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Implementation and simulation of an intelligent intersection light controller based on multi-agent system

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Appreciation

First,

We would like to thank the good "Allah", the merciful who gave us courage, strength and patience to complete our work.

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At the same time, we would like to thank all those who have agreed to judge our work.

That every person who has at any rate in the preparation of this study finds here the expression of our deepest sympathy.

Abdou

Mrizak

Dedication

I dedicate this modest work to

My dear parents who watch over me to see me succeed, and who have never stopped from supporting me, to advise me ... they have all given me.

To my grandmother who has been praying for me throughout my school career that "ALLAH" protects her.

To my dear sister and brothers: Ali, Djamel, Amine, Wissal, Ikram,Younes.

To my partner and my friend OUDJOUADJ Abderahmane

To my dearest friends: Riadh, Jilali, Hamza, Redha, Izou

To all university colleagues 2016/2017

MRIZAK

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To my dear sister and brothers: Imene, Khoudir, Amine, mouadh.

To My Partner and Friend AGGOUN Abderrazek

To my dearest friends: Ghanou, moumen, Ahmed, redouane

To all university colleagues 2016/2017

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List of acronyms

GPS: Global Position System.
DSRC: Data Short Rang Communication.
MAS: Multi-Agent System.
ABM: Agent Based Model.
USB: Universal Serial Bus.
IDII: Interaction Design Institute.
PCB: Printed Circuit Board.
LCD: Liquid Crystal Display.
IDE: Integrated Developer Environment.
DT: Data time.
MV: Maximal Vehicles.
TIA: Time Interval Algorithm.

ملخص

الغرض من هذا العمل هو تصميم نظام التحكم في إشارة المرور لتقاطع الطرق باستخدام نظام متعدد الوكلاء. اقترح نموذج اين الهدف الرئيسي من نظام الذكي هوالتقليل متوسط وقت انتظار المركبات في التقاطع الطرق. للتحقق من صحة النهج المقترح. تتم مقارنة النظام المقترح ضد نظام التحكم التقليدية. وقد أظهرت نتائج الاختبارات والمحاكاة فعالية النظام المقترح

كلمات مفتاحية : إشارات المرور, مفترق طرق,نظام المتعدد العملاء , نظام ذكي , وقت انتظار السيارات.

Abstract

The aim of this work is the design of a signaling control system of an intersection using a multi-agent system. A model has been proposed where the main objective of the intelligent system is minimizing the average waiting time of vehicles at the intersection. To validate the proposed approach. The proposed system is compared with a conventional control system. The results of tests and simulations showed the effectiveness of the proposed system.

Keywords: Intersection, Multi-Agent system, system intelligent, Traffic lights, Waiting time of the car.

Résumé

Le but de ce travail est la conception d'un système de contrôle des feux de signalisation d'une intersection en utilisant un système multi-agents. Un modèle a été proposé où l'objectif principal du système intelligent est la minimisation du temps d'attente moyen des véhicules au niveau de l'intersection. Pour la validation de l'approche proposée. Le système proposé est comparé par rapport à un système classique de contrôle. Les résultats de tests et simulations ont montré l'efficacité du système proposé.

Mots clé : feux de circulation, Intersection, Système Multi-Agent, Système intelligent, Temps d'attente des véhicules

General introduction

In recent times, the transport industry is facing challenges in regard to time spent waiting on the roads as opposed to movement. This could be attributable to situations like unfavorable rush hour vehicles loading on the highway, or a vehicle that fails to start at a highway etc., leading to pilings of vehicles on the roads. Over the years, population growth and economic prosperity in urban centers has resulted into increased acquisition of automobiles in urban centers. Hence increase on the number of vehicles on the roads and continual expansion of urban centers. The *United Nations Population Foundation* published in its technical report [1], that for the first time, more than half the world's population lives in urban areas and the balance of people continue shifting to the cities. Consequently, drivers and passengers spend a large percentage of their day stuck in traffic.

For efficient management of the traffic at intersection according to the changing traffic conditions, this project proposes a multi-agent approach for traffic light control in intersection. It aims to introduce agents at the intersection to manage traffic and replace the interval time system of the lights. The aim is to reduce each vehicle's waiting time., the agent continuously observes the prevailing traffic condition by collecting traffic data, and the data is then used for reasoning with the traffic-light-control rules by the agent's inference engine to determine how a signal will be changed on each traffic light, so that the traffic can be controlled efficiently and effectively.

As part of this study. We organized this thesis in 4 main parts, after a general introduction, In Chapter I a general view is presented on the systems of traffic lights that exist by giving some experiences in the world. Then in Chapter II we gave a presentation of Multi-Agent System and microcontroller (Arduino). In chapter III we presented the design of the project with the necessary tests to improve the system and output a perfect system that gives the right results.

At the end our brief is completed by a general conclusion and perspectives.

Chapter 1:
State of the Art of Traffic Light control

I. Introduction

A traffic light system has different characteristics that depend on various parameters such as the flow of cars, the arrangement of traffic lights and stop signs, the speed limit in various zones, and so on.

Traffic lights are used to regulate the flow of vehicles; they were used from the end of the 19 century to handle the growing traffic of cars. They now have a real impact on urban traffic and can sometimes cause traffic congestion.

In this chapter. First, different types of traffic lights are presented with giving experiences of the traffic lights that exist in different countries.

II.History of traffic light systems

Traffic lights control system allow the regulation of road traffic and the cohabitation of road users in total safety. Traffic lights have a century of existence. The return on the history of this indispensable invention today.

Nowadays, it is essential to manage the traffic flow of cities, the traffic light has not always been the one we know. It was in 1868 in a district of London that the first traffic light appeared to regulate the flow of horses and pedestrians in the streets. Very different from ours, it took the form of a gas lantern emitting a red or green light, and was manually controlled by a police officer[2].

However, it was in 1914 in Cleveland in the United States that the first (two-colored) road electrical light was born. Six years later in 1920, the first traffic lights known were installed in Detroit and New York.

After 3 years, in 1923 the first traffic light regulating motorist traffic was installed in Paris (France). It was a single color (red) and sounded when the driver had to stop. It took ten years to see traffic lights in France [3].

The year 1933 saw the installation of the first pedestrian light in Copenhagen. The first automatic pedestrian light with the message "Do not Cross" was used for the first time on 5 February 1952 in New York [2].

The same system was also introduced in Germany shortly afterwards, but with the "Wait" and "Cross" messages, which pedestrians rarely respected. Finally, road traffic psychologist Karl[4,] Peglau invented the green light in 1961 in East Germany.

At present, new intelligent traffic lights control traffic in Toronto, Canada. The latter evaluate road traffic and adapt the lighting time of the lights in order to allow a smoother traffic flow and to avoid traffic congestion [3].

III.General information on traffic signals

A traffic light is a device for regulating road traffic between road users, vehicles and pedestrians.

Traffic lights intended for motor vehicles are generally of the tricolor type, to which may be added directional arrows. Those for pedestrians are bicolored and are often distinguished by the reproduction of a silhouette of pedestrians. The tricolor lights for cyclists are distinguished by the reproduction of a bicycle [5].

The following four points generally characterize traffic lights:

- Traffic lights regulating vehicular traffic or crossing pedestrians are green, yellow or red, yellow and red may be flashing.
- They can be grouped into sets of tricolor or bicolor lights.
- Vehicle traffic lights are generally circular. They may include a pictogram that specifies which vehicles they are addressing.
- Pedestrian traffic lights are green and red. They have a pictogram.

The purpose of traffic signals is to:

- To make road traffic safer.
- To facilitate this traffic.
- To indicate or recall various specific police requirements.
- Provide information on the use of the road.

IV.Uses of traffic signals

The use of traffic signals is intended to ensure the safety of pedestrians and vehicle users and to improve the flow of traffic [6].some examples are given below:

- Traffic management at crossroad.
- Crossing pedestrians.

- The use of alternating meanings of a section where the crossing is impossible or dangerous (narrow structure, I.e.).
- The assignment of certain tracks of a roadway to a direction of traffic according to needs, or their temporary condemnation.
- The control of access to certain fast lanes.
- Protection of intermittent obstacles (Crossings, Crossings of roads exclusively reserved for vehicles of scheduled public transport services, Mobile bridges, Avalanches, I.e.) [5].

V.Different categories of traffic light signals

Traffic lights are green, yellow or red, except those specifically reserved for regular transit vehicles, which are white. They can be grouped into tricolor, bicolored or single color signals. They are generally circular and may include pictograms or specific signs for vehicles used for regular transit services. The yellow, red, and traffic light lights for regular transit vehicles may be flashing (i.e. alternately on or off every second, for equal periods) [5].

V.1. Intersection light signal

The intersection light signals are intended to separate in time the main movements of vehicles and pedestrians in conflict in an intersection.

V.1.1. Circular tricolored signal

These signals are used to regulate traffic at intersections. They allow vehicles to cross the intersection depending on the color of the fire.

It is normally composed of three circular lights green, yellow, and red (FigureI-1).



Figure I-1: Circular tricolor signal

The red light: a red light indicates that the vehicle must stop.

Green light: Green light means clearance.

Yellow light: The yellow light means that no vehicle must cross the plumb line of the signal or the line of effect of the signal when it exists or the pedestrian crossing if it precedes the signal [9].

V.1.2 Modal tricolore signal

They consist of three lights with identical pictograms (figure I-2): cycle or bus, or trolley [8]

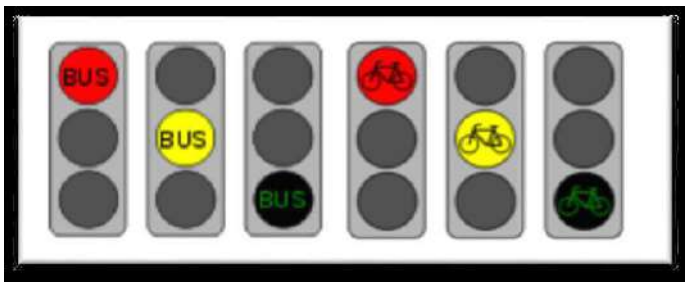


Figure I-2: Modal tricolor signals.

