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UofKEJ Vol. 8 Issue 1 pp. 44-49 (February 2018)

UNIVERSITY OF KHARTOUM ENGINEERING JOURNAL (UofKEJ)

Vehicle to Infrastructure Communication for Dynamic Navigation Application

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Abstract: Nowadays, traffic congestion is a serious problem; it wastes people's time, increases collision rate, delays emergency and contributes in environment pollution. This paper aims to reduce these effects and enhance road traffic infrastructure by using video cameras to monitor the streets, the video is processed to estimate traffic density then traffic status stored in web database and updated continuously. Users can easily install the developed android application, indicate their destination and in time, three optimum routes based on the traffic volume are shown on the map. This technique was shown to be an effective way in reducing traffic congestion and enhancing roads traffic.

Keywords: *traffic density, ITS (V2I), MatLab, computer vision, MySQL database, android*

1. INTRODUCTION

People started to travel more frequently due to the rapid development of the world. They need to reach their destinations in the minimum time, safe and in efficient way.

High traffic density wastes time and causes delays hence late arrival of emergency vehicles and late arrival to the workplace, meetings and education institutes which adversely affects the economy. As a matter of fact, traffic congestions according to the World Bank study in 2010 costs Egypt $8 billion annually and Kenya lost 37 billion shillings in 2014 [1]. Gridlocks cost the United States, France, Germany and the United Kingdom $200.7 billion in 2013, which is expected to increase to $293.1 billion by 2030 making the total cumulative costs $4.4 trillion over the 17 year for these nations [2]. Traffic congestion leads to road accidents which are responsible of 1.25 million deaths in the world each year beside injuries [3]. Traffic jams reduces the efficiency of transportation infrastructure, increases fuel consumption and air pollution.

The concept of Intelligent Transportation Systems (ITS) was first announced in "City of Tomorrow" exhibit at the 1939 World's Fair in New York [4] and defined as integrated applications of the advanced technologies of electronics, computers, communications and sensors, used to establish an advanced information and telecommunication networks for users, roads and vehicles, as illustrated in figure 1, in order to provide travelers with important real-time information while improving the safety and efficiency of the transportation.

Later the Institute of Electrical and Electronic Engineers (IEEE) defined ITS as:

Those systems utilizing synergistic technologies and systems engineering concepts to develop and improve transportation systems of all kinds" [5].

Fig. 1: Intelligent Transportation Systems Integration

2. LITERATURE REVIEW

Many researchers work on traffic monitoring, inductive loop detectors are used to manage traffic and detect incidents [6], a real-time traffic monitoring based on similarity between signals coming from magnetic sensors on roads and a reference signal is deployed in [7]. However, major drawbacks are related to inductive loop and magnetic sensor detection such as destruction of road pavement for installation and maintenance hence gridlocks due to lane closure, limited spatial sensing, and stopped vehicles are not detected via magnetic sensors and both methods are inappropriate for wide deployment. Expert system to control traffic lights, road intersections and traffic density are simulated thus the system is not a real-time processing of traffic flow, [8].

Managing traffic lights at intersections can enhance navigation, minimize heavy traffic and helps in finding optimum routes. Since motion tracking is one of the active research topics in computer vision, [9] proposed a system which controls traffic light state by image processing using edge detection technique. [10] Deployed an intelligent timing mechanism to control traffic lights state based on Gaussian mixture model. [11] Controlled traffic lights at intersections based on background subtraction image processing for non-real traffic and fuzzy logic functions to make timing decisions. [12] Proposed a system that calculates the traffic flow rate and vehicles speed by processing real-time video images then traffic condition is displayed on the front roadways. [13] Proposed an algorithm based on background subtraction to classify and count vehicles and calculate traffic density in real-time. Subsequently, vehicles detection for intersections management is introduced without storing and broadcasting the analyzed data for trips planning.

The data thus obtained can be stored and used in the next stage to maximize its benefit. [14] Provided a method for finding optimal routes, adaptive difference method is applied on video images to detect motion then traffic density is analyzed to obtain optimal routes on online portals using geographical information system.

Google Maps is a navigation application running on smart devices which predicts traffic status. Traffic flow is estimated by accessing users' locations, aggregating the data in servers and reporting it back. Consequently, traffic conditions given by Google Maps are approximate; it need all drivers to enable their location to be accessed by the application so it can predict an accurate traffic data, the more people use the application the more accurate the traffic data. Furthermore, people don't feel comfortable with Google monitoring their every move thus they disable location access service which result in inaccurate traffic density [15] [16].

