have actively engaged in developing or converting smartphones into optical sensing devices such as optical microscopes [4], spectroscopy [5–7], surface plasmon resonance biosensors [8,9], crystal integrated label-free biosensors [10,11], blood glucose monitors [12], or pH sensors [13,14].. These devices have been applied for food quality analysis, for diagnosing disease, for monitoring of nutritional status and water quality, or for determining the presence of environmental contaminants.

Methylene blue (MB) is one of the most widely used substances for dyeing cotton, wood and silk. It is also commonly used in textile industry. The release of MB into the water is a concern due to the toxicity, mutagenicity and carcinogenicity of the MB and its biotransformation products [15–17]. Several procedures have been reported for measurement of MB in different matrices, including UV-VIS analysis, liquid-liquid extraction and solid phase extraction and final analysis by high performance liquid chromatography [18,19]. UV-VIS analysis is a relatively simple method that is the most widely used in various areas.

In the present study, a low-cost, portable, sensitive smartphone based optical sensor for environmental applications is reported. The optical sensor is based on UV-VIS method includes an entrance slit, a single lens, a diffraction grating, and a smartphone. This CMOS camera is a wavelength-independent photon collector that can function as a detector. The images captured by the sensor are then converted into intensity distribution plots versus wavelength. The cradle held the smartphone and the optical elements were made by 3D printing. As a proof of concept, the variation in absorbance of MB with different concentrations was measured. The obtained results were then compared with that of a conventional laboratory spectrometer to determine the accuracy, and the sensitivity of the sensor.

## 2. CONTENT

### 2.1. Material and methods

Methylene blue (MB) was purchased from Merk. In this work, six solution samples corresponding with six concentrations of 0.5 mM, 1 mM, 1.5 mM, 2 mM, 2.5 mM, and 3 mM were prepared.

### 2.2. Optical setup

The smartphone-based sensor was designed to interface with an iPhone 5s smartphone by the Apple Inc., of which the camera can function as a digital light detector. A polylactic acid (PLA) plastic cradle was printed by a 3D imprint machine with the resolution of 0.05 mm. It was installed to hold all the optics including a cuvette holder, an entrance slit (50 µm, Thorlab), a collimating lens (focal length of 50 mm, Thorlab), and a diffraction grating (1300 grooves/mm, Edmund Optics). It is robust and can exclude light from external source. On top of the cradle, the smartphone camera was fixed firmly. For absorption measurement, a LED with the wavelength from 400nm to 700nm was used to illuminate the sample cuvette. Only transmitted light collected was allowed to pass through the entrance slit. Light that entered the optical chamber was then collimated by the collimating lens, and guided to the diffraction grating. The diffraction grating, aligned at an angle of ~ 47 degrees with respect to the fluorescent beam so as only the first-order diffracted light was directed onto the CMOS camera (8 MP, 3264×2448 pixels) of the smartphone. The captured images were then analysed and converted into intensity distribution plots versus wavelength using ImageJ software. Due to the spectral responsibility of the Si-based sensor and internal infrared cut-off filters within the camera optics, the sensor can function in a wavelength range from 400 nm to 700 nm. A schematic diagram of the designed detection system is shown in Figure 1.

Prior to studying the sensor characteristics, the pixel information of the captured fluorescent spectrum was calibrated in wavelength scale. To do this, the established procedure for calibrating smartphone based optical devices was applied in this work [5]. In detail, the entrance slit was illuminated by two lasers: HeCd and HeNe laser with known wavelength of 442 nm and 532.8 nm respectively. The known wavelengths of the two lasers and their wavelength separation were used to set the wavelength span corresponding to the pixel scale along the illumination direction. In this work, the wavelength span of 190.8 nm corresponds to 571 pixels, leads to a spectrum/pixel resolution of 0.334 nm/pixel. In comparison with other works on smartphone based devices, the smartphone based sensor exhibits compatible spectrum/pixel resolution [14115].

