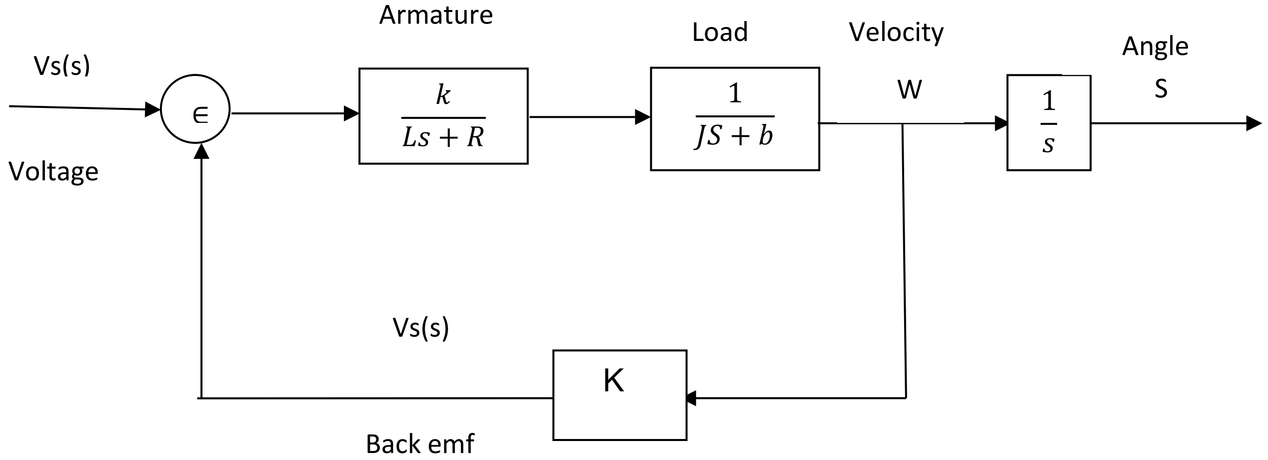

Figure 2: Block diagram of DC Motor

To find an ideal speed the robot will move in the environment, we have that

$e_m = K_e W_m$ --- (2)

Make W_m the subject formula in equation (2)

$W_m = E_m / K_e$

The following parametric data were collected from the measuring equipment (given data)

e_m - Motor back emf = 800N

Ke - motor voltage constant = 51.948V

R – Resistor of the motor = 5 ohms

Ki or K - motor torque constant = 4

$Wm = \frac{800}{51.948}$

W_m= 15.4rpm --- 18

The two things to be considered in this robotic operation are the area of the environment the robot will operate which is a large space = 400m^2

