# A Fuzzy Approach for an Intelligent Traffic Light Controller

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*Abstract:* - As the transportation system will continue to grow, new technologies of intelligent traffic control have to be employed to face road traffic congestion problems. This is why the traffic control at intersections gained more interest.

The present paper aims to present a targeted solution for the clearing of the busiest crossroad of Constanta. This study is using fuzzy logic approach for the purpose to design a fuzzy controller for traffic optimization. We present a case study, namely how the green light is controlled by the cars arriving to the crossroad but also by cars which are standing in line at the traffic light. Thus, the membership functions, the fuzzy rules and the simulation software designed for the crossroad load evaluation are represented.

At the end, the performance of the fuzzy logic approach is 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.

*Key-Words: - Fuzzy logic, fuzzy controller, Intelligent Transportation Systems*

## 1 Introduction

The traffic jam in the city of Constanta has become a serious problem. One must note that similar problems exist and have existed in the big metropolitan areas.

Despite the fact that, the city of Constanta-at least from a formal point of view-cannot be included in the conurbations' category, one must say that this type of problem is also present in the relatively smaller cities. Situated on the Black Sea coast, Constanta has a supplementary problem, namely the fact that during summer the flow of tourists, mostly drivers, leads to the overload of the road infrastructure.

Delay reduction at city intersections and travel time savings are a major goal of Intelligent Transportation Systems (ITS). ITS encompass a broad range of applications from basic traffic signal control systems to advanced systems that provide operational benefits to the transportation system: reduce congestion, reduce operating costs, provide alternate routes to travelers, enhance productivity and increase the capacity of infrastructure.

The present paper aims to present a possible solution for one of the most important cross-roads, located at the entrance in the city of Constanta. One has to mention that the solutions proposed by Tien I Liu [7] but very importantly the solutions suggested by Chen and Yang [2], as well as the later evaluations by Wen and Yang [9] represent a starting landmark. Yet one must say that any analysis has to take into account the ideas stated by Kurt Dresner and Peter Stone [4]but also Dresner and Peter Stone [5].

## 2 Problem Formulation

The present paper aims to present a targeted solution for the clearing of the busiest crossroad of Constanta. Figure 1 shows a schema of this crossroad.

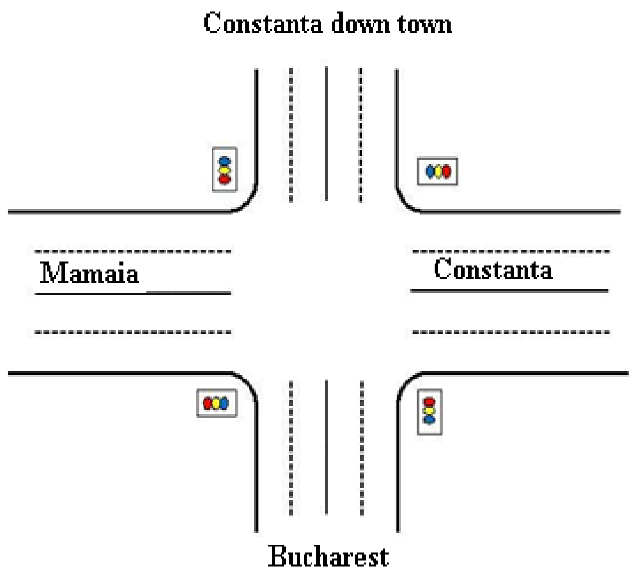


Figure 1: The crossroad of the Northern entrance of Constanta

One must say that:

- During the year the crossroad is overwhelmed on the ways:
    - Constanta Centre - Bucharest (it is the way to Carrefour)
    - Constanta Centre - Constanta City-belt Road (it is the way to the industrial area, Metro, etc.)
- During summer the crossroad is supplementary used on the way Mamaia-Bucharest.

Presently, the traffic lights which exist in the junction work according to an algorithm which doesn't take into account the number of vehicles which arrive at the crossroad on the four lanes. Ineffcient configuration of traffic lights based on a "fixed cycle" protocol can lead to unnecessarily long waiting times for cars and even to traffic jams.

Simplifying, in this case, the present paper presents a possible solution using the fuzzy logic.

Fuzzy logic is an approach that allows the implementation of real-life rules by using computer algorithms. It provides effective tools for dealing with imprecise or noisy data input.

