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Traffic management using Image Processing

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Abstract— *Conventional methods of traffic light systems are unable to deal with the ongoing issues surrounding congestion. The current traffic light models are not suited to tackle problems such as traffic jams, ease of access for emergency vehicles and prevention of accidents. In order to counteract these issues, we propose the 'Smart traffic light control system'. The adopted Traffic Light Controllers (TLC) in Gaza, are based on microcontroller and microprocessor. These TLCs have limitations because they use the pre-defined hardware, which is functioning according to the program that does not have the flexibility of modification on real time basis. Due to the fixed time intervals of green, orange and red signals the waiting time is more and car uses more fuel. The intended project will focus on two aspects of implementation. First and foremost, to make traffic light controlling more efficient, image processing alongside with embedded system, will be used. This system will intelligently decide when to alternate signals based on the total traffic on each road detected by cameras on each lane which will increase road capacity and traffic flow. Secondly, the minor component consists of the ability to control the traffic signals by an android application throughout the Bluetooth and wireless connection. This will be controlled by the traffic warden or police officer. The prototype of the system has been built and tested. The model is better than the current system which is limited to the Fixed Mode Traffic Light Controller. It is observed that the proposed smart Traffic Light Controller is more efficient than the conventional controller in respect of less waiting time, more distance travelled by average vehicles and efficient operation during emergency mode.*

Keywords— smart traffic lights, embedded system, Arduino applications, image processing.

I. INTRODUCTION

Gaza Strip is one of the most densely populated regions in the whole world. More than two million people live in a small strip of land. Therefore, most parts of Gaza city are badly affected by huge traffic jam with increasing number of existing vehicles.Aged traffic signaling systems, insufficient police manpower, limited road spaces and bad driving habits create pro-longed traffic congestions. Traffic jam has a negative impact on economy, causes serious air pollution, and noise pollution and thus worsens the overall environmental conditions. To reduce traffic jam, a proper smart signaling systems is critically needed to be developed and installed. Under ordinary conditions, the used conventional traffic control signals in Gaza mainly have two defects whereby time slots are fixed and the controller is unable to detect emergency vehicles approaching.This project is a simple, low-cost, and real time smart traffic light control (STLC) system which is based on AT mega (Atmel in the megaAVR family) microcontroller installed on Arduino to control the various operations.

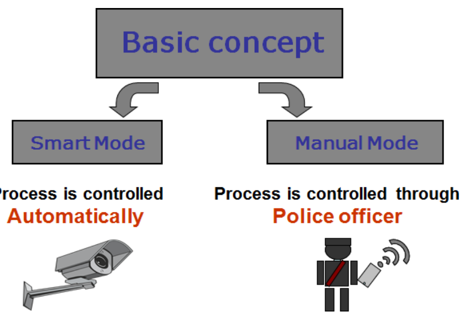

Fig. 1. Basic concept of smart traffic light.

Fig. 1 illustrates the basic concept of the STLC where the time is set automatically according to the number of detected cars via processing captured images through the installed cameras. Furthermore, an android application communicates wirelessly with the traffic controller where the warden can control the process semi-automatically in cases of emergency or any other situations where the field police officer decides to interrupt the process.

Fig. 2 demonstrates the system block diagram and its components, where the main controller combines all the system together. The Liquid Crystal Display (LCD) is an interface to select the required mode for which the main controller will work on. The input data will be received according to the selected mode from either the laptop digitally to describe the level of congestion or from the android application according to the warden choice.

The output signals will be applied to two different lanes modules, directly to a Direct current (DC) lane and the other way will be to an Alternating current (AC) driver which will drive the AC lane.

The modern systems adopt DC LEDs while the old ones use AC lamps. In our system we considered both AC and DC lanes to prove compatibility with old systems and scalability to the modern ones.

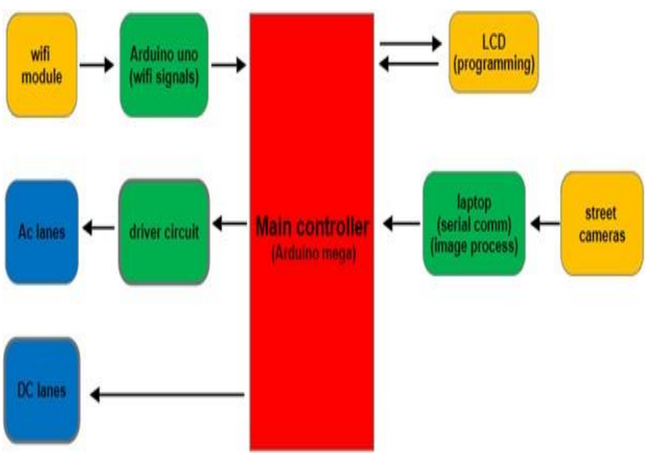

Fig. 2. Block diagram of the project.

