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# Traffic signal using cellular automata

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**Abstract**
A cellular automata is a discrete model of computation studied in automata theory. Cellular automata are also called cellular spaces. Cellular automata have found application in various areas, including physics, theoretical biology and microstructure modelling. It consists of a regular grid of cells, each in one of a finite number of states, such as on and off (in contrast to a coupled map lattice). The grid can be in any finite number of dimensions. An initial state (time t = 0) is selected by assigning a state for each cell. In this research paper, optimization of traffic signal timing at signalized intersections on road network is presented. The large number of vehicles in big cities has become a serious problem in adjusting the timing of traffic signal at intersections of road networks. Traffic light control is an important factor in road traffic system. One of the solution to reduce heavy traffic congestion is by readjusting traffic signal with the number of incoming and outgoing vehicles in or der to remain proportionate. The solution refers to adaptive setting of traffic light control system. The movement of vehicles on road network is modeled by cellular automata while the fuzzy inference system is used to obtain optimal traffic signal timing. The performance of fuzzy inference system is determined by the delay time average at signalized intersections. Delay time is addition time required by a vehicle to pass through signalized intersection compared to road without intersection. Cellular automata and fuzzy inference system are running together through computer simulation program. The numerical results show that traffic signal duration obtained from fuzzy inference system is more efficient than the existing historical data of observation and it can reduce the level of congestion. The simulation results also show that the traffic signal timing can adjust with the number of incoming and outgoing of vehicles at the intersections on road network. These results can be used to improve the traffic signal system.

**Keywords:** Cellular automata, non deterministic finite state machine, fuzzy inference system

## Introduction
In big cities with huge population, the amount of vehicles are increasing each day. In distinction, there's no improvement of traffic infrastructures like light at associate degree intersection. The hold up is obtaining worse the answer for this is to readjust light with the number of incoming and outgoing vehicles so as to stay proportionate. The answer refers to adaptive setting of light system. Fuzzy reasoning system may be a methodology that may be used to assign associated degree adaptative setting of light system. Through the adaptative management scheme, temporal order of the light will be a lot of applicable with the amount of vehicles on every road. There are many ways in light management, like genetic algorithmic program, fuzzy inference system, queue theory, and PSO algorithmic program.
Fuzzy reasoning system solely shows the inexperienced light-weight temporal order while not mensuration its performance. Therefore, besides fuzzy reasoning system, it needs another methodology to live the performance. Cellular automata will be accustomed estimate fuzzy reasoning system performance.
A fuzzy inference system is the key unit of a fuzzy logic system. The typical structure of a fuzzy inference system consists of various functional blocks. It uses new methods to solve everyday problems.
A fuzzy inference system may be a computer paradigm supported by fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. A nonlinear mapping that derives its output from fuzzy reasoning and a group of fuzzy if-then rules. The mapping domain and range can be multidimensional spaced fuzzy sets or points.
A fuzzy inference system is a system that uses a fuzzy set theory to map inputs to outputs.

## Problem Definition
We try to find the optimal cycle of traffic lights during a fixed period. This cycle is repeated indefinitely. The restrictions are the following:

1. There can only be a green traffic light by intersection every cycle step.
2. Too short traffic light transitions are forbidden. Every cycle step comprises a constant number of simulation iterations — 'Traffic light granularity'.
3. In our work we only consider two traffic light states namely green and red.
4. The input data for our optimization is set off-line, and is based on statistical information.

**Non Deterministic Finite State Automata**

NFA stands for non-deterministic finite automata. It is easy to construct an NFA than DFA for a given regular language. The finite automata are called NFA when there exist many paths for specific input from the current state to the next state. Every NFA is not DFA, but each NFA can be translated into DFA. NFA is defined in the same way as DFA but with the following two exceptions, it contains multiple next states, and it contains ε transition.

An NDFA can be represented by a 5-tuple $(Q, \sum, \delta, q_0, F)$ where −

- Q is a finite set of states.
- $\sum$ is a finite set of symbols called the alphabets.
- $\delta$ is the transition function where $\delta: Q \times \sum \rightarrow 2^Q$

(Here the power set of Q ($2^Q$) has been taken because in case of NDFA, from a state, transition can occur to any combination of Q states)

- $q_0$ is the initial state from where any input is processed ($q_0 \in Q$).
- F is a set of final state/states of Q ($F \subseteq Q$).