The conventional speed = 15.4rpm

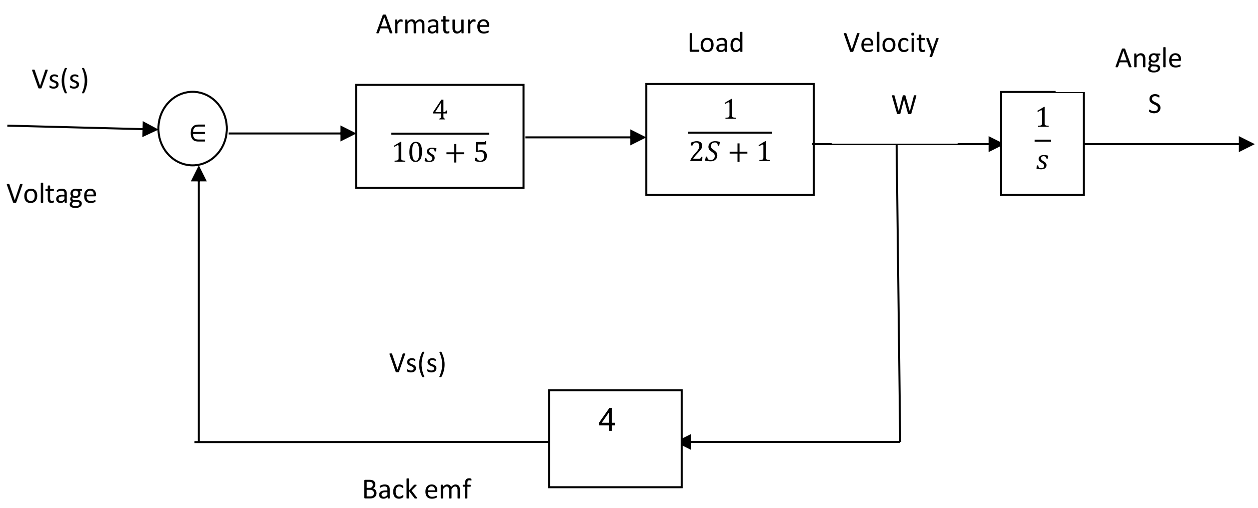

Figure 3: Block diagram of DC Motor

To Design a Simulink Model for the Characterized Production Process

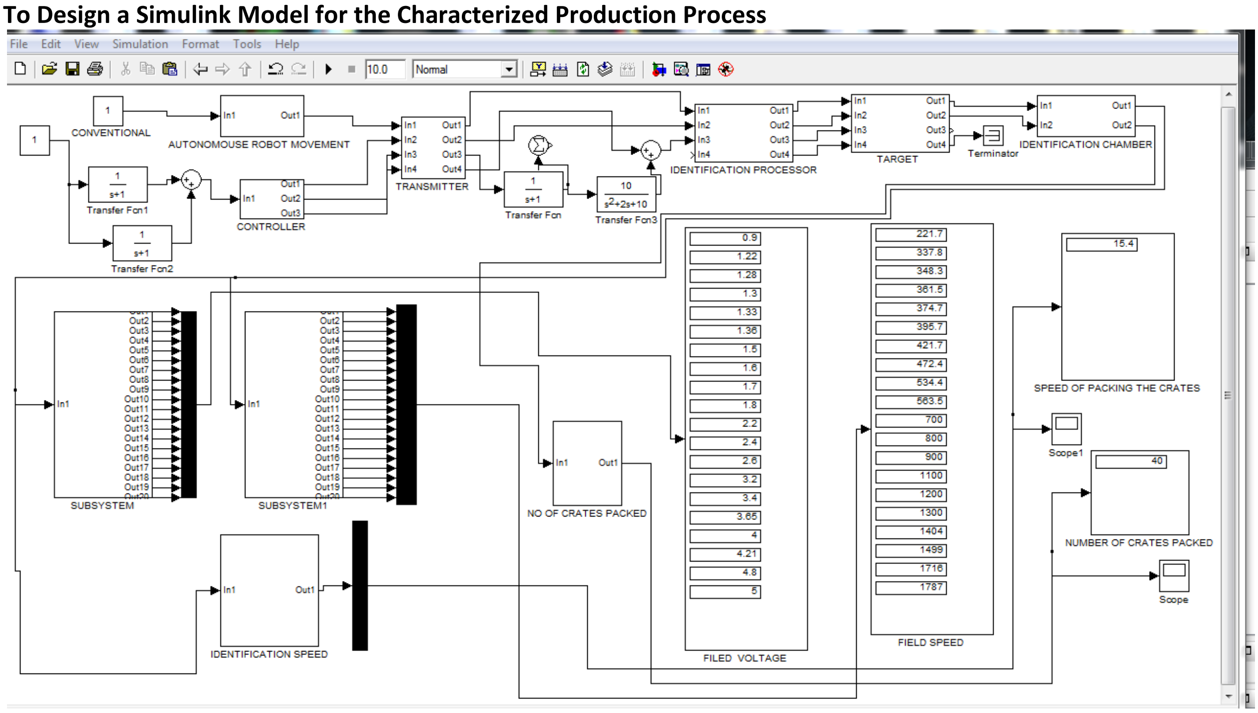

Figure 4: Designed Simulink model for the characterized production process (data)

Figure 4 shows designed Simulink model for the characterized production process. The characterized voltage coupled with its speed were imbibed in the model and simulated. Figure 4 shows the simulated model for the characterized environment. The results obtained are as shown in Figures 7 and 8

