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Fuzzy Logic Model for Traffic Congestion

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Abstract: *Traffic congestion has become a serious problem in the urban districts. This is mainly due to the rapid increase in the number and the use of vehicles. Travel time, travel safety, environmental quality, and life quality are all adversely affected by traffic congestion. Many traffic control systems have been developed and installed to alleviate the problem with limited success. Traffic demands are still high and increasing. The main focus of this report is to introduce a versatile fuzzy logic traffic flow model capable of making optimal traffic predictions. This model can be used to evaluate various traffic-light timing plans. More importantly, it provides a framework for implementing adaptive traffic signal controllers based on fuzzy logic technology. When implemented it solved the problem of waiting time, travel cost, accident, traffic congestion.*
Key words: *Traffic Congestion, fuzzy logic, Traffic Density, fuzzy controller, conventional controller.*

I. Introduction

Recently, traffic congestion has become a serious problem. However, the construction of new roads alone is not the solution to effective traffic management. To manage the traffic congestion effectively, traffic information such as vehicle speed, number of passing vehicles, travel time, and vehicle classification data should be supplied by various traffic detectors. Especially, vehicle classification data can serve as the fundamental data for planning new road constructions, establishing road maintenance policies, and calculating number of passing vehicles.

The conversional traffic lights which we use to reduced traffic also help in causing traffic congestion since it cannot detect if there are no cars coming from the other direction to stop that side and allow the side that has much vehicles waiting. This report will use fuzzy logic traffic lights to solve the problem of traffic congestion affecting our cities.

Many methods and techniques have been proposed by scientists and research communities to solve the problem of traffic congestion on highways as well as in the metropolitan cities. Computer scientists have also been in the same hunt to find out a better solution; especially people working in the area of Artificial Intelligence (AI) are also trying to make their mark by solving the problem by using various intelligent agents such as soft computing etc. Soft computing (SC) is a concept that was introduced by Zadeh (1992), the discoverer of fuzzy logic. He envisioned SC as being concerned with modes of computing in which precision is traded for tractability, robustness and ease of implementation. Soft Computing is the fusion of methodologies that were designed to model and enable solutions to real world problems, which are not modelled, or too difficult to model, mathematically. These problems are typically associated with fuzzy, complex, and dynamical systems, with uncertain parameters. These systems are the ones that model the real world and are of most interest to the modern science.

Among the techniques of Soft Computing are fuzzy logic, genetic algorithms, neural networks, Evolutionary Computation, Machine Learning, and Probabilistic Reasoning etc it has emerged as an effective tool for dealing with control, modelling, and decision problems in complex systems. Briefly, fuzzy logic is used to deal with imprecision and uncertainty, genetic algorithms are used for search and optimization, and neural networks are used for learning and curve fitting. In spite of these dichotomies, there are natural synergies between these technologies.

Fuzzy algorithms have been successfully applied to a variety of industrial applications, including automobiles, autonomous vehicles, chemical processes, and robotics. These successful applications are attributed to the fact that fuzzy systems are knowledge-based or rule-based systems (Tang, Poo and De Silva 2001).

In the traffic application area, which is the main aim of this seminar work with the case study of MCC Junction in Owerri we are going to use fuzzy logic traffic light to control the traffic congestion in intersections.

II. Statement of the Problem

- Rapid growth in population has its impact on traffic congestion in the cities of developing world.
- The conversional traffic lights which we use to reduced traffic also help in causing traffic congestion since it cannot detect if there are no cars coming from the other direction to stop that side and allow the side that has much vehicles waiting.
- Construction or rehabilitation of roads can also cause traffic congestion, because when roads are being maintain there is every tendency that one of the lane will be close to enable work go smoothly thus it causes traffic congestion on the other lane.
- Traffic congestion leads to delay in travelling time and increases the cost of travelling because more fuel is used up in the Process of accomplishing a delayed journey (go-slow / traffic jam).

This research makes data integration to assess traffic situation within Owerri metropolis and proffer ways of reducing congestions. Thus, the aim of this study is to develop a fuzzy logic traffic light System as an application for the management of traffic congestion in urban city. To achieve this aim, the research determines factors responsible for the nature of their congestion and provides solution using fuzzy logic.

III. Objectives

The objectives of this research are to use fuzzy logic to:-

1. Provide efficient option for urban traffic demand management.
2. Ensure that, for these who have to use the roads journey times are quicker and more reliable.
3. Control the traffic congestion in MCC junction in Owerri.
4. Formulate generalize fuzzy control rules for traffic control in different cases using linguistic variables.
5. Ensure that traffic congestion is reduced if not totally eradicated.
6. Present fuzzy logic as a control method in adaptive traffic congestion control.

