UJEAS

UNIZIK JOURNAL OF ENGINEERING AND APPLIED SCIENCES

UNIZIK Journal of Engineering and Applied Sciences (2023), 78 - 88
Journal homepage: https://journals.unizik.edu.ng/index.php/ujeas

A fuzzy based modelling of a smart car parking system using Arduino

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Abstract
Smart parking system obtains information about available parking space, process it and then place the car at certain position. Many people are facing problems on parking vehicles in parking slot in some cities or most urban cities. This technology is inevitable for all vehicle users to acquire parking slot in cities. The objective of this research work is to design a smart parking system within a mall so as to implement the usage of small parking spaces for parking lots by implementation of story's/floors so as to allow the parking of vehicles based on their weight. The smart parking system was implemented with the use of Arduino set, Matlab/simulink and fuzzy logic. Arduino was interfaced with the RFID card reader used as a medium to identify a user parking in a given parking lot. A set of rules are implemented in the fuzzy logic to control two sets of parking decisions, namely vehicle entry decision and parking decision by considering the weight of vehicles and the availability of parking spaces in the parking mall. The results obtained revealed a high value when the tag number corresponds to vehicles and a low value when the tag number does not correspond to vehicles at their corresponding weight. Also, RFID tag normally goes high when a light weighted vehicle was detected and goes low when a medium or heavy weighed vehicle was detected. In conclusion, the availability of a park lot depends on the presence of inactive RFID reader and the availability of a park for a sensed weighted vehicle depends on the availability of free parking lot.

Keywords: Fuzzy logic, Arduino, Smart parking system, Parking lot

1. Introduction

Recently, transport has increasingly become an important economic, environmental and political issue. As the urban population increases, there is an increase in the density of urban mobility and this has brought about several transportation problems. Statistics shows that at the end of 2016, the worldwide vehicle population was at 1.32 billion automobiles and trucks substantially double the volume for 20 years when vehicles in service reached 670 million. By 2035, annual sales might reach 127 million bringing the worldwide vehicle total to 2 billion (Belkhala, 2019). The observation reached by both governments and people is with regards to the desperate need to ease the traffic congestion. There are large numbers of people or organization searching for parking spaces thereby contributing to traffic congestion in large cities. Again, the lot of vehicles searching for parking spaces contributes about 30% of traffic congestion experienced in large city areas. On a daily basis, each vehicle on the road wastes 8-20 minutes cruising for a vacant parking spot. This causes not only a loss of time, money and effort for the drivers looking for parking space, it also contributes to an extra loss of time, money and effort for other drivers as a result of traffic congestion (Patil and Sakore, 2014).

With the exponential increase in car population and sales, as well as increased urbanization, the issues of obtaining parking places for these vehicles, efficiently managing available parking spaces, and ensuring the security of the parking spaces have become increasingly difficult. The search for parking places consumes a large amount of the world's oil each day, creating carbon footprints in the environment and contributing to traffic congestion in our cities (Canli and Toklu 2021). To tackle such environmental challenges caused by traffic congestions as a result of searching for parking spaces in order to improve economic opportunities, numerous countries seek to improve and manage their existing transportation systems and road infrastructure to enhance traffic flow, mobility and safety. One example of such a response is the building and deployment of guidance-based systems, such as Parking Guidance and Information (PGI) systems for a better parking management (Bhonge and Patil, 2013).

Parking guidance and information systems provide the drivers with dynamic information within controlled areas about the availability of parking spaces and directions to them. Data about the vacancy of parking spaces are extracted from sensors deployed on or off the roadway, and then they are conveyed to the drivers through Virtual Message Signs (VMS) on the road or through the internet (Reve and Choudhri, 2012). With the advent of Internet of Things (IoT) and sensing technologies, smart parking has the potential to address these challenges. Internet of Things has gone a long way to utterly altered habitual human behavior by providing them with numerous facilities and comfort options to have ease in everyday life. Equipped with an Internet connection and sensor networks, electronic devices in the digital world are connected through IoT technology. A Smart Parking System (SPS) is a system that employs IoT devices and sensors to acquire real-time data regarding park availability so as to reduce the time required in searching for parking slots (Lee, 2019).

Over the last few years, a considerable amount of research has been conducted in the area of Parking Reservation Systems (PRS), this system allows the users to obtain parking data before and during their journey and obtain guaranteed parking reservations at their desired destinations. PRS usually integrate PGI systems for the parking spaces monitoring component (Kaur and Singh, 2013). Parking reservation system services are usually online services accessed by the internet, IoT and SMS. The parking reservation system is responsible for receiving reservations requests and effectively offering parking reservations that match the driver needs. The reservations offers can be generated based on Parking Space Optimization Service (PSOS) which is usually designed to maximize the parking resource utilization and minimize the drivers cost (Geng and Cassandras, 2013).

1.1 Automated Parking

In Automated Parking, driver drives up to a bay at the entrance of the parking lot, leaves the car and machines afterward move the vehicle automatically to its allocated spot. Automated parking is designed to provide more parking spaces for the same piece of land as compared to conventional multi-story car parking lots. This is achieved by providing parking on multiple levels stacked vertically. Since vehicles are transported by a mechanical system, the need for pedestrian walkways, drive lanes, ramps, stairways and elevators are eliminated, hence utilizing the most of land use for storing cars only (Ahad et al., 2016). The automated car parking systems are more cost effective compared to previously used traditional parking systems. The multilevel automated car park systems are less expensive per parking slot, since they require less building space and less ground area compared to the a traditional parking facility with same capacity. A multilevel car parking is essentially a building with number of floors or levels for the cars to be parked.

