Simulation of traffic management systems using Arduino boards

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Abstract – Any adaptive traffic control system applied for an entire network must be flexible, in order to adjust the signalling times for each junction according with real traffic data, according to a macroscopic vision. Also, it must be network synchronized, in order for each signalling time modification to be correlated with the other junctions in the network. The system must also be able to properly respond to special traffic events, meaning that all the vehicles “neglected” at some point must be considered with priority at a later moment, in order to avoid long queue formation, even on secondary roads. A model for traffic management system evaluation is useful both for didactic purpose and for existent systems’ evaluation, by monitoring their responses to different scenarios and determining their efficiency. Obviously, for the big cities (and not only) congested traffic, may occur many situations that cannot be anticipated at system installation time. Therefore, the main purpose for a traffic management system evaluation model may be to determine the system’s responses in special situations which, however small their probability is, can negatively affect the traffic on a large area of the network and hence the implemented system cannot counter-balance the perturbation incurred in a short time manner.

Keywords: traffic management system evaluation, traffic signal modelling, congestion avoidance, traffic priority management

I. INTRODUCTION

Traffic density is variable according to some parameters, such as: time of day, day of the week, season, weather conditions, special events (like sport or artistic events) or construction works. Even considering all the foreseeable factors, there is some unpredictability of the traffic generated by traffic accidents or events that involve special vehicles (ambulance, police, and firefighters). [1]

All these parameters must be taken into consideration, otherwise the traffic control system may produce traffic jams and delays. An automated traffic adjustment system, composed of a traffic signals network, which can solve such problems by continuous monitoring and control of traffic situations and by adjusting the signalling times for the traffic signals is called an adaptive traffic control system.

An adaptive traffic control system applied for an entire network must be flexible, in order to adjust the signalling times for each junction according with real traffic data, according to a macroscopic vision. Also, it must be network synchronized, so that each signalling time modification must be correlated with other junctions in the network. This option is not available in the “variable horizon” mode, in which each junction is totally independent. [2]

For any adaptive traffic control system, it is essential that the traffic parameters automatic measurements are reliable and accurate. Traffic detection may be obtained through a variety of techniques, including embedded inductive loops, microwave infrared detection, video detection.

The main objective of the software responsible for administrating a complex traffic management system is the adaptive coordination of traffic signals, with possible inclusion of additional modules dedicated to driver information and interaction with public transport.

The main benefits of an adaptive traffic management system, especially when it is integrated with other systems, such as public transport management, driver/traveller information, incident management, emergency management, are [3]:

- Traffic jams reduction, by real time coordination and traffic signal synchronization, in order to obtain optimum traffic flows.
- Priority for public transport vehicles at junction crossing.
- Priority for emergency vehicle at junction crossing.
- Traffic flow video monitoring and incident detection.
• Traffic operative state visualization and system functionality control through a digitized road network.
• Data provision for planning, information and sub-system control.
• Real time information for drivers.
• Real time information for travellers, in public transport station and vehicles.
• Traffic information and route guidance through variable message signs.
• Environmental parameters monitoring, in order to actuate the pollution levels and to correlate with variable message signs information for traffic redirecting.
• Maintenance works for equipment and infrastructure
• Actuation of traffic data for simulation and modelling.
• Strategic recommendations for sub-systems operating and control.
• Communication with other interconnected systems.
• Parking monitoring and parking guidance.

II. DATA ACQUISITION SYSTEM ARCHITECTURE AND COMPONENTS DATABASE

As mentioned before, in this article we propose a laboratory model that is useful for evaluate existent systems’ functioning, by monitoring their responses to different scenarios and determining their efficiency the real field condition. The model allows configuring and testing both the hardware and software solutions that will be implemented.

The model has also a didactic purpose, offering the opportunity for the students to understand and to test their capacity to modify the software, in order to simulate various situation and traffic light diagram. Being connected to a hardware platform, the model offers the possibility to visualise the effects of the simulation and assure a better understanding of the system functioning in real world.

The main objective is to avoid conflicting and potentially dangerous commands, such as antagonist green or red light malfunctioning. The second objective is to test if the system is capable to generate proper responses in different special situations, like priority requirements (to be able to recover from this special case and properly manage the vehicles that get additional red time during this phase), but also successive priority requirements, which may not occur very often in real life, but, if it does, may seriously disturb the traffic in that junction or even in the whole surrounding area.