IV. Methodology

With the advancement of information technology in Nigeria, computers are used to automate the manual processing of making decisions in a wider range of disciplines. This research will concentrate on MCC junction in Owerri. Signal control is basically a process for allocating green time among conflicting movements. Alternatively, signal control is a process for determining whether or to extend or terminate the current green phase. The proposed fuzzy logic controller (FLC) works in the same way but it is significantly different from actuated control. The proposed fuzzy logic controller determines whether to extend or terminate the current green phase based on a set of fuzzy rules. The fuzzy rules compare traffic conditions with the current green phase and traffic conditions with the next candidate green phase.

Fuzzy logic is a model that matches the relationship between inputs and outputs based on the probability theorem. It can handle situations where there are uncertainties involved, such as problems that depend on human feeling and experience. Therefore, it is suitable for reporting road traffic where different people may feel differently in the same congestion situation.

Askerzade, Askerbeyli and Mustafa (2009) Describes how to compute the optimal extension time that will add to the fixed time control system. The system has been developed to simulate an isolated traffic junction based on fuzzy logic.

V. Fuzzy Logic

Fuzzy Logic can be considered to be a generalization of a logic system that includes the class of all logic systems with truth-values in the interval (0, 1). "In a broader sense, fuzzy logic is viewed as a system of concepts, principles, and methods for dealing with modes of reasoning that are approximate rather than exact." Klir, St. Clair, and Yuan (1997). Fuzzy logic is useful in representing human knowledge in a specific domain of application and in reasoning with that knowledge to make useful inferences or actions.

In fuzzy logic, the knowledge base is represented by if–then rules of fuzzy descriptors De Silva (1995). An example of a fuzzy rule would be 'if the speed is slow and the target is far, then moderately increase the power', which contains the fuzzy descriptors slow, far and moderate. A fuzzy descriptor may be represented by a membership function, which is a function that gives a membership grade between 0 and 1 for each possible value of the fuzzy descriptor it represents. A typical Fuzzy controller consists of four modules: the rule base, the inference engine, the fuzzification, and the defuzzification. A typical Fuzzy Control algorithm would proceed as follows:

1. Obtaining information: Collect measurements of all relevant variables.
2. Fuzzification: Convert the obtained measurements into appropriate fuzzy sets to capture the uncertainties in the measurements.

3. Running the Inference Engine: Use the fuzzified measurements to evaluate the control rules in the rule base and select the set of possible actions.
4. Defuzzification: Convert the set of possible actions into a single numerical value.
5. The Loop: Go to step one.

5.1 Data Collection

In the development of the fuzzy traffic lights control system the following assumptions are made:

1. The junction is an isolated four-way junction with traffic coming from the north, west, south and east directions;
2. When traffic from the north and south moves, traffic from the west and east stops, and vice versa;
3. The fuzzy logic controller will observe the density of the north and south traffic as one side and the west and east traffic as another side;
4. The East-West lane is assumed as the main approach;
5. The minimum and maximum time of green light is 20 seconds and 20 minutes respectively.

5.2 Analysis

The use of fuzzy logic technology in traffic lights control system which has the capability of mimicking human intelligence for controlling traffic lights. Software based on C++ will be developed to simulate an isolated traffic junction. The control of the traffic lights using both conventional fixed-time and fuzzy logic controllers can be simulated in the software. Analysis on the traffic lights simulation such as waiting time, density, cost, etc. can also be made using the software. The software can also be used as an exercise for undergraduate and graduate students to understand the concept of fuzzy logic and its application to a real environment. The rules and membership functions of the fuzzy logic controller can be selected and changed and their outputs can be compared in terms of several different representations.

The fuzzy logic traffic lights control is an alternative to conventional traffic lights control which can be used for a wider array of traffic patterns at an intersection (Filippidis, Jain and de Silva1999). A fuzzy logic controlled traffic light uses sensors that count cars instead of proximity sensors which only indicate the presence of cars. This provides the controller with traffic densities in the lanes and allows a better assessment of changing traffic patterns. As the traffic distributions fluctuate, the fuzzy controller can change the signal light accordingly. The fuzzy logic controller is responsible for controlling the length of the green time according to the traffic conditions.