V.1.3. Directional tricolor signals

They are intended for all vehicles intended for the direction indicated by the arrow (figure I-3), or one of the indicated directions. Under no circumstances may a flashing yellow light replace the green light [5].

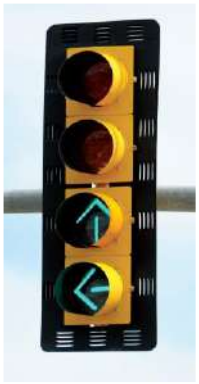


Figure I- 3: Directional tricolor signals.

V.2. Pedestrian signal

They are two-color system with a red light and a green light, these lights are arranged either vertically or horizontally, with the red light either top or left (Figure I-4), The red light has the form of a stationary pedestrian, the green light in the shape of a walking pedestrian, these two lights cannot be switched on simultaneously [5].



Figure I- 4: Pedestrian signal.

VI.The principles of Circulation Signals

Traffic light signals should be used in accordance with the following principles:

Characteristics of the main traffic lights:

- Number and composition: three lights arranged vertically or horizontally.
- Lens shape and dimensions.
- The lenses are round.
- They shall have a diameter of at least 200 mm. This dimension shall be greater when circumstances require, for example, when the lights are placed above the roadway.

Lights intended exclusively for pedestrians shall have the following symbols:

- Pedestrian motionless for the red light.
- Pedestrian in motion for the green light.
- Those special lights may be rectangular.

The visibility distance of light signals should be set taking into account the following factors:

- The speed of traffic.
- The presence of elements intended to improve the visibility of lamps (visors, i.e.).
- This distance should be sufficient for the prescription (s) to be observed on time.

The determination of green and red phase times should be based on traffic intensity. The duration of the yellow phase must be between three and five seconds [10].

VII.Coordination of traffic signals

Traffic signals are synchronized to minimize stops and wait for all vehicles using the intersection. Many factors contribute to the disruption of the ideal progression, including various speeds, the presence of lights turning to the left, the distance between traffic lights, the variable duration of the green lights required for traffic on transverse streets and congestion due to a very high flow rate.

A perfect timing for a traffic direction on a street leads to frequent stops and expectations in the other direction. A compromise that favors the direction where there is the most traffic is usually the best [11].

VIII.Are traffic lights the answer to all traffic problems?

The function of traffic lights is to share the priority of passage between two or more lanes at a crossroads. A well-adjusted traffic light system can significantly increase the number of vehicles crossing a crossroads or improve the safety of pedestrians as well as vehicle [10].

IX.Different types of intelligent traffic lights in the world

Intelligent traffic light gives big intention to many developers in cities around the world, so some examples are given below of intelligent traffic light:

IX.1. Intelligent Traffic Lights in Montreal (Canada)

Traffic lights in Montreal, which sometimes seem to have been deliberately out of synchronization, are instead set to a quarter turn to encourage traffic fluidity, as Jean-Sebastian Cloutier discovered by talking with Daniel Beaulieu, engineer Transportation and traffic to the City of Montreal.

Optimization of traffic signals in order to secure and improve the mobility of all users in cities.

The Montreal Executive Committee has approved the establishment of a fiber optic main network to remotely manage video cameras and traffic lights [12].

IX.2. Intelligent Traffic Lights in Boucherville (Canada)

Firefighters will be able to travel more safely on the main thoroughfares of Boucherville. The City has a system that allows a traffic light to go green when approaching an emergency truck.

This system improves everyone's safety in addition to accelerating the response time of firefighter works by infrared signal or GPS, which is sent from the fire truck to a detector installed on the traffic light. The technology turns the traffic light from red to green when a fire truck with lighted beacons arrives nearby. The traffic is then stopped in the other direction and allows the vehicles in front of the fire truck to circulate and release the road more easily.

The Fire Department requested municipalities in its territory to include this system in their future intersection repair work. Some twenty cities in Quebec use this system. It is used in Montreal and Longueil for the fleet of buses [13].

IX.3. Intelligent traffic lights in China

In China, there are many types of traffic lights. The latter groups together on the same group three different sets of lamps (figure I-7):

- For motorists wishing to go straight.
- For motorists wishing to go left.
- For cyclists going left.



Figure I-5: Intelligent traffic light in China.

It saves space and offers an aesthetic appearance in modern districts. This type of tricolor lights is placed after the crossroads.

Each of the lamps in this light changes color independently.

- The so-called smart traffic lights, in fact, a common traffic light, plus an electronic display, the screen content may vary depending on the traffic situation in the pre-set program options, such as the need to Control the intersection of traffic, turn right, the screen prompts will show "in front of the intersection to allow single bus

grand touring, taxi, turn right." At that time, the track in the same direction maps will also be displayed simultaneously. "In addition to the large passenger bus, taxi, turn right to prohibit" text message screen prompts two participants on the roads suggest that while the lights are synchronized accordingly the adjustment. For example, in the national holiday period, the driver drove into the intersection, you can see the word "prohibit right motor vehicles" or "In addition to the external bus prohibited turn left" signs on The road, you can follow the instructions on the driving display panel [10].

- Emergency Vehicle Pass Control: Emergency Vehicles Vehicle Communication Emergency No Controlled by-pass switch. Emergency car lighting without the normal synchronization control. There are emergency vehicles arrived, the switch from emergency vehicle is activated, regardless of the state of the original signal, cannot be forced to allow emergency vehicles to drive the direction of the vehicle. Green light, so that emergency vehicles be released until the emergency vehicle by far.

IX.4. Intelligent Traffic Lights in Texas (United States)

Siemens Traffic Intelligent Solutions develops intelligent transport technology for the rapid and orderly evacuation of citizens. In this project, the traffic light timing systems only estimate the number of vehicles by recording the signals.

Bluetooth emitted by drivers' cell phones and adjust the phases of the red and green light accordingly. The Siemens global search unit provides the associated software.

The anonymous addresses of nearby Bluetooth devices are detected and transmitted from each intersection to the traffic management center, which calculates the travel time between intersections.

The traffic density data collected by the systems are also incorporated into the digital road maps; pilots can download on their smartphones or navigation systems in order to find the fastest routes out of town. In an emergency, the system can centrally control all traffic lights.

With Bluetooth, facilities include GPS and Short Range Communication (DSRC) dedicated antennas. Emergency vehicles on board the equipment sends the GPS location via DSRC to a software in the controller indicating that the approaching vehicle should be a priority. The application is able to read direction of approach and speed allowing the

synchronization of the signal to initiate a green regardless of the speed in the opposite direction of the emergency vehicle approach. This means that priority can be applied specifically to the route to follow either straight to the intersection or turn left [14].

IX.5. Intelligent traffic lights in Brussels (Belgium)

The Brussels Region is investing in a central traffic management system. The red lights will soon be controlled remotely by intelligent beings depending on traffic density. Prolonging the duration of the green light to smooth traffic during rush hours is one of the possibilities of these so-called intelligent lights. Depending on traffic density, Accidents or construction sites, they will adapt. Thanks to the surveillance cameras already installed at the main crossroads of the capital, experts will be able to intervene in real time on traffic lights [15].

X.Advantages of intelligent traffic light

Intelligent traffic lights have many advantages:

- Improved travel conditions.
- Increased capacity of intersections.
- It also improves the flow of everyday traffic.
- By imposing a total shutdown for users who are likely to cross their trajectory, the vehicles rarely have to stop there to give way.
- Traffic lights are particularly adapted to the management of the dense and fast traffic generated by motorized vehicles on major axes in built-up areas.
- Simplified shuttle trends with likely reductions for time needed to get specific points to destination.

XI.Conclusion

Traffic signals are the most common means of managing the flow of automobiles at road junctions. Their role is to make the movement of the cars fluid and to make them as safe as possible by preventing accidents between vehicles and involving pedestrians. Several methods have been used to efficiently manage traffic signals.

Chapter 2:
context of the study Multi-agent system and Arduino

I. Introduction

In the previous chapter, we talked about traffic lights with its different types, characteristics, and we noted that we have to make it intelligent so it can solve traffic problems, in our project, our purpose is to make traffic light intelligent using multi-agent system and Arduino Microcontroller.

In this chapter, we present the context of the study of our project by essentially giving a theoretical study on the multi-agent system and the microcontroller (Arduino).

II. Multi-Agents

A multi-agent system (M.A.S.) is a computerized system composed of multiple interacting intelligent agents within an environment. Multi-agent systems can be used to solve problems that are difficult or impossible for an individual agent or a monolithic system to solve. Intelligence may include some methodic, functional, procedural approach, algorithmic search or reinforcement learning. Although there is considerable overlap, a multi-agent system is not always the same as an agent-based model (ABM). The goal of an ABM is to search for explanatory insight into the collective behavior of agents (which do not necessarily need to be "intelligent") obeying simple rules, typically in natural systems, rather than in solving specific practical or engineering problems. The terminology of ABM tends to be used more often in the sciences and MAS in engineering and technology. Topics where multi-agent systems research may deliver an appropriate approach include online trading, disaster response, and modelling social structures.

II.1 Agents technology

Agent technology has been the subject of extensive discussion and investigation within the scientific community for several years, but it is perhaps only recently that it has seen any significant degree of exploitation in commercial applications [16]. According to Pěchouček [16], agent-based computing is a subfield of computer science and artificial intelligence that studies the concepts of autonomy of individual computational processes (running either software applications or hardware robots), and inter- action between such heterogeneous autonomous processes. As the society continues to face complex problems, there continue to

be thoughts of how solutions can be found. Therefore, agent technology is an approach that is widely being studied to offer solutions in the face of complexities.

Intelligent agents possess the ability to decompose and solve problems in a collaborative manner. They observe their environment, reason about their own and other agent's actions, interact with other agents, and execute their actions concurrently with other agents. Interactions may communicate facts or beliefs via an agent communication language and may depend on ontology to reach a common understanding of a situation.