This paper adopted the Vehicle to Infrastructure (V2I) communication branch from the Intelligent Transportation Systems (ITS) concept which bases on data exchange between vehicle on board unit or device (e.g. cellular devices) with some infrastructure (e.g. database) over wireless network, to issue advisories and warnings for drivers about the instantaneous traffic conditions. The road traffic data is obtained from analyzing real-time traffic flow videos since the road networks are already monitored by video based systems.

3. METHOD

A design based methodology was employed with three main phases: the road traffic analysis, the web database and finally the user interface application, figure 2 shows the model's design. As a case study, 29 seconds road traffic video of ElArda Street, Omdurman, Sudan (240×320) 29.9 fps had been analyzed using MatLab simulink to estimate the traffic volume which is stored in MySQL database with the aid of MySQL open database connectivity then hosted in the web. The user interface application was an android simple map application built by using Eclipse open source platform and connected to the web database for illustrating the three optimum routes for the user desired destination based on two factors; the traffic density and the distance.

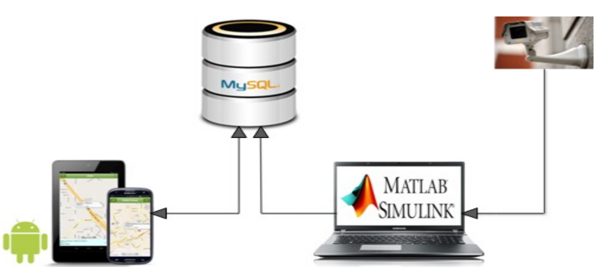

Fig. 2: Model Design.

A. Phase 1: Road Traffic Analysis

Mat Lab simulink model was designed to detect and track cars in the video sequence using background estimation method.

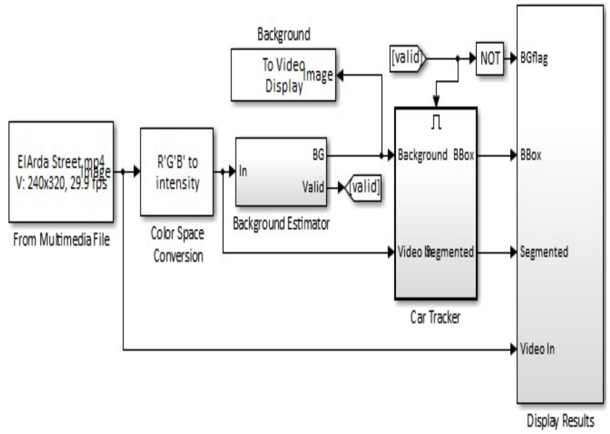

Fig. 3: Simulink Model for Tracking Cars Using Background Estimation.

In the beginning, low resolution colored video captured and applied to the model in figure 3, then the video converted to gray level for reducing file size and the background estimated using the median filter method. The determined background pixels were subtracted from the whole video frames, thus the remaining pixels are foreground (cars) pixels. Auto threshold process applied on foreground frames to convert them to binary frames using Otsu's Method and a morphological closing was done for removing noise. Blob analysis was performed on the thresholded frames for determining the cars regions and with the aid of some simulink blocks the count shown on the top left corner of the display.

The video was processed according to computer vision steps, as follows:

1) Image Enhancement: Original images are processed to be enhanced and more appropriate for a certain application. Image enhancement is based on direct manipulation of pixels in an image, the input image $f(x, y)$ is processed via operator T over some neighborhood of (x,y) resulting $g(x, y)$ as shown by the equation:

$$G(x, y) = T[f(x, y)] \quad (1)$$

When the neighborhood is a single pixel (i.e. 1×1) T becomes a gray level intensity since g depends only on the value of f at (x, y) and the equation become:

$$s = T(r) \quad (2)$$

where, at any point (x, y) r is the gray level of $f(x, y)$ and s is the gray level of $g(x, y)$ [17].