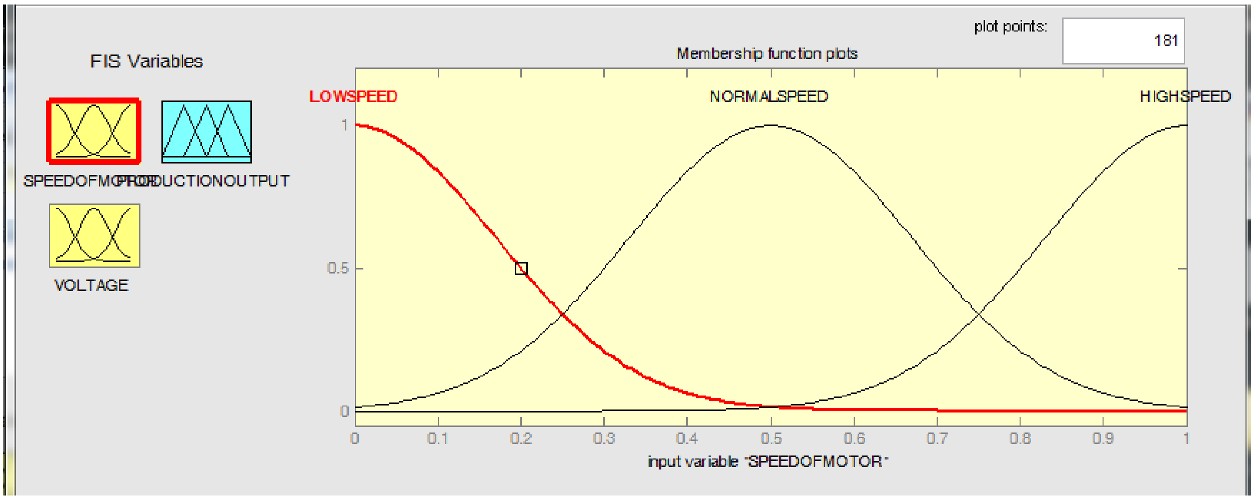

Figure 5: Membership function for robotic speed control analysis

Figure 5 shows membership function for robotic speed control analysis. Figure 5 shows a comprehensive analysis of the robotic speed condition. These conditions are low speed, normal speed and high-speed. These conditions specifically determine the speed by which robot accomplishes its assigned duty.

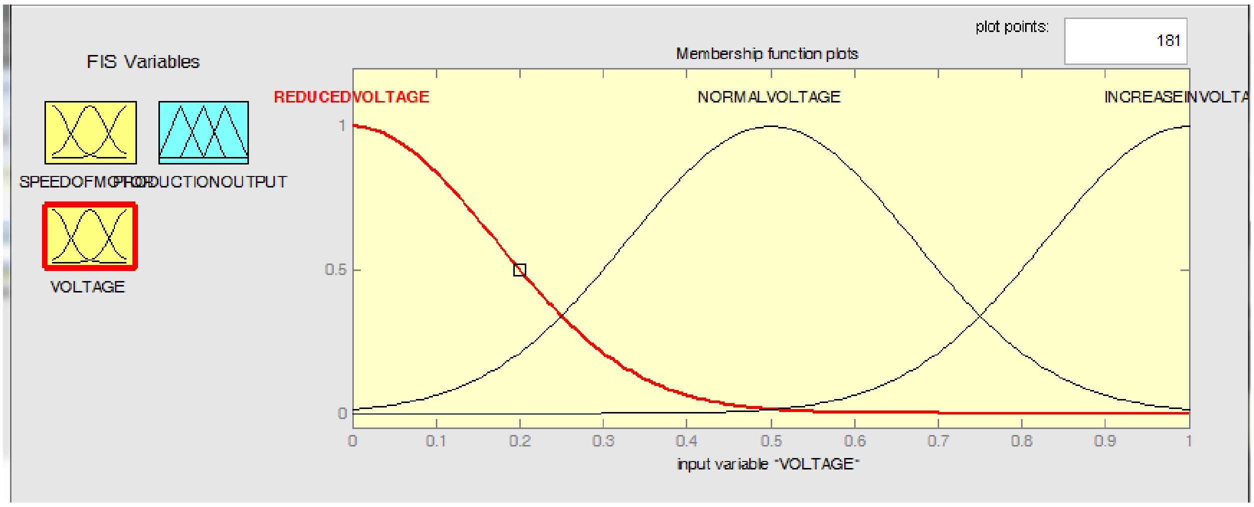

Figure 6: Membership function for robotic motor voltage control analysis

Figure 6 shows membership function robotic motor voltage control analysis. This voltage analysis helps to control the non-linearity observed in motor.