Agent-based computing can also support peer-to-peer knowledge and data sharing in social networks, by allowing intelligent agents to negotiate various data confidentiality policies, and thus support wider exploitation of knowledge and experience. Adoption of agent-based techniques in these domains not only facilitates control of distributed systems, but also provides scalability, robustness and reliability, which cannot be achieved by centralized control [17].

II.2 Characteristics of Agents

Agents normally have a set of features. The main features of agents include the following:

- *Autonomy*: the agent is accountable for execution of its own actions and is not controlled from outside.
- *Reactivity*: the agent is able to react quickly to the events in the environment and to the requests from other agents; it is able to reconsider her activity according to the change of the environment in timely fashion.
- *Intentionality*: the agent is able to maintain her long-term intention encoded by the agent's designer and is capable to consider both the long-term intentions and immediate reactive inputs when selecting the next action.
- *Social capability*: the agent is able to interact, collaborate and form teams. It is also able to perform different levels of reasoning about the other agents.
- *Reactiveness*: Agents do not only act in response to their environment, but also exhibit goal-directed behavior by taking the initiative.

III. Agents in Traffic Flow Control

According to [18], an agent is an encapsulated computational (or physical, even human) system, that is situated in some environment, and that is capable of flexible, autonomous behavior in order to meet its design objective. These agents can be organized to form a multi-

agent system. Multi-agent system is therefore a decentralized computational (software) system, often distributed (or at least open to distribution across hardware platforms) whose behavior is defined and implemented by means of complex, peer-to- peer interaction among autonomous, rational and deliberative unit agents.

Improving traffic flow is very important, as the urban traffic has shown that how congestion is managed, can either slow or accelerate the economic output of a population. However, [19] observes that improving traffic control is difficult because the traffic system, when it is modelled with some degree of realism, is a complex, nonlinear system with large state and action spaces, in which substandard control actions can easily lead to congestions that spread quickly and that are hard to dissolve. This therefore called for the intelligent approaches towards management of traffic in major areas, since traffic control is fundamentally a problem of sequential decision-making, and at the same time, is a complex task that is challenging to the straightforward approaches such as the pre-timed interval traffic lights.

IV. Multi-Agents System levels design

Although a single agent can act and perform a set of tasks, the increasing interconnection and networking of computers is making such situations rare. A distributed computing model can be set to have a set of agents interact and share information. Multi Agent System is used to describe several agents, which interact with each other. According to [17], the concept of agent use is considered at the following design levels:

- *Organization-level*: related to the agent communities as a whole (organizational structure, trust, norms, obligations, self-organization, etc.);
- *Interaction-level*: concern communication among agents (languages, interaction protocols, negotiations, resource allocation mechanisms);
- *Agent-level*: concern individual agents (agent architecture, reasoning, learning, local processing of social knowledge)

Agents and multi-agent systems will be one of the landmark technologies in computer science of the years to come. It will bring extra conceptual power, new methods and techniques that will essentially broaden the spectrum of our computer applications because this new paradigm shifts from the single intelligent entity model to the multi-intelligent entity one, which is in fact the true model of human intelligence acting.

V. Characteristics of Multi Agent Systems (MAS)

The following are the major characteristics of MAS:

- Each agent has limited capacities and information of problems resolution.
- Each one has a partial point of view.
- The MASs have no global control.
- All data are decentralized.
- All calculations are asynchronous.

VI. The role of Multi Agent Systems (MAS) in traffic light control

The benefits of using MAS technology in large software systems as:

- *Speed and efficiency*: due to the parallel and asynchronous computation, provided that the overhead of coordination does not offset the gain.
- *Robustness and reliability*: in the sense that the whole system cannot be seriously affected when one or more agents fail. The available agents can take their part.
- *Scalability and flexibility*: It is easy to add new agents to the system, hence can make it possible to manage a large area of problem.
- *Cost*: It is more cost effective compared to a whole centralized system since it is a subsystem of low cost units.
- *Development and reusability*: specialists can develop agents separately. The beauty of this is that you can replace or add any one component without affecting the rest of the system. Therefore, the overall system can be maintained and tested easily. It is also possible to reuse the functionally specific agents in other fitting engagements in the system.

VII. Arduino

Arduino is an open source, computer hardware and software company, project, and user community that designs and manufactures microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. The project's products are distributed as open-source hardware and software [20].

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to

various expansion boards (*shields*) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler tool chains.

VIII. History of Arduino

The origin of the Arduino project started at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy. At that time, the students used a BASIC Stamp microcontroller at a cost of $100, a considerable expense for many students. In 2003, Colombian student Hernando Barragán created the development platform *Wiring* as a Master's thesis project at IDII, under the supervision of Massimo Banzi and Casey Reas, who are known for work on the Processing language. The project goal was to create simple, low cost tools for creating digital projects by non-engineers. The Wiring platform consisted of a printed circuit board (PCB) with an ATmega168 microcontroller, an IDE based on Processing and library functions to easily program the microcontroller [20].

In 2003, Massimo Banzi, with David Mellis, another IDII student, and David Cuartielles, added support for the cheaper ATmega8 microcontroller to Wiring. But instead of continuing the work on Wiring, they copied the Wiring source code and renamed it as a separate project, called Arduino [20].

The initial Arduino core team consisted of Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, and David Mellis. However, Barragán was not invited to participate [20].

Following the completion of the Wiring platform, lighter and less-expensive versions were distributed in the open-source community [20].

Adafruit Industries, a New York City supplier of Arduino boards, parts, and assemblies, estimated in mid-2011 that over 300,000 official Arduinos had been commercially produced. Moreover, in 2013 that 700,000 official boards were in users' hands [20].

IX. Arduino hardware

The Italian company Smart Projects produced the original Arduino hardware. Some Arduino-branded boards have been designed by the American companies Spark Fun

Electronics and Adafruit Industries [21]. As of 2016, 17 versions of the Arduino hardware have been commercially produced, some examples of Arduino boards given below:



Figure II.1: Arduino RS232 (Thru-hole parts)



Figure II.2: Arduino Diecimila



Figure II.3: Arduino Duemilanove (rev 2009b)



FigureII.4: Arduino Uno R2



FigureII.5: Arduino Uno SMD R3



Figure II.6: Arduino Leonardo



Figure II.7: Arduino Pro (No USB)



Figure II.8: Arduino Mega



Figure II.9: Arduino Nano (DIP-30 footprint)



Figure II.10: Arduino Lily Pad 00 (rev 2007) (No USB)

X. Arduino shields

Arduino and Arduino-compatible boards use printed circuit expansion boards called *shields*, which plug into the normally supplied Arduino pin headers. Shields can provide motor controls for 3D printing and other applications, Global Positioning System (GPS), Ethernet, liquid crystal display (LCD), or bread boarding (prototyping). Several shields can also be made do it yourself . [20]



Figure II.11: Multiple shields can be stacked. In this example the top shield contains a solderless breadboard.



FigureII.12: Dragino Lora Shield allows the user to send data and reach extremely long ranges at low data-rates.



Figure II.13: Screw-terminal breakout shield in a wing-type format



Figure II.14: Adafruit Data logging Shield with a Secure Digital (SD) card slot and real-time clock (RTC) chip

XI. Arduino Software

Today, electronics is increasingly being replaced by electronics Programmed. also talking about embedded electronics or embedded computing [22].

X.1 Arduino IDE

The interface of the Arduino software is as follows:

1. Software configuration options.
2. Buttons for boards programming.
3. Program to create.
4. Debugger (display of programming errors).

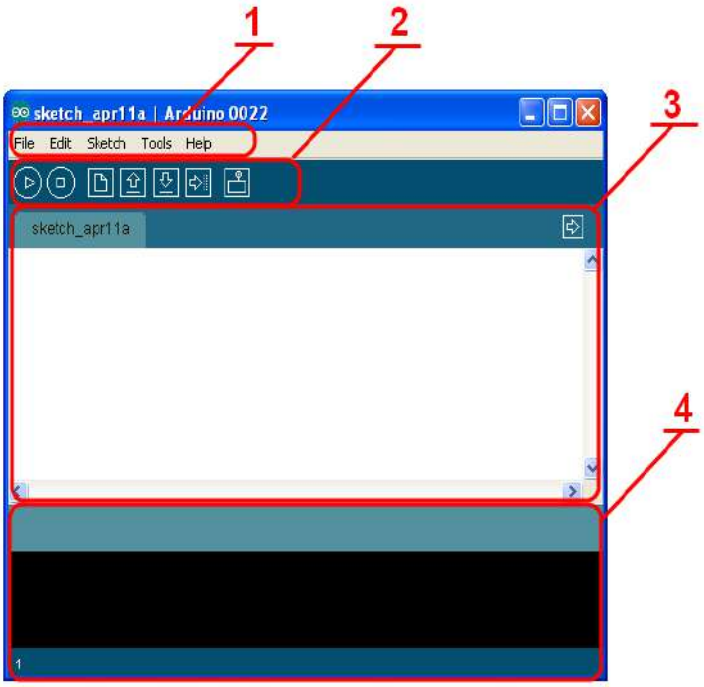


Figure II.15: Arduino IDE

The File menu has a number of things that will be very useful:

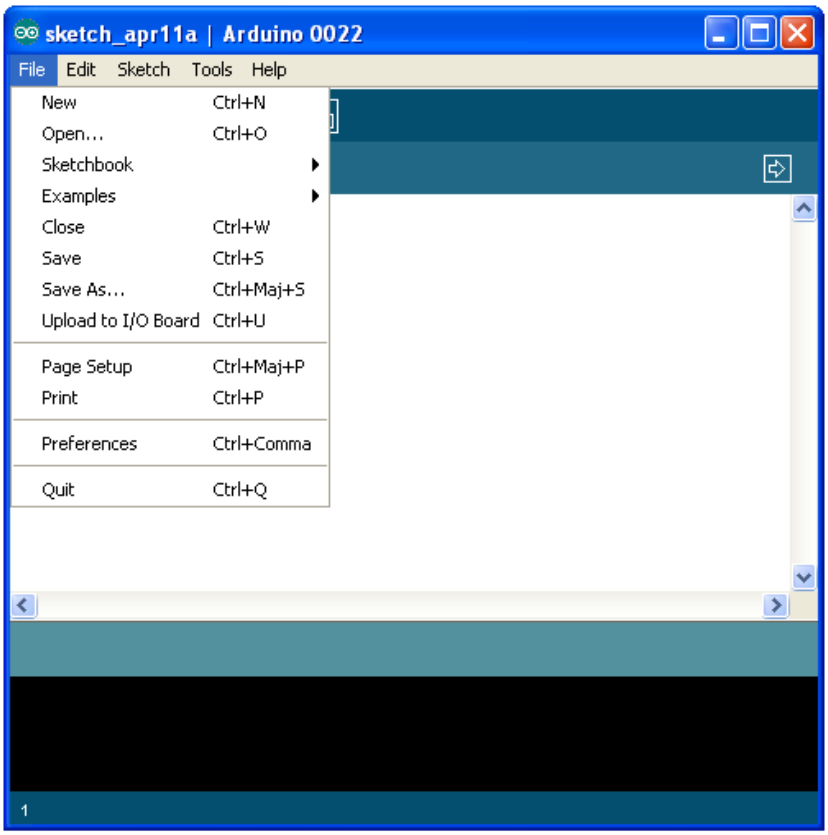


Figure II.16: Arduino IDE

- New: will create a new program. When press this Button, a new window identical to the one shown appears on the screen.
- Open: With this command, an existing program can open.
- Save / Save as: Save the current document / ask where to save the current document.
- Examples: This is important, a whole list goes to show the names of Examples of existing programs [22].

X.2 Arduino language

A program for Arduino may be written in any programming language for a compiler that produces binary machine code for the target processor. Atmel provides a development environment for their microcontrollers, AVR Studio and the newer Atmel Studio [22].

The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java. It originated from the IDE for the languages *Processing* and *Wiring*. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple *one-click* mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus.

A program written with the IDE for Arduino is called a *sketch* Sketches are saved on the development computer as text files with the file extension.ino. Arduino Software (IDE) pre-1.0 saved sketches with the extension *.pde*.

The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub *main()* into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program *avrdude* to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

XII. Advantage, Purpose and the Use of Arduino

The Arduino system gives us the possibility to combine the performance of programming with those of electronics. More specifically, we will program electronic systems. The big advantage of programmed electronics is that it simplifies the electronic schemes and therefore the cost of implementation, but also the workload at the Design of an electronic card.

The Utility is probably something that is perceived badly when you start, but once you get back into the World of Arduino, you will be fascinated by the incredible power of which it is question and possible applications

The Arduino system allows us to realize many things, which have an application in all areas,

The scope of use of the Arduino is gigantic. To give some examples, we can:

- Check household appliances.
- Make your own robot.
- Make a play of lights.
- Communicate with the computer.
- Remote control a mobile device (modeling).
- Etc.

With Arduino, we will make electronic systems such as an electronic candle, a simplified calculator, a synthesizer, etc. All these systems will be designed based on an Arduino board and a wide panel of components electronic devices [22].

XIII. The right reasons to choose Arduino

There are, however, in trade, a multitude of platforms that allow to do the same thing. Notably the microcontrollers "PIC" of the manufacturer Microchip. We'll see why we choose the Arduino [22].

XII.1 The cost

In view of the performance they offer, Arduino cards are relatively inexpensive, which is a major criterion for the beginner. The one we use in our project Arduino mega 2560 cost 6000 DA, which is a good quality/money [22].

XII.2 Freedom

It is a great word, but it defines in a rather concise manner the spirit of the Arduino. It constitutes in itself two things:

- The software: free and open source, developed in Java, whose simplicity of use depends on the knowledge click on the mouse.
- The equipment: electronic boards, the diagrams are free on the internet.

This freedom has one condition: the name "Arduino" should be used only for "official" cards. In short, you cannot make your own card on the Arduino model and assign it the name "Arduino".

Unofficial cards can be found and bought on the Internet and are almost entirely compatible with official Arduino cards [22].

XII.3 Compatibility

The software, like the card, is compatible under the most common platforms (Windows, Linux and Mac), unlike other commercial programming tools that are generally only compatible with Windows [22].

XII.4 The community

The Arduino community is impressive and the number of resources about it is constantly changing on the internet.

More, we find the references of the Arduino language as well as a complete page of tutorials on the site arduino.cc [22].

XIV. Conclusion

In this chapter, we have reviewed all the technologies relevant to the study, we talked about multi agent system and its characteristics and also the agent and its characteristics and we note that it has a big role in traffic lights management.

Multi-agent system can be adapted on an Arduino microcontroller, which has several advantages to be the object of an implementation target of our project.

Chapter 3:
Project design, tests and results

I. Introduction

To address the problem of vehicle flows at an intersection, it is necessary to use an adapted modeling of the traffic sharing the conflict space.

Our intention is to improve traffic by optimize the waiting time.

II. Problem definition

The main objective of traffic lights at the intersections is to manage traffic efficiently. This is to ensure minimum queue length at the roads intersection. This can be achieved by ensuring efficient coordination of the traffic lights at the intersections with respect to density of vehicles. In this day traffic light control is based on interval time, these time intervals are mostly scheduled to have equal intervals during morning, mid-day and evening hours, with the assumption that these are peak hours. In between the peak hours, they show different intervals with the assumption that these are off-peak hours. This does not solve the problem effectively since such changes are still pre-timed. There is also poor interaction between the existing traffic control systems of various intersections to the adjacent ones, thereby resulting into traffic snarl-up. The police officers are used in such circumstances, to coordinate the movement of traffic, hence usually leading to biasness from the part of the officers resulting to massive time wastage to motorists waiting on the roads not released. This pre-timing therefore, presents traffic snarl-up as a static problem, not a dynamic in nature of which is a false impression.

II.1. Proposed solution

The aforementioned problem therefore presents a scenario, which could easily be solved by an agent-coordinated traffic light system. A traffic light is a device emitting light in different colors, i.e. green, red and yellow, to issue different instructions. Green illustrates move forward, red means stop and yellow shows caution. The project seeks to present a system of agents that coordinate, cooperate and share information based on the average waiting time and queue lengths on the roads to the intersections. The agents are to control the traffic lights and determine for how long to set the lights to achieve minimum waiting time and reduced queue lengths based on the prevailing traffic conditions.

II.2. Intersection description

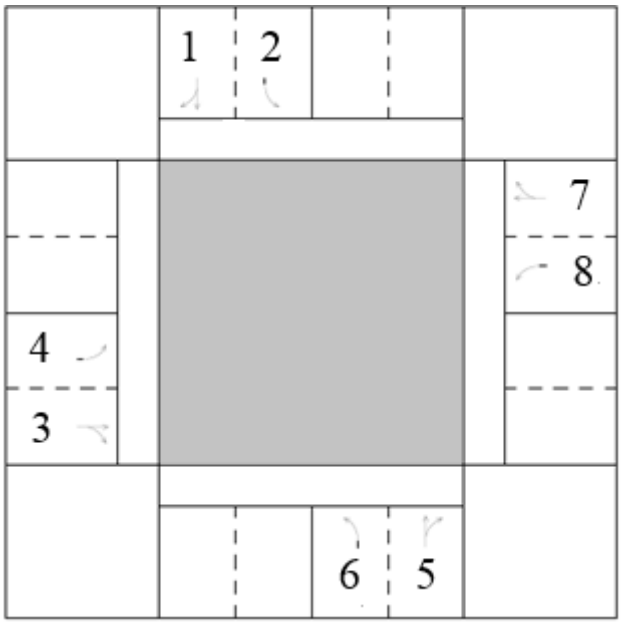


Figure III-1: crossroad design in question

The conventional intersection model shown in Figure II-1 is composed of a set of four directions or roads, this model is used in most of the literature, but nothing prevents it from being extended. Each direction can be decomposed into one direction ingoing and outgoing direction, or both. An incoming direction allows the vehicles, distributed on one or more paths, to cross the intersection to an outgoing direction, which makes the link with a neighboring intersection. On each incoming direction, the vehicles turning to the left use the leftmost lane, While the rightmost lane is usually used for vehicles going straight or turning right.

We put ourselves in a scenario where drivers drive on the right side of the road.

The outgoing tracks can make neighboring with other tracks, in another meaning two cars can get out from the intersection safely and without crossing each other.

The Table III.1 shows which tracks have the green light to move at the same time.

Table III.1: Green Light Table

	1	2	3	4	5	6	7	8
1								
2								
3								
4								
5								
6								
7								
8								

III. Terminology

Several terms must be defined in order to adequately describe the situation and the problem.

This section explains, among other things, the terms common to each traffic signal management model.

- The intersection is an area where several streams share a conflict space represented by the gray rectangle in the Figure III-1.
- The number of vehicles waiting in a lane is called "tail".
- A signal cycle is a complete set of green + red light for each path Its length is called cycle time.
- The "all-red" time is the length of time when all the tracks have a red light. It is considered for security reasons.
- The distance between vehicle is two seconds, it is called advancement.
- The waiting time of a vehicle is the time of departure minus the time of arrival.
- Once a vehicle has arrived at an intersection, the time it takes for the Next arriving vehicle is called arrival interval.

IV. Arrival of vehicles

The vehicles arrive from the different tracks at the intersection in a random and uncorrelated manner, making the Poisson process a good arrival model. In a Poisson process, the arrival intervals follow an exponential distribution relation (III.2) [31].

$$f(x) = \lambda e^{-\lambda x} u(x) \tag{III.2}$$

Where:

λ: is the arrival rate of vehicles per hour per track.

$\boldsymbol{u}$ ($\boldsymbol{x}$): is the unit function of relation (III.3).

This function is used for negative time intervals.

$$u(x) = \begin{cases} 1 \; si \; x \geq 0 \\ 0 \; si \; x < 0 \end{cases} \tag{III.3}$$

The Poisson distribution given by the relation (III.2) allows for instantaneous time intervals. Because of the geometric and physical considerations of the traffic network road, a minimum distance must be considered between vehicles. To avoid this problem, a shifted exponential distribution is used for the arrival intervals.