1.2 Fuzzy logic based Small Parking System

Fuzzy logic is a reasoning based approach which perform likely human reasoning based on a set of rules given to the system on how the access or manipulate some set of input(s) in order to decide an output(s). It uses multi-valued logic, which means there is no absolute truth or absolute false value in fuzzy logic. Fuzzy logic is used in small parking system for predicting parking lot occupancy status.

1.2.1Fuzzy logic based rule

With increase in complexity of systems whose performance exhibits non linearity, more complex design approaches based in space state variables are preferred. In 1965, Zadeh presented the foundations of the fuzzy set theory.

1.2.2 Fuzzy inference system

Fuzzy logic is a partly new technology that can solve problems using value concepts and rules based on linguistic terms. Fuzzy systems are used for decision- making problems and control systems because of their high transparency and quick reasoning and having simple concepts (Hatte et al., 2020). Fuzzy Inference Systems (FIS) are conceptually very simple. They consist of an input(s), a rule system, and the output. The input stage maps the input membership functions, usually in a superlative metric such as low, medium and high, and so on, to the appropriate membership functions and truth values.

Fuzzy Inference Systems depends on the variables and its values in fuzzy sets and the operations on it which are fuzzy sets within the system either to process it as inputs or as outcomes from a system. Through this, fuzzy system use fuzzy set theory to maps inputs to outputs. The fuzzy system in classical design is performed for all kinds through three stages, namely fuzzification, fuzzy processing fuzzy inference and defuzzification.

1.3 LITERATURE REVIEW

1.3.1 Related works

In the work of Narayana et al, (2018) titled design and implementation of a smart parking system using IoT technology. Their paper was aimed at providing a low-cost solution to the problem of parking space by designing a Smart Parking Space using the technology of IoT and an inexpensive processor-Node MCU that would be beneficial to both the users and provider in terms of time, fuel and infrastructure. Sakthivel et al (2020) researched on smart car parking system using Arduino. In their work, car parking was a major issue in modern cities of today. There are too many vehicles on the road and not enough parking spaces. This has led to the need for efficient parking management systems. Khushboo et al (2021) researched on a review of smart parking system. In their work, the common strategy for finding a parking space was manual where the driver usually finds a space in the city or on the streets. This process requires time and effort and can prompt to the worst scenario of failing to discover any parking space if the driver is driving in a city with high vehicle density. They suggested ways in which cars can be parked using various smart parking systems. Despite the good work carried out by these researchers, their work was only based on review and mathematical modeling of smart parking system was not used.

2.0 Material and methods

The materials used in this paper to reduce traffic congestion, time spent waiting for a free parking slot in malls/ shopping center are hardware and software materials such as Arduino- uno Controller, the weight in motion sensor, Arduino Integrated Development Environment (IDE) software and Matlab/Simulink software.

2.1 Method

Smart parking system involves the principle of mathematical modeling using the Mamdani fuzzy inference system (MFIS). Smart Parking systems are designed to save time and stress in determining a safe parking lot for parking. Decisions need to be taken by any smart park system from the user identifies a parking lot on the cloud database using the IoT. Weight transducers are used to sense weight of vehicles and convert it to an electronic form used by Arduino. Arduino then reports this signal to the Matlab/simulink smart parking model based on the fuzzy rules. The block diagram of the smart parking system is shown in figure 1.

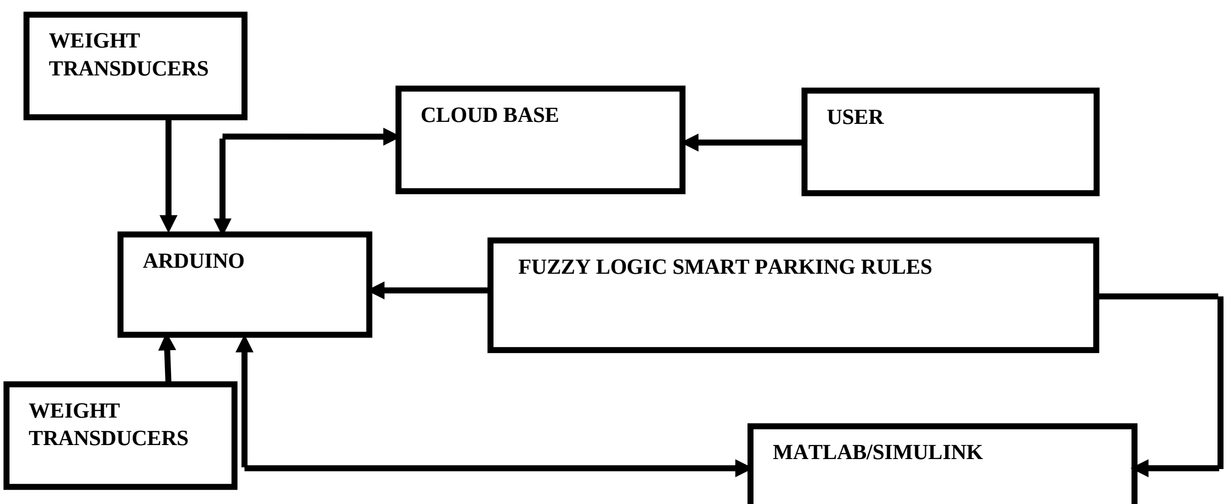

Figure 1: Block diagram of the smart parking system

In figure 1, the smart parking system focuses on the decision to give users best services. A fuzzy logic based smart parking model served as a rule decision to the hardware support (Arduino). The model shows an interfacing of Arduino and Matlab/simulink with the Arduino acting as a hardware control of the smart parking model.

