

every time step, each cell's state is updated according to the states of its neighbors, with respect to the transition rules. For simple CA models, there are usually only two states. A set of cells is a generation, and as the transition rules are applied to one generation, the next generation is formed.

For the proposed ITLCS, CA is used to simulate the progression of traffic flow – the car's movement through the grid. The movement of the vehicles in the simulated environment is governed by certain rules discussed further in the next section.

. System Mathematical Modeling

The proposed smart traffic light system mathematical modeling is presented in this section. The system is majorly defined by three factors: vehicle velocity, vehicle position, and the cost function, each of which is expressed as an ordered pair. The velocity of vehicles approaching the intersection is defined as

$$V_i(t) = [v_i^-(t), v_i^+(t)]$$

where

$v_i^-(t)$ is the lower-end point and $v_i^+(t)$ is the upper-end point.

The lower and upper end points are updated according to:

$$\begin{aligned} v_i^-(t) &= \min\{v_i^-(t-1) + 1, g_i^-(t), v_{max}^-\} \\ v_i^+(t) &= \max\{v_i^+(t-1) + 1, g_i^-(t), v_{max}^+\} \end{aligned}$$

where

$v_i^{-/+}(t-1)$ is the lower-end/upper-end position of vehicle i at time step t-1

$g_i^-(t)$ is the number of empty cells in front of vehicle i at time step t

$v_{max}^{-/+}$ is the lower-end/upper-end maximum velocity

The position of the vehicles,

$X_i(t) = [x_i^-(t), x_i^+(t)]$ are updated with respect to the vehicle velocity:

$$\begin{aligned} x_i^-(t+1) &= x_i^-(t) + v_i^-(t) \\ x_i^+(t+1) &= x_i^+(t) + v_i^+(t) \end{aligned}$$

where

$x_i^{-/+}(t+1)$ is the predicted lower-end/upper-end position of vehicle i at time step t+1
 $x_i^{-/+}(t)$ is the current lower-end/upper-end position of vehicle i at time step t

A cost function is used to determine the cost of possible control actions, and from this, the control action with the lowest cost is selected and executed. The cost is defined in terms of time delay intervals

$C(\alpha) = [c^-(\alpha), c^+(\alpha)]$ and it is obtained by:

$$\begin{aligned} c^-(\alpha) &= \min\left\{\sum_i \sum_i w_i^-(t), \sum_i \sum_i w_i^+(t)\right\}, \\ c^+(\alpha) &= \max\left\{\sum_i \sum_i w_i^-(t), \sum_i \sum_i w_i^+(t)\right\}, \end{aligned}$$

where

$$w_i^-(t) = \begin{cases} 1, & v_i^-(t) = 0, \\ 0, & \text{else.} \end{cases}$$

$$w_i^+(t) = \begin{cases} 1, & v_i^+(t) = 0, \\ 0, & \text{else.} \end{cases}$$

SYSTEM IMPLEMENTATION

The proposed smart traffic light system is implemented in software using MATLAB programming language.

System efficiency is measured and compared against that of the existing system. System efficiency was measured in terms of the average flow of cars with respect to the level of traffic density.

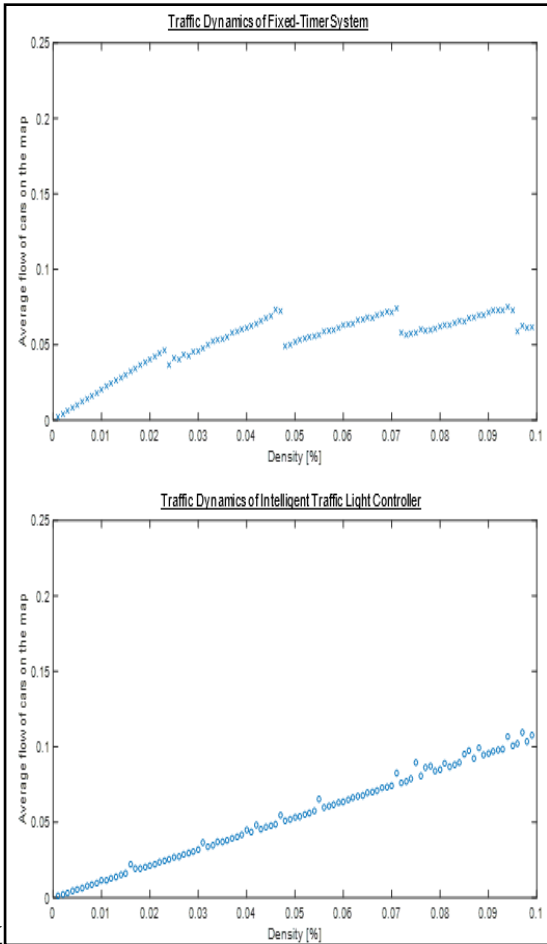


Fig. 2. Computer simulation results in low traffic density.

