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Vehicular communication using Optical Wireless Communication System

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***Abstract*— Optical wireless communication is a very popular area having various applications. In this paper automotive application of optical wireless communication is taken into consideration. We have generated the GUI for simulating this system which includes preprocessing, feature extraction, selecting area of interest and data extraction. Basically we are considering the visible light communication for this automotive application which will be using LEDs in the vehicle and the camera as a receiver which is mounted on the vehicle. Lane change indication, vehicle to road infrastructure and vehicle to vehicle communication are the major applications of this system.**

***Index Terms*— Optical wireless communication, Visible light communication, Light emitting diodes (LED), communication pixel.**

I. Introduction

Vehicular communication is the major area of interest for many researchers since to reduce the accidents causing because of lack of information in lane departures or the driving speeds etc. Thus the design of optical wireless communication for vehicle communication is the important task. It has been more than 30 years since optical wireless (OW) was proposed as an alternative broadband technology for wireless data transmission applications.Optical wireless communication (OWC) is being a viable candidate to cope up with the demand of the recent scenario in the communication fields. The OWC systems have several advantages over the traditional radio frequency communication systems like high data rates.

Visible light communication (VLC) is another part of optical wireless communication which includes the use of LEDs for transmission of the information and the light sensing diodes like Pin-diode for reception of that information. Harald Haas a German physicist from University of Edinburgh, UK invented the VLC. VLC uses the visible light spectrum (between 400 THz to 790 THz) as the communication medium.The concept of VLC is being used today in various applications like VIDAS is becoming more popular because of which the traffic problems and accident cases will reduce by remarkable scale. Similar to it the visible light communication is used in marine applications and also in the defence area for high security communication. It has many applications indoor and outdoor lighting. VLC uses the LEDs for transmitting the light. Both white and colour LEDs are used in VLC. Here LEDs play dual role one is illumination and other one is to transmit a data. VLC is two way communication uses light as a medium. The photons of LED are used to carry the information. LEDs are intentionally used in VLC because of several advantages like low cost, small size, fast switching capacity, etc. The visible light communication is nothing but the modulation of an intensity of light. LEDs can switch on and off thousand times in a second.VLC takes an advantage of the fast switching of LEDs which is not possible to recognise by human eye. And it uses the photo diodes at the receiver side as a main receiver component.

This paper elaborates the optical wireless communication system which is based on LEDs and the image sensor which includes the communication pixel and image pixel. The very first section is nothing but the introduction to optical wireless communication and VLC. The second section of this paper states the overall literature survey of the system, and then third section is the system overview. Fourth section is results outcome from the system. Lastly the fifth section concludes the paper and future scope.

II. Literature review

Recently, optical wireless communication (OWC) systems based on light emitting diode (LED) transmitters have attracted significant attention as next-generation communication systems. Especially, the OWC using visible light LEDs are referred to as visible light communication (VLC). Such systems are expected to be particularly useful in automotive applications aimed at enhancing driving safety and comfort. LEDs are highly suitable for use as OWC transmitters because they can modulate at very high speeds in comparison to traditional light sources such as

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incandescent light bulbs and fluorescent lamps, and because LEDs have already been used for various light sources in automotive fields, including headlights, taillights, brake lights, and traffic lights. This background provides a foundation for the practical achievement of automotive OWC systems [2]. VLC originated in Japan and the visible light communications consortium (VLCC) was established in November 2003. The VLCC has major companies in Japan on board and aims at publicising and standardising VLC technology. The formation of the VLCC has stimulated worldwide interest in VLC technology, and the first IEEE standard for VLC IEEE 802.15.7 has emerged recently. University of Edinburgh academics have worked on VLC since 2004 and have developed enhanced modulation schemes that enable high data rates to be achieved using standard LED light bulbs.