2) Otsu's Segmentation Method: In computer vision image segmentation is used to divide digital image into multiple segments (sets of pixels). Otsu's method converts gray level images into binary images based on cluster thresholding. Gray level image is segmented to two pixel classes (background pixels and foreground pixels) and an optimum threshold is calculated to separate the two classes (i.e. the pixels that either fall in foreground or background) so that their combined spread (i.e. intra-class or within-class variance σ_w) is minimal [18]:

$$\sigma_w^2 = w_b(t)\,\sigma_b^2(t) + w_f(t)\,\sigma_f^2(t) \quad (3)$$

$$w_b(t) = \sum_{i=0}^{t} p(i) \quad (4)$$

$$\mu_b(t) = \frac{\sum_{i=0}^{t} i\,p(i)}{\sum_{i=0}^{t} p_{w_b}} \quad (5)$$

where, w_b background weight, σ_b background variance, μ_b background mean and p_{wb} background weight probability. The foreground weight w_f and the foreground variance σ_f A fast approach for calculation is to maximize the between-class variance σ_B:

$$\sigma_B^2(t) = \sigma^2 - \sigma_w^2(t) \quad (6)$$

$$= w_f(t)w_b(t)[\mu_f(t) - \mu_b(t)]^2 \quad (7)$$

where σ is the total variance and μ_f the foreground mean [18].

3) *Motion Estimation:* Is a low level task in computer vision tend to detect moving objects in a sequence of images, it is widely used in traffic monitoring, video surveillance and sign language recognition. Background subtraction is used when the camera is stationary, two scenes are detected, a static scene referred to as background the other scene with moving objects denoted as foreground which is built after comparing every frame of video to background frame in order to distinguish the regions of motion [19].

For applying the background subtraction on a video using the mean filter (median filter) method, a series of preceding images are averaged to calculate an image containing only the background. At the instant *t* the background image is given by:

$$B(x,y) = \frac{1}{N}\sum_{i=1}^{N} V(x,y,t-i) \quad (8)$$

where *N* is the average number of images in progress, it depends on the video speed and the amount of movement in the video [20].

The foreground is obtained by subtracting the background *B(x,y)* from the image *V(x, y, t)* at time *t* and given by:

$$|V(x,y,t) - B(x,y)| > Th \quad (9)$$

where *T h* is threshold.

B. Phase 2: MySQL Database

The database was uploaded using Wamp server for testing locally, figure 4, after that it has been uploaded to Hostinger hosting website. The created database was connected to MatLab and an user interface application.

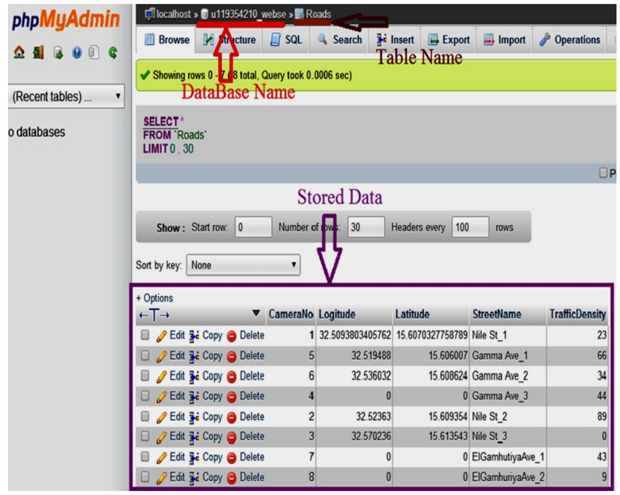

Fig. 4: Database Information.

C. Phase 3: User Interface Application

The user interface application is basically an android simple map application built with Eclipse open source platform and connected to the web database for illustrating the three optimum routes for the user desired destination based on navigation time and the instantaneous traffic status by the formula:

$$T = T_0 \times \left[\frac{Traffic\ Density}{100}\right] + T_0 \quad (10)$$

Google developers provide detailed maps that could be modified according to the required purpose. Another feature provided by Google developers is the ability of giving the directions between two locations or more. The first location could be called origin and the others called destinations. The contact between the map application and the Google maps server is established through the following command line:

https://maps.googleapis.com/maps/api/directions/outputForm at? parameters", on this command two parameters should be specified, the form of output which could be in JSON form or Extensible Markup Language (XML) form and the parameters needed in the application such as number of routes.

