

**DEVELOPMENT OF TRAIN CONTROL SYSTEM USING FUZZY
LOGIC**

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ABSTRACT

Railroad is an important mode of transportation for passenger and freight services. The capacity of rail network is increasing every year to improve passenger journeys and to support economic growth. Railway safety is a major focus in railway transportation system in most of the country in the world. The occurrence and frequency of train accidents has been escalating year by year due to the increasing of railway network. Many major train accidents occurred due by failure of track, equipment, human factors, signal, and miscellaneous. In this study, an automatic train control system using predictive fuzzy controller that uses rules based on a skilled hostler experience has been proposed and simulated using Matlab Simulink software. The Matlab Simulink model is designed based on 16.65 kilometres railroad layout from Station A to Station B within 1030 seconds travel time. The train model used for the Simulink simulation is 22 tonnes two-car train and its stability control was performed using a tuning PID control. In the simulations, two types of input variable are used which are train weight and weather. The main objective of this automatic train operation is to prevent collision and ensuring reliable performance. The fuzzy controller selects the most likely control output and also direct evaluation of the control objective. The proposed fuzzy controller has been applied for automatic train operation where the control system was developed based on the evaluation of safety, riding comfort, accuracy stop gap and running time. The results from nine simulations of different inputs parameters shows that the train has stop accurately at 16.65 kilometres from Station A to Station B in duration between 17 minutes 12 seconds to 18 minutes 2 seconds and the average stopping time for the train is about 30 seconds. This demonstrated that fuzzy controller could be used to operate the train for automatic train control representing an expert hostler. Therefore, the proposed train control system using fuzzy controller is an effective method for overcoming collision problem of conventional train control system.

ABSTRAK

Pengangkutan kereta api merupakan mod pengangkutan yang penting kepada penumpang dan barangan. Jumlah rangkaian pengangkutan kereta api bertambah setiap tahun bagi meningkatkan kualiti dan kuantiti perjalanan serta merangsang pertumbuhan ekonomi. Keselamatan pengangkutan kereta api merupakan tumpuan utama di kebanyakan negara diseluruh dunia. Jumlah kemalangan kereta api telah meningkat dari tahun ke tahun dan terdapat pelbagai faktor yang menyebabkan berlakunya kemalangan kereta api seperti trek, peralatan, kesilapan manusia, isyarat, dan sebagainya. Dalam kajian ini, sistem kawalan automatik kereta dengan menggunakan kawalan logik fuzzy telah dicadangkan dengan cara mengaplikasikan teknik-teknik kawalan pemandu yang mahir. Proses simulasi dijalankan dengan menggunakan perisian Simulink Matlab. Model didalam Simulink adalah antara Stesen A dan Stesen B yang berjarak 16.65 kilometer dan mengambil masa perjalanan 1030 saat. Model kereta api yang telah digunakan merupakan kereta api 22 tan, dan kestabilan pada model tersebut dilaras dengan menggunakan kawalan PID. Dua jenis input yang digunakan merupakan berat kereta api dan cuaca. Tujuan utama sistem kawalan ini direka adalah untuk mengelakkan kemalangan dan memastikan kereta api beroperasi dengan baik. Kawalan logik fuzzy akan memilih keputusan yang bersesuaian dan membuat penilaian secara terus kepada sistem kawalan. Kawalan logik fuzzy yang direka untuk mengawal kereta api adalah berdasarkan penilaian keselamatan, keselesaan penumpang, ketepatan lokasi berhenti dan masa perjalanan. Keputusan daripada sembilan simulasi parameter input yang berbeza telah menunjukkan bahawa kereta api tersebut telah berhenti tepat pada 16.65 kilometer dari Stesen A ke Stesen B dalam tempoh antara 17 minit 12 saat hingga 18 minit 2 saat dan purata 30 saat untuk tempoh berhenti. Kawalan secara logik fuzzy dapat meniru teknik kawalan keretapi oleh manusia yg mahir dan berpengalaman. Ini menunjukkan kaedah kawalan ini adalah lebih cekap bagi menggantikan teknik kawalan kereta api cara lama.

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CHAPTER 1

INTRODUCTION

1.1 Background

Railway is a major form of passenger and freight transport in many countries, and it is ubiquitous in Europe, with an integrated network covering virtually the whole continent [1]. The Western Europe region has the highest railway density in the world and has many individual trains that operate through several countries despite technical and organizational differences in each national network. Freight rail transport is widespread and heavily used in North America, but intercity passenger rail transport on that continent is relatively scarce outside the Northeast Corridor due to the loss of competition to other preferred modes, particularly automobiles and airplanes. In India, China, South Korea and Japan, many millions use trains as regular transport [2]. Demand for railway transportation is high and has grown significantly over the last decade, and according to UIC High Speed Department, the worldwide network for high-speed lines will be increasing about 31 percent from 2013 to 2025 [Appendix B].

Railway transport occupies a significant role in the transport system of a country because the development of trade, industry and commerce of a country largely depends on the development of railways [4]. The advantages of railway are as follows:

- [i] It helps in the industrialization process of a country by easy transportation of coal and raw materials at a cheaper rate.

- [ii] It helps in the quick movement of goods from one place to another at the time of emergencies like famines and scarcity.
- [iii] It encourages mobility of labour and thereby provides a great scope for employment.
- [iv] Railway is the safest form of transport. The chances of accidents and breakdown of railways are low as compared to other modes of transport. Moreover, the traffic can be protecting from the exposure to sun, rain snow etc.
- [v] The carrying capacity of the railways is extremely large. Moreover, its capacity is elastic which can easily be increasing by adding more wagons.
- [vi] It is the largest public undertaking in the country. Railways perform many public utility services. Their charges are based on charge what the traffic can bear principles which helps the poor. In fact, it is a national necessity.
- [vii] Electrified train is more ecosystems. By encouraging people to use trains rather than cars will contribute to the carbon reduction targets.

Since this mode of transportation has major advantages if compared with other modes, it has been voted more preferable by the passenger and freight transportation where the development of railway network increases year by year.

1.1.2 Railway signalling

Railway signalling is a system used to control railway traffic safely, essentially to prevent trains from colliding. The earliest railways had no signal systems, therefore station employees had to use hand gestures to train drivers indicating whether to stop or go on. They worked well enough as long as trains were slowed and stopped at stations.