Testing the microcontrollers between the field employments of the hardware is a mandatory job, and the laboratory model proposed can be used for assuring the correct programming and also for testing improvements of the software and of the junction control strategy.

Below it is described the control module for a signal group, using an Arduino testing board. The controlled signal group is simulated through a testing board, following the general architecture of the system.

The Arduino board will be connected to the computer, in order to upload the control software for the simulated signal group. Also, on the Arduino board it will be created a database structure in which it will be registered a series of data for a signalized junction.

The computers corresponding to different junctions will be interconnected, in order to facilitate the network control and to ensure a correlated signalization for all the network’s junctions.

For the system described in Figure 1, two databases will be created, in order to upload the necessary commands for the traffic signals included in the junction allocated signalling group. The two databases will be correlated and synchronized, in order to permit an independent performance and also a correlated or integrated performance.

At the Arduino testing board level, two database structures will be implemented: one containing a log file in which data related to the signal group command will be registered and the other containing different signalling programs and a program dedicated to correlate the signalization for more junctions within the network. The writing process for the log file and for writing/reading the database at the Arduino testing board level is described below.

![Figure 1. Data acquisition system structure and system interconnection](image-url)
The system will have three functioning modes:

- **Independent functioning mode** – the Arduino testing board is functioning independent of the traffic signal command module. The data regarding the signalling times, signalling phase order and signalling cycle modification according to external condition will be extracted from a database structure that could be found at the developing board level and which have been uploaded in the same time with the main command software.

- **Local functioning mode** – The Arduino testing board will be connected to the computer. The dedicated computer software will command the traffic light from the
model, through the developing board. At computer level it will be built a database structure where it will be registered the main characteristics of the controlled junctions and the corresponding signalling diagrams. When the Arduino board will start functioning in computer controlled mode, the database will be synchronized in real time with the Arduino board level database. In this functioning mode, more junctions will be connected with the same computer and will access the data stored in the database. The database interrogation will extract the necessary data for each junction – figure 5.

Figure 6. Correlated functioning mode – Data base correlation

The data regarding the signalling phases and times for each junction in the network will be available in a database loaded in a computer (server). On interrogation, each computer connected in the network will extract only the data corresponding to its affiliated junctions. The relative data will be transferred at each computer level. Following the transfer at the local computer level, the data will be stored in the computer’s database. In order to transfer the data at the Arduino developing boards’ level, the interrogation will be made at the computer database level, and the relative data will be transferred to the Arduino board database – figure 6.

III. PRESENTATION OF THE TRAFFIC MANAGEMENT SYSTEM SIMULATION MODEL

We will use the model for a junction equipped with six vehicle traffic signals and four pairs of pedestrian traffic signals.

Figure 7. Junction laboratory model

The traffic lights LEDs are controlled through the octal memories 74 ACT573, 4 pieces. These memories receive data in octets, parallel bus, the byte being loaded in the memory that receive the command (latch enable). Each memory controls the traffic lights LEDs corresponding to its board corner. As an exception, the pedestrian traffic lights LEDs are controlled in pairs. The pedestrian traffic lights are controlled by the
memory integrated circuit which is placed, physically, orthogonal to the relative pedestrian traffic light. The “0” memory control the top pedestrian traffic light, the “1” memory control the right pedestrian traffic light, the “2” memory control the bottom pedestrian traffic light and the “3” memory control the left pedestrian traffic light.

The integrated circuit 74ACT573 is an octal memory with D flip-flop circuit, having the possibility of parallel asynchronous writing and three state outputs, controlled by the OE (output enable) signal, active in 0, which was wired for this configuration.

Figure 8. 74ACT573 pin connection [7]

Figure 9. 74ACT573 logic diagram [7]

The main characteristics of 74ACT573 are [7]:
- High speed: $t_{pd} = 5\text{ns}$ (typical) at $V_{CC} = 5\text{V}$
- Low power dissipation: $I_{CC} = 4\mu\text{A}$ at $T_A=25^\circ\text{C}$
- Compatible with TTL outputs: $V_{IH} = 2\text{V}$ (min.), $V_{IL} = 0.8\text{V}$ (max.)
- $50\Omega$ transmission line driving capability
- Symmetrical output impedance: $|I_{OH}| = I_{OL} = 24\text{mA}$ (min.)
- Balanced propagation delays: $t_{PLH} = t_{PHL}$
- Operating voltage range: $V_{CC}(\text{OPR}) = 4.5\text{V}$ to $5.5\text{V}$
- Improved latch-up immunity.