4. RESULTS & DISCUSSION

A. Phase 1: Road Traffic Analysis

Traffic status is obtained from 29 seconds video of ElArda Street and figure 5 shows the original captured video frame before processing. Comparison between video frames is done to estimate the reference background (i.e. unchanged themes, shown in figure 6) and then subtracted from the entire video frames and Otsu thresholding is applied to obtain the moving objects (i.e. vehicles) as illustrated in figure 7. In figure 8 the count of vehicles present in video frame is displayed on top left corner.

Fig. 5: The Original Video Frame.

Fig. 6: The Estimated Background.

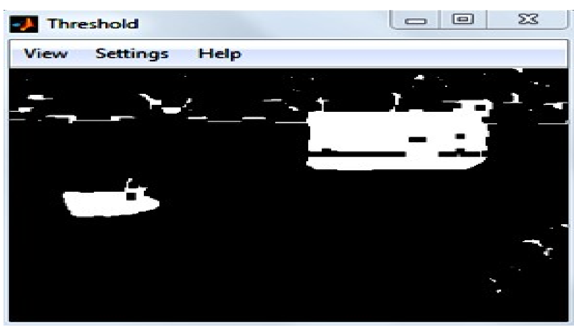

Fig. 7. Video Frame After Autothresholding.

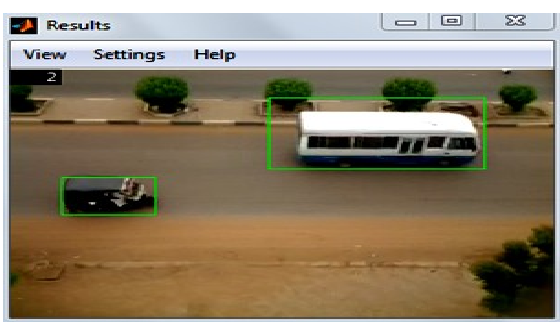

Fig. 8. Count on Top Left Corner of The Display.

B. *Phase 2: MySQL Database*

Traffic data is then stored on MySQL database. Figure 9 & 10 show that the connection between the two applications is succeeded. Figure 11 illustrates that the android application accesses and retrieves the database information correctly.

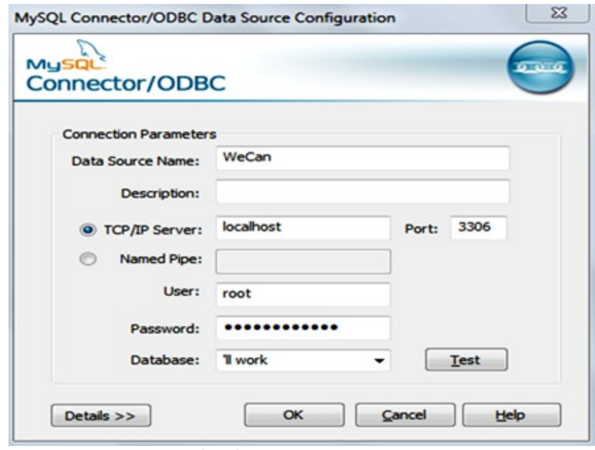

Fig. 9: MySQL Connector.

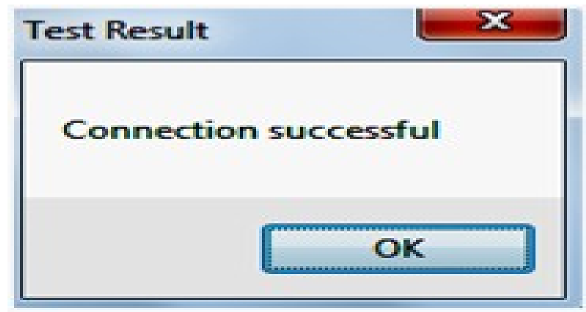

Fig. 10: Success Message.

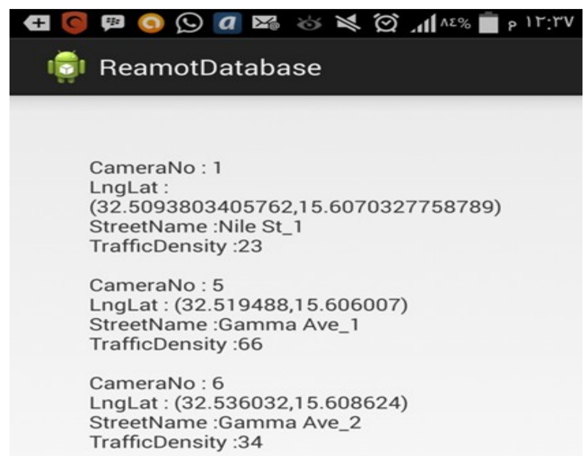

Fig. 11. Successful DB retrieval by Android App.