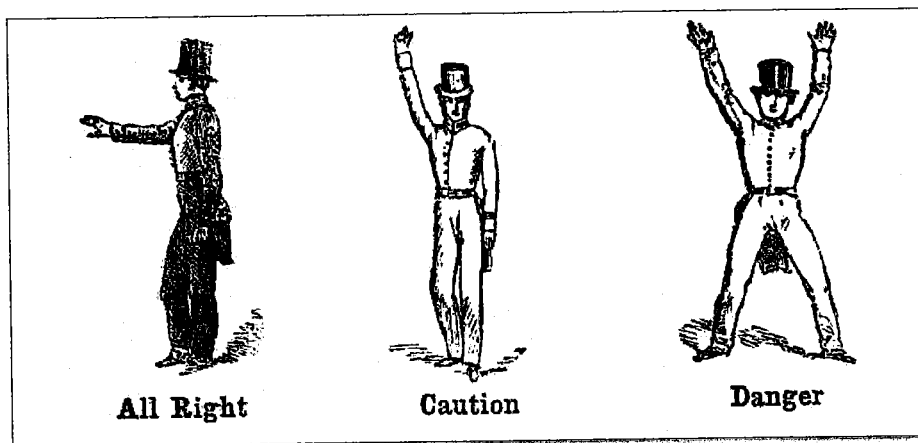


Figure 1.1: Hand signals by policeman between 1838 and 1841, [6]

Figure 1.1 show ‘policeman’ using three types of hand signals in earliest railway signalling between 1838 and 1841. Trains in this era were using hand brakes (manual) to stop. [6]. As train speeds increased, it became increasingly difficult for enginemen to see hand signals give by the policemen, so many types of signalling system were devised afterward, but the most successful was the semaphore, introduced in 1841 that used a signal arm with could be positioned at different angles with a oil lamp for night operation[5].

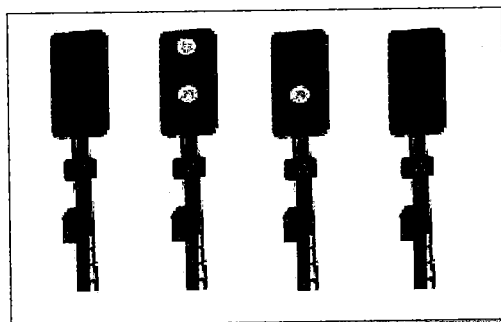


Figure 1.2: Four aspects signalling [7]

Modern British signalling is based on two, three, and four aspects colour of light system as shown in Figure 1.2 using non-permissive block rules [7]. It is a basic progression of the original semaphore signalling that can still be found on many secondary lines [7]. The use of lineside signals in Britain is restricted to railways with a maximum permissible speed of up to 125 mph (201 km/h) [7].

1.2 Problem statement

Train speeds in the previous time are slower if compared to the present system, and its equivalent with the exist signalling system in that era. But when train technology become more sophisticated, the speed of train increase year by year, therefore the old signalling system is not suitable anymore and need to be changed. For example a train at speed 40 mph will take half a mile to stop and 60 mph will take a mile and a quarter, therefore man standing on the ground simply could not be seeing within stopping distance at over 40 mph, this factor will cause to collision hazard [6].

Railway signalling system was upgraded and more advance from time to time to ensure the high speed rail service will operate safely. The prevailing train control system on the U.S. rail network relies on dispatchers at central locations who track the location of trains and signal to train operators when it is safe to proceed onto a stretch of track. This system is somewhat analogous to the air traffic control system, in that the dispatchers can see the location of trains but cannot directly control those trains. Thus, when a train operator does not respond correctly to an operational signal, a collision may occur [6].

Table 1.1: Accident database of class I freight railroads in U.S., 2001–2010 [8]

| Track Type | Derailment | Collision | Highway–Rail | Other | All Accident Types |
|------------|------------|-----------|--------------|-------|--------------------|
| Main | 4,439 | 302 | 1,343 | 590 | 6,674 |
| Yard | 2,848 | 355 | 12 | 378 | 3,593 |
| Siding | 436 | 23 | 4 | 40 | 503 |
| Industry | 369 | 21 | 6 | 49 | 445 |
| All | 8,092 | 701 | 1,365 | 1,057 | 11,215 |

Table 1.1 shows train accident statistics supplied by the railroads to Federal Railroad Administration (FRA) of the U.S. Department of Transportation. This table shows freight train accident data for Class I railroads indices the number of FRA-reportable accidents, the average number of cars derailed per accident, and the total number of cars derailed by accident type and track type for the period 2001 to 2010. Four types of tracks are recorded in the FRA are main, siding, yard and industry tracks. These track types are use for different operational functions and consequently have different associated accident types, causes, and consequences. Train accidents are categorizing into derailment, collision, highway–rail grade crossing accident, and several other less frequent types. Train derailment was the most common type of

accident on each track type, and 60% of all type of accidents occurred at main track. The train accident major causes are track structure, equipment, human factors, signal, and miscellaneous. According to analysis made by Xiang Liu, M. Rapik Saat, and Christopher P. L. Barkan, the greater mass and speed mean that the force and potential impact concerning property damage, casualties, and environmental effects are all correspondingly greater [8].

As highlighted by Australian Transport Council (2003) in the National Railway Level Crossing Safety Strategy Report, accident at railway level crossing giving a greater impact to everyone involved especially when it is involved with fatality. It will result in incalculable pain and suffering for families and others associated with victims as well as any operator staff involved in the crash. Direct financial costs in term of medical and repair costs, loss of personal income and loss of business and consequential financial loss were also the result of the incidents [9].

1.3 Objective

Train operation is typical uncertain nonlinear system, improvement of performance indices such as safety, riding comfort of passengers, and accuracy of the stopgap is great challenge for automatic train operation. In this dissertation, a predictive fuzzy control method is proposed. The train hostler control knowledge is converted into an automatic control algorithm. The objectives of this project were as follows:

1. To design and develop a train control systems, which indicates speed control, accurate stop position at each station and running time of the train.
2. To simulate a train parameter model for the control methods using fuzzy logic.
3. To analyze the train control performance of the proposed control method whether it can be use as a controller for automatic train operation.

1.4 Scope of research

The scope of the design controller is divided into three variables that are train, track layout and controller parameter.

The parameter values of a train such as weight and friction force used, are based on the real train parameters obtain from project attachment with Rapid Rail and studies. The train system and its stability is enhanced using mathematical model that converted into mathematical transfer function using a controller, which will determine the rise time of the train velocity to a constant value and this is equal to the stopping time for the train.

The velocity parameter for the train is determined using the designed predictive fuzzy controller and mathematical function. The algorithm for fuzzy controller is implemented based on the skill hostler that is operating the train on the same track layout.

The accurate stopping position control is related with the velocity control and reliable running time of the train. A few factors affecting the train performance on the track are determined and are set as inputs parameter for the fuzzy logic controller. The complete controller model is simulated using Matlab Simulink software.

1.5 Thesis outline

Chapter 1 describe the railway transportation background and it advantages, histories of previous collisions, causes and casualty. Objectives and scopes of research for the proposed train control method is also described in this chapter.

Chapter 2 is the review of other technical method that is proposed from different country of train control system.

Chapter 3 explain the design steps of the proposed control method using a two-car train with self-design track condition layout. The complete Matlab Simulink model is displayed on the last page of this chapter.