**Finite State Automata**

Finite-state machine (FSM) is a mathematical model of computation. It is an associate abstract machine that may be in just one among a finite variety of states at any given time. The FSM will amendment from one state to a different in response to some inputs, the amendment from one state to a different is termed as transition associate FSM and is outlined by listing of its states, its initial state, and therefore the inputs that trigger every transition. Finite-state machines square measure of 2 types—deterministic finite-state machines and non-deterministic finite-state machines. A settled finite-state machine may be created akin to any non-deterministic one.

The behaviour of state machines may be discovered in several devices in fashionable society that perform a preset sequence of actions counting on a sequence of events with that they're conferred to like easy examples square measure vendition machines that dispense product once the right combination of coins is deposited, elevators, whose sequence of stops is set by the floors requested by riders, traffic lights, that amendment sequence once cars square measure waiting, and combination locks, that need the input of a sequence of numbers within the correct order.

The finite-state machine has less procedure power than another models of computation like the electronic computer. The procedure power distinction means that there square measure procedure tasks that a electronic computer will do however associate FSM cannot and this can be a result of associate FSM's memory is restricted by the amount of states it's. A finite-state machine has identical procedure power as a electronic computer that's restricted such its head might solely perform "read" operations, and continually has got to move from left to right. FSMs square measure studied within the additional general field of automata theory.

**Methodology**

Cellular automata methodology will model the movement of vehicles. By victimization cellular automata, all vehicle delays at a signalized intersection are hold on as information. Then, the data is analysed so the performance of any given light length will be calculated. By combining cellular automata and fuzzy reasoning system into simulation program, the best light temporal order will be obtained, fastened time or static light temporal order that is obtained from historical knowledge of observation will be used as a comparison for fuzzy reasoning system performance. This study focuses on improvement of light temporal order on road networks victimization cellular automata and fuzzy reasoning system.

Traffic jams are a big problem in most major cities throughout the world. Several researchers have attempted to reproduce real-world traffic flow as accurately as possible and to predict possible traffic jam conditions based on simulations.

One approach is to use a cellular automaton (CA) for modeling traffic flow. In order to develop a traffic light simulator one needs to use different techniques for optimization. Algorithms are required for the chromosome encoding. This is accomplished by creating a string of complete solution. In our implementation, we have created a separate class that controls the values of signals.

The performance of the fuzzy logic controller is evaluated by comparing it with the fixed-time controller. It done by using the Controller facility. Two simulation tests are carried out. One is the fixed flowrate and the other is the varied flowrate. The varied flowrate allows slightly complex traffic situation which reflects real-life. In order to see the effectiveness of the controllers, we set higher traffic density for one of the lanes. The flow densities for the lanes are varied differently every minute using the Flowrate facility to reflect real-life traffic condition.

**Implication of Research**

Automata theory is the study of abstract machines. It is related to formal language theory. In this context, automata are used as finite representations of formal languages that may be infinite. Automata are often classified by the class of formal languages they can recognize, as in the Chomsky hierarchy which describes a nesting relationship between major classes of automata. Automata play a major role in theory of computation, compiler construction and artificial intelligence. The ultimate goal is to form a traffic signal using fuzzy inference system.

**Scope of this Work**

This research paper offers extensive study for automata and how can it be used in day to day life.

It consists of details about cellular automata and how traffic can be organised using this concept. It also consists details about fuzzy inference system. This research paper is written after in depth study of many other research papers which provide details on similar topics. This research paper can also help other aspiring researchers understand this topic well.

**Result**

Utput of fuzzy inference system and fixed time scheme is

then analyzed to measure the performance. The output of simulation is delay time average and traffic light timing on road network with six signalized intersections. Delay time is addition time required by a vehicle to pass through signalized intersection compared to road without intersection. Delay time average obtained from simulation for six intersections is summarized in Table 3. It can be observed from the table that the delay time average resulted by the fuzzy inference system is faster than the fixed time scheme except for Terusan Buah Batu Street – Buah Batu Exit Toll Gate intersection. It can be revealed that fixed time (historical data) has inappropriate green light duration which yields longer delay time average.

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In the last, in [12-21] readers, students, researchers can be found interesting works on emerging topics like Industry 4.0, Society 5.0, etc., and their importance for the smart era.