The weight transducer detects when a vehicle tries to enter the park and when a vehicle leaves the park. Also, the transducer collects and post record for the availability of a park lot for a light, medium or heavy weighted vehicle once a park lot is free.

2.2 Smart park design

The design of the smart park model in MATLAB/SIMULINK is shown in figure 2. The smart park model investigating the park entry and in park decision of the smart parking system can be formulated by taking into consideration the number availability of parking lots at a previous timet_0, $NAOP_{t1}$, the number of available parking lots at an initial time t_1, $NAOP_{t1}$, the number of vehicle entry at an initial time t_0, $NVEN_{t1}$, the number of vehicle exit at an initial time t_0, $NVEN_t$, expression in equation 1 gives the relationship amongst the variables,

$$NAOP_{t1} = NAOP_{t0} + NVEN_{t1} - NVEX_{t1} \quad (1)$$

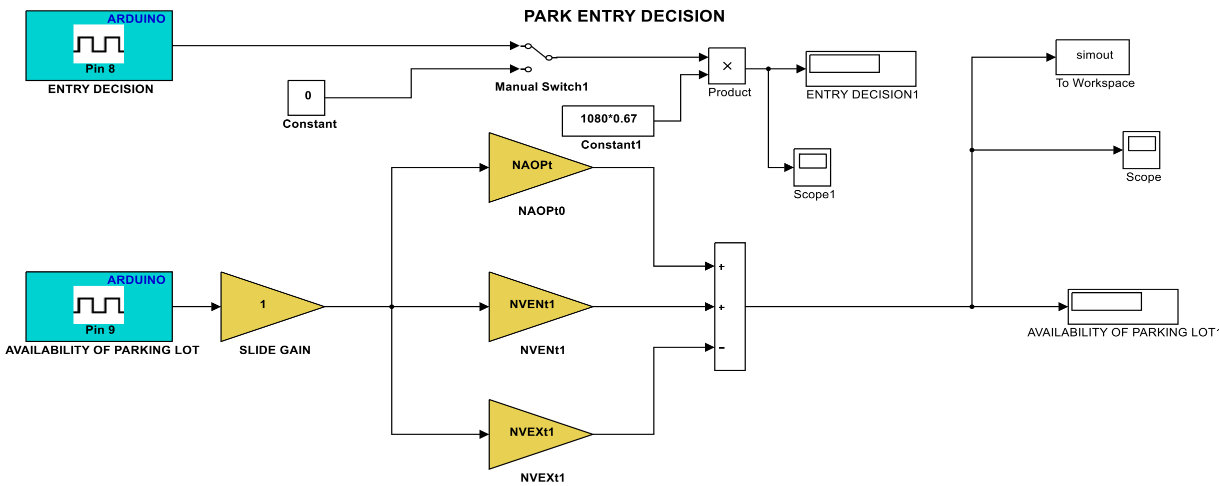

Figure 2: Smart park model in Matlab/Simulink Source: (Hatte et al., 2020).

Figure 3 shows the floor base of each parking lot. The mall park is designed to quickly allow an incoming vehicle into the mall park if it meets the criteria's of park lot availability for sensed vehicle weight and billing. Each vehicle is given a tag corresponding to the parking lot number and violation of the parking lot number will deny entry into a parking lot, this is detected by the weight transducers mounted on the park floors and the RFID reader situated behind the park lots, from the design, a green parking lot shows the presence of a car in the parking lot.

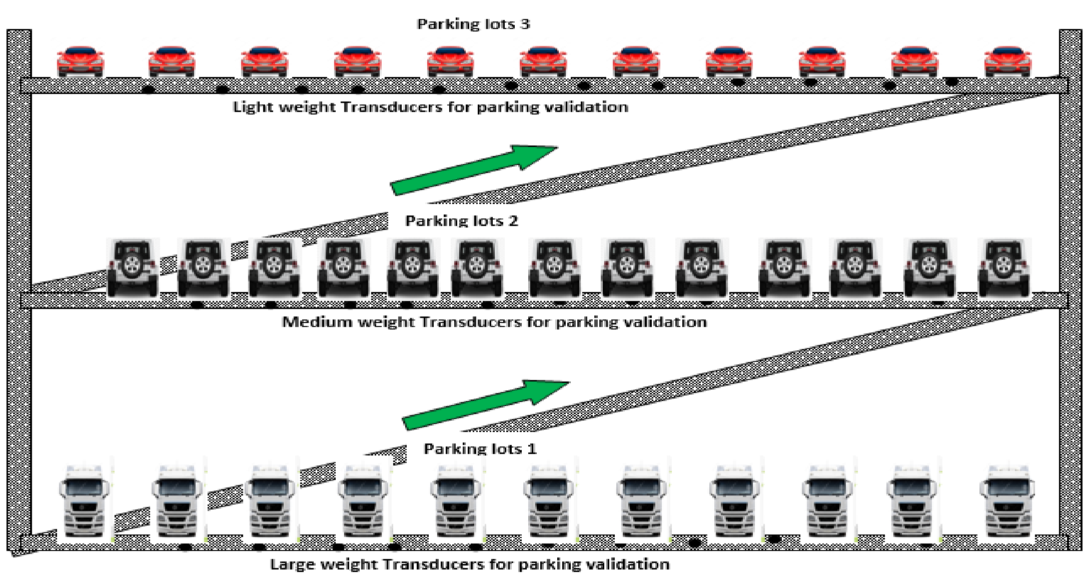

Figure 3: Front view showing floors of the parking based on vehicle weight (Canli and Tokln, 2021).