Chapter 4 describe the results of train accelerations, train velocities and train positions of the control system are displayed and being discussed. All the results are generated from nine different stimulations that are based on different parameters of input variables.

Chapter 5 evaluate the findings of the study and recommend some idea for future endeavours that related with train control system.

Appendix A is attached as references of two-car train specifications that used in the simulation and appendix B is the statistic of high-speed lines network in the world that show the capacity of the network in operation, under construction and planned from 2013 until 2025.

CHAPTER 2

LITERATURE REVIEW

The methods of controlling train speed and stop position control system have been improved many times since 1901 by Union Switch and Signal Company that has developed the first automatic train stop system for the Boston Elevated Railway. This chapter reviews some of the related journal and previous research including the fundamental of train control system that can contribute some ideas towards completing this project.

2.1 Fuzzy Rule based Automatic Braking System in Train using VHDL

ML Sharma and Sheetal Atri (2011) from Institute of Engineering & Technology, Sangrur, applied Fuzzy Logic Controller (FLC) to an automated train braking system and simulated the response of the system using Fuzzy Logic Toolbox in VHDL (Very High Level Design Language). The first step in the design is to select the number of stations where the train stops. The distances between the stations are calculated and stored. The fuzzy logic controller is fed with the instantaneous values of speed and distance [11]. The controller constantly compares the distance between the previous and the next station to distance travelled by the train towards the approaching station. The main objective control system creates by ML Sharma and Sheetal Atri that the braking system is automatically activated as the train is near the halt point. For the braking system to be activated the brake controller is supplied with two inputs, current distance and speed of train from halt point from the station. Variable distance has been divided into four fuzzy sets. These are very close, close, far, very far. Same way base variable speed is divided into three fuzzy sets i.e. slow, medium, fast [11].

Fuzzy rules that ML Sharma and Sheetal Atri design is a Sugeno algorithm MISO (multiple input single outputs), which the inputs are distance and speed and output is braking force [11]. The variable distance has been divided into four fuzzy sets:

- i. Very close - zed function
- ii. Close - triangular function
- iii. Far - trapezoidal function
- iv. Very far - sigma function

Same way base variable speed is divided into four fuzzy sets:

- i. Very slow - zed function
- ii. Slow - triangular function
- iii. Fast - trapezoidal function
- iv. Very fast - sigma function

From the simulation result that generated using VHDL code by ML Sharma and Sheetal Atri state that the brake was applied at a distance of halt position from the station. The speed gradually decreases and exactly at the station train stops [11].

2.2 Improvement of Automatic Train Operation Using Enhanced Predictive Fuzzy Control Method

In Ali and Babak (2012) control method, a skilled operator strategy for train movement is extracted in forms of sentences by using fuzzy and predictive control this strategy is implemented. The passenger-riding comfort, trip time, energy saving, traceability of target curve and accurate stopgap indices are defined in forms of fuzzy membership functions. Driving strategies are written as fuzzy rules [12].

In Ali and Babak thesis, train movement control is divided into two phases. The first phase is called constant speed control which is from the start position of the train and continues up to the point where the train enters automatic stop zone. In this phase before reaching the mentioned point, the train goes into coasting mode and coasting point is selected smartly by ATO system according to line situation. The

second phase, which is called automatic train stop control, has responsibility of adjusting precise train velocity until the train accurately and completely stops [12].

Figure 2.1 represents Ali and Babak train model simulation in MATLAB software environment, which was used in this article. As it is shown in this Figure, system inputs are voltage and torque that enter train model from power and braking controllers respectively. The resistive torque used in this simulation is gained from the total resistive torque divided by the number of traction motors [12].

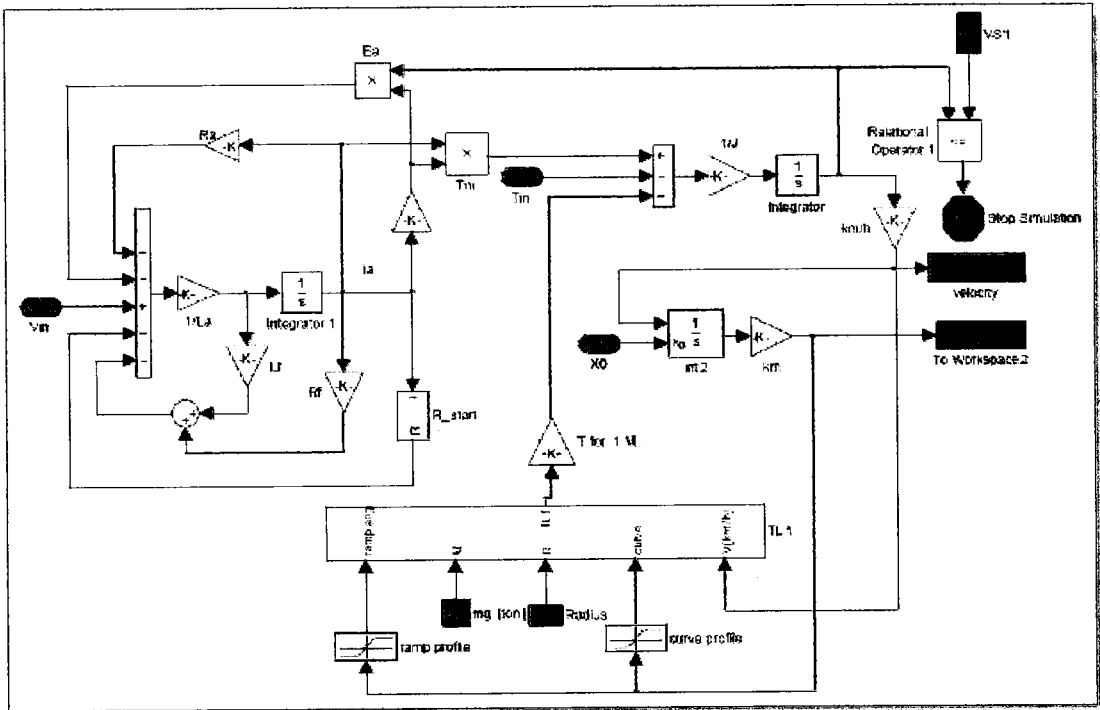


Figure 2.1: Ali and Babak train model simulation [12]

Figure 2.2 shows the general diagram of predictive fuzzy control for ATO presented in Ali and Babak article. As it is exhibited in this Figure, control system required inputs are fed into an s-function in which the control algorithm is written. Some inputs are used for predicting system dynamic and some others for defining indices. A coefficient for converting control region from CSC to ATSC is generated via a latch memory, so that the control system uses this coefficient to know in which region it has to operate [12].

