THE PHILIPPINE-AMERICAN Academy of Science & Engineering

Adaptive Optimal Scheduling of Public Utility Buses in Metro Manila Using Fuzzy Logic Controller

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ABSTRACT

Tactical transit planning is a crucial task in transportation industry. It mainly concentrates in the scheduling and setting of trip frequencies. One way of solving the scheduling pattern is the selection of the optimal dispatching interval of the transit system. This paper aims to optimize and monitor the scheduling and dispatching of public utility buses plying along EDSA. A fuzzy logic controller is designed based on the passenger and vehicle data. The self-adaptive controller will decide for the best dispatch interval of public buses from terminals based on given fuzzy sets or conditions. It seeks to choose solution in such a way that the travel time of passengers and number of buses running along EDSA are minimized while the operational constraints such as the traffic demand, departure time and maximum (minimum) headway are satisfied. The fuzzy logic controller is developed using Matlab. Effectiveness, accuracy and robustness of the system are evident in the results.

KEYWORDS: fuzzy logic; transit system; bus scheduling; dispatch system; headway; Matlab

1 INTRODUCTION

The role of transportation in development of a country is very essential as it defines economic condition and productivity. It is the movement of people and goods from one place to another. It enables trade between people, which is essential to the development of the society. Good public transportation system provides more mobility and increased productivity (Ezell, 2010).

During rush hours in the morning and in the afternoon, taking public mass transportation particularly bus commuting has been a daily burden for every Filipinos in Metro Manila. The ability of transport systems to respond to mobility needs of citizens and goods is hampered by a continuous increase in traffic demand as a result of higher levels of motorization, urbanization, population growth and changes in population density (Mercier – Handisyde, 2010).

Traffic has long been a problem in Metro Manila -- and it's costing the country. The gridlocks turn investors away and a study shows the Philippines loses P2.4 billion a day in potential income from the traffic jams in Metro Manila alone. This includes lost work hours, lost business opportunities due to delays and missed deadlines and wasted fuel (Francisco, 2014). Significant savings in resources can be made by reorganization of bus frequency to suit the actual travel demand (Deb, Karim, & Marwah, 2005).

Improving transit service reliability has been a long-standing objective in the transit industry. Reliability problems are a major concern of transit system users and operators (Starthman, 1999). Service that is not on time affects passengers in terms of increased wait time, travel time uncertainty and a general dissatisfaction with the system (Starthman, 1999). Unreliable service ultimately leads to lost patronage, revenue and public support when passengers leave transit for alternative modes (Chunli, 2012).

The rise of population and large volume of vehicles lead to the exigency for faster and more efficient transportation system (Lye, 2012). Intelligent public transportation system is the effective integration of transportation, communications, computing and sensor technologies incorporated into the transportation system's infrastructure to relieve congestion, improve safety and enhance productivity (Chunli, 2012).
Fuzzy logic is an extension of Boolean logic by Lotfi Zadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory (Dadios & Maravillas, 2001). By introducing the notion of degree in the verification of a condition, thus enabling a condition to be in a state other than true or false, fuzzy logic provides a very valuable flexibility for reasoning, which makes it possible to take into account inaccuracies and uncertainties (Dernoncourt, 2009).
Fuzzy logic based controller is developed in this study. The system is designed to find the best dispatch interval for a given set of parameters such as number of passengers aboard, rate of boarding passengers and vehicles headway to the preceeding vehicle.

2 BUS SCHEDULING SYSTEM

The main goal of most transit agencies is to offer to the population a service of good quality that allows passengers to travel easily (Mo, 2009). Tactical planning problems concern the decisions related to the service offered to the public, namely the frequencies of service along the routes and the timetables. These problems are usually solved on a seasonal basis, with occasional updates (Corcuran & Wainwright, 1995). One of the main reasons of traffic congestion in Metro Manila is the large volume of buses all the time. Relatively short bus headways results in congestion of the highway (Land Transportation Franchising and Regulatory Board, 2012). The presence of multiple overlapping routes contributes to the overcrowding and slow vehicular flow. Congestion in urban city yields to the uneven arrival of public transport vehicles at station causing delays and un-productivity. Multiple bus lines having multiple overlapping routes implement different dispatch and scheduling timetables. Unfortunately, there is no coordination between different bus lines that leads to congestion of the road.
A strategic timetable setting of bus dispatch is one of the solutions to the congestion problem in EDSA. Departure intervals will be computed based on passenger demand and actual headway relative to the followed bus.