The system was designed to obtain the gross vehicle weight of the vehicle, including cargo, added features, luggage and passengers, the range of weight for vehicles based on heavy, medium and light weighted car.

Table 1: Weight ranges for vehicle type consideration

Vehicle Type	Average weight of vehicles
Light weighted vehicles	1500 to 3000 pounds
Medium weighted vehicles	2500 to 4000 pounds
Heavy weighted vehicles	3500 to 5000 pounds

2.3 FIS for the Vehicle Entry Decision

The variable to be considered for the vehicle entry decision includes weight of vehicle (WOV) and availability of parking space (AOP). The limitation of each parameter in the membership function is based on the mechanical scale used. The weight of the vehicle is measured by the weight transducer. The weight transducer take on motion weight of all vehicles approaching the parking mall and sends this data to the database for availability of parking slot. While the availability of parking space variable checks the availability of parking spaces for heavy, medium and light weighted vehicles, the variable is checked by the RFID sensor that report back to the database cloud also. The fuzzy inference system describing the vehicle entry decision rule is given in 4.

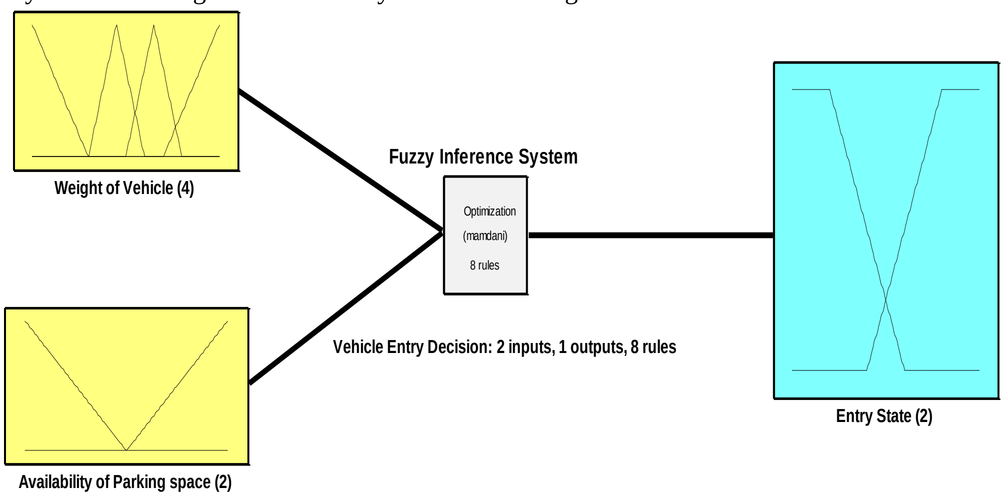

Figure 4: FIS showing Vehicle Entry Decision

Also, Membership Function (WOV) is arranged in line with triangle functions. Vehicle weight with weight transducer has 3 membership functions as shown in Figure 5.