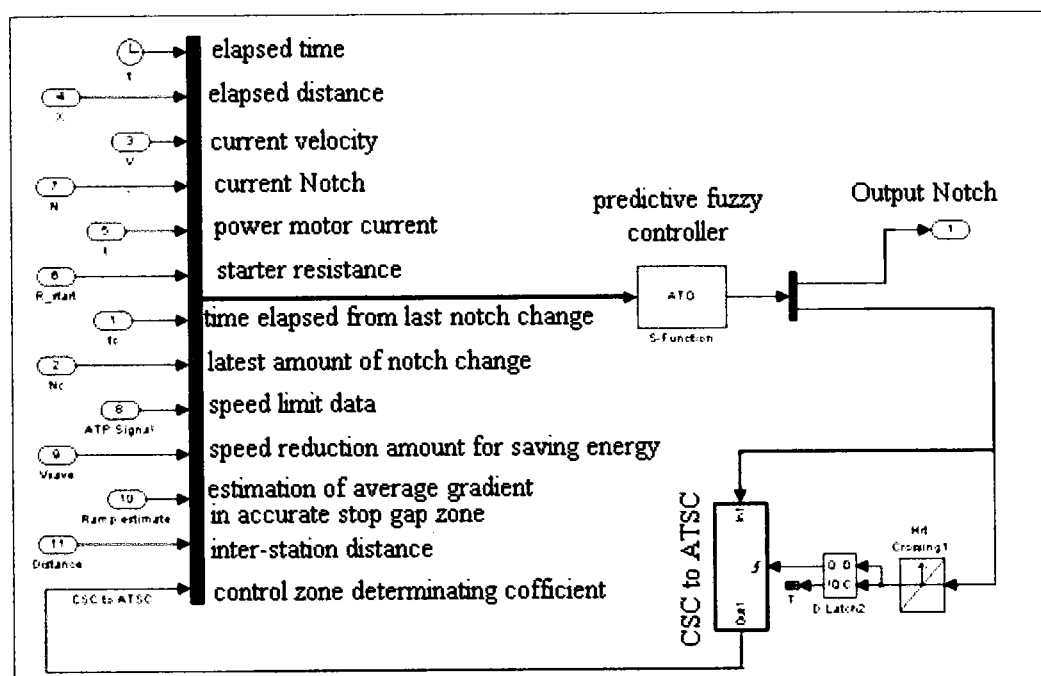


Figure 2.2: General Diagram of Predictive Fuzzy Control For ATO System [12]

The simulation of Ali and Babak made for train travel route was assumed to be a path between two stations with a distance of 1000 meters. Speed limit was assumed to be 40 km/h between distances of 550 and 650 meters. Curve radius was assumed to be 200 meters along the path. Gradient and altitude are assumed 2 % and 5% respectively along the path [12].

The result displays in the simulation in a path with the length of 1000 meters with the same velocity profile and route attributes, time and energy consumptions are both reduced compared to S. Yasunobu methods. In the S. Yasunobu method running time was 97 seconds and energy consumption was 0.65 KWh, however in Ali and Babak method time and energy consumptions are reduced by 1 second and 16% respectively [12].

2.3 Automatic Train Control based on the Multi-Agent Control of Cooperative Systems

Ali Siahvashi and Bijan Moaveni (2010) developed an Intelligent Decentralized ATC (ID-ATC) approach based on the Multi-Agent systems theory, which can provide high transportation capacity, high-safety and high-reliability. In this method, Ali and

Bijan combine the Voronoi concept of cooperative systems theory with Multi-Agent control theory by using of fuzzy control logic [13].

According to the ATC definition, an ATC system consists of Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS). In Figure 2.3, the fundamental structure of a typical ATC system which contains the ATP, ATO and ATS is shown. There are many kinds of ATC systems but in all of them, the ATP helps to prevent collisions through a driver failure to observe a signal or speed restriction. The ATO provides partial or complete automatic train piloting and driverless functions and the ATS, which is the basis of the train protection function and the automatic speed control devices. The ATS system, by using of the block information, specifies the speed constraints and sends them to the trains by using of Track circuit, Loop and/or Balises [13].

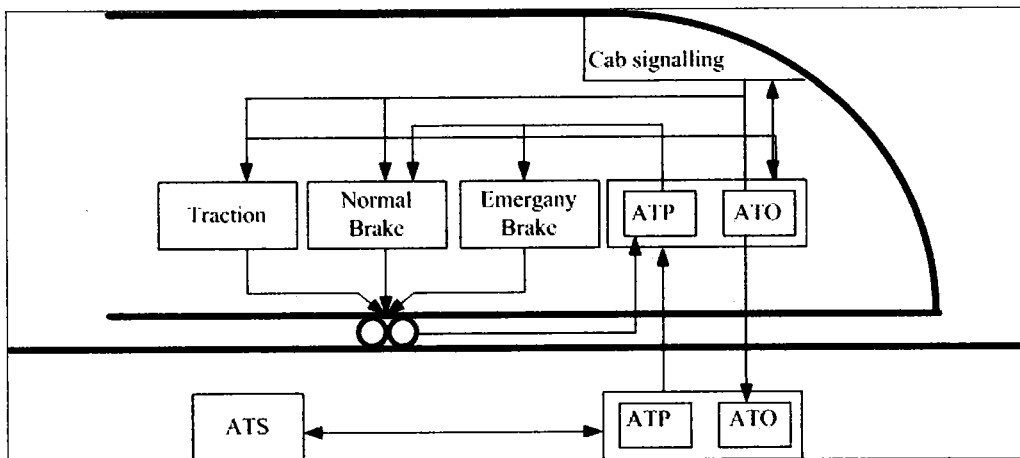


Figure 2.3 Structure of an Automatic Train Control (ATC) System [13]

Ali and Bijan introduce a new ATC method by using of Voronoi algorithm in cooperative systems theory. In 2004, Magnus Lindhe introduced the Voronoi algorithm by combining the Ogren effect of Navigation function and Cortes effect of Coverage Control to navigate a group of mobile robots [14]. Voronoi algorithm by using of a potential function and by finding the smallest path to achieve the goal presents a safe method to run the mobile robots. In this approach, a Voronoi diagram is defined as in Figure 2.4 that guarantee collision avoidance [14].

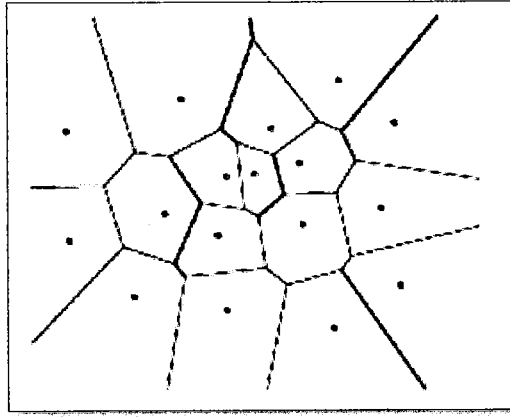


Figure 2.4: Voronoi diagram [13]

The Voronoi algorithm and Mutli-Agent control systems is combined by employing the fuzzy logic controller to present an intelligent ATC system, which contains the D-ATC advantages and it is called ID-ATC. The ID-ATC can solve the problems of railway transport systems by defining the trains as agents and by using of the decentralized fuzzy controllers. In other words, each agent contains a fuzzy controller, which receives the information from receptors and by analyzing them and considering the Voronoi conditions generates a control policy. In this procedure and in railway transportation system, distances between the current train and front and back trains are measured and by using of this information the decision-making will be done to keep the current train in the middle point, which can guarantee the safe motion of the trains [13].