The traffic grid is a cross intersection with a torus geometry. Both systems were simulated on the same grid, and two sets of results were taken – low density and high density. The density range is from 0% to 10%, with intervals of 0.01%.

As shown below in Figure 2 above, the fixed-timer system showed peaking average flow at three different densities of about 4.5%, 7%, and 9.5%. The proposed ITLCS showed much better results with a robust linear progression, with a steady increase of average flow as densities increased. Simulation results for densities ranging from 0% to 100% at intervals of 0.1%.

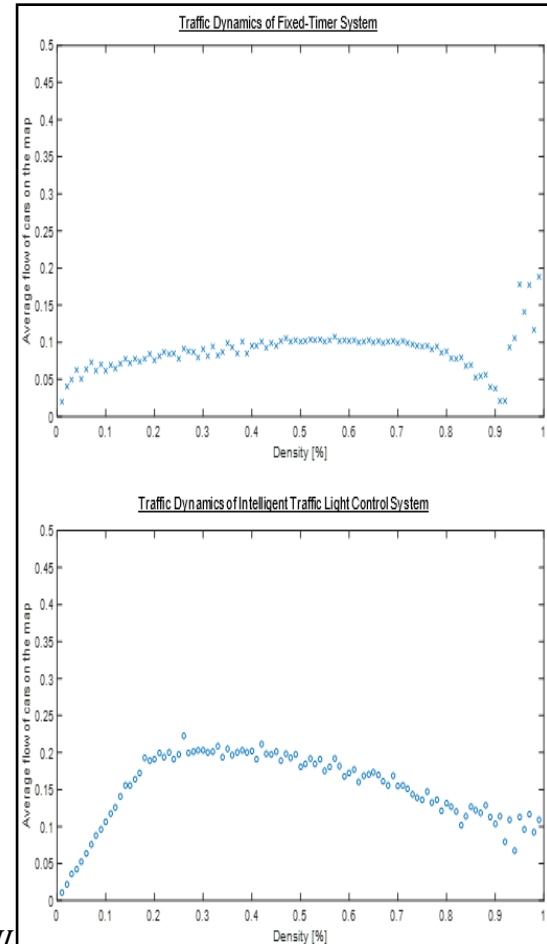


Fig. 3. Computer simulation results in high traffic density.

As shown in figure 3 shown above, the fixed-time system results indicated a constant average flow for densities of approximately 45% to 70% with high outlying values towards a density of 100%. However, after the density reaches roughly 75%, the efficiency drastically declines until 90%.

The proposed ITLCS demonstrated a short constant average flow for densities of about 20% to 50%. While the efficiency seems to drop toward a 100% density, it still performs much better than the existing system.

Computer simulation results show a clear indication of the efficiency of the proposed ITLCS over the existing fixed-time system. For low densities (0-10%), the fixed-time system demonstrated acceptable efficiencies for most low

densities. However, there are unexpected and sudden 'drops' at specific densities. As seen in Figure 2, as the average flow steadily increases, it reaches a sudden drop, which is immediately beginning to steadily increase again. It can be assumed that the sudden drops are due to the probable lull in traffic. As the traffic density is low and the system is expected to manage traffic efficiently. As expected, the proposed ITLCS performs much more efficiently than the existing system.

For higher densities of traffic, the proposed ITLCS still demonstrates a more than acceptable efficiency. However, the existing system unexpectedly can cope with densities of up to 80%. However, the proposed ITLCS has again proven to manage traffic at high densities without losing too much efficiency.

CONCLUSION

This paper discusses the design, implementation of an intelligent traffic light system based on input data gathered from sensors. Computer simulation and actual prototype were used to validate the proposed system design and to show its effectiveness.

The introduction of new algorithms has enhanced the decision-making strategies of the control agents of the intelligent traffic light control system. The data related to vehicle detection such as position and velocity parameter which is also a major system variables were obtained. These variables/parameters then were utilized to derive the cost function with predicted delays and evaluation, which then executes the optimal control decisions for the state of each traffic lights at a particular junction.

In proportion to the proposed approach, an existing road network i.e. T-junction network consisting of six lanes approaching the intersection was modelled while also considering the pedestrian crossing. The simulation result exhibits that the intelligent traffic light control system has many capabilities to clear the traffic flow during high traffic densities and low traffic densities. Since the ITLC system's simulation

deals efficiently with distributed densities, note that density is not only the parameter that the intelligence only considers. The system's intelligence was the mathematical technique known as cellular automata, which was employed to work with data on interval microscopic level to procure an optimal control decision. Also, note that more transition states ITLCS enables the system not to follow the sequence like the fixed timer system, which allows the system to work well with non-uniform traffics.

Obtained results show that the proposed system is promising and effective in controlling road traffic flow and easing traffic congestion. We plan to further extend this work by applying other techniques and adding intelligence to the system controller to optimize performance better.

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