In the fuzzy logic system there are two electromagnetic sensors placed on the road for each lane. The first sensor behind each traffic light counts the number of cars passing the traffic lights, and the second sensor which is located behind the first sensor counts the number of cars coming to the intersection at distance D from the lights. The number of cars between the traffic lights is determined by the difference of the reading between the two sensors. This is in contrast to conventional control systems which place a proximity sensor at the front of each traffic light and can only sense the presence of a car waiting at the junction, not the number of cars waiting at the traffic.

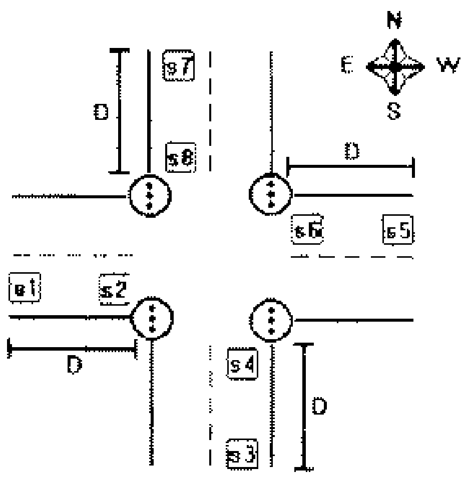

Fig 1: Location of sensor

5.3 Fuzzification

The first step in fuzzy logic processing involves a domain transformation called fuzzification. Crisp inputs are transformed into fuzzy inputs. To transform crisp input into fuzzy input, membership functions must first be defined for each input. Once membership functions are defined, fuzzification takes a real time input value, such as time, and compares it with the stored membership function information to produce fuzzy input values.

5.4 Defuzzification

This stage is used to convert the fuzzy output set to a crisp number. Two of the more common techniques are the Centroid and Maximum methods. In the Centroid method, the crisp value of the output variable is computed by finding the value of the center of gravity of the membership function. In the Maximum method, the crisp value of the output variable is the maximum truth-value (membership weight) of the fuzzy subset.

5.5 Fuzzy Rule Base

The inference mechanism in the fuzzy logic controller resembles that of the human reasoning process. This is where fuzzy logic technology is associated with artificial intelligence. Humans unconsciously use rules in implementing their actions. For example, a traffic policeman manning a junction say, one from the north and one from the west; he would use his expert opinion in controlling the traffic more or less in the following way:

IF traffic from the north of the city is HEAVY
AND traffic from the west is LESS
THEN allow movement of traffic from the north LONGER.

The beauty of fuzzy logic is the possible utilization of approximate reasoning in the rules such as HEAVY, LESS, AVERAGE, NORMAL, LONGER, etc. Due to the membership assignment techniques as discussed, such linguistic variables, though fuzzy in nature, can be taken care of in the computer through fuzzy logic technology. In the development of the fuzzy logic controller, we use almost similar rules and some examples are given below:

If there are too many cars (TMY) at the arrival side
And very small number of cars (VS) queuing
Then extend the green light longer (L).

If there are almost no cars (AN) at the arrival side
And very small number of cars (VS) queuing
Then do not extend the green light at all (Z).

These rules can be shorten as follows:
IF Arrival is TMY AND Queue is VS THEN Extension is L
IF Arrival is F AND Queue is VS THEN Extension is S
IF Arrival is AN AND Queue is VS THEN Extension is Z
Where "Arrival" and "Queue" are the antecedents and "Extension" of the green light is the consequent.

Table 1: Fuzzy variables of *arrival*, *queue* and *extension* of the traffic light control.

Arrival		**Queue**		**Extension**	
Almost	AN	Very small	VS	Zero	Z
Few	F	Small	S	Short	S
Many	MY	Medium	M	Medium	M
Too many	TMY	Long	L	Long	L

VI. Result

A fuzzy logic controller was designed for an isolated 4-lane traffic intersection: north, south, east and west. In the traffic lights controller two fuzzy input variables are chosen: the quantity of the traffic on the arrival side (Arrival) and the quantity of traffic on the queuing side (Queue). If the north and south side is green then this would be the arrival side while the west and east side would be considered as the queuing side, and vice-versa. The output fuzzy variable would be the extension time needed for the green light on the arrival side (Extension). Thus based on the current traffic conditions the fuzzy rules can be formulated so that the output of the fuzzy controller will extend or not the current green light time. If there is no extension of the current green time, the state of the traffic lights will immediately change to another state, allowing the traffic from the alternate phase to flow. The benefits of fuzzy logic controllers that make it different from the conventional control could be summarized as follows:

1. Fuzzy controllers are more robust than conventional controllers because they can cover a much wider range of operating conditions than conventional.
2. Developing a fuzzy controller is cheaper than developing a model-based or other controller to do the same thing.
3. Fuzzy controllers are customizable, since it is easier to understand and modify their rule, which not only use a human operator's strategy, but also are expressed in natural linguistic terms.
4. It is easy to learn how fuzzy controllers operate and how to design and apply them to a concrete application.