In ID-ATC, Ali and Bijan consider each train as an agent and the first train as a leader that the other agents adjust their position and consequently their velocity with the leader. In this section, three trains in a line and between two stations is consider to simplify the algorithm discussion but without any loss of generality of the problem. These three trains start the motion from the first station and stop in the last station respectively. Obviously, the number of trains is more than three in real states and to solve this problem, all trains without 1st and last trains can be considered as middle trains [13].

In ID-ATC system, Ali and Bijan propose the decentralized control structure and consequently consider a controller for each train. The train controller plan by using of fuzzy strategy is shows in Figure 2.5. In control procedure, each train receives the position and velocity of itself and previous and next trains. After this phase, the controller provides the appropriate control effort to control the train

velocity and position. In real train control systems, this control effort specifies the notch of traction system or brake system [13].

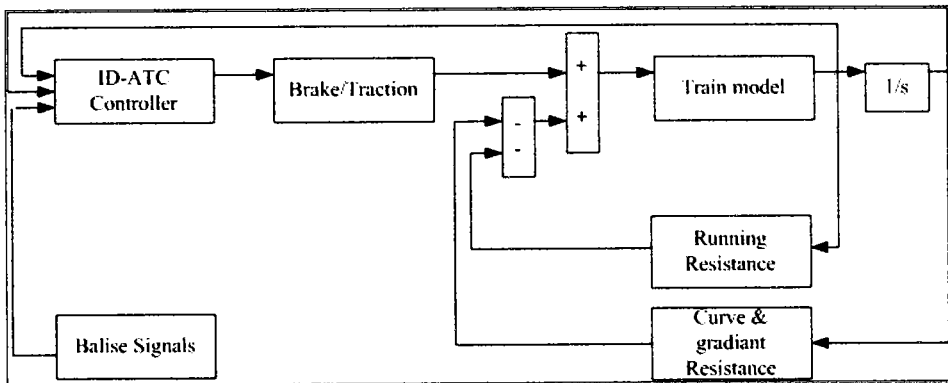


Figure 2.5: Block diagram of the control system in ID-ATC system [13]

Figure 2.5 show the closed loop control system for a train. This control loop contains the train dynamic model and resistance forces as running resistance and curve and gradient resistance. In this closed loop control system, Ali and Bijan consider a controller to control the train velocity and position by using of the torque control strategy. According to Voronoi algorithm, this controller should keep the second train in the middle point of two other trains to obtain the safe railway transportation system [13].

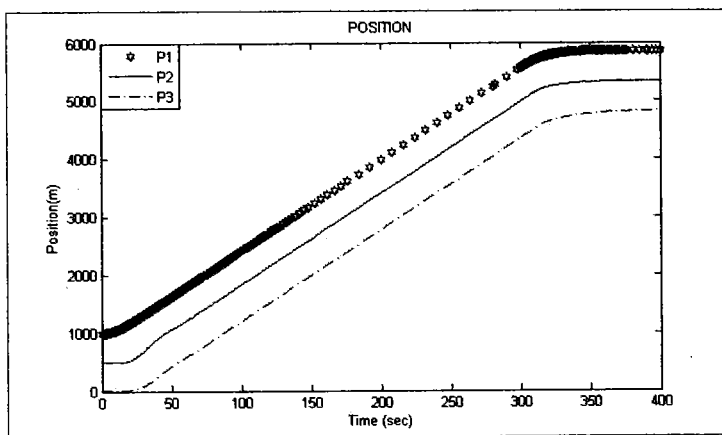


Figure 2.6: Trains running are controlled by ID-ATC system (Star: Position of 1st train; Solid line: Position of 2nd train; Dash-dot: position of 3rd train) [13]

Figure 2.6 show the position of all three trains by using of ID-ATC system. In this procedure, the first train starts running according to the control centre plan. After that, the ID-ATC system and the local controllers run the second and third trains

respectively. In this process, the two local controllers of the second and third trains keep the second train in the middle point of the leader and the last trains, which are shown in Figure 2.6. Whenever the control centre stops the leader train in a station, the two other trains will be stopped automatically in an appropriate distance of the leader, which is specified by the control centre [13].

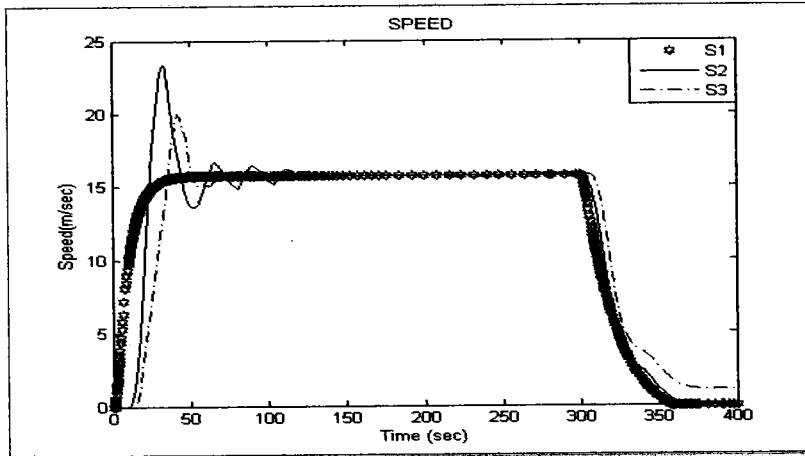


Figure 2.7: Trains velocity (Star: Velocity of 1st train; Solid line: Velocity of 2nd train; Dash-dot: Velocity of 3rd train) [13]

In Figure 2.7, the velocities of all three trains show the effort of controllers to keep the trains in equal distance from each other and it shows that all velocities satisfy the maximum speed limitation [13].