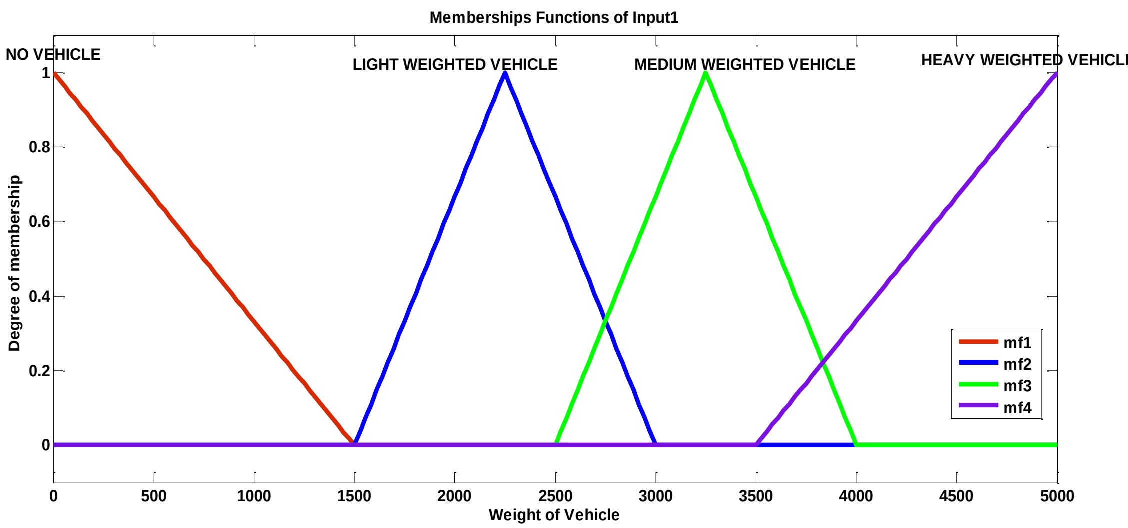

Figure 5: Input variable 1 (Weight of Vehicle) with membership functions

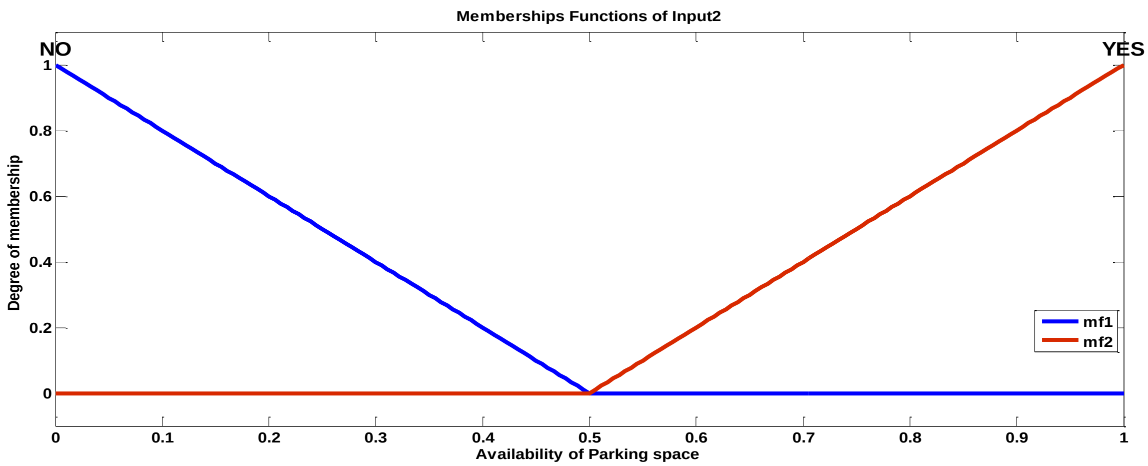

Figure 6: Input variable 2 (Availability of Parking Space) with membership function

The availability of parking space variable is composed of only two memberships as shown in figure 6. The output variable is the result of the decision around the inputs, its membership functions includes NO_ENTRY and YES_ENTRY with range of 0 to 1 is shown in figure 7.

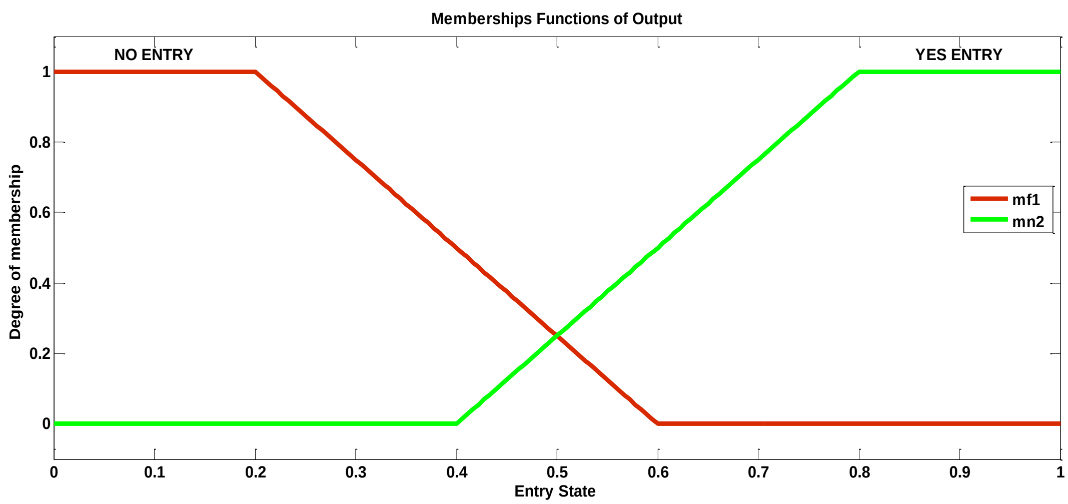

Figure 7: Output variable (ENTRY DECISION) with membership functions

The 3D plot showing the relationship amongst variables in the vehicle entry decision is shown in figure 8. The surface viewer was plotted in three dimensions. The aggregation and implication of the rules for availability of parking space and weight of vehicle against entry state are explained using surface plot for each vehicle. However, the rules fired with a higher entry state of 0.3-0.7 and also have a good system performance for weighted vehicle.

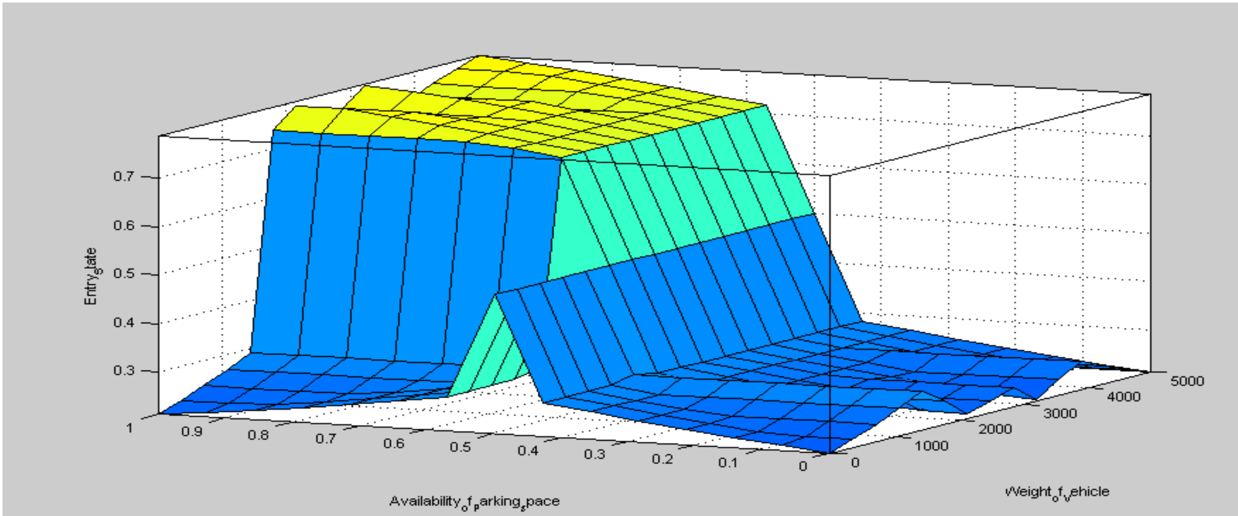

Figure 8: Relationship amongst entry state (output), availability of parking space and weight of vehicle (inputs)

2.4 FIS for the in-Park Vehicle Decision

The decision consider two input variables which are the tag number correspondence to the park slot number and the floor weight correspondence to the vehicles weight type and the fuzzy inference system describing the in-Park vehicle decision is shown in figure 9.