This paper will discuss the limitations of current conventional system and proposes two techniques to reduce traffic jams. Then we will briefly look at previous research undertaken to tackle the traffic jams. Next we will demonstrate how we implemented and built a prototype. Finally, a discussion about the results will be viewed and summarized, with future developments.

There have been recent developments within the smart traffic control field [1-3]. The intelligent traffic control system developed in [4] enables more internal memory compared to old microcontrollers with little flexibility to allow modification in real-time. The new systems ensure detection of traffic volumes using genetic algorithm and the ability to detect vehicles such as ambulances simply through the use of a wireless network .

Another project conducted was the Prototype of Virtual Traffic Lights on Android Based Systems [5]. This project used the proliferation of Wi-Fi devices with the already available hardware components. The Virtual Traffic Lights (VTL) again alleviates traffic with vehicle to vehicle communication. Through the implementation of this, traffic was reduced by 60% .

Digital wave radar technology the Wavetronix smart sensor is used in [6] another method to detect the vehicles presence speed with a detecting range of 500 m. The sensor is mounted on a traffic signal head mast arm. Manufacturer claims its immunity to weather and changing temperature and light conditions and little or no maintenance requirements. One of its unique features is its auto-configuration and operation software developed for Pocket handheld devices and laptop computers.Haimeng Zhao, Xifeng Zheng, and Weiya Liu in [7] designed an intelligent traffic control system using a DSP and Nios II. Their model utilises dual-CPU with the logic control of FPGA (Field Programmable Gate Array), enabling cross-phase adjustment, the exchange of related information, and allowing live human-computer interaction. It is different from conventional traffic signal controllers in that it works dynamically, according to user demand as well as mode of timing and multiple phase functionalities. Based on the literature review, there are the two suitable techniques for smart detection of vehicles. These are the use of smart sensors and the image processing algorithms.In conclusion, we went for implementing the image processing code due to many reasons. Hardware components are very hard to be imported to Gaza strip due to political reasons and become highly restricted after the siege has been imposed since 2008. Most importantly availability, feasibility of local implementation and the ease of use.

This paper is organized as follows. In Section II, the description of the introduced system is provided. The Aim and Research objectives is introduced in Section III. Section IV demonstrates all the materials that have been used through building the prototype with the specification of each components Finally, the methodology and steps that have been taken to reach the final results are reported in Section V, and the conclusions are given in Section VI.

II. AIM AND RESEARCH OBJECTIVES.

The final aim of our research is to implement our prototype project in real-life scenarios. This can improve the movement on pedestrian roads, and it will reduce the traffic jam. Moreover, it can be easily fitted with the ambitious aim of building a centralized station where through it can control the Gaza traffic process.

Our current objectives as follows: the first thing is to show how the prototype will reduce the amount of cars waiting time. Furthermore, we aim to enable an easy passage for emergency purposes and to help the police officer to focus on other tasks other than changing the lanes direction.

III. MATERIALS.

STLC is a combination between codes, electronic modules and electronic circuits in order to obtain improvements on the conventional traffic lights. The core of the prototype is the Arduino which is a universal open source electronic board primarily developed for educational purposes. In simple terms, you can control and build anything with Arduino [8].

Two modules have been used, an Arduino Mega type as the system primary controller. It has been chosen because of its high specifications. These include a 54-digital input-output pins of which 14 can be used as PWM (pulse width modulation), a 16 MHz crystal oscillator, a USB (universal serial bus) connection, and a power jack. Mega is compatible with most shields designed for the Arduino [9].

The other module was Arduino Uno. It has been used as a method to connect the wireless and Bluetooth modules in order to get the collected data which is going to be processed by the primary controller. The Uno has 14 digital input- output pins of which 6 can be used as PWM outputs. analogue inputs, a 16 MHz quartz crystal, a USB connection, and finally a power jack [10].

Moreover an AC (Alternating Current) driver have been designed for the purpose of controlling the AC lane as shown in Fig. 3.