## 3 Problem Solution

In this study, two input fuzzy variables are chosen: the number of vehicles which are standing in line at the traffic lights (nc), and the number of vehicles which arrive within 1 minute at the crossroad (ns).

The output fuzzy variable is the allocated time for the green light.

A possible membership function for the number of vehicles which are standing in line at the traffic lights is represented below.

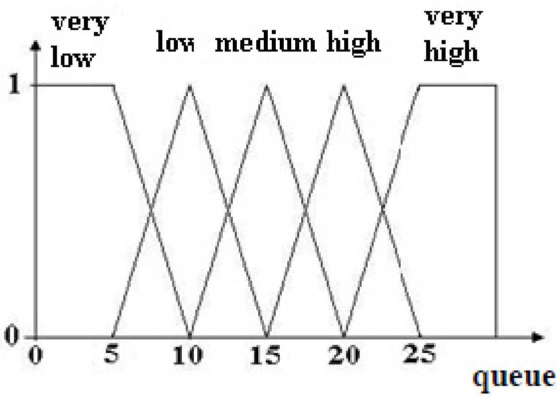


Figure 2: The membership function for the number of vehicles which are standing in line at the traffic lights (nc)

A possible membership function for the number of vehicles which arrive within 1 minute at the crossroad is represented below.

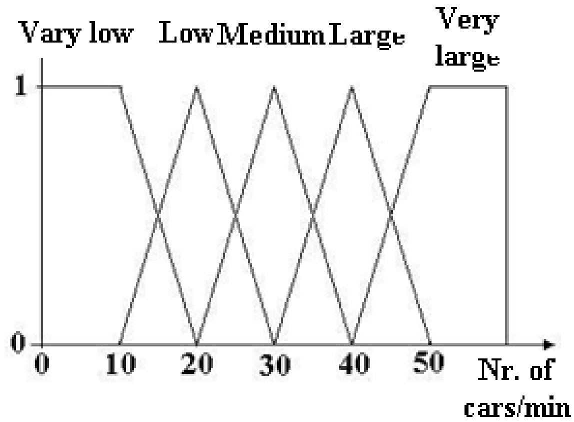


Figure 3: The membership function for the number of vehicles which arrive within 1 minute at the crossroad (ns)

Observations:

- The four traffic lights "work" in four sequences, every light having a variable sequence from 10 to 30 seconds, depending on the "load" (the number of vehicles from the queue but also the number of the ones which arrive every minute at the junction)
- All the four traffic lights will be controlled by the same soft type.

A possible membership function for the allocated time for the green light is:

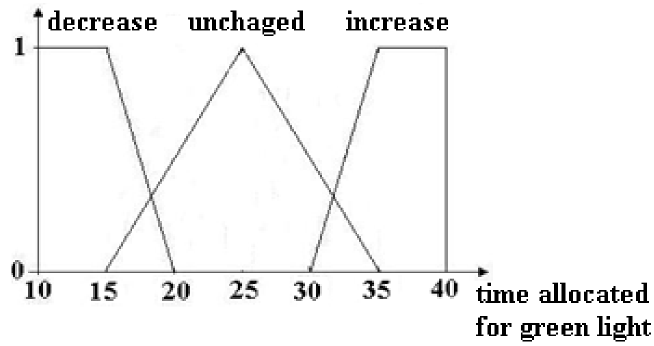


Figure 4: The membership function for the allocated time for the green light.

**The fuzzy rules set**: There are normally many rules for each decision. A part of the 25 fuzzy rules defined is presented below:

- If the number of the vehicles waiting in line is medium and the number of the vehicles which arrive within 1 minute is low then the allocated time for the green light decreases (v1);

- If the number of the vehicles waiting in line is large and the number of the vehicles which arrive within 1 minute is small then the allocated time for the green light doesn't change (v2);
- If the number of the vehicles waiting in line is very large and the number of the vehicles which arrive within 1 minute is medium then the allocated time for the green light increases (v3);
- If the number of the vehicles waiting in line is very small and the number of the vehicles which arrive within 1 minute is medium then the allocated time for the green light decreases (v1).