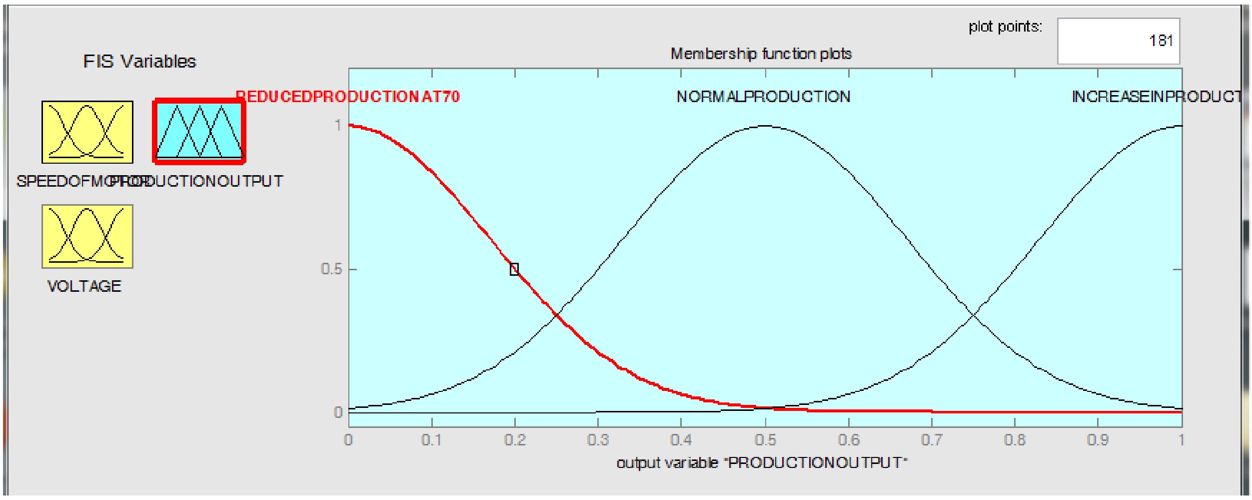

Figure 7: Membership function for robotic production output analysis

Figure 7 shows the production capacity analysis of robot.