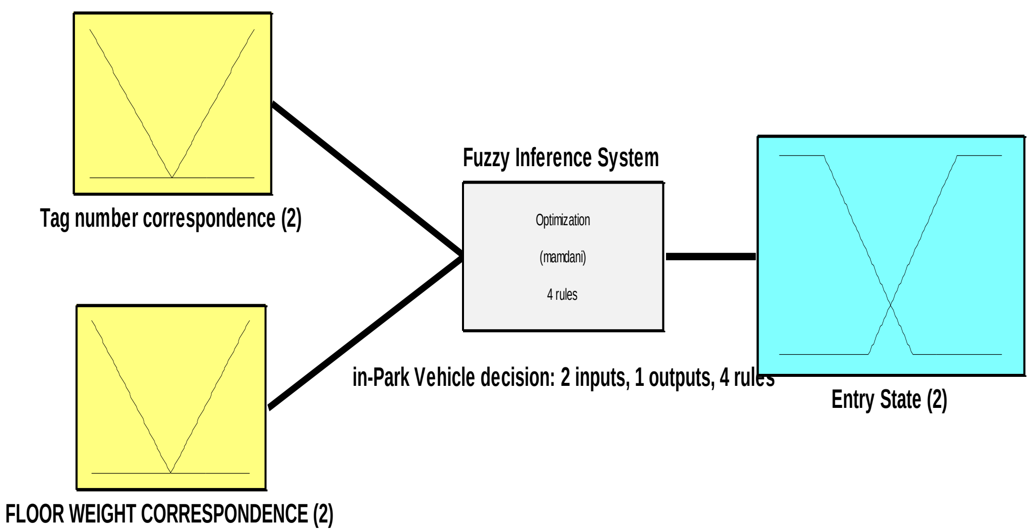

Figure 9: FIS showing in-Park Vehicle Decision

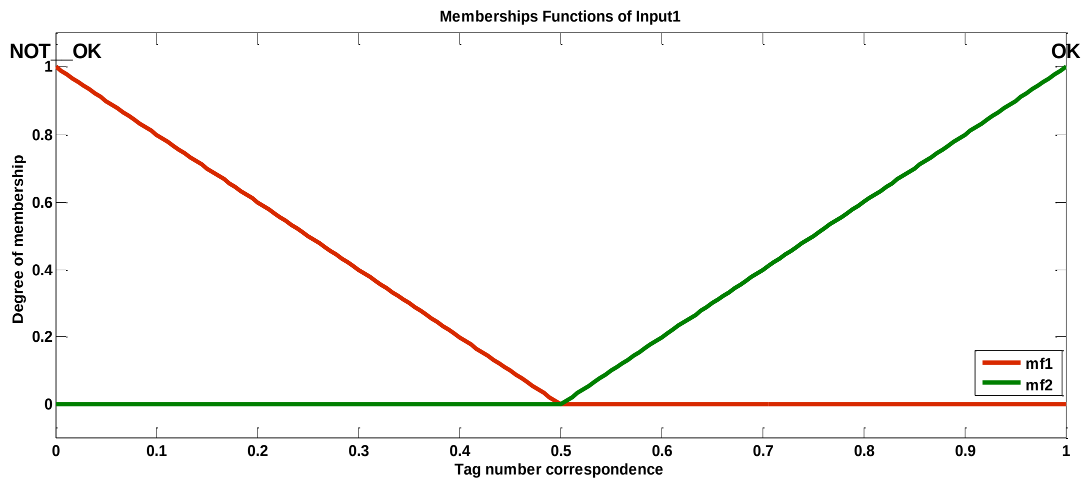

Figure 10: Input variable 1 (Tag Number Correspondence) with membership functions

The tag number correspondence variable (input 1) contains two membership functions as shown in figure 10.

The Floor weight correspondence variable (input 2) contains two membership functions as shown in figure 11.

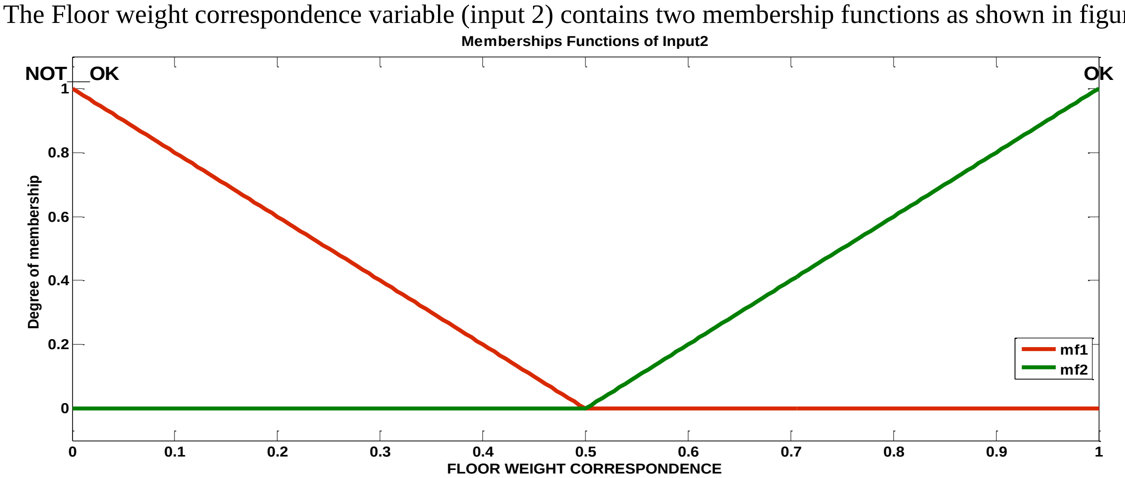

Figure 11: Input variable 1 (Floor Weight Correspondence) with membership functions