Where relation (III.4) can give the probability density function.

$$f_x(x) = \frac{\lambda}{1-\lambda dm} e^{\frac{-\lambda}{1-\lambda dm}(x-dm)} u(x - dm) \tag{III.4}$$

Note that for the function given by the relation (III.4) to have a meaning it is necessary that$1 - \lambda dm > 0$

Vehicle arrival times can be generated by the relationship (III.5).

$$t_{a2} = t_{a1} + dm - \left(\frac{1}{\lambda} - dm\right) \ln(r) \tag{III.5}$$

Where:

$\boldsymbol{dm}$: is the time to leave the intersection.

$\boldsymbol{ta2}$: Next arrival time.

$\boldsymbol{ta1}$: Previous arrival time.

$\boldsymbol{r}$: Random value uniformly distributed over [0 1].

The number of scheduled vehicles arriving during an interval of time is required to calculate the time of a vehicle during a signal cycle. This is difficult to do with an exponential distribution shifted from the relation (III.4). The reason is that there is a loss of the property. The duration of a signal is longer, so the expected number of vehicles can be approximated Poisson distribution function. The probability of arrival of n vehicles during Δt seconds is given by the equation (III.6).

$$p(n) = \frac{(\lambda \Delta t) e^{-\lambda \Delta t}}{n!} \quad \text{(III.6)}$$

In a Poisson distribution, the expected number of new vehicles arriving during Δt seconds is $\lambda \Delta \mathbf{t}$.

V. General scheme of Project

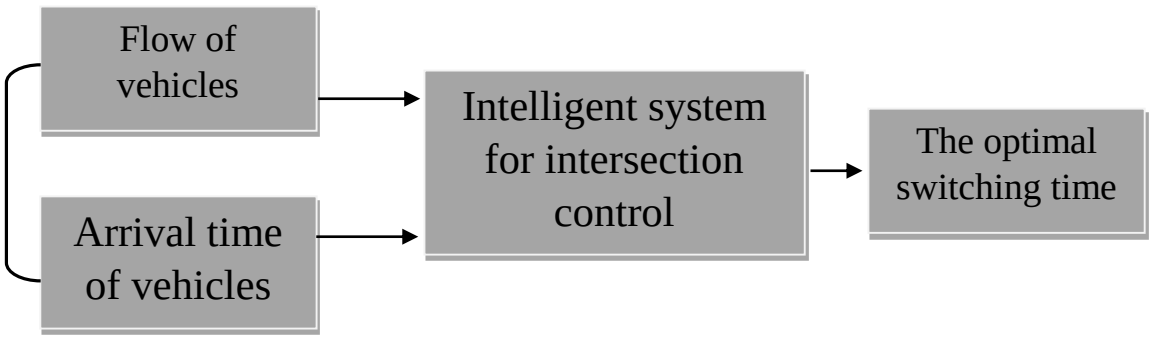


Figure III.2: General scheme of Project

Figure III.2 gives a global description of the project, the system receives two main information with are: the vehicles flow and the arrival time of each vehicle at each path, this system can calculate the minimum time period to switch to green light and release vehicles from the path, and also minimize the average waiting time of the vehicles.

VI. Agents diagram

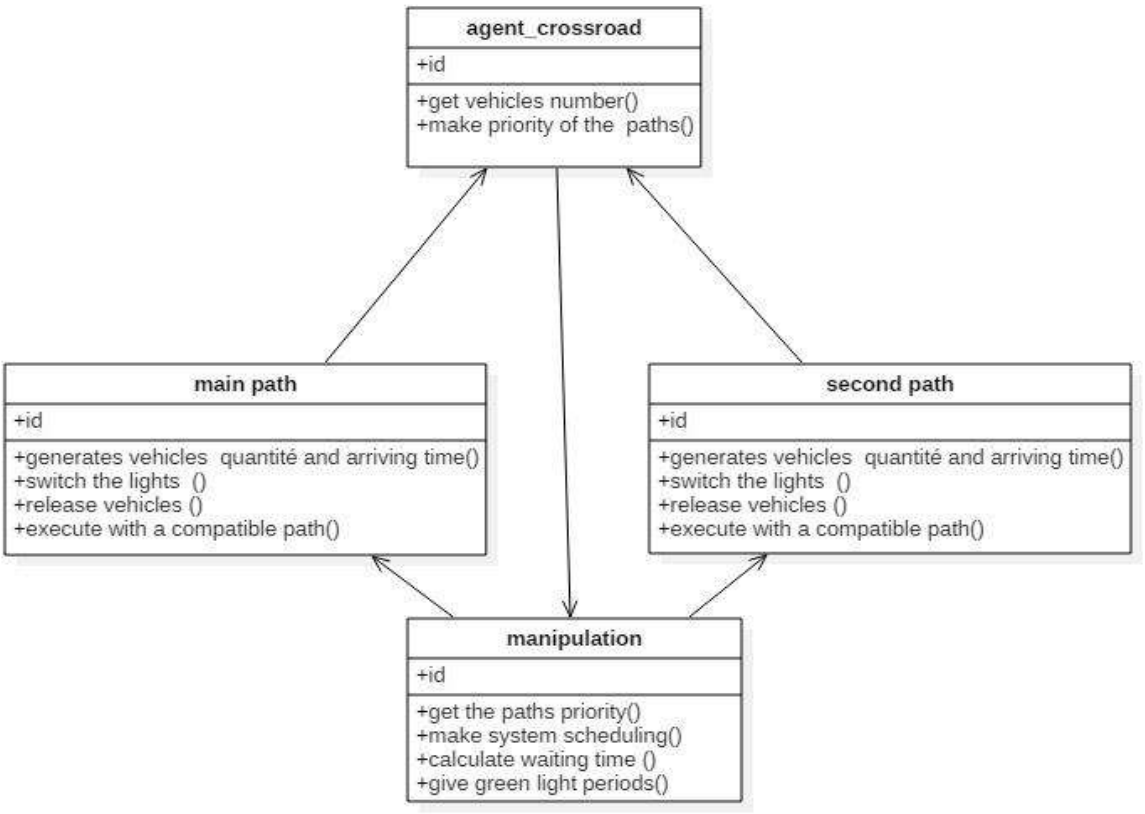


Figure III.3: Agents diagram

The diagram of figure III.3 demonstrates the communication lines between the agents of the system, agent main path and agent second path generate vehicles arriving time and send it to crossroad, therefore that agent make a priority of the paths to get a main path and second path agents and they can release vehicles in parallel and without crossing each other and it results goes to Agent manipulation to schedule the green lights period of times.

VII. Project classes diagram

The class diagram of figure III.4 demonstrates each class in the project (attributes, functions) and the communication between them.

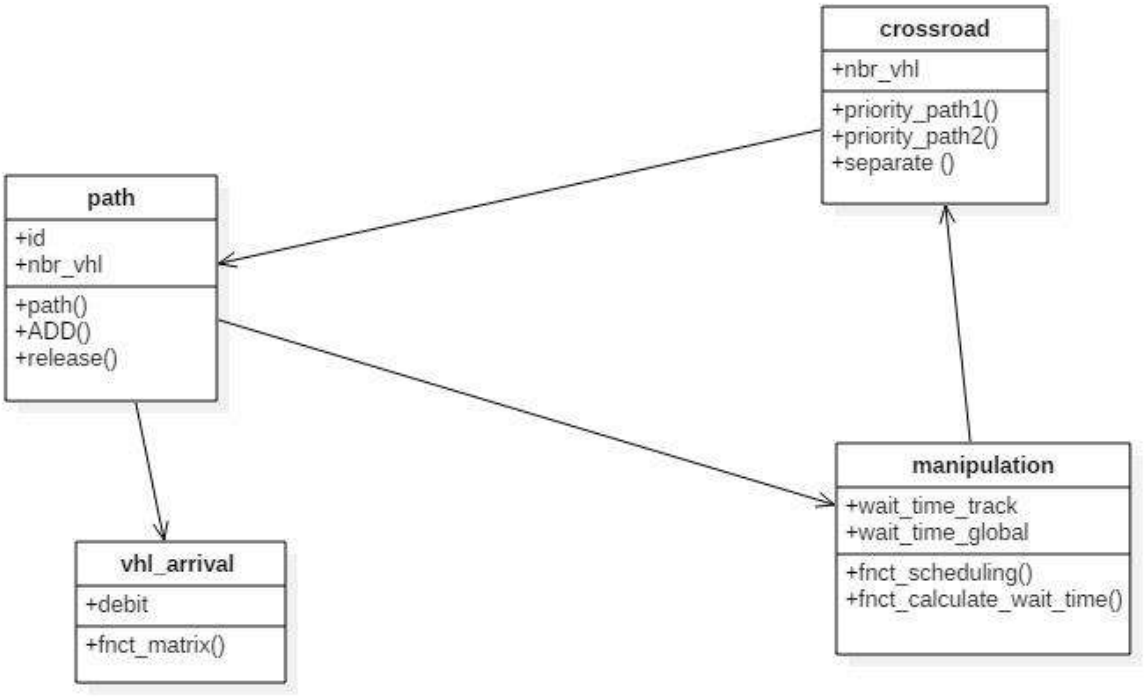


Figure III.4: project class diagram

***Vhl_arrival*:** this class function (funct_matrix) generate a matrix of vehicles arriving time according to the path traffic flow, and thanks to matrix, the number vehicles can also be calculated.

***Path*:** each path has identifier (id) and vehicles number, this class give second paths id (3 of the paths can release vehicles in parallel with main path without crossing each other), and receive vehicles from **vhl_arrival** class and release them according to the results of **crossroad** class.

***Crossroad*:** this class receive vehicles arriving time to select the priority of the main path and the second path with can be chosen from 3 paths giving by path class and send this results to **manipulation** class.

***Manipulation*:** when it receives the results from **crossroad** class, this class do the scheduling of the vehicles and the results is a period of green light for each path so they can release vehicles accordingly

VIII. System scheduling

The data from vhl_arriving class are received in each period of time [t1 t2] called DT (data time) and this period can be changed according to the path flow.