To Design a Rule Base in the Environment

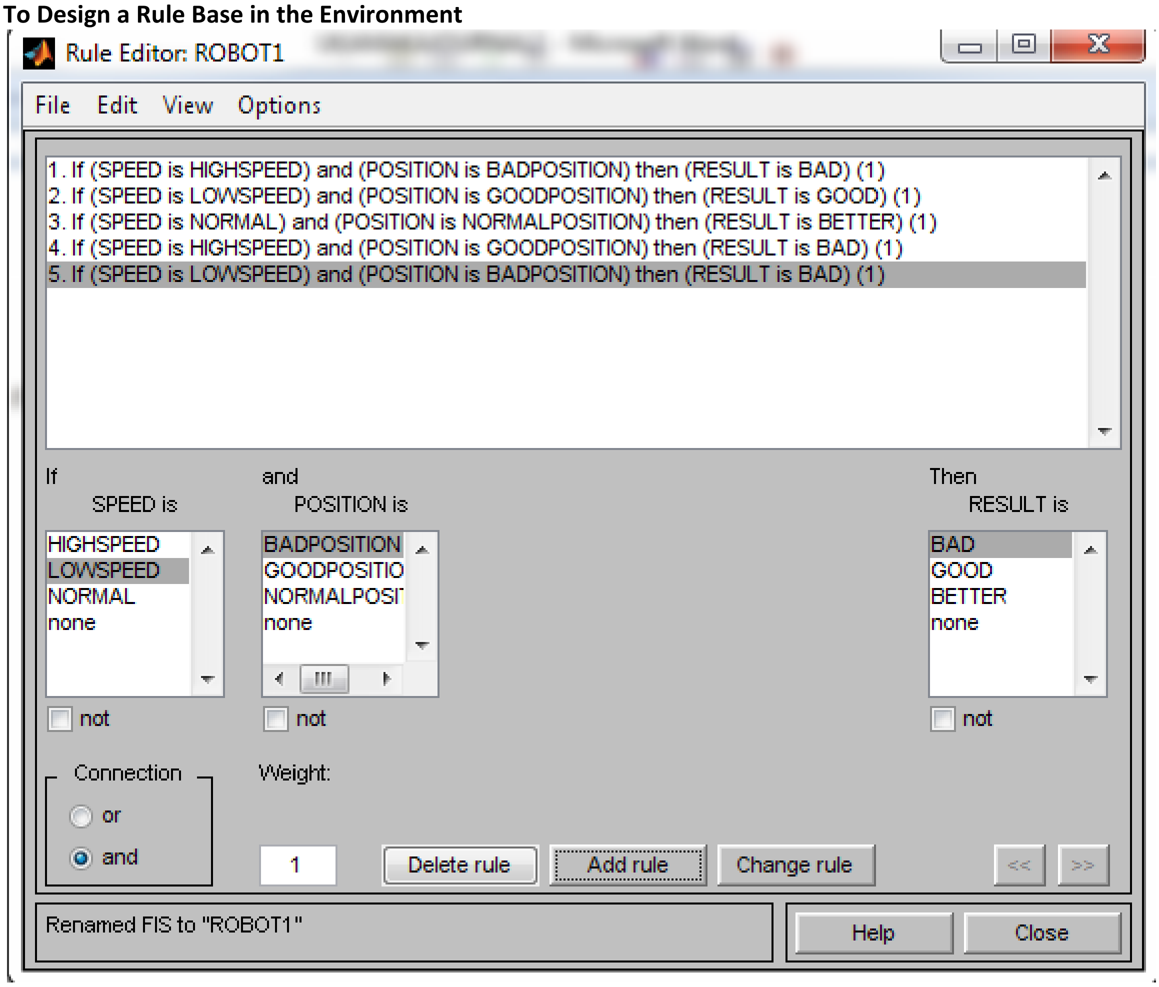

Figure 8: Designed rule base in the environment

Figure 8 shows the rule that guides the effective packing of the crates by the robot as detailed in Figures 11 and 12. Fuzzy logic is an intelligent agent that mimics human intelligence in executing the job he is allotted to carry out. The number of rules to

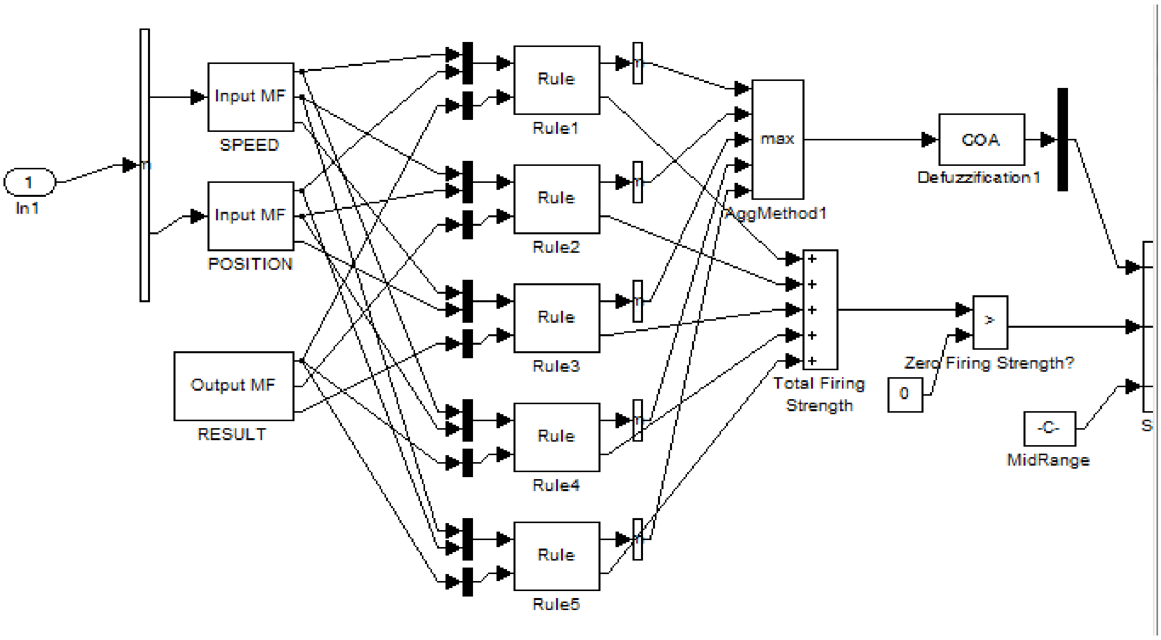

Figure 9: Simulated rules base in the environment

To design a Simulink model for Autonomous robot

To design a Simulink model for Autonomous robot non-linear system speed control in an industrial packing section for an increased output using fuzzy.