The output variable (Entry State) is the result of the decision around the inputs, its membership functions includes ENTRANCE_REMAINS_CLOSED and OPEN_ENTRANCE with range of 0 to 1 and is described in figure 12.

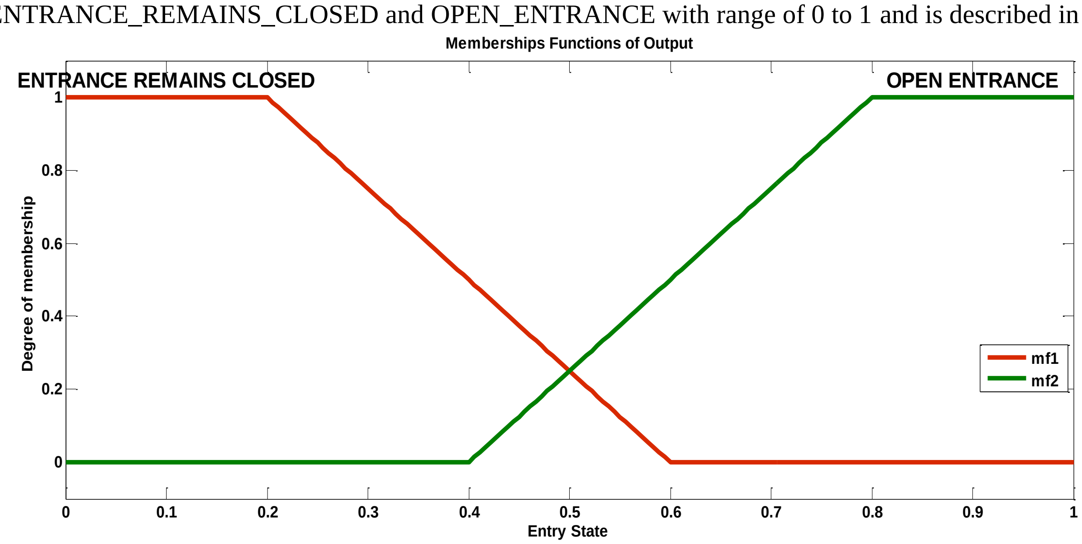

Figure 12: Output variable (in-Park Decision) with membership functions

3.0 Results and Discussions

The results obtained from the in park entry decision are shown in figures 13, 14 and 15, respectively.