Navin Kumar, N. Lourenco, M. Spiez, R. Aguiar highlight the advantages of VLC and the advanced driver assistance system which is designred using visible light communication system. The advanced driver assistance system is helpful for accident avoidance [3]. Design basics of CMOS image sensor is highlighted by M. El-Desouki, M. Deen, Q. Fang, L. Liu, F. Tse & David Armstrong. An image sensor is the integrated part of optical wireless system for automotive application. The design layout of this image sensor consists of the array of pixels for quick image capturing & for high speed transmissions [4].M Akanegawa, Y Tanaka, M Nakagawa in his paper explained that neglecting the heavy vehicle in front (shadowing problem) Vehicle and traffic light communication is described. LOS is again the problem in such cases. On-off keying and intensity modulation are the key technologies used [5].The challenges in VLC like dimming control & duplex communication are described in this paper. It also highlights the processing required in VLC like finite impulse response equalizers, OOK modulations are explained by C. W. Chow, C. H. Yeb, Y. Liu, and Y. F Liu. Also the digital signal processing for light emitting diode based visible light communication explained in this paper [6].H. Chinthaka, N. Premachandra, T. Yendo, M. Panahpour Tehrani, T.Yamazato, Hiraku Okada, Toshiaki Fujii, M.Tanimoto explained the vehicle and road infrastructure communication. In this the transmitter tracking is the crucial part. Thus the two LED frames are required one for source tracking & other for actual data transmission. This causes the wastage of LED power after source tracked [7].

Rakesh Gupta, Amit Sharma developed design of low cost communication system which has large range & high accuracy .The basic design of transmitter & receiver is done through the microcontroller [8].The system described by A. Cailean, B. Cagneau, L. Chassagne, S. Topsu, Y. Alayli and J-M. Blosseville requires the cooperation between the vehicles involved in communication system. This is designed for security in traffic. The performance again depends on the weather conditions [9].R Meshleh. H Elagala, H Hass are the main inventers in visible light communication system. They stated the effects of LED nonlinearity in VLC, also explained the problem like inter channel interference. Further research explains different techniques to compensate for induced nonlinearity distortions. To resolve the high peak to average power ratio in OFDM is resolved using SC-FDMA [10, 11].

Thus Visible light communication (VLC) is considered as a promising future wireless communication technology due to the improvements of light emitting diode (LED) technologies and the existing pervasive lighting infrastructure. Compared to radio communication technologies such as WiFi and cellular technologies, VLC has the following advantages:

- A large amount of bandwidth in the visible light spectrum is available for use and is not yet regulated;
- VLC is more secure because light does not penetrate walls or other thick materials and in most cases communication is only possible when the transmitter and the receiver have line-of-sight (i.e. the adversary needs to be within the visual range of the receiver to perform attacks);
- Visible light poses no harm to the human body and the eyes when the transmitted optical power is below a certain level [10].

A number of applications based on the VLC between vehicle lighting, traffic lights and smart-phone cameras (V2LC) can be implemented with this new form of communications and can help us to build vehicles or transportation systems that are more intelligent. Thus application of visible light communication in designing the optical wireless communication system is the good option for the automotive application. The proposed system is explained in next chapter.

III. System Overview

Image sensor based optical wireless communication system has several beneficial characteristics that are not found in other wireless communication systems such as systems using radio waves or single-element PDs. One of these is non-interference communication. When an image sensor is used as a receiver, light sources are almost perfectly separated on a focal plane (a pixel array) because there are a massive number of pixels, and optical signals are separately output from each pixel. This prevents signals from becoming mixed, thus allowing communication, even if many LED transmitters and superfluous lights (noise sources) such as sunlight and streetlights are present. The system for automotive application is an Image Sensor based Optical Wireless Communication system. It mainly depends on VLC along with the image sensor which is in detailed explain in next section. We are considering the LEDs are transmitting the data & the image is taken by camera receiver along with optical image sensor. First of all the image of LEDs in the indicators are taken and the area of interest that is only LED part is highlighted. Then after processing that image, the data transmitted from the LEDs will be extracted at the receiver side. The OCI chip mainly consists of the image pixel (IP) and the communication pixel (IP) [4]. The OCI is nothing but the array of the both image pixels and the communication pixels. The main function of the image pixel is the quick LED detection so that there should not be the delay in the system. Then the key use of the communication pixel is to provide the higher data rate to the proposed optical wireless communication system. And as our system is mainly focused for the automotive application, the high speed and quick as well as the accurate image detection is the crucial part. The figure 2 shows the internal structure of the image sensor which is designed using the CMOS technology. In proposed system the images of LEDs in the indicator are taken and then by applying some processing techniques we are going to extract the data from that image. First the image pixel captures the image using (X, Y) co-ordinates and then it is sent to the external image processor. The optical signals are then captured by the communication pixel. The 1-bit flag image function is used to improve the data rates.