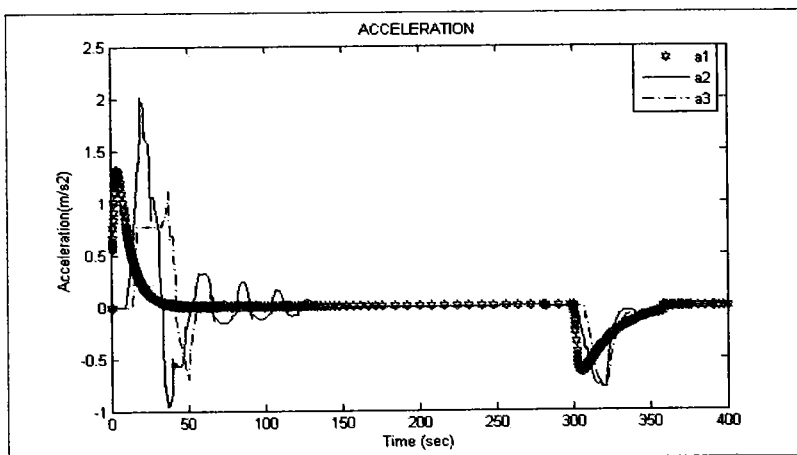


Figure 2.8: Trains acceleration (Star: Acceleration of 1st train; Solid line: Acceleration of 2nd train; Dash-dot: Acceleration of 3rd train) [13]

In Figure 2.8, acceleration of the trains are shown. The acceleration curves are used to evaluate the ride quality, which should be less than 1.4 m/s^2 according to UIC standards. Obviously, all trains satisfy this constraint [13].

2.4 Automatic Braking System for Trains using Radio Frequency

Rohit Sharma, Pankaj Singh, Pankaj Agarwal, and Himanshu Tiyagi (2011) from SRM University NCR Campus, Modinagar, implement automatic braking system for trains using radio frequency by design a pair of RF transmitter and receiver circuit working as train sensor at a common track. The project that they proposed was regarding two trains destined on a rail track. The RF sender/receiver device will provides necessary range detection and application for the paddle brakes of the train [15].

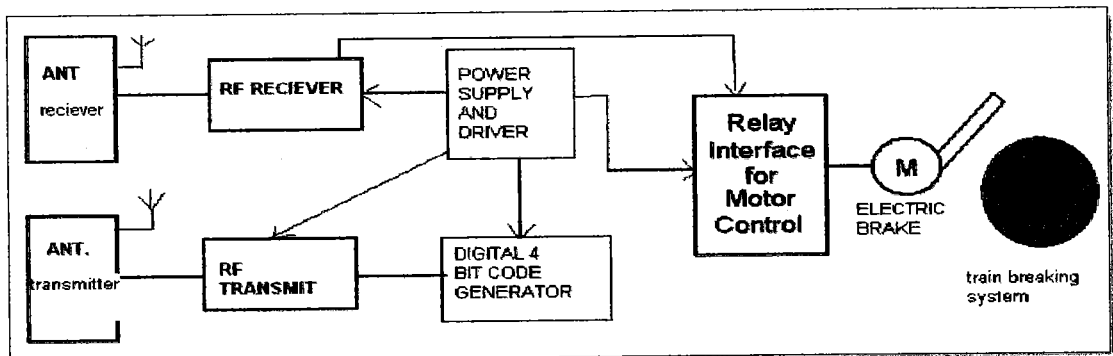


Figure 2.9: Block Diagram of RF kit and the whole setup [15]

The block diagram in Figure 2.9 suggests the required components for the implementation of their project. The most important and integral parts or components being the transmitter and receiver kits that aligns with the power supply and the relay circuit to support the setup [15].

2.4.1 Working principle

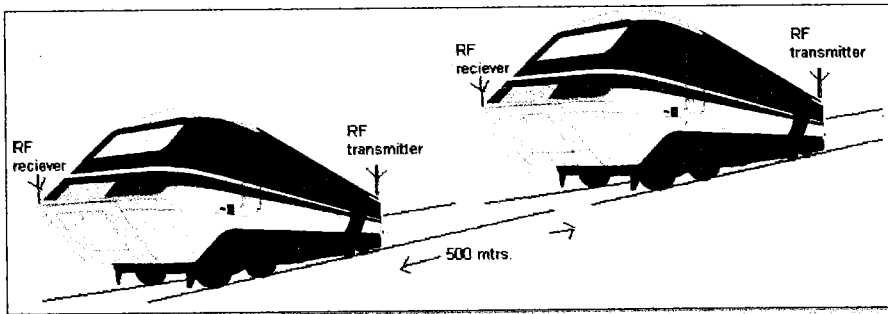


Figure 2.10: Train Setup [15]

Figure 2.10 shows the device working principle on the two trains that was designed by Rohit Sharma, Pankaj Singh, Pankaj Agarwal, and Himanshu Tiyaagi. Each train is fitted with both the RF transmitter and receivers for the sake of detecting the signal. Now as soon as the range is breached the motor controlling the brake is powered and the paddle brakes are applied. When the two trains approaching on the same track within range 2km then they are forced to stop by an automatic brake [15].

2.5 Dynamic Braking Control for Accurate Train Braking Distance Estimation under Different Operating Conditions

Ahmad, H.A (2013) research focused on the application of Model Reference Adaptive Control (MRAC) for better controlling wheel-rail interface dynamics and longitudinal train forces in order to bring a moving train to stop without exceeding the maximum wheel longitudinal creep forces or the allowable inter-train dynamics [18]. The main contributions of this study were:

1. To provide an extensive study of MRAC for controlling longitudinal train dynamics
2. To develop a first study of its kind of a relationship between creep forces, creep ages, and the braking torque for different weights of the locomotive using the longitudinal train dynamic model.
3. To extensively study the interaction between dynamic braking control and dynamic braking provided by the traction motors.

The approach of Ahmad, H.A research is described as follows. First, a two-dimensional train model was developed using multimode dynamics formulation. The model included all forces and moments that resist the train motion, beyond braking forces, and the general equations of motion are applied to each railcar within the train [16]. The model was then verified by comparing the simulation results with a model developed in SIMPACK, which is a toolbox that can be used to perform multimode simulations. Next, a parametric study is performed to investigate the train braking distance under different operating conditions. For each operating condition, the train braking distance and time needed to stop the train are estimated [16]. The dynamic model is used to develop a closed-loop control of the dynamic braking forces. The Model Reference Adaptive Control method was used to enable adapting the dynamic braking forces for minimizing the braking distance. The MRAC method actually adjusts the current supplied to the DC traction motors which directly adjusts the dynamic braking force. Then the same control method is used to control the dynamic braking force by controlling the synchronous frequency of the AC traction motor [16].

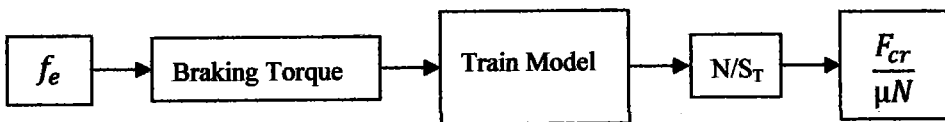


Figure 2.11: Block diagram of the train system inputs and outputs [16].

Figure 2.11 illustrate the input and output of the train system. The input starts with the motor excitation frequency, f , which determines the braking torque. The output of the train model is N/S_T , which is used to determine the normalized creep force, $F_{cr}/\mu N$ [16]. Train system parameters will be changed rapidly to investigate the MRAC system ability to resist these changes and adapt control parameters without changing the initial conditions of the train operation. System parameters that will be varied include coupler forces, primary suspension forces, longitudinal creepage, normal load, and braking torque [16].