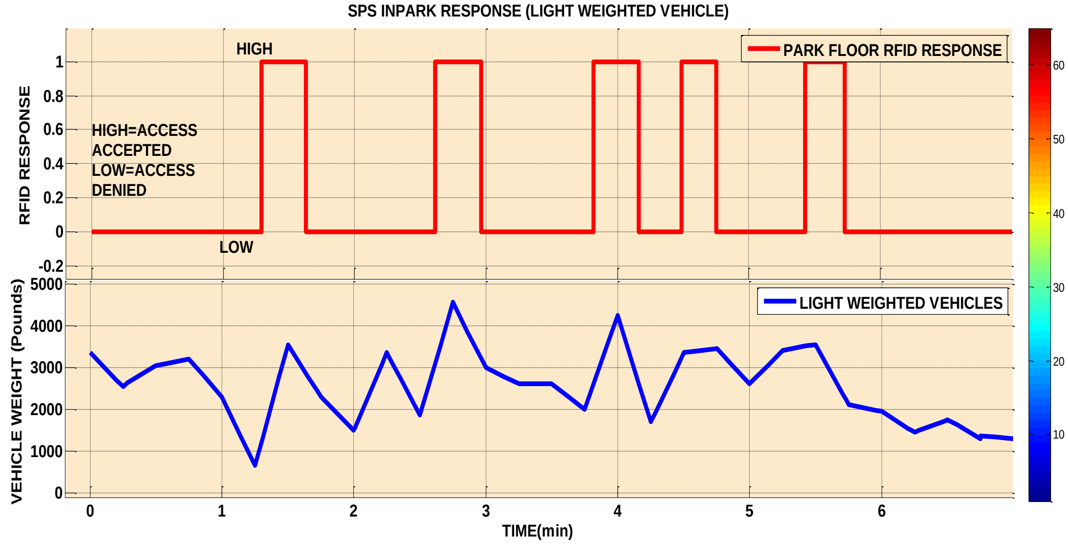

Figure 13: Plot of RFID reader response for light weighted vehicle

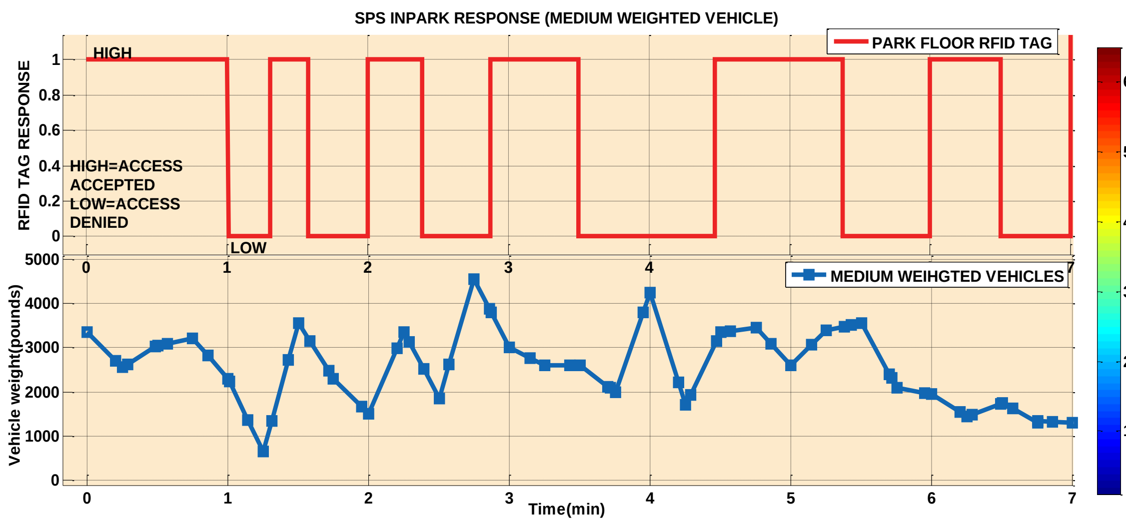

Figure 14: Plot of RFID reader response for medium weighted vehicle

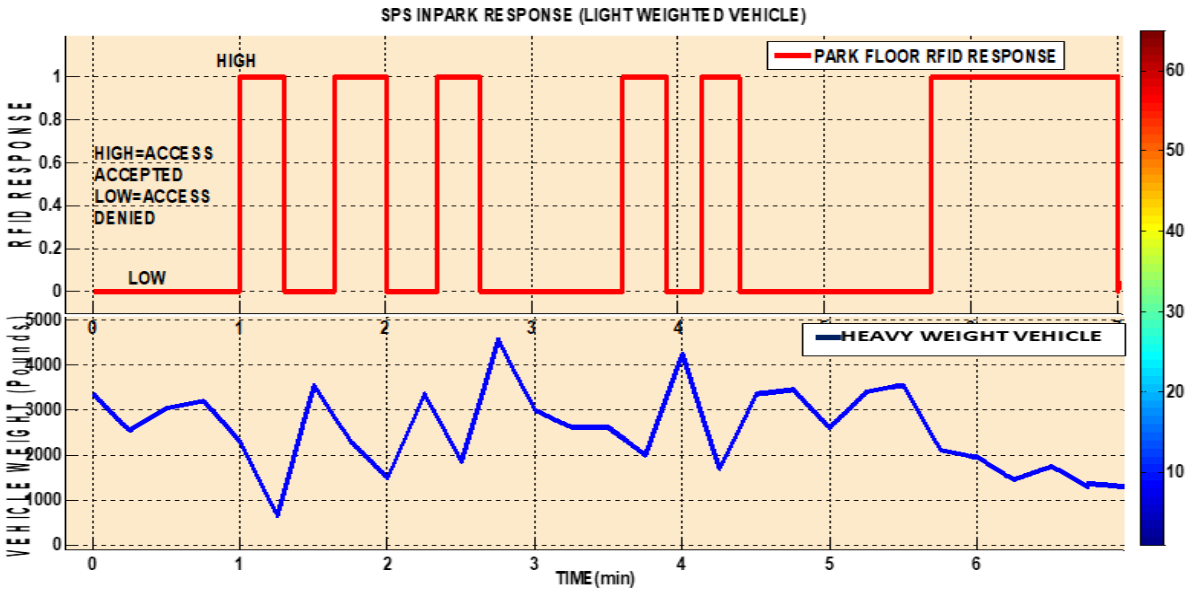

Figure 15: Plot of RFID reader response for heavy weighted vehicle

From the results obtained, it was observed that when the RFID tag reader was programmed, it gave a HIGH value when the tag number corresponds to vehicles at their corresponding weight and also the RFID tag reader gave a LOW value when the tag number does not corresponds to vehicles at their corresponding weight.

The simulation of the RFID reader for the vehicles depends on their corresponding weight as indicated on their graphs. The results shown in figure 13 indicated that the tag only goes high value when a light weighted vehicle is detected and the tag goes low value when a medium or heavy weighted vehicle shown in figures 14 and 15 is detected. The results also show an access value if the RFID tag read HIGH for figures 13, 14 and 15, respectively.

4.0. Conclusion

The vehicle detection at entry is achieved when using the weight transducer and the weight transducer detects when a vehicle tries to enter the park and when a vehicle leaves the park. The electronic data keeps information of the available number of park lot using this transducer and the transducer also collect and post record the availability of a park lot for a light medium, medium or heavy weighted vehicle once a park lot is free. The availability of a park lot depends on the presence on the of RFID reader and the availability of a park lot for a sensed weighted vehicle depends on the availability of free parking for lot either of the three different parking lots

5.0 Recommendation

It is recommended that Matlab toolboxes other than fuzzy logic should be used to design and model smart car parking system in order to compare the results obtained from it with that of the fuzzy logic.

Acknowledgements

The authors wish to acknowledge the assistance and contributions of the laboratory staff of Department of Electrical/Electronic Engineering, Michael Okpara University of Agriculture, Umudike toward the success of this work.

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