These decisions can be transformed into the augmented fuzzy relation matrix presented below:

**Queue**

| Arrival | $N_{c1}$ | $N_{c2}$ | $N_{c3}$ | $N_{c4}$ | $N_{c5}$ |
|---|---|---|---|---|---|
| $N_{s1}$ | $V_1$ | $V_1$ | $V_1$ | $V_1$ | $V_2$ |
| $N_{s2}$ | $V_1$ | $V_1$ | $V_1$ | $V_2$ | $V_2$ |
| $N_{s3}$ | $V_1$ | $V_1$ | $V_2$ | $V_2$ | $V_3$ |
| $N_{s4}$ | $V_1$ | $V_2$ | $V_2$ | $V_3$ | $V_3$ |
| $N_{s5}$ | $V_2$ | $V_2$ | $V_3$ | $V_3$ | $V_3$ |

Figure 5: The augmented fuzzy relation matrix for the traffic lights control

## 4 Case study. Digital simulation results

The essential aim of the study has been focused on the testing and validation of the fuzzy approach developed on the basis of the presented methodology.

To achieve this, a simulation software was written in C++ language in the Microsoft Visual Studio Development environment.

As seen in figure 6, the program is divided into the following modules:

- **FunctiiIO.h, FunctiiIO.c** – functions for reading the discrete sets corresponding to the membership functions for nc/ ns/ v.
- **Dreapta.h, Dreapta.c** – functions for calculating equations of the lines from the block diagram of the membership functions for nc/ ns.
- **FunctiiUtil.h, FunctiiUtil.c** – elementary functions for calculating Maximum and Minimum.
- **MultimeDiscreta.h, MultimeDiscreta.c** – functions for transforming the discrete sets corresponding to the membership functions for nc/ns into vectors (IntervalArrayNC, IntervalArrayNS) containing these values.
- **Fuzzy.h, Fuzzy.c** – include the steps of the Fuzzy algorithm:

- read the discrete sets corresponding to the membership functions for nc/ ns/ v
- read the set of Fuzzy rules
-generate the vectors IntervalArrayNC, IntervalArrayNS
- calculate the equations of the lines from the block diagram of the membership functions for nc/ ns.
- apply the set of Fuzzy rules and calculate the membership level for the green light.
- calculate v - the allocated time for the green light (in seconds)

- The global function **main.c:**

- import data from files
- read for k – the number of steps of the algorithm
- for step 1:
    - nc and ns are read from the console
    - calculate v = Fuzzy(nc,ns)
- for the next k-1 steps:
    - nc=(nc+ns)-v
    - ns is read from the console
    - calculate v = Fuzzy(nc,ns)

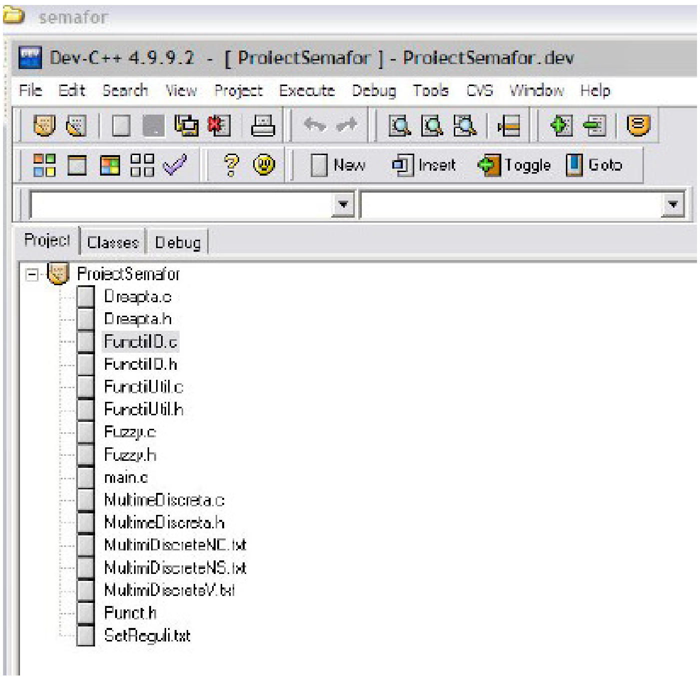


Figure 6: The proposed Fuzzy algorithm

Fuzzification is carried out using the Zadehian min-max AND and OR operations. For the defuzzification process, the Centroid strategy is used: each fuzzy output is multiplied by its corresponding singleton position; the sum of this product is then divided by the sum of all fuzzy output. The result from this calculation is the final single output, which can be used to control the green light.

A simulation experiment was carried out to compare the performance of the fuzzy logic approach with a fixed-cycle time (conventional) control system. In the conventional control system, the traffic lights change at constant cycle times. We assigned the test value v - the allocated time for the green light: **v =15; v= 20; v=25** (in seconds).