2.6 Related previous works summary

Some of the previous works that are related with automatic train control system is summarized in Table 2.1.

Table 2.1: Previous works summarization

| Author/Year | Method control system | Input | Output |
|--|--|----------------------------|------------------------|
| ML Sharma & SheetalAtri (2011) | Fuzzy logic using VHDL code | Speed & Distance | Braking control |
| Sandidezadeh, M.A. & Shamszadeh, B. (2012) | Fuzzy logic | Train parameter | Output notch |
| Siahvashi, A. & Moaveni, B. (2010) | Multi-Agent Control of Cooperative Systems | Number of train | Speed and distance |
| Sharma, R., Singh, P., Agarwal, P., & Tiyagi, H (2012) | Radio Frequency | Distance between two train | Braking Control |
| Ahmad, H.A (2013) | Model Reference Adaptive Control (MRAC) | Motor excitation frequency | Normalized creep force |
| Umi Mariana (2014) | Fuzzy logic | Train weight & weather | Train speed |

From Table 2.1, it shows that train automatic control system using fuzzy logic controller has become more preferable for the researchers to develop a new control method for automatic train operation. This is because fuzzy logic controller is easy to be understood by a human expert and it is more simpler to formulate rules to control the train system. In addition, it is also easy to work with nonlinear system such as train.

CHAPTER 3

METHODOLOGY FOR DEVELOPING THE TRAIN CONTROL SYSTEM

In this chapter, the methodology for automatic train control system development using fuzzy logic controller is described briefly in Figure 3.1. The designed model is simulated using Matlab Simulink software.

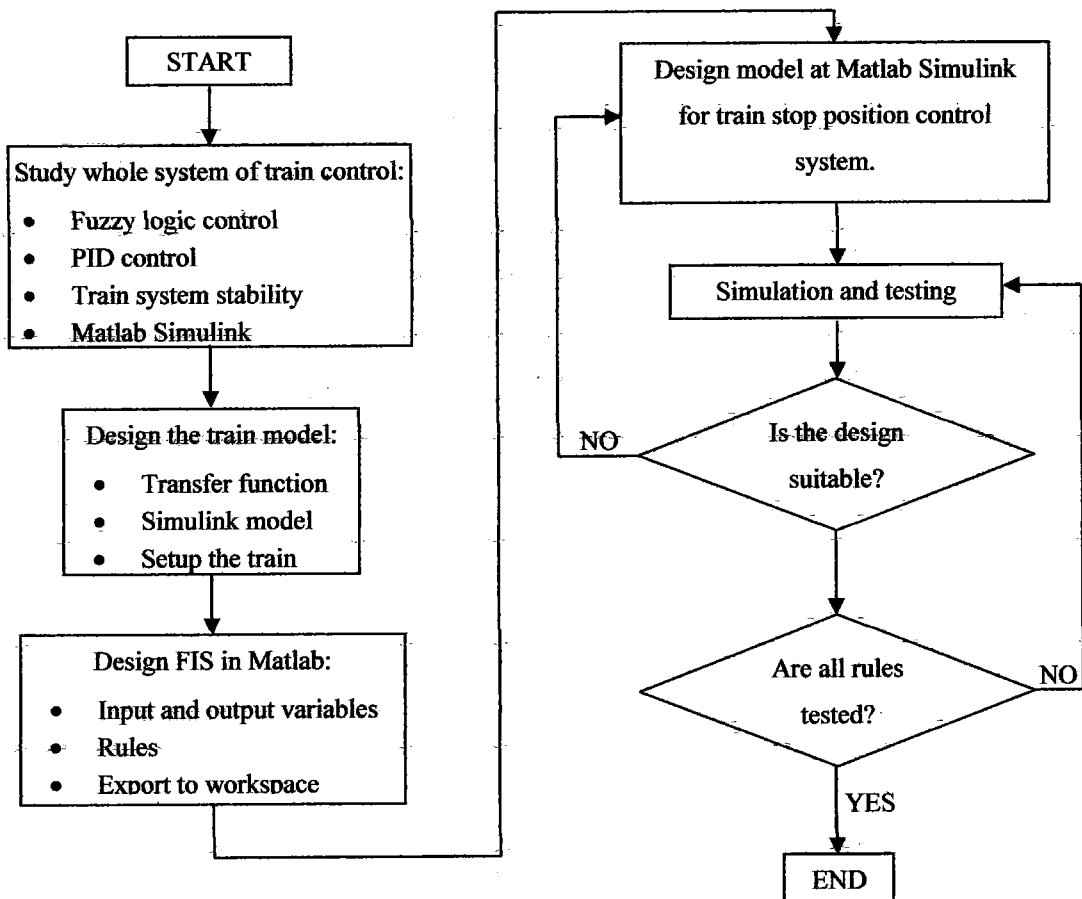


Figure 3.1: Development of automatic train control system

3.1 Track design for speed control

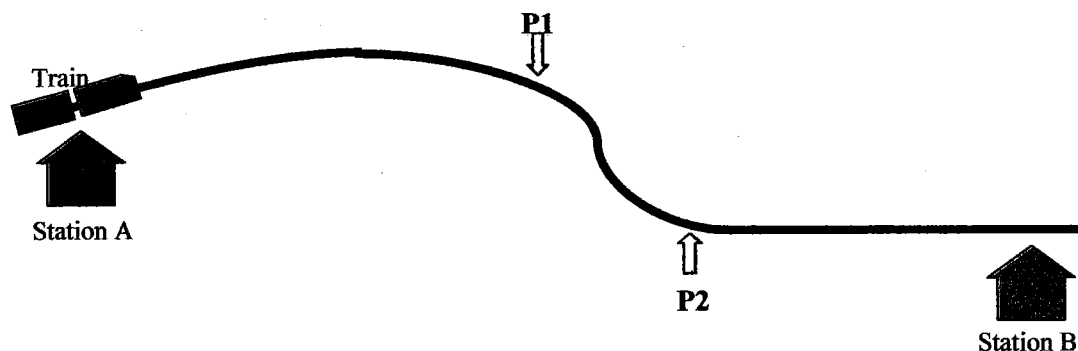


Figure 3.2: Railroad design layout

Figure 3.2 shows the proposed railroad design layout indicating two station, station A and station B. The distance between these two stations by railroad is 16.65 kilometres, and the average travel time using the proposed train model is about 17minutes 50 seconds (1070 seconds). The railroad design layout has three sections of track length, which is from station A to point P1 (SAP1), point P1 to point P2 (P1P2), and point P2 to station B (P2SB). These track sections are divided based on track condition such as curvature, sharp turn, and straight line, and the purpose of the dividing into three track sections is to determine the speed restriction at each section using predictive fuzzy logic.