The GUI is created which is shown in fig. 1. It includes the options like selection of the image, pre--processing, feature extraction, selection of region of interest (ROI) which is LEDs in vehicles and lastly the data extraction is achieved in binary form.

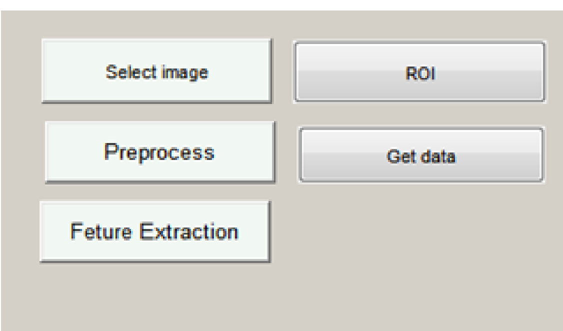

Fig. 1: GUI for the system

IV. Results

The optical wireless communication system using LEDs and an image sensor is simulated using the software Matlab. The fig. 2 is the image captured using the camera receiver. Then next figure is the histogram to explain the distribution of the pixels and the intensities in an image. Figure 4 and 5 are the thresholding and the edge detection respectively which are the parts of pre-processing methods. After preprocessing, feature extraction is performed. Figure 6 is the result of feature extraction process.

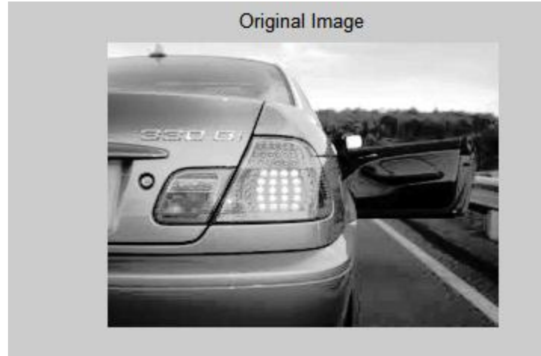

Fig 2 : Captured Image of a vehicle

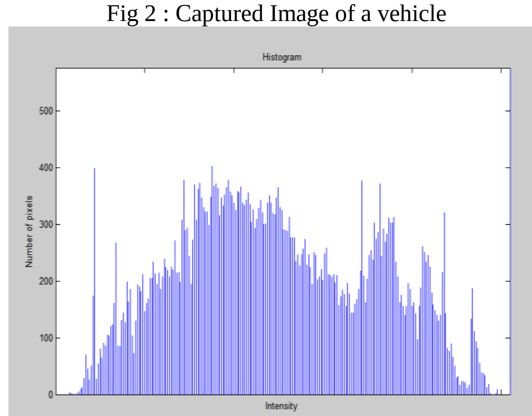

Fig 3 : Histogram of captured image

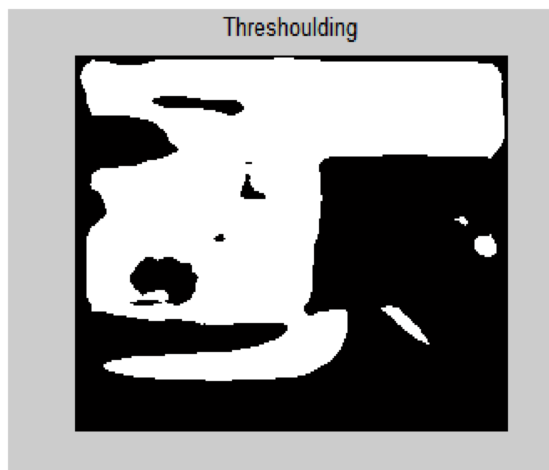

Fig 4 : Thresholding

Then the region of interest which includes the LEDs in the indicators, headlights, break lights and the road infrastructure like traffic lights are selected to get the data. Figure 7 is the Selected area of interest i.e. LEDs in indicators of the vehicle in image 2. And lastly thefigure 8 is the binary data extracted from the selected ROI in figure 7.