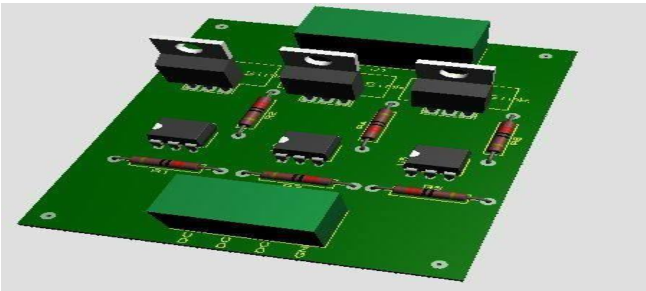

Fig. 3. AC voltage driver.

A Bluetooth module with HC-05 model was selected in which it will obtain a wireless connection and transfer the data from and to the microcontroller, the module has 3 Mbps Modulation with complete 2.4 GHz radio transceiver and baseband. It uses CSR Blue core 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It has a small size as small as 12.7 mm × 27 mm.

The module sensitivity typically -80 dBm and the radio frequency transmit power is up to +4 dBm. Moreover, it operates with a low power ranges from 1.8 to 3.6 V(DC) with an integrated antenna [11].

Finally, an LCD (liquid crystal display) Keypad shield was built to monitor and change the system status and settings. Moreover there were minor components such as leds resistors, LCD, push buttons, wires, and power supplies.

I. METHEDOLOGY

In this part, we discuss all the steps of project design and implementation, including the software and hardware design. The details of each object will be demonstrated and discussed.

The design process went through many steps, which are divided into two main routes: software design and hardware implementation. The software design started by drawing the program flow chart and writing the code that suits it. The next step was designing the circuit diagram and building it on a simulator. The last step was testing and measuring the input and output functionality and efficiency. On the other hand, the hardware design started by designing and building the wood board, controller system circuits and the traffic system lanes. The final step was to paint the board and to place all the components on it.

According to the requirements of the project idea the software was divided into three main programs. Each one of them was installed in a different device and as a result the programs should be compatible with each other. The first is the main program which processes all the data that is collected from the other two programs and then to set the output according the input data.

The program starts with the set point and all the traffic system lanes will be set to red. The next stage is the category selection which operates manually by using the LCD screen.It consists of four sub-categories divided into conventional system, smart system, WiFi system, and standby system.

If the conventional system was chosen to operate, its functionality will be the same as the local current traffic light system. The red, yellow, and green colors operate with fixed time delay, and by sequential order.

In comparison to the conventional mode, the smart mode has more intelligent features among them. The mode decides automatically the time interval for each lane. The decision is based mainly on the number of cars approaching the junction. An image processing code with installed cameras on the junction are needed for this approach. The cameras will detect all the cars on the lanes and the code on laptop will read the number of cars on each road. As a result, the controller decides a time that proportional to the number of waiting cars to pass.

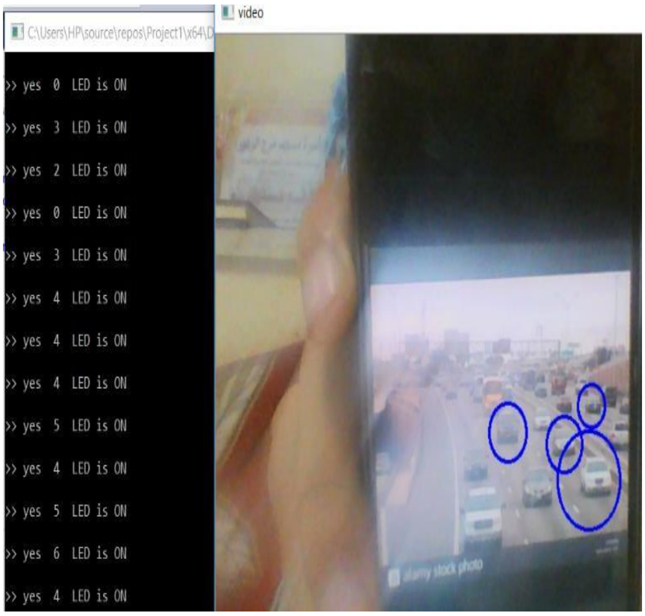

Fig. 4: Car detection experiment.

Throughout the implementation we have used OpenCV library alongside with C++environment. Intel introduced OpenCV library as a free and open source for the purposes of real time image processing manipulation.

The library contains more than 2500 algorithms such as face detection, identify certain shapes and objects, detection of body movements and tracking purposes. The library supports many environments such as C++, Python, Java and MATLAB interfaces and supports Windows, Linux, Android and Mac OS [12].