3 FUZZY LOGIC CONTROLLER

The objective of this paper is to create a fuzzy logic controller that can limit the vehicular volume in EDSA by setting different dispatch interval based on different input parameters. The controller will set the time when the bus company should dispatch another bus depending on figures given by the preceding bus.
Figure 1 is the Mamdami inference system of the fuzzy logic controller. In Mamdami system, crisp output is generated using defuzzification method (Dernoncourt, 2009).

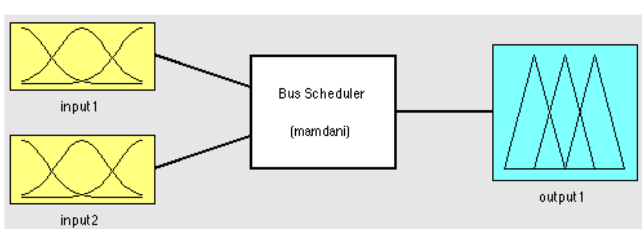

Figure 1: Mamdami inference system of the controller

3.1 Input Parameters

Load factor and headway from the preceding vehicle will be the input parameters. These data will come from a real-time monitoring system through sensor networks or historical date from on-board survey.
Load factor is the ratio between the number of the on-board passengers and the maximum capacity of bus. In a load factor below 1, the passenger volume is considered to be low to moderate. Whereas load factor equal to 1 means the bus is just in its capacity. Load factor exceeding 1 tells that the bus is overloaded. Load factor can be a very good indicator of passenger volume.
Vehicular headway is the time interval between buses. It tells the frequency of trips along the stretch of the road for that specific time. Short headway indicates large volume of buses, otherwise small volume of vehicle. Short headways also indicate heavier traffic congestion. Headway membership function is expressed in minutes. Figures 2 and 3 are the fuzzy input membership functions. Load factor is set to be the input 1 while headway is input 2.

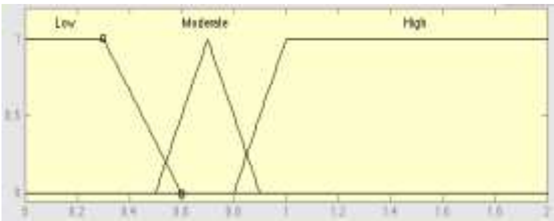

Figure 2: Load Factor Membership Function

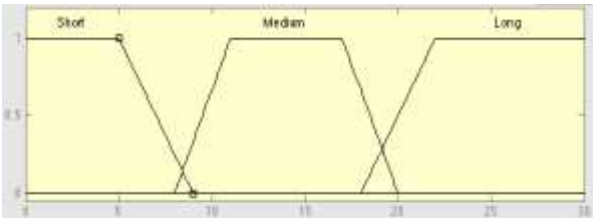

Figure 3: Headway Membership Function

3.2 Fuzzy Output

Below is the fuzzy output used in the controller. Given the values of the load factor and headway, the fuzzy controller will set the time that the succeeding bus must be dispatched from the terminal. Mode 1 denotes that the succeeding bus must be dispatched right away. Mode 2 tells that after 3 minutes, the succeeding bus must now be dispatched. Mode 3 denotes that the succeeding bus must be dispatched 6 minutes after the preceding bus while Mode 4 is to have a 9-minute interval. It can be adjusted to the desired time interval.

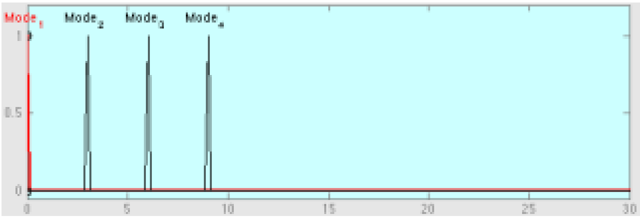

Figure 4: Fuzzy Output Membership Function

3.3 Tables and Figures

In order for the fuzzy logic to control the system, fuzzy rules must be set first. *If-then* statement is used in setting the fuzzy rules. Logical operator *and* is used for multiple inputs. Expert in transportation engineering is consulted for setting of rules.
Below are the fuzzy rules and the fuzzy associative matrix designed for the controller:

1. If load factor is Low and headway is Short then output is Mode 4.
2. If load factor is Low and headway is Medium then output is Mode 3.
3. If load factor is Low and headway is Long then output is Mode 2.
4. If load factor is Moderate and headway is Short then output is Mode 3.