The model is connected to the Arduino board through two ribbons, as follows:

**TABLE I. FUNCTIONING TABLE FOR THE 74ACT573 INTEGRATED CIRCUIT**

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>OE</td>
<td>LE</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>

X: Doesn’t matter
Z: High Impedance
NOTE: Outputs are latched at the time when the input is taken LOW logic level.

**TABLE II. RED RIBBON: DATA BYTE CORRESPONDENCE**

<table>
<thead>
<tr>
<th>Conductor No.</th>
<th>Correspondence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (red)</td>
<td>D0: Pedestrian GREEN</td>
</tr>
<tr>
<td>1</td>
<td>D1: Pedestrian RED</td>
</tr>
<tr>
<td>2</td>
<td>D2: Vehicle GREEN - Left (missing for 1 and 3 corners)</td>
</tr>
<tr>
<td>3</td>
<td>D3: Vehicle GREEN - Right</td>
</tr>
<tr>
<td>4</td>
<td>D4: Vehicle YELLOW - Left (missing for 1 and 3 corners)</td>
</tr>
<tr>
<td>5</td>
<td>D5: Vehicle YELLOW - Right</td>
</tr>
<tr>
<td>6</td>
<td>D6: Vehicle RED - Left (missing for 1 and 3 corners)</td>
</tr>
<tr>
<td>7</td>
<td>D7: Vehicle RED - Right</td>
</tr>
</tbody>
</table>

Note: Left and Right correspond to the vehicle movement direction

**TABLE III. BLUE RIBBON: POWER AND MEMORY CONTROL**

<table>
<thead>
<tr>
<th>Conductor No.</th>
<th>Correspondence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (blue)</td>
<td>+5Vcc.</td>
</tr>
<tr>
<td>1</td>
<td>GND (ground)</td>
</tr>
<tr>
<td>2</td>
<td>LE0</td>
</tr>
<tr>
<td>3</td>
<td>LE1</td>
</tr>
<tr>
<td>4</td>
<td>LE2</td>
</tr>
<tr>
<td>5</td>
<td>LE3</td>
</tr>
</tbody>
</table>
Simulation modes

The model allows simulation for traffic management system functions, as detailed, the main facilities being as follows:

1. Planning the signalling system in static mode, that means no response to sudden increase or decrease of traffic flows.
2. Planning the signalling system according to the traffic vehicle flows obtained at a specific moment (adaptive traffic management system).
3. Handling the priority request: the system allows creating a response for emergency situations, by an adequate change of the signalling plans. It is possible to shorten or to extend some phases and also to skip a phase. The system is programmed to recover after the emergency, in order to permit the passing of the vehicles which were stopped during the emergency, and also to react in case of multiple emergencies, simultaneous or consecutive.

IV. CONCLUSIONS

A model for traffic management system evaluation is useful both for didactic purpose and for existent system evaluation, by monitoring their responses to different scenarios and determining their efficiency. Obviously, for the big cities (and not only) congested traffic, may occur many situations that cannot be anticipated at system installation time. Therefore, the main purpose for a traffic management system evaluation model may be to determine the system’s responses in special situations which, however small their probability is, can negatively affect the traffic on a large area of the network and hence the implemented system cannot counter-balance the perturbation incurred in a short time manner.

Real traffic management systems occupy a lot of space and are expensive, meaning that buying several items and putting them in a research room is difficult. Replacing those systems by small and versatile boards (that also have affordable price), like Arduino, completed with simple and cheap interface modules, is a better choice to test different scenarios and functioning modes, for didactic and research purposes, relevant results being able to achieve. Different software programmed in Arduino boards, network connected, produce valuable data about their operation, which can be compared in order to choose and optimize Arduino software.

Regarding the didactic advantages, it can be mentioned the fact that the proposed laboratory model offers the opportunity for the students to understand and to test their capacity to modify the software. Also, being connected to a hardware platform, the model ensures the possibility to visualise the effects of the simulation and a better understanding of the adaptive management traffic system functioning. Using real boards instead a PC simulation permits data transmission reliability analysis. For students, using real boards and physical connections is more instructive.

REFERENCES