C. *Phase 3: User Interface Application*

When the application, Best Way, is started, it asks the user to define the origin and the destination (it is also provided with a button to go directly to current location) as shown in figure 12 & 13. After locating the origin and destination, the application exchanges information with the database to figure out three optimum routes based on two factors: the traffic density and navigation duration, routes will appear on map according to its optimality colored green, yellow and red as illustrated in figure 14.

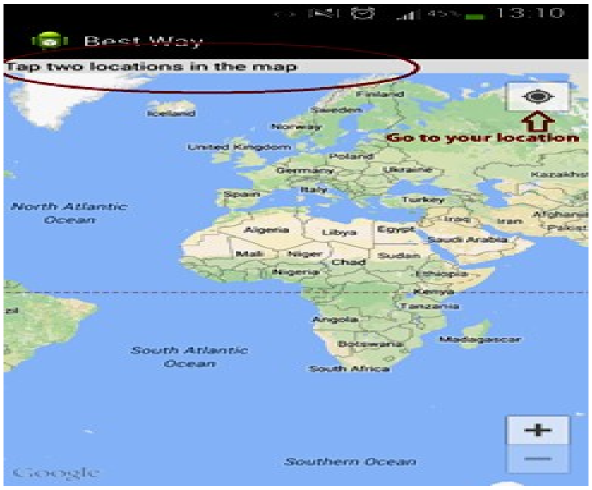

Fig. 12. Map Main Screen.

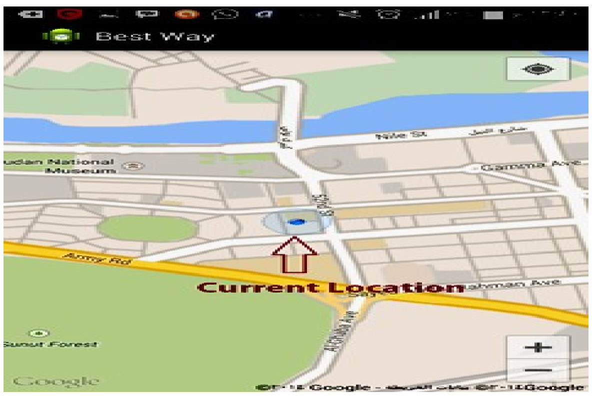

Fig. 13. Current Location.

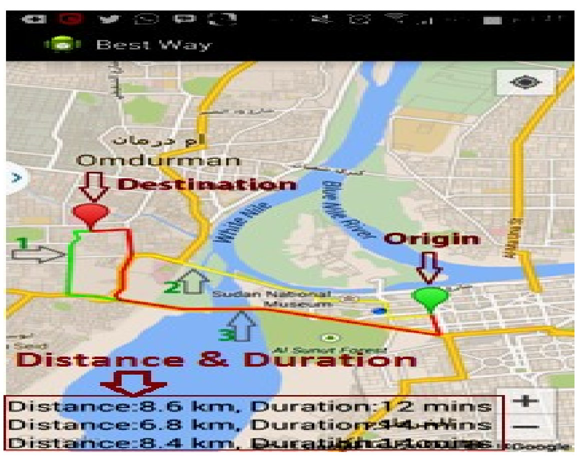

Fig. 14. Routes.

5. CONCLUSIONS

The proposed vehicle navigation system, with the road sensors and the traffic density volume database, generates efficient routes and adapts routes dynamically based on current conditions of the street which resulted in enhancing transportation infrastructure hence reducing traffic density, time wasted in journeys, fuel consumption thus minimizing environmental pollution. Due to the decreasing cost of navigation systems; intelligent transportation systems will start to appear in developing countries.

For better existence, the system needs to:

- Perform more security checks on the database.
- Predict traffic density volume in different days and times times; so that users can pre-manage their trips.
- Indicate accidents and send warnings to drivers, alerts for emergency centers.
- Develop the mobile application to work on all mobile operating systems.

6. ACKNOWLEDGMENT

The authors would like to acknowledge the enthusiastic help of Engineer Anas Mohamed Hassan and Engineer AbdElfatah ElKhalefa AbdElate during this work.

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