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However, in fact, the FIS has a mechanism that can produce more appropriate green light duration than fixed time scheme.

Fuzzy inference system is used to determine optimal timing of the traffic light on signalized intersections. Through fuzzy set, it can be represented and addressed various uncertainty parameter. In this case, it can be doubt, inaccuracy, uncomplete information, and partly truth. Fuzzy inference system consists of fuzzyfication, inference, and defuzzyfication [4]. In this study, the process of fuzzyfication, inference, and defuzzyfication use a combined of fuzzyfication trapezoidal-triangular function, Sugeno inference, and weight average defuzzyfication method [11].

Further, Sugeno inference method is used since it has fast computational process. Thus, it appropriates to apply in control system [4]. The combined functions of trapezoid-triangles are used, since based on observations, and also consideration of the utilization of these functions in [12-13], it appears that these two functions have more variation output value so that making it possible to minimize the delay time of vehicles at intersections.

**Conclusion**

The slow-to-stop rule is predicated on the actual fact that once drivers see a holdup or congestion ahead, they begin decelerating to avoid collision. Note that these models are designed for single-lane traffic usage of one-dimensional CAs. This study focuses on improvement of light temporal order on road networks victimization cellular automata and fuzzy reasoning system. The results of this study are delay time average and best inexperienced light-weight temporal order for every signalized intersection. This paper is organized as follows. Vehicles movement model on road network victimization cellular automata is in short bestowed. Output of fuzzy reasoning system and glued time theme is then analyzed to live the performance. The output of simulation is delay time average and light temporal order on road network with six signalized intersections. Delay time is addition time needed by a vehicle to undergo signalized intersection compared to road while not intersection. Optimization of traffic signal timing has been successfully conducted via numerical simulation. Cellular automata were used to model vehicles movement on the signalized intersections and fuzzy inference system was used to optimize the duration of traffic light for each signalized intersection. The numerical results show that fuzzy inference system method is more efficient than the existing historical data of observation and it can reduce the level of congestion. Further, it has been shown that fuzzy inference system can generate delay time average faster than the fixed time scheme and the traffic signal timing can adjust with the number of incoming and outgoing of vehicles at the intersections. The future works of this research are implementation to the real time, parallelization of the algorithm, and vehicles movement can be adjusted based to the driver behaviour. Traffic signal timing using FIS scheme has made an adaptive regulatory system. In this study, an adaptive traffic system is defined as the decision of traffic signal timing depends on the number of vehicles that was predicted from the simulation not from real traffic situation. In general, the duration of the green light resulted from FIS scheme is lower than the duration of the green light resulted from fixed time scheme. If the duration of green light is lower, then the duration of the red light becomes faster. If the adjustment of green light duration is appropriate with the state of the queue of vehicles, then the delay time can be reduced so that the level of traffic congestion can be reduced. The results can be suggested to the local government to improve the traffic signal system.

Optimization of traffic light timing has been with success conducted via numerical simulation. Cellular automata were used to model vehicles movement on the signalized intersections and fuzzy abstract thought system was wont to optimize the length of stoplight for every signalized intersection. The numerical results show that fuzzy abstract thought system technique is additional economical than the prevailing historical information of observation and it will cut back the amount of congestion.

Fuzzy inference is a method that interprets the values in the input vector and, based on some sets of rules, assigns values to the output vector. In fuzzy logic, the truth of any statement becomes a matter of a degree.

Fuzzy inference 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 membership functions, fuzzy logic operators, and if-then rules.

Further, it's been shown that fuzzy abstract thought system will generate delay time average quicker than the fastened time theme and therefore the traffic light arrangement will modify with the quantity of incoming and outgoing of vehicles at the intersections. Traffic signal temporal arrangement exploitation FIS theme has created associate reconciling of regulative system. During this study, associate reconciling traffic system is outlined because the call of traffic light arrangement depends on the quantity of vehicles that was foreseen from the simulation not from real traffic scenario. In general, the length of the inexperienced lightweight resulted from FIS theme is not up to the length of the inexperienced lightweight resulted from fastened time theme. If the length of inexperienced lightweight is lower, then the length of the red lightweight becomes quicker. If the adjustment of inexperienced lightweight length is suitable with the state of the queue of vehicles, then the delay time is reduced in order that the amount of tie up is reduced. The results is advised to the regime to boost the traffic light system.

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