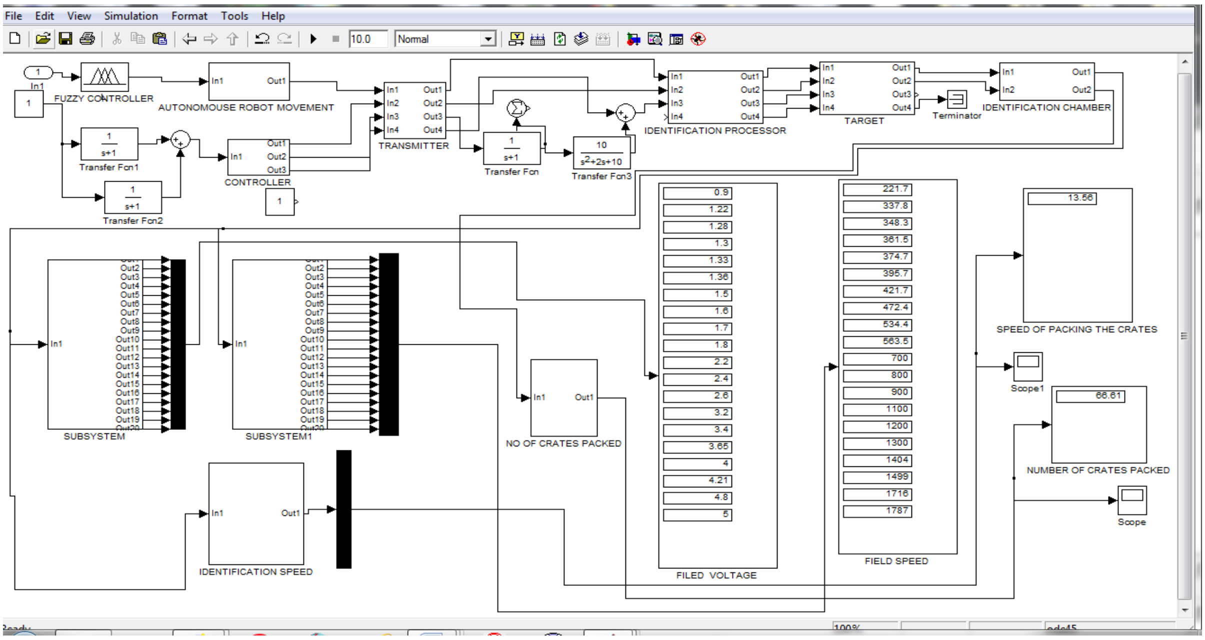

Figure 10: designed Simulink model for Autonomous robot non-linear system speed control in an industrial packing section for an increased output using fuzzy.

Figure 10 shows simulated model for autonomous robot non-linear system speed control in an industrial packing section for an increased output using fuzzy. The simulated result obtained is shown in Figures 11 and 12