It is also worth to notice that fuzzy logic can be blended with conventional control techniques. This means that fuzzy system does not necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.

VII. Discussion

A fuzzy logic controlled traffic light uses sensors that count cars instead of proximity sensors which only indicate the presence of cars. This provides the controller with traffic densities in the lanes and allows a better assessment of changing traffic patterns. The general structure of a fuzzy traffic lights control system is illustrated as in Fig. 1. There are two electromagnetic sensors placed on the road for each lane. The first sensor behind each traffic light counts the number of cars passing the traffic lights, and the second sensor which is located behind the first sensor counts the number of cars coming to the intersection at distance D from the lights. The number of cars between the traffic lights is determined by the difference of the reading between the two sensors. The distance between the two sensors D, is determined accordingly following the traffic flow pattern at that particular intersection. Then to determine the density of the other lanes the value of D added to sensors values that gets the number of cars changed their path to the left or to the right of the specified lane.

The fuzzy logic controller is responsible for controlling the length of the green light time according to the traffic conditions. The state machine controls the sequence of states that the fuzzy traffic controller should cycle through. There is one state for each phase of the traffic light. There is one default state which takes place when no incoming traffic is detected. This default state corresponds to the green time for a specific approach, usually to the main approach. In the sequence of states, a state can be skipped if there is no vehicle queues for the corresponding approach.

When traffic from the north moves, traffic from the West, south and east stops, when traffic from the South moves, traffic from the west, north and east Stops and when traffic from the north and south Moves traffic from east and west stops and when traffic from the east and west Moves traffic from north and south stops. The fuzzy logic controller will observe the density of the north and south traffic as one side and the west and east traffic as another side.

VIII. Conclusion

Due to the flexibility of the fuzzy logic in dealing with uncertainty, it can be used advantageously for traffic light monitoring systems. In this paper, the fuzzy control of a four-phase traffic light has been taken into account. The performance of the fuzzy logic approach was evaluated by comparing it with the fixed-cycle time (conventional) control system, using the same input data to allow a consistency check and cross-validation. It can be observed that fuzzy logic control system provides better performance in terms of improving the safety and efficiency by reducing the waiting delay of vehicles on signals. Less traffic congestion and less waiting time at red traffic lights will reduce the fuel consumption, air pollution, sound pollution, and time and energy waste.

Traffic signal control using fuzzy logic model for full intersections with four ways was developed. The fuzzy logic model strategy simulates the control logic of experienced humans such as police officers directing traffic who often replace signal controls when intersections experience unusually heavy traffic volumes (e.g., during special Events.) The Fuzzy logic model controller makes the decision whether to extend or terminate the current green phase based on a set of fuzzy rules and real-time traffic information. Fuzzy logic model was compared with conventional fixed time and actuated control strategies using a typical intersection with varying traffic volume levels. Measures of effectiveness including delay, speed, time in queue, and throughput-to-demand ratio were examined. Fuzzy logic model showed substantial improvements over conventional fixed time and actuated control strategies for all Measure of Effectiveness under heavy traffic volumes. Overall, the simulation results indicated that Fuzzy Logic model has the potential to improve operations at oversaturated intersections.

IX. Recommendations

The essence of Traffic Information System (TIS) in cities that are bedevilled with traffic congestion can no longer be over emphasized. This is because the traditional ways of traffic management such as one way, odd and even numbers, flyovers, construction of new routes, use of Para-mass transit, etc have not been able to eradicate traffic congestions in places like Owerri, Lagos, Port Harcourt, Benin-City etc. To manage traffic therefore, the following recommendations are made:

1. Putting in place a dynamic Traffic Information System (TIS) structure to monitor congestions in the city. Provision of more fuzzy logic traffic lights at congested junction for effective management of traffic.
2. Government should put in place independent and efficient electricity that will Power all the fuzzy logic traffic lights stationed at road junctions rather than rely on the Present epileptic power supply from Enugu Electricity Distribution Company (EEDC).

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