From those periods, the load of vehicles in the path can be calculated, so the system can choose a main path, it's the path that have a high load of vehicles, after that the system choose the second path from 3 paths that can release vehicles in parallel with the main path, the path chosen has also the high load of vehicles.

With this process the system schedules a table of paths priorities classifying from the high to the low load of vehicles in that period DT and generates the green light time, which is the number of vehicles in the path multiply by 2 seconds of the distance between vehicles and the system give to that time a maximum and changeable value of vehicles called MV (maximum vehicle) to be released until the end of the period DT.

The same process happened to the next period DT until the system release all vehicles in question.

IX. Project organizational chart

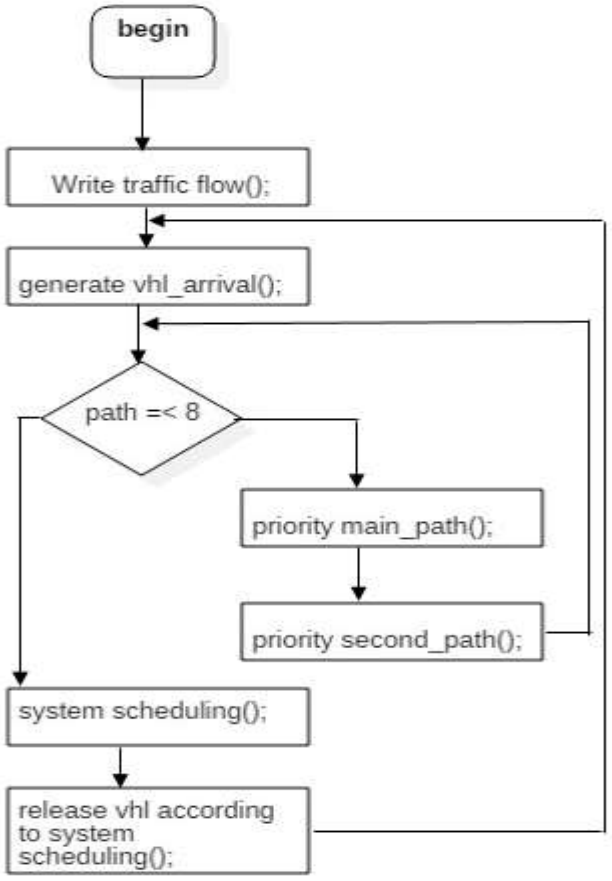


Figure III.5: Project organizational chart

This organizational of Figure III.5 chart present the system steps from generating vehicles to releasing theme, after the traffic flow value is given the system generate the vehicles arrival time and it give the results to give the priority of the main path and the second path of the 8

paths, after generating the priority the system schedules the green time to release vehicles accordingly.

X. Principle of the time interval algorithm

to test the qualification of the multi-agent system in its performance a comparison has to be made between the average waiting time of the multi-agent system and time interval algorithm.

In the figure (III.1), Assuming that the green light is initially turned on in the two opposite directions (1B) and (3B), There is a motion sensor that sends information to the system to trigger the green light in the other paths, after a time of 5 seconds without passing of vehicles. This sensor when it detects a movement (vehicle), it sends information to the system to increase the time of 5s to each vehicle arrives until reaching the maximum system value (30s), at this moment the green light automatically triggers in another two channels.

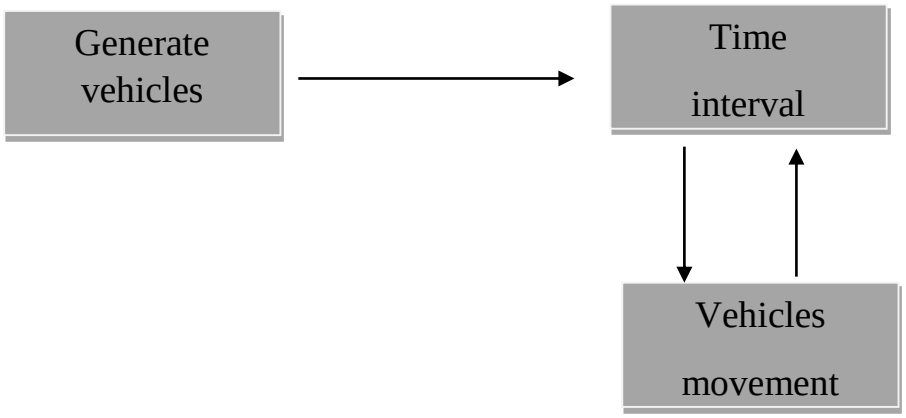


Figure III.6: Program steps of the time interval algorithm.

XI. Project tests and results

Project tests has been done to observe the waiting time of the vehicles and to choose a perfect conditions to get a minimal waiting time, and those condition are the data time periods DT and the maximum value of vehicles MV.

In this test the data time period DT is changeable for a maximum value of vehicles MV and compare the system (MAS) with the time interval algorithm (TIA) to see the difference of the waiting time:

Table III.2: Average waiting time in function of traffic flow for MAS and TIA for MV = 10 vehicles

For MV = 10 vehicles	Traffic flow/h	1600	2000	2400	2800	3200	3600	4000	4400	4800
	For DT = 30 seconds									
	MAS	1.254	1.863	3.616	8.260	20.914	46.908	66.234	91.575	96.941
	TIA	29.429	29.758	38.760	44.880	50.602	53.682	61.230	75.141	82.161
	For DT = 60 seconds									
	MAS	3.887	4.530	6.414	7.851	16.121	18.429	42.286	44.289	66.938
	TIA	33.693	37.440	38.750	41.933	46.660	55.104	63.094	71.007	75.998
	For DT = 90 seconds									
	MAS	4.238	4.778	14.255	22.420	37.363	40.313	53.426	71.036	75.652
	TIA	30.391	34.056	39.252	42.295	51.030	54.141	65.745	79.666	83.604
	For DT = 120 seconds									
	MAS	5.083	17.273	22.254	43.145	56.323	88.194	93.611	98.555	120.224
	TIA	33.232	31.878	33.561	35.817	42.429	61.810	66.523	70.442	82.779

Table III.3: Average waiting time in function of traffic flow for MAS and TIA for MV = 15 vehicles

For MV = 15 vehicles	Traffic flow/h	1600	2000	2400	2800	3200	3600	4000	4400	4800
	For DT = 30 seconds									
	MAS	1.605	1.814	2.511	3.494	11.409	42.996	78.085	92.083	105.924
	TIA	32.161	33.340	34.845	38.372	42.412	54.222	70.168	71.899	79.277
	For DT = 60 seconds									
	MAS	2.585	4.561	6.256	8.668	21.871	34.652	55.650	103.112	105.028
	TIA	34.563	36.967	37.295	40.914	50.480	55.194	60.637	78.385	85.836
	For DT = 90 seconds									
	MAS	3.627	6.688	9.016	15.836	19.219	37.136	43.745	58.689	74.875
	TIA	30.529	33.488	35.094	44.365	51.161	59.661	69.1200	75.366	84.881
	For DT = 120 seconds									
	MAS	4.064	9.283	13.555	18.942	25.294	30.791	50.528	54.298	75.001
	TIA	31.476	32.592	37.402	41.178	49.466	55.673	69.397	79.713	92.645

Table III.4: Average waiting time in function of traffic flow for MAS and TIA for MV = 20 vehicles

For MV = 20 vehicles	Traffic flow/h	1600	2000	2400	2800	3200	3600	4000	4400	4800
	For DT = 30 seconds									
	MAS	1.060	2.097	3.120	5.536	14.396	55.337	64.508	102.565	124.579
	TIA	28.141	32.700	37.746	42.507	49.977	59.736	64.770	82.570	84.101
	For DT = 60 seconds									
	MAS	2.439	5.082	5.713	9.986	10.040	33.121	59.620	84.751	102.715
	TIA	30.194	34.865	36.144	40.865	48.068	55.232	59.346	73.369	85.041
	For DT = 90 seconds									
	MAS	3.261	5.625	9.735	13.330	20.470	42.037	85.532	86.693	112.131
	TIA	30.146	34.589	41.985	42.191	47.478	52.073	70.615	74.865	80.727
	For DT = 120 seconds									
	MAS	5.586	8.322	12.056	16.426	20.417	32.620	58.855	62.595	70.032
	TIA	32.091	33.297	35.800	43.015	49.776	59.347	65.744	73.122	79.564

Table III.5: Average waiting time in function of traffic flow for MAS and TIA for MV = 25 vehicles

For MV = 25 vehicles	Traffic flow/h	1600	2000	2400	2800	3200	3600	4000	4400	4800
	For DT = 30 seconds									
	MAS	1.108	2.129	2.834	4.970	7.245	13.904	49.858	86.304	104.955
	TIA	26.820	33.431	37.089	39.886	42.677	48.288	57.593	68.741	80.744
	For DT = 60 seconds									
	MAS	2.242	3.321	7.248	12.179	20.041	39.282	64.639	97.726	114.880
	TIA	29.359	34.865	39.124	43.264	54.436	54.867	70.294	75.018	88.016
	For DT = 90 seconds									
	MAS	2.682	6.285	10.955	16.644	26.001	41.609	78.366	98.269	111.499
	TIA	28.166	31.862	43.500	49.446	58.821	66.365	76.648	76.949	79.642
	For DT = 120 seconds									
	MAS	6.072	7.837	10.299	15.994	21.176	38.252	52.087	99.426	101.522
	TIA	30.222	34.747	39.678	41.381	44.949	49.622	72.004	75.024	86.101

Table III.6: Average waiting time in function of traffic flow for MAS and TIA for MV = 30 vehicles

For MV = 30 vehicles	Traffic flow/h	1600	2000	2400	2800	3200	3600	4000	4400	4800
	For DT = 30 seconds									
	MAS	1.018	1.858	2.779	4.968	17.020	56.724	81.965	102.377	111.297
	TIA	33.379	33.860	37.253	44.891	46.784	63.174	67.978	74.493	76.223
	For DT = 60 seconds									
	MAS	1.667	4.725	5.937	8.204	16.932	34.168	86.100	102.021	128.720
	TIA	31.791	32.343	35.348	40.003	51.342	53.317	62.351	77.021	80.720
	For DT = 90 seconds									
	MAS	3.539	5.802	8.665	13.587	22.456	39.266	58.318	101.128	107.747
	TIA	30.902	34.318	37.478	39.291	47.940	54.956	95.063	71.665	80.188
	For DT = 120 seconds									
	MAS	4.403	10.387	12.120	15.309	21.047	46.342	83.214	108.887	115.371
	TIA	28.081	34.297	39.646	43.845	49.790	58.225	65.022	77.157	87.363

XII. Project conclusion

The observation from the tests shows that there is in same condition where the system give a remarkable optimized results, for MV = 15 vehicles and for DT = 30 seconds traffic flow from 1600 vehicles/h to 3200 vehicles/h the results are very optimized according to MV = 10 or 20, 30 vehicles, and also according to those MV values the results are optimized from 3600 vehicles/h to 4800 vehicles/h.