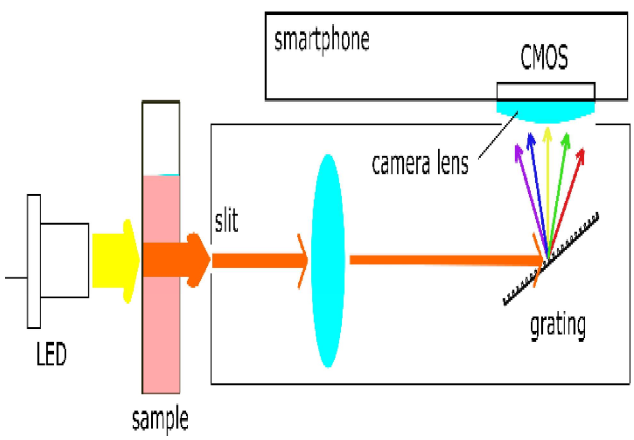


**Figure 1.** *Schematic of the smartphone based optical sensor*

**Figure 2.** *Final assembly of the smartphone-based sensor*

### 2.3. Results and discussion

The absorption spectra of MB with different concentrations measured by a laboratory UV VIS spectrometer (AvaSpec-ULS2048, Avantes) are presented in Figure 3. The six samples were illuminated by a LED. The laboratory spectrometer's detector is a CCD having a spectral resolution of 0.5 nm. Similar to previous published reports, absorption spectrum of MB has a strong absorption peak at 663 nm[20]. The absorption spectra of the same MB with different concentrations from the smartphone-based sensor are presented in Figure 4.

As seen in the figure, the sensor exhibited similar absorption responses in comparison with that of the laboratory spectrometer. A clear increase at 663 nm with respect to the increase of MB concentrations observed in both cases demonstrates the potential of using the sensor for MB detection.

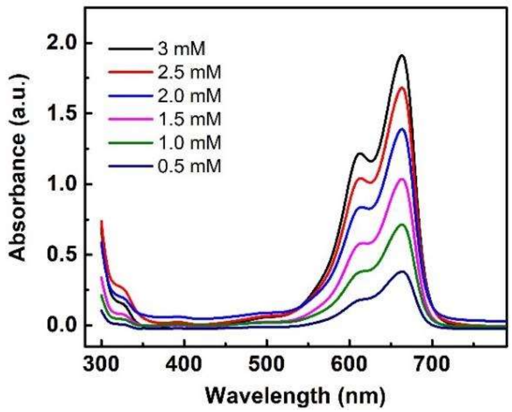


**Figure 3.** *Spectra absorption of MB measured by a laboratory UV VIS Avantes spectrometer*

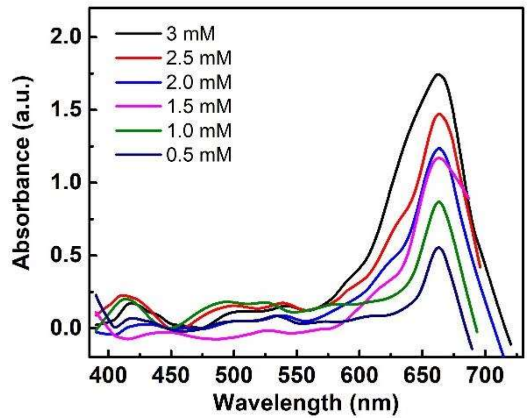


**Figure 4.** *Spectra absorption of MB measured by smartphone-based optical sensor*

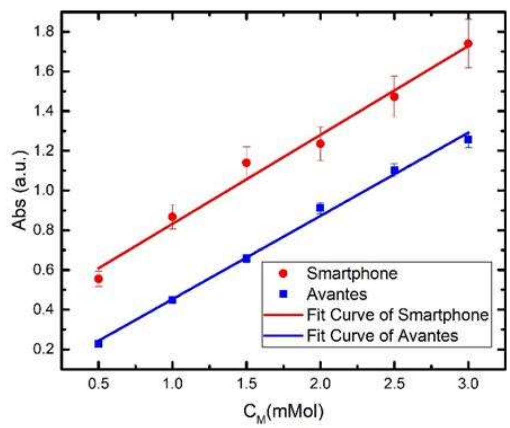


**Figure 5.** *Calibration curves obtained from smartphone based optical sensor and laboratory UV-VIS spectrometer results.*

In order to evaluate the accuracy and the sensitivity of the smartphone-based sensor, calibration curves which demonstrate the dependence of peak intensities at 663 nm as a function of the MB concentrations were taken into account (Figure 5). The slopes of the two calibration curves which demonstrate the sensitivity of the two sensors are of 0.44 for the smartphone-based sensor and of 0.41 for the Avantes laboratory spectrometer. The linear correlations ($R^2$) are relatively relevant of 0.97 and of 0.99. The error of the laboratory sensor is of 3%, while the error of the smartphone-based sensor is 7%. These positive agreements confirmed the sensitivity, the accuracy of the smartphone-based sensor. In addition, the smartphone-based sensor was made from inexpensive components. It is also compact and portable, making it suitable for safety food inspection and in-field testing.