As seen in Fig. 4, the C++ code was mainly used to detect the number of cars and then transfer the decision to the Arduino mega whereby the Arduino is responsible for setting the access time for each lane. Throughout the testing, we have considered three stages of congestion at each lane: low, medium, and high. If the Arduino received a low level of congestion signal from the laptop it then sets the time for the greenlight to 10 seconds. Whereas, if it detects medium it sets the time to 25 seconds and 50 seconds for high congestion.Moreover, the Wi-Fi mode will function manually by an android interface. This enables the police man to choose which lane to open or close. The interface simulates the lanes and by pressing on any one of them a character will be sent to the receiver. According to the type of character the lanes will open and close as illustrated in Table-1 .

TABLE I.CHARACTER FUNCTION BOOK

Manual function		
Number	***Char acter***	***Function***
1	A	Lane 1 is on
2	B	Lane 2 is on
3	C	Lane 3 is on
4	D	Lane 4 is on

The connection between the mobile and the system was established by interfacing the H-05 with the Arduino. The control process is done by an android application that have been programmed.

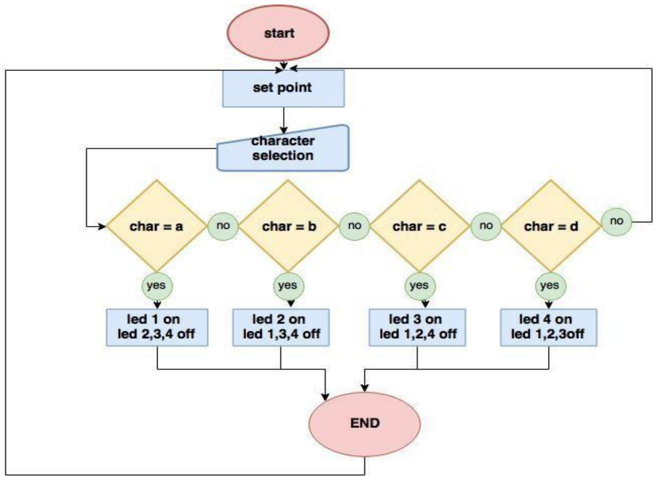

Fig. 5. Arduino Uno code.

The last category was the standby system which turns off all the lanes and turns on the yellow blinking which indicates that there is no traffic and no need to operate the system. The main controller program will be installed in the Arduino Mega.

Fig. 5 demonstrates a flowchart of a minor code to detect the signal received from the Bluetooth data and transfer the data into a digital signal. The digital signal will be sent to the main controller and according to the signal a set of functions will be applied as it was mentioned above in the Wi-Fi mode. Fig. 6 is the Bluetooth Android application which was built and coded on the IMT APP Inventor. The interface consists of Bluetooth status, lanes status, and the cross road with lanes. The lanes are the buttons to send the needed data over the Bluetooth. Each lane has a unique character and according to its value, the lanes will be opened or closed.

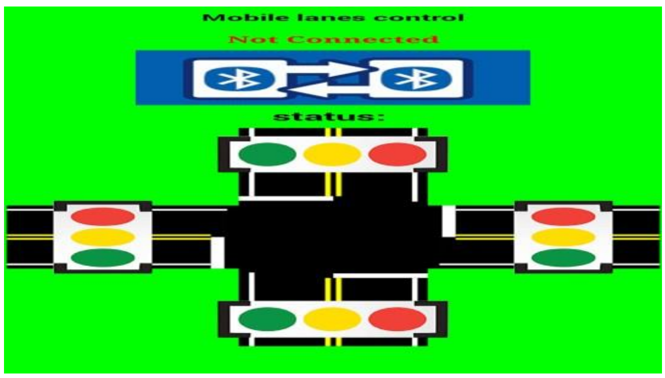

Fig. 6. Bluetooth Android application.

In order to detect a number of standby cars, we built a code on visual studio by using the image processing algorithm alongside with the OpenCV. The code will run inside the PC and the camera will detect the cars and according to the number of cars the PC will send a serial data to the Arduino. The Arduino will set the time of green light according to the car numbers. So as to implement this project, there was a need to build a prototype which simulates one of the most important junctions in Gaza city which is known as Al-Saraya. The prototype will enable us to test the codes and to present the final results.

The hardware design went through three steps which are the wood board design, lanes design, placing all the components together. The wood board in Fig. 7 went through many fabrication processes to meet the requirements of the design. First of all the design was drawn in Corel ID program and implemented on a CNC machine to extract the unneeded parts. The next step was polishing and painting the wood board to get exactly the same look as a real cross junction. Finally, the board was decorated to make the same appearance as close as possible to reality.