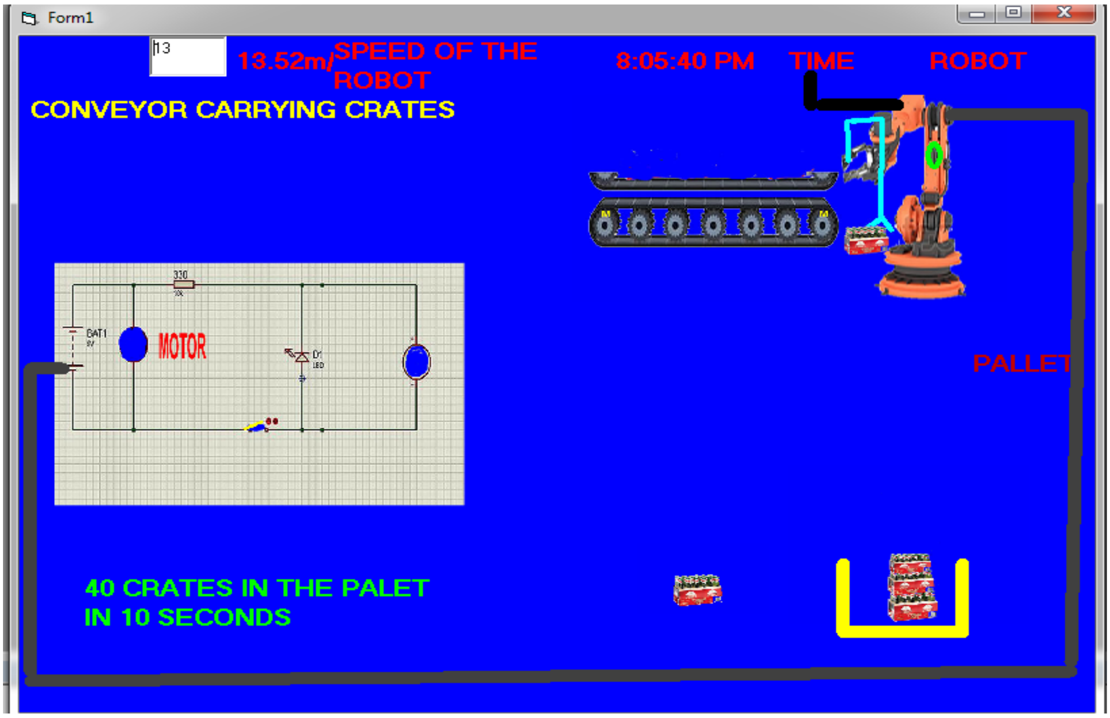

Figure 11: Designed working mechanism of an industrial robot showing overall speed to pack one pallet

The Figure 11 shows the speed used to pick and pack one pallet which is equivalent to forty crates of 50cl or 48 crates of 35cl of the product. The speed as shown from Figure 11 is 13.52m/s. The design shows that the robot carries the crates in a group of ten crates at once and also separates the incomplete crates from the complete crates. With this result it shows that robot accomplished its allotted duty at shorter speed and time.

Result Analysis

Table 2.1: Comparing conventional and fuzzy logic industrial crate packing

Time (s)	Conventional No of crates packed	No. of crates packed using fuzzy
0	0	0
2	35	60
4	40	66.61
10	40	66.61

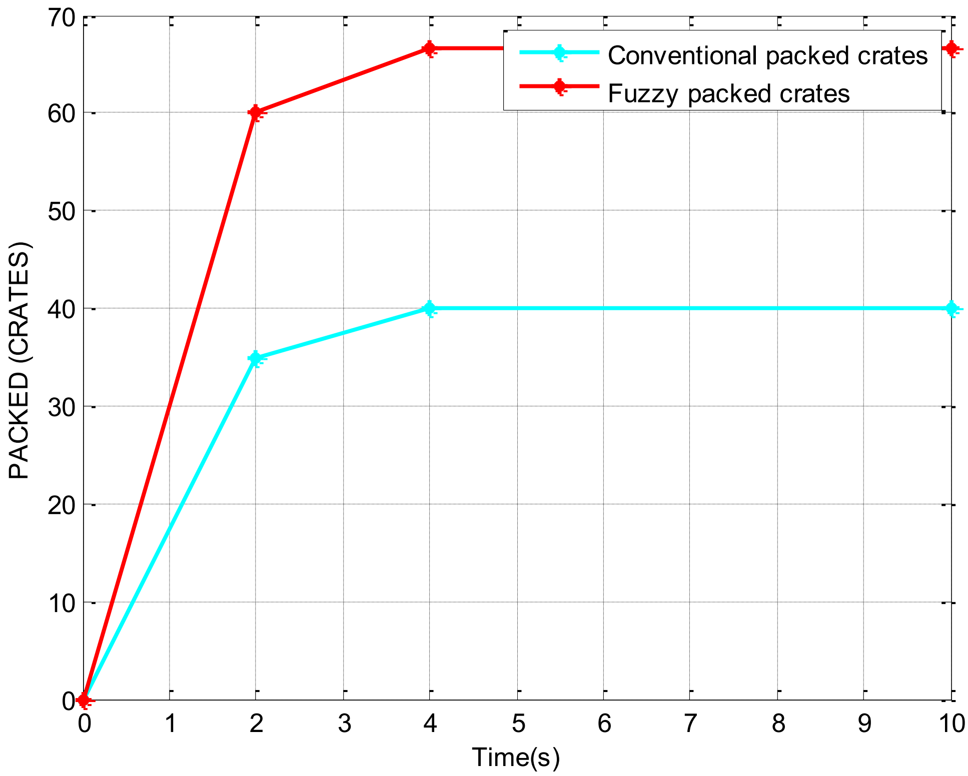

Figure 12: Comparing conventional and fuzzy logic industrial crate packing

Figure 12 shows Comparing conventional and fuzzy logic industrial crate packing. Figure 11 shows that the quantity of crates packed by conventional approach is 40 while that by fuzzy is 66.61crates. with these results it shows using fuzzy is better than using conventional method.