Speed restrictions on railroad are based on a number of factors such as curvature, signalling, track condition, and the physical condition of the train and the presence of grade crossing. The purpose of speed restrictions at each track section is to prevent collisions, and increases railroad capacity.

Table 3.1: Speed restriction location

| Location | Station A – P1 | P1 – P2 | P2 – Station B |
|-----------|------------------------------------|------------------------------------|-------------------------------------|
| Max Speed | 80 km/h (22.2ms ⁻¹) | 50 km/h (13.9ms ⁻¹) | 120 km/h (33.3ms ⁻¹) |
| Distance | 8.3 km | 1.39 km | 6.96 km |

Table 3.1 show the length of each track section and their speed restriction. A heavy freight train, especially those with light and heavy wagons mixed up, may have problems going through very sharp curves, as the draw gear forces may

pull intermediate wagon off the rails causing derailments. One of the solutions for this problem is by reducing the speed. According to CSX (Chessie Seaboard Multiplier) Vice President for Passenger Operations, Jay Westbrook said a slower train puts less stress on the track [24]. Especially on the switching point and sharp curved line.

3.2 Block Diagram of proposed train control system

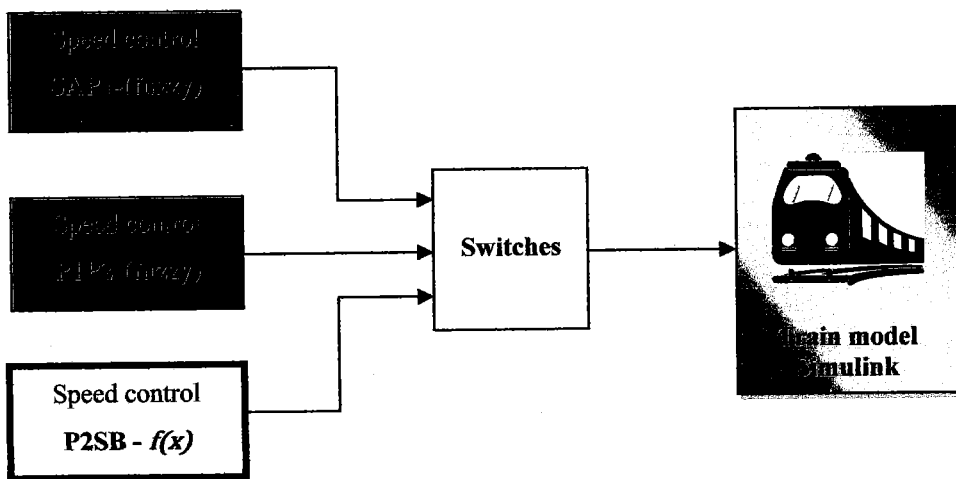


Figure 3.3: Train Stop Position Control system block diagram

Figure 3.3 is a simple diagram of train control system from station A to station B. The blue, pink and white blocks representing three values of different speeds that will be generated based on the weight of the train and the weather when the train is about to travel from station A to station B in Figure 3.2. The blue block in Figure 3.3 represents FIS for speed control from station A to point P1 (SAP1), while the pink block represents the FIS for speed control from point P1 to point P2 (P1P2). The speed values that generated from the blue and pink blocks are based on the real skills of expert hostler when they control the train in the two types of situation, which are variety weight of train and variety of weather when the train was in the location (station A to station B), Figure 3.2. The white block is representing the speed control for point P2 to station B (P2SB). The generated speed at this block is based on the mathematical function where the variables are from FIS SAP1 and FIS P1P2.

The Switches block represents all switches that are used in the Simulink model at the end of this chapter. These switches will switch to another speed control

value when the train arrive at the position point of speed tuning, P1, P2 and after 16 minutes 40seconds (1000 seconds).

Inputs for fuzzy controller are chosen as train weight and weather while the output is train velocity control. Based on Mamdani method two sets of 3x2 (6 rules) have framed using Fuzzy Inference System (FIS) GUI in Matlab. This method will be shown in Figure 3.16.

In this control model, fuzzy logic control will mimic the control operation strategy of a human operator. It would perform the control operations even better than a skilled human operator. Some examples of skilled operator experience-based control rules that can be implemented by using fuzzy logic control system such as:

1. For safety, if train speed goes beyond the speed limit, brake command with the maximum force is selected.
2. For shorter running time, if speed falls too much below the limit, power notch is selected.
3. For passenger comfort and safety, if train location is at sharp curve, the speed will be reduced.
4. In bad weather, the train will reduce the speed at curved track, and the next speed will automatically tuned as the train will arrive at the exact position in the exact time.
5. When the train weight increase, speed will be reduced at curved track and increase at straight and safety track.

3.3 Fuzzy logic control system

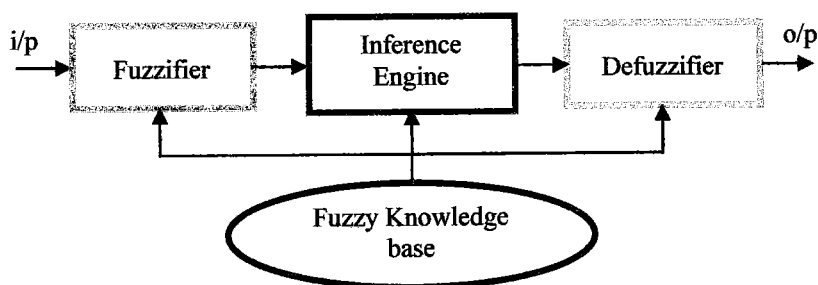


Figure 3.4: Fuzzy System

Figure 3.4 is a fuzzy logic control block diagram that contains three main processes which is fuzzifier, inference engine and defuzzifier. Fuzzifier is a first process to convert the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base. Fuzzy inference engine is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in Membership Functions, Logical Operations, and If-Then Rules. Defuzzification is a process to convert the fuzzy output of the inference engine to crisp using membership functions analogous to the ones used by the fuzzifier.

3.3.1 Benefits of fuzzy controllers

Fuzzy logic is a multi-valued logic which is similar to human thinking and interpretation. The benefits of using fuzzy controller in control system are as follows:

- Fuzzy controllers are more robust than PID controllers because they can cover a much wider range of operating conditions than PID can, and can operate with noise and disturbances of different natures.
- Developing a fuzzy controller is cheaper than developing a model-based or other controller to do the same thing.
- Fuzzy controllers are customisable, since it is easier to understand and modify their rules, which not only use a human operator strategy but also are expressed in natural linguistic terms.
- It is easy to learn how fuzzy controllers operate and how to design and apply them to a concrete application

3.4 Classification of fuzzy inference methods

Fuzzy rule-based models are classified as Non-Additive rule models and Additive rule models as shown in Figure 3.5. Mamdani and Sugeno fuzzy are the most commonly used. These two models only differ in how they obtain the outputs.

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