And the results are:

Table III.7: Average waiting time in function of traffic flow comparison between MAS and TIA

	DT = 30 seconds					DT = 120 seconds			
Traffic Flow/h	1600	2000	2400	2800	3200	3600	4000	4400	4800
MAS	1.110	2.130	2.867	4.473	12.769	24.226	48.976	54.254	60.526
TIA	31.401	33.211	39.950	40.828	47.007	53.933	67.044	76.713	79.164

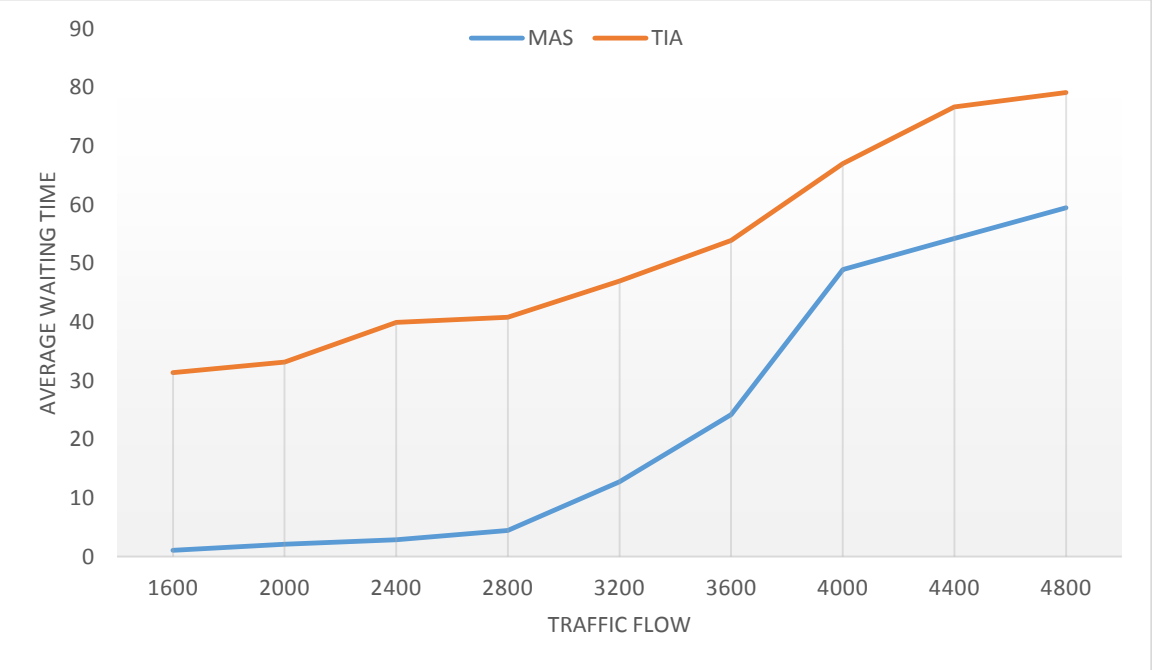


Figure III.7: Result of execution of average waiting time in both systems

XIII. Project system scheduling examples

Some examples of the system scheduling the green light time and priority 3 examples of 3 successive cycles, note that the priority changes from one cycle to another the table shows the data of the cycle and the figure shows the scheduling in a chart:

Cycle 1:

Table III.8: scheduling for Cycle 1(0-60 seconds)

Main path	7	5	3	1
Second path	8	6	4	2
Releasing vehicles	0	16	30	42
Second path stop	12	28	34	46
Main path stop	16	30	42	52

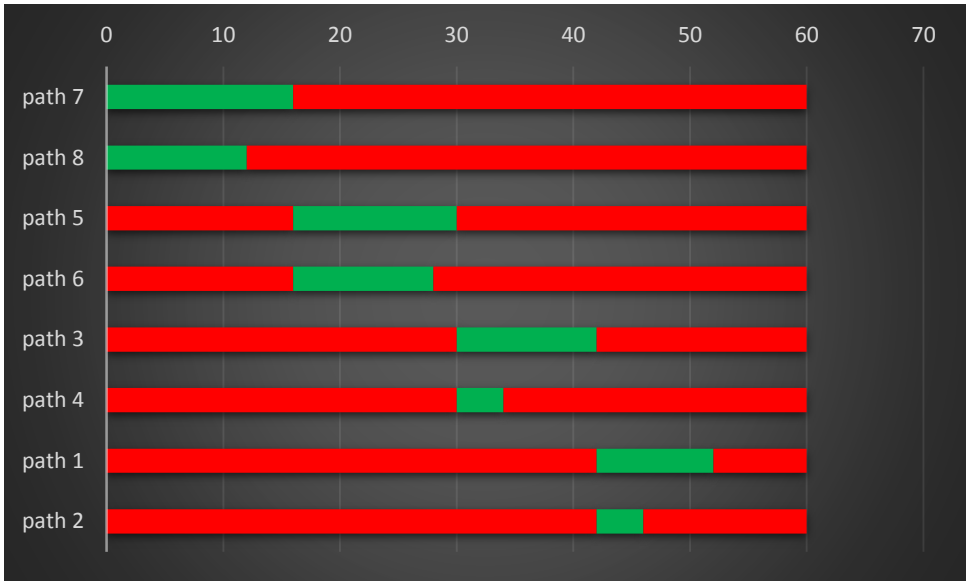


Figure III.8: system scheduling for cycle 1 (0 – 60 seconds)

Cycle 2:

Table III.9: scheduling for Cycle 2(60-120 seconds)

Main path	5	3	8	6
Second path	4	7	1	2
Releasing vehicles	60	78	90	98
Second path stop	70	86	98	104
Main path stop	78	90	98	104

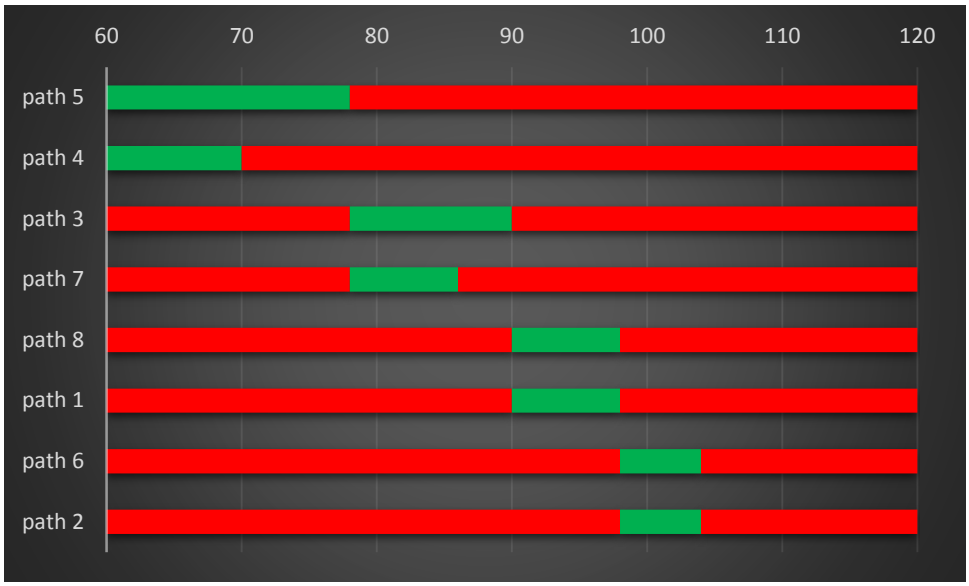


Figure III.9: system scheduling for cycle 2(60 – 120 seconds)

Cycle 3:

Table III.10: scheduling for Cycle 3(120-180 seconds)

Main path	7	5	4	2
Second path	6	1	8	3
Releasing vehicles	120	138	156	168
Second path stop	128	150	160	172
Main path stop	138	156	168	172

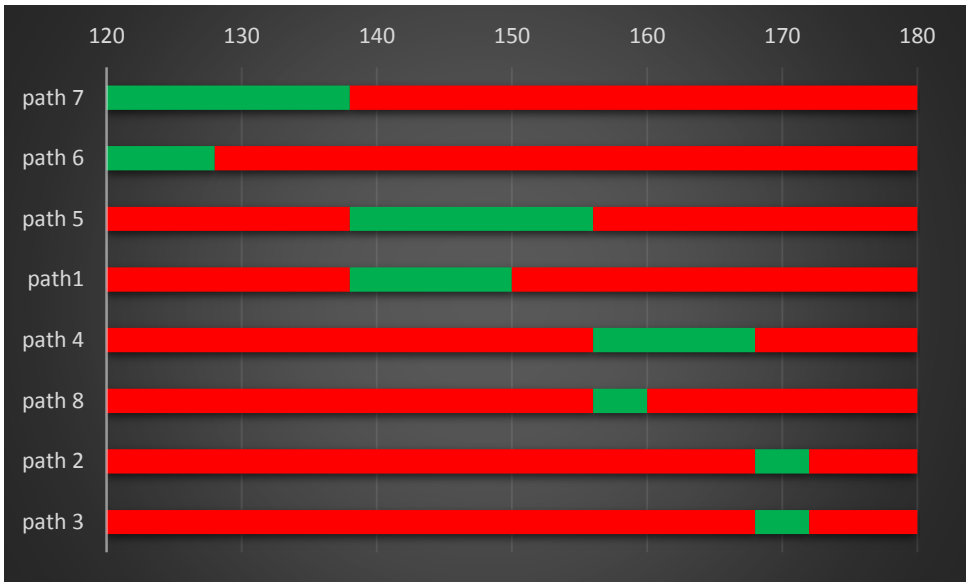


Figure III.10: system scheduling for cycle (120 – 180 seconds)

XIV. Project implementation:

The project aim is to implement the system in a microcontroller (Arduino) and control the traffic light, so we made a prototype of a crossroad as shown in the figure III.10.