5. If load factor is Moderate and headway is Medium then output is Mode 2.
6. If load factor is Moderate and headway is Long then output is Mode 1.
7. If load factor is High and headway is Short then output is Mode 2.
8. If load factor is High and headway is Medium then output is Mode 1.
9. If load factor is High and headway is Long then output is Mode 1.

Table 1 Fuzzy Associative Matrix

Load Factor	Headway		
	Short	Medium	Long
Low	Mode 4	Mode 3	Mode 2
Moderate	Mode 3	Mode 2	Mode 2
High	Mode 2	Mode 1	Mode 1

Table 1 is Fuzzy associative membership matrix. It depicts the fuzzy rules in a tabular form. It shows the truth table of the system. Corresponding output has been set for every given input parameter condition.

3.4 Results and Analysis

Presented here are the data and results of Matlab simulations. Figure 5 is the surface view of the simulation result. It shows the appropriate time when the next bus must be dispatched according to a given set of input parameters. Dispatch pattern varies depending on the situation of the vehicle. Output varies from 0 to 9 minutes interval. It can be changed depending on user preference. The output changes with change in the input condition. The controller easily adapts with change in input parameters. Time values are shown to indicate the exact time interval when the bus company must dispatch another bus. Noticed in the figure is one of extreme cases. When the number of passengers is extremely high and the there are few buses running along EDSA, the bus company must dispatch another bus right away

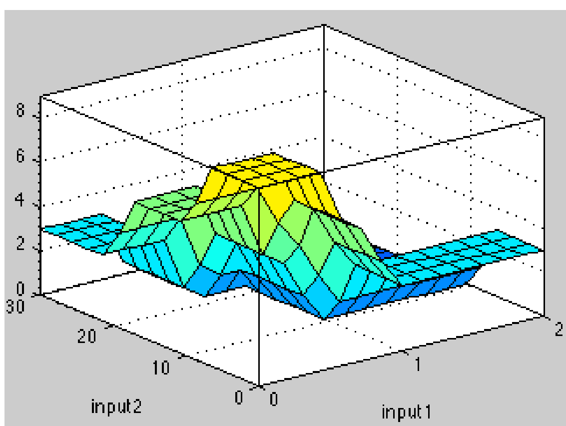

Figure 5: Surface view of the result

Table 2 Tabulated Results

Load Factor	Headway (min)	Dispatch Interval (min)
0	0	9
0	30	3
0.174	8.32	7.85
0.211	3.14	9
0.725	14.6	3
0.853	19.2	1.4
1.5	25.2	0
1.53	19.2	0
2	0	3
2	30	3

Table 2 presented are sample output data given by the fuzzy controller. A dispatch interval of zero means the bus company must dispatch another bus right away. Inputs that are within the non-overlapping range yields to a whole number dispatch interval. Otherwise, the dispatch interval is a non-integer. Headways vary from 0 to 30 min. Zero headway means 2 succeeding vehicles are just moving bumper to bumper. This is the most unlikely scenario in a heavily congested lane. One goal of the controller is to regulate the vehicular flow to reduce traffic congestion. On the other hand, a too long headway (i.e. close to 30 min.) will be another burden to the passengers. It only means that passengers would have to wait longer before they can be boarded inside the bus and will take longer before they reached their destination. Another important goal of the controller is to minimize the travel time of passengers. The results reflect the objective of this paper. Output intervals adapt to changes in input parameters. The controller tells the appropriate intervals the company must follow in order to optimally regulate trips. A well-regulated trip will yield to reduced operational cost since dispatch will be based on the actual traffic demand and road condition. It is evident that the system adapts to the need of the passenger and traffic condition.

4 CONCLUSION

A more efficient bus dispatch interval controller is developed using fuzzy logic system. The controller is developed using the load factor and headway as inputs. Mamdami inference system is used to provide crisp value as output data. The controller was able to set the appropriate dispatch interval depending on the input conditions. The fuzzy logic controller uses the centroid method in defuzzifying output. Fuzzy rules were derived using the help of experts in traffic engineering.

The results show that adaptive behaviour of the controller. Output adapts to changes in input condition. Results suggest as passenger volumes increase, dispatch interval must be reduced in order to deploy more buses to accommodate more passengers. However, when the headway of moving vehicles gets shorter, dispatch interval must be increased to regulate vehicular flow.

5 ACKNOWLEDGEMENT

The authors would like to thank the Transportation Engineering department of De La Salle University and the PubFix project for providing the technical information on traffic and the raw data from the transportation survey.

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