Table 2.2: Comparing the conventional speed and fuzzy speed in carrying crates

Time (s)	Conventional speed (rpm)	No. of crates packed using fuzzy (rpm)
0	0	0
1	20	18
2	14	13
3	16	14
4	15.4	13.56
10	15.4	13.56

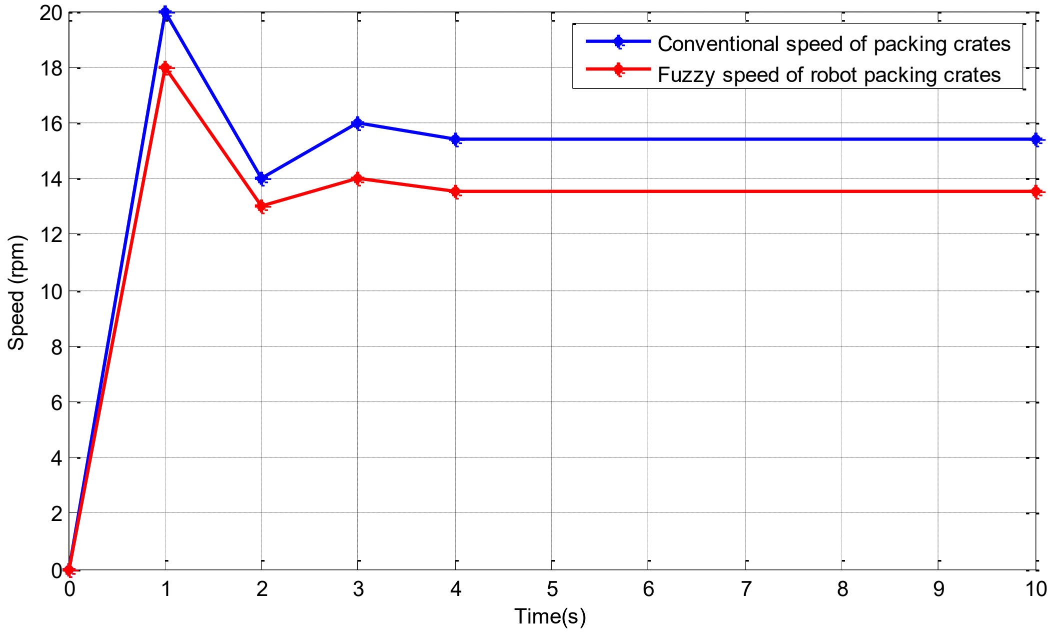

Figure 13: Comparing the conventional speed and fuzzy speed in carrying crates

Figure 13 shows that the conventional speed is 15.4 rpm, while that of using fuzzy is 13.56rpm. With these results it shows that using fuzzy gives a shorter speed.

3. Conclusion

The decrease in packing crates in the brewery industry can be overcome by autonomous robot non linear system speed control in an industrial packing section for an increased output using fuzzy. This is done in this manner characterizing the study environment and study the identified dynamic properties of a robotic system (speed and position), designing a Simulink model for the characterized environment, designing a rule base in the environment, designing a Simulink model for Autonomous robot non-linear system speed control in an industrial packing section for an increased output using fuzzy and validating and justifying the quantity of product packed when conventional and when fuzzy is incorporated in the system.

References

Laurens Bliek, Nonlinear System Identification and Control for Autonomous Robot, 2013.

Mattias Wahde, Introduction to Autonomous Robots, Department of Applied Mechanics Chalmers University of Technology G¨Oteborg, Sweden 2016.

Qidan Zhu, Yu Han, Peng Liu, Yao Xiao, Peng Lu and chengtao Cai (2019), Motion Planning of Autonomous Mobile Robot using Recurrent Fuzzy Neural Network Trained by Kalman filter. *Journal of Computational Intelligence and Neuroscience*, Volume 2019. Article ID 1934575, 16 pages.

Saeid Reza Nazari, Mgtaba Vakilian and Zahra Kheirandish, Control of a SCARA Robot using feedback Linearization and Kalman Filter Observer, Journal of Evolutions in Mechanical Engineering, 2(3) EME 000539, 2019.

Voldek, A.I. (1978). Electric machines. Textbookforhighschoolstudents.tech.institutions.-3rded., Energia, Leningrad

Zhou Y.S., LaiL.Y. Optimal Design for Fuzzy Controllers by Genetic Algorithms, *IEEE Trans: On Industry Application*, 36(1): 93-97,2000.