## 3. CONCLUSIONS

A low-cost, accurate, and portable smartphone-based sensor for environmental applications was developed. The sensor uses a LED as the light source, a CMOS camera of a smartphone as the detector, and a grating as the dispersive unit. The spectrum/pixel resolution is 0.334 nm/pixel. As a proof of concept, the smartphone-based sensor was applied to measure the concentrations of MB. Experiment results showed that if the percentage of MB increased, a linear increase in absorbance intensity at wavelength of 663 nm occurred. The smartphone-based sensor showed a comparable sensitivity with that of a laboratory UV VIS spectrometer. With the noticeable advantages such as small, low-cost, portability, and high accuracy, the smartphone-based sensors can be effectively used in field trip for fast detection of toxic dyes in waist of textile industry.

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# PHÁT TRIỂN CẢM BIẾN QUANG HỌC SỬ DỤNG ĐIỆN THOẠI THÔNG MINH ỨNG DỤNG TRONG XỬ LÝ NƯỚC THẢI MÔI TRƯỜNG

***Tóm tắt:*** *Trong những năm gần đây, các thiết bị sử dụng điện thoại thông minh đang được phát triển mạnh mẽ. Trong công trình này, cảm biến quang học sử dụng điện thoại thông minh đã được nghiên cứu và phát triển. Cảm biến bao gồm một nguồn sáng, một thấu kính chuẩn trực, một cách tử nhiễu xạ và sử dụng chip CMOS của điện thoại thông minh thay cho detector. Cảm biến có thể đo được phổ hấp thụ, và phổ truyền qua trong dải bước sóng khoảng 300 nm (từ 400 đến 700nm) và với độ phân giải 0,26nm/pixel. Thiết bị cũng được sử dụng để đo nồng độ xanh methylene (MB), một loại thuốc nhuộm trong nước thải từ ngành dệt may. Mặc dù có cấu tạo đơn giản và được chế tạo với chi phí thấp nhưng cảm biến cho thấy kết quả đáng tin cậy, có thể so sánh được với thiết bị trong phòng thí nghiệm.*

***Từ khoá:*** *Cảm biến quang học, điện thoại thông minh, phổ hấp thụ, xanh methylene.*

# ABOUT A MULTICLASS TRAFFIC FORECASTING MODEL OF HANOI

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*Hanoi Metropolitan University*

***Abstact:*** *Multiclass traffic forecasting problem is one of the essential problems in programming and developing traveling system today. In this paper, we represent one multiclass traffic forecasting model using to forecast transportation of many classes of objects travelling. Studying this model maybe useful in setting up and organizing the interprovince traveling system in the Hanoi.*

***Keywords:*** *Forecasting model using to forecast transportation.*

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## 1. INTRODUCTION

Hanoi city has now been expanded into a large enough area with a large population. Transport infrastructure connecting urban districts and suburban districts has been relatively completed. The problem that we need to construct a usable transport network for Hanoi city leading to the development of the city. In order to have a good transport network, in addition to invest in consolidating, upgrading and renewing traffic routes as well as purchasing equipment and facilities,... an important step is to come up with a network organization model which is a optimal interdistrict and inter-provincial transportation network to serve the city's socioeconomic development needs. In order to build an optimal transportation network, we have to conduct surveys on roads, traffic and goods, etc. at the central points (districts , towns, townships). This is a relatively difficult work, requiring a lot of time, effort and money. Due to the growing demands of the transportation network, in order to have a good transport network and can be used for a long time, we must predict the flow of passengers, goods and other means at central points and traffic flows of every area. Then we can make plan developing transportation network for the next years, so that it meets the needs and demands of current and future economic and social development of each region. In recent years, when researching on traffic, people are often interested in choosing the mode of transportation of the participants and dividing these objects into classes. Road