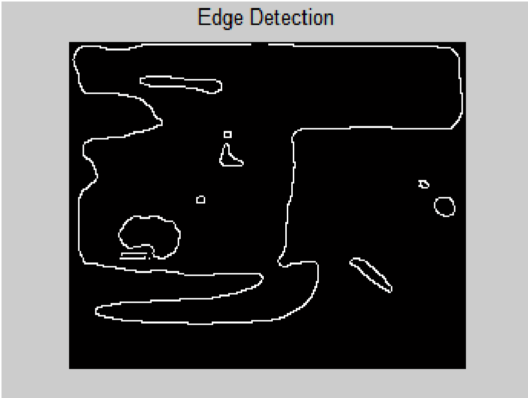

Fig 5 : Edge detection

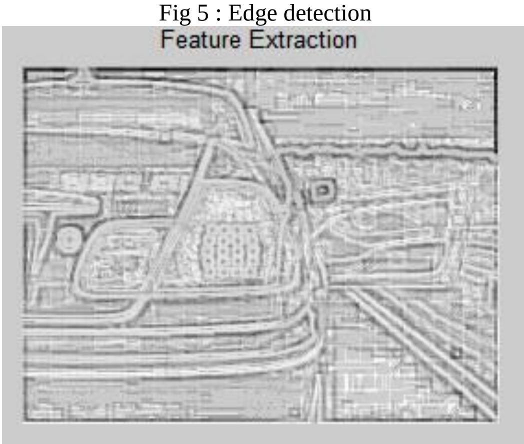

Fig 6 : Feature extraction

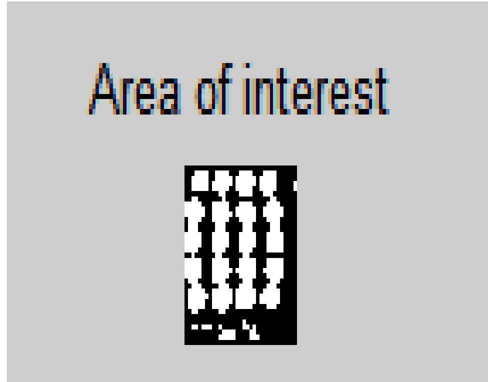

Fig 7 : Selected area of interest i.e. LEDs in indicators

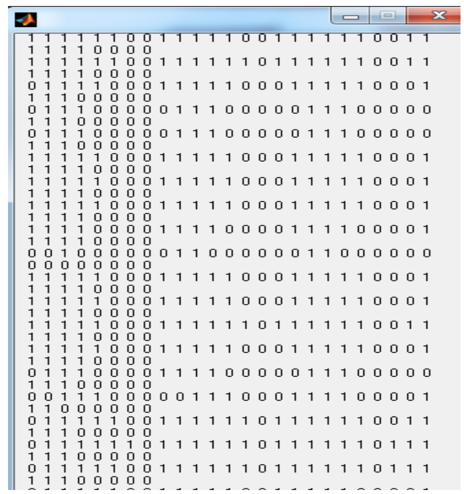

Fig 8 : Data extracted from LEDs

Table 1: Comparison of the various parameters for different colors of LEDs

Parameters	White LEDs	Blue LEDs	Red LEDs	Yellow LEDs
PSNR dB	17.32749	18.50292	18.46098	17.22858
MSE	1212.6376 3	1020.5105 2	925.09757	1241.3516
RMSE	34.82295	31.94543	30.41542	35.23285
UIQI	0.54862	0.60214	0.71623	0.38200
PCC	7533.3999 1	6473.8609 3	4406.29872	1704.8754 2
SNR	6.97148	6.48719	5.59775	6.79743
MAE	6.63672	6.84984	5.78694	6.33709
Entropy	7.2217	7.6803	7.4	6.5
Energy	6.5308e+1 1	1.6154e+1 2	3.4467e+11	2.6182e+11
Correlation	0.9827	0.98766	0.96301	0.97488

I. Conclusion

Thus our system is designed for the communication between the vehicles and also road infrastructure to vehicle communication. From results we can conclude that the data can be transmitted from LEDs which are already present in the lights in cars or the other vehicles as well as in the traffic lights on the road. In previously existing system onle single LED detection is performed. But in this paper we are applying different preprocessing techniques on the vehicle image and lastly the data is extracted in the form of 0s and 1s i.e. binary data.

II. Future Scope

The optical wireless communication system explained in this paper is considered only for the line-of-sight applications. So the future work will be overcoming on this line-of-sight problem.

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