The prototype is tested with 3600 vehicles/h as traffic flow and DT = 120 seconds and MV = 15 vehicles, the results is in TableIII.24 below shows that Path 7 has the ultimate priority in this cycle and release its vehicles with path 3 which is chosen from 3 deferent paths that can release vehicles in parallel with path 7 as Figure III.11 shows, Figure III.12 and Figure III.13 and Figure III.14 shows the next phases 2 and 3 and 4 successively in the end of the cycle all red goes on.

Table III.11: results of the implementation

Phase	1	2	3	4
Main path	7	5	1	8
Second path	3	6	2	4
Releasing vehicles	0	30	60	88
Second path stop	30	60	74	96
Main path stop	30	60	88	102

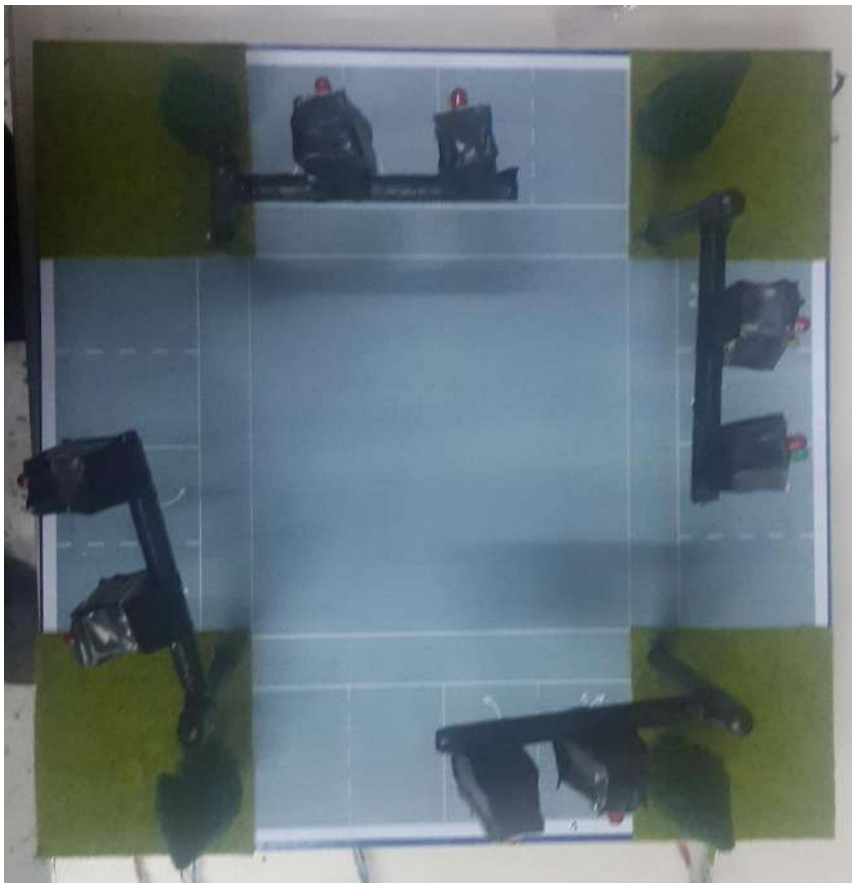


Figure III.11: Test on real prototype.

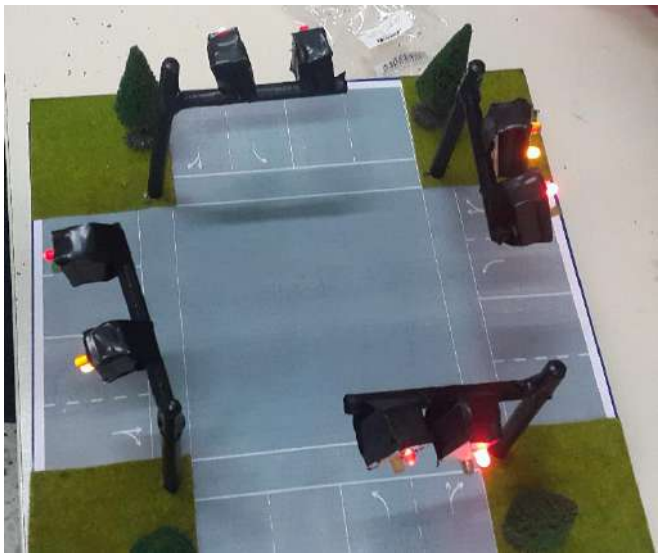


Figure III.12: Phase 1.

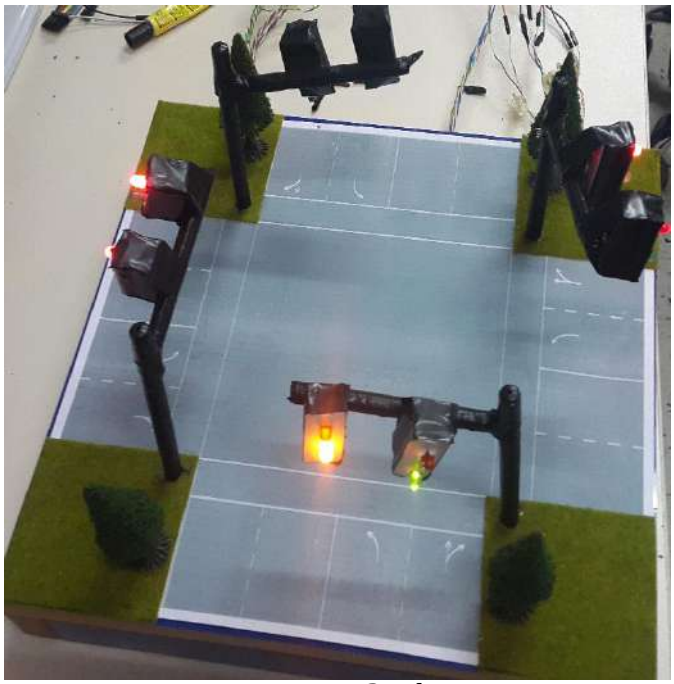


Figure III13: Phase 2.



Figure III.14: Phase 3.

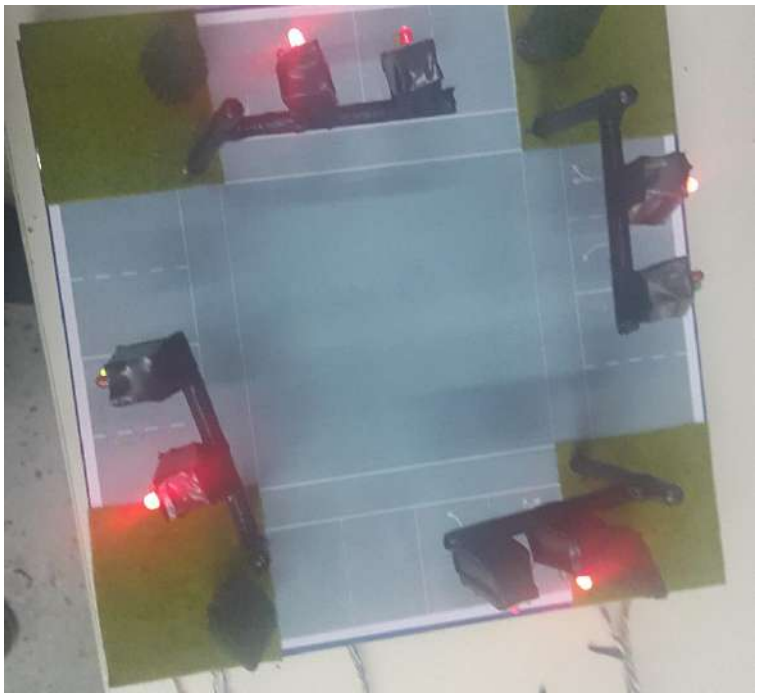


Figure III.15: Phase 4.

XV. Conclusion

At the end and after many tests, we can say that multi-agent system is a successful system to control traffic light because the results of the waiting time were good when we compare them with classical traffic light control algorithm.

General conclusion

In order to do so, a theoretical study on traffic lights and their management was necessary. we trait the main problem of traffic congestion and make it a problem of waiting time optimization, after the many tests of the system we can say that multi-agent system is a succeful system to control traffic light.

This work did not happen without difficulty. Indeed, it was necessary to take knowledge of the study of the various fields which are the subject of the present work:

- Road traffic control.
- Multi-Agent system.
- Adapt the multi-agent system to the problem of road traffic control.
- Implementation of Multi-Agent System on Arduino.
- Generation of vehicle flows at an intersection.
- Simulation of vehicle movement at an intersection.

to make sure that the system is showing the right results, a comparison has to be done with interval time algorithm and the compare done for high traffic flow and the results were positive for multi-agent system.

The adoption of our solution has many advantages, the most important of which are listed below:

- Reduced traffic.
- Reduction of the CO2 emission rate.
- Arrangement of more comfort for the driver.
- Modularity of the designed system can be applied to any other intersection.

in the end we are so confident of the system capability and being a potential candidate solution for traffic light control and real life implementation of the system on road networks can be and hopefully expected in the near future.

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