To test our model, identical conditions have to be set during the simulation**: nc=60** and **ns=25**.

For each test, the results show the output values of the following variables (Table 1):

- **nc and v** for fuzzy approach
- **nc** for the conventional control system.

Table 1: the results obtained for each test

| Fuzzy approach | case v =25 (fixed-cycle time) | case v =23 (fixed-cycle time) | case v =20 (fixed-cycle time) |
|---|---|---|---|
| Input nc=**60**, Input ns=25, Output v=35 | Input nc=**60**, Input ns=25, v=25 | Input nc=**60**, Input ns=25, v=23 | Input nc=**60**, Input ns=25, v=20 |
| Output nc=**50**, Input ns=25, Output v=35 | Output nc=**60**, Input ns=25, v=25 | Output nc=**62**, Input ns=25, v=23 | Output nc=**65**, Input ns=25, v=20 |
| Output nc=**40**, Input ns=25, Output v=35 | Output nc=**60**, Input ns=25, v=25 | Output nc=**64**, Input ns=25, v=23 | Output nc=**70**, Input ns=25, v=20 |
| Output nc=**30**, Input ns=25, Output v=35 | Output nc=**60**, Input ns=25, v=25 | Output nc=**66**, Input ns=25, v=23 | Output nc=**75**, Input ns=25, v=20 |
| Output nc=**20**, Input ns=25, Output v=25 | Output nc=**60**, Input ns=25, v=25 | Output nc=**68**, Input ns=25, v=23 | Output nc=**80**, Input ns=25, v=20 |
| Output nc=**20**, Input ns=25, Output v=25 | Output nc=**60**, Input ns=25, v=25 | Output nc=**70**, Input ns=25, v=23 | Output nc=**85**, Input ns=25, v=20 |
| Output nc=**20**, Input ns=25, Output v=25 | Output nc=**60**, Input ns=25, v=25 | Output nc=**72**, Input ns=25, v=23 | Output nc=**90**, Input ns=25, v=20 |
| Output nc=**20**, Input ns=25, Output v=25 | Output nc=**60**, Input ns=25, v=25 | Output nc=**74**, Input ns=25, v=23 | Output nc=**95**, Input ns=25, v=20 |
| Output nc=**20**, Input ns=25, Output v=25 | Output nc=**60**, Input ns=25, v=25 | Output nc=**76**, Input ns=25, v=23 | Output nc=**100**, Input ns=25, v=20 |
| Rezulta nc=**20**, Input ns=25, Output v=25 | Output nc=**60**, Input ns=25, v=25 | Output nc=**78**, Input ns=25, v=23 | Output nc=**105**, Input ns=25, v=20 |

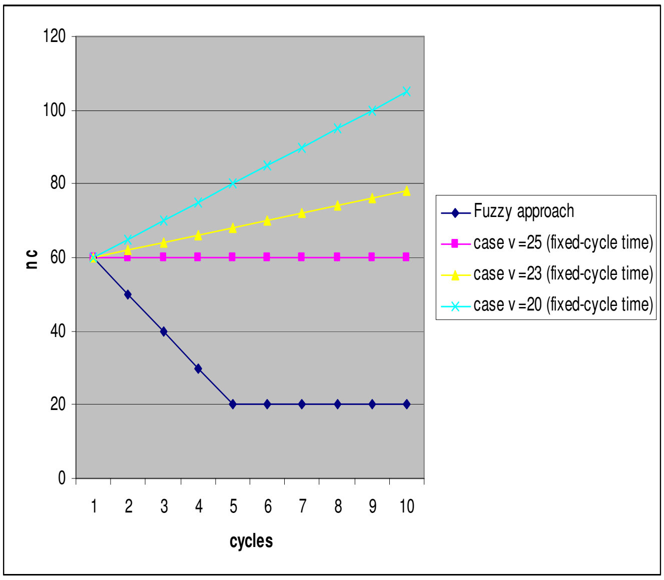


Figure: 7: The comparison of the number of vehicles standing in line at the traffic lights in both models that shows greater performance in the fuzzy model

## 5 Conclusion and future works

Because of 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 one of the states 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 from the results that the 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, time and energy waste.

Our approach can be easily extended for different types of junctions. Furthermore, we are planning to extend the model for coordinated signalized intersections.

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