Fig. 7. wood board design.

We designed a traffic lane for the purpose of presenting our project results as shown in Fig. 8. The design consists of a bread board, three colored leds, and resistors. The three leds were installed to represent the traffic lights from the codes.

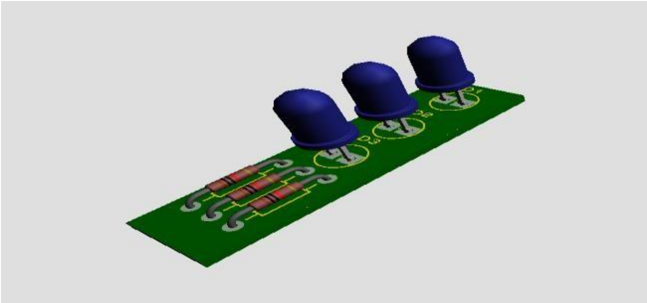

Fig. 8. lanes design.

II. PROJECT SCOPE AND CONCLUSION

The STLC smart features implemented successfully such as the camera can detect the number of cars in each road and due to that, the timing of each lane is variable according to it. The android app functionality were established and tested and the results were as designed. The final prototype is shown in Fig. 9.

It is observed that the proposed smart Traffic Light Controller is more efficient than the conventional controller in respect of less waiting time is, more distance travelled by average vehicles and efficient operation during emergency mode as shown in Table-2 and Table-3.

TABLE II. MAJOR DIFFERENCES BETWEEN THE TWO SYSTEMS

Results		
Feature	***STLC***	***Conventio nal TLC***
Waiting Time	Varia ble	Fixed
Manual Control	Flexi ble	Fixed
Architcture	Simp le	More Complex

Future Expansion	Yes	NO
Emergency Mode	Yes	NO

The test was implemented using a recorded video of a traffic junction by presenting it in front of the mounted cameras. The results are shown in Table 3.

TABLE III. Test results.

Round number	Lane	No. of cars detected	Result
Round 1	L2	6 cars detected by camera	output time green light=10 secs
	L4	13 cars detected by camera	output time green light=25 secs
Round 2	L2	32 cars detected by camera	output time green light=50 secs
	L4	8 cars detected by camera	output time green light=10 secs

The efficient role to determine and evaluate a project is its ability to include future expansion. The STLC has many technological features that enable us to install any new development or upgrades.

The STLC is the building block for the future developments. The future development of the project include an ambitious of constructing a centralized station to monitor and control the traffic in Gaza which the STLC can be a part of it. Moreover, we will improve the image code to be not just for detecting vehicles but for more purposes like reading the plate number, writing bills on cars passing through the red signal etc. Although we developed a fully operating prototype, in order to map this into a real life setting there would be certain challenges that we would need to overcome.

Through the commercialization of technology and replacement of conventional traffic lights, road safety would be enhanced with reduced collisions. However, having said this there may be instances where accidents on the road occur. As a result, negligence of the traffic light system may be blamed for being the cause of the accident. This could jeopardize future developments and adoption of the STLC. This could be tackled by having regular maintenance of the new system whereby faults are detected and resolved as well as various testing conducting on multiple areas. In the case of an accident, the situation will need to be investigated and the due to vigorous testing before the STLC is installed, liability will not lie with us.

Fig. 9. Prototype final result

I. CONCLUSION

In conclusion, we observed that the conventional traffic light systems were unable to efficiently deal with the variable flows of traffic. This often leads to a buildup of congestion and accidents. Furthermore with the increases in the population in Gaza, it is expected that the problems with the conventional traffic lights will worsen. The new STLC system will cater for traffic flows in various areas in Gaza and more specifically will be able to detect the number of cars in each lane and simultaneously respond to the changes.

Our prototype successfully operated using image processing and embedded system. It was clear that traffic congestion can be reduced and there will be less delays in real waiting time. Furthermore the system is more consistent in detecting vehicle presence because it used actual traffic images. It visualized the reality so it functioned much better than those systems that rely on the detection of the vehicles' metal content. The proposed system was able manage traffic at a particular unction, dedicating longer periods for the green light where there are more cars in one lane than the other. Furthermore the system is complemented with the android system whereby the policeman and warden were able to effectively to monitor the traffic in lanes.

For future development, further testing would need to be considered for various areas within the city. The design can be promoted and improved through maintenance measures as well failure modes. Data could be collected based on traffic flows and system performance. This data could then be analyzed as to which areas require more attention than others such as which areas have the heaviest congestion and accidents.

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