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On the use of Computer Vision to Estimate Chemical Concentration based on Colorimetric Analysis

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Abstract—**In this paper, we report an investigation on estimation of chemical concentration by using computer vision-based image processing techniques. Eleven liquid samples have been prepared by mixing copper (II) sulphate salt with distilled water with their concentrations varying from 0.0 – 1.0M (molar concentration). Images of the colored chemical solutions, kept in transparent test tubes, are acquired by using a camera module interfaced with Raspberry Pi single board computer. A customized python program has been developed by incorporating OpenCV libraries in order to analyzed the acquired images of the samples in LAB color space. Experimental observations have shown good correlations between the color component values and molar concentrations of the liquid samples. Novelty of the proposed method includes portability, rapid analysis, low-cost and applicability in out-of-the-lab scenario.**

Keywords— chemical concentration, computer vision, LAB color, OpenCV, raspberry pi

I. Introduction

In recent times, research works on chemical analysis based on computer vision-based has gained significant interest. This is due to several advantages such as low cost, ease of use and applicability in out-of-the laboratory scenarios. Most of the vision-based methods reported for chemical analysis in the literatures consider color as the key parameter for analysis. The change in color is recorded with various imaging devices such as scanners [1]-[2], digital still cameras [3]-[4], smartphones [5], webcams and other portable camera modules. Scanners are not a good candidate for developing portable and compact system since an external computer is always needed for capturing and transferring of image files. Digital cameras do provide portability, however for extracting color information, image files need to be transferred to external computer. Smartphones, being equipped with high resolution cameras and high processing capability, have been mostly used by researchers to perform chemical analysis in real-time [5]-[7]. However, low-cost camera modules interfaced with compact single board computer (e.g., Raspberry Pi, Banana Pi etc.) can also perform in the similar manner with minimum investment as compared to smartphones.

In this paper, we report a method to determine concentration of Copper (II) Sulphate in distilled water in real-time. In the proposed method, we have used a low-cost camera module and Raspberry Pi single-board computer for image acquisition and onboard processing respectively in real-time. A python-based program has been developed with OpenCV libraries for analysis of the captured images in LAB color space. LAB color model is chosen as it gives uniform color perception irrespective of the image acquisition device used. In LAB color space, L represents lightness or brightness, A and B represent change in color from red to green and yellow to blue respectively.

II. Related Works

In the domain of computer vision-based analytical chemistry, many approaches were reported in the literature. These approaches differ depending on the types of imaging devices used, color space model chosen to quantify colors and illumination methods employed to illuminate the sample under test. The color of the chemical samples is quantified using various color space models such as RGB [8]-[9], HSV [10]-[12], LAB [12]-[13], Gray [14] etc. Each color space has its own advantages and disadvantages. In most of the methods reported in the literature, the analysis of colorimetric information has been carried out by using various open source (ImageJ, GIMP etc.) and commercially available software (Adobe Photoshop, Photomatix etc). Use of such software increases manual task and real-time results can't be obtained. Some researchers rely on the use of image processing capability of MATLAB platform [15]. Few researchers have also utilized machine learning algorithm for optimum results [16-17].

One of the crucial parts of a computer vision-based system is the use of stable illumination during image acquisition process. Most of the reported works have employed controlled illumination conditions in order to avoid ambient light interference during image acquisition procedure [3-5, 14]. However, in a few reported methods, images have been acquired in normal ambient light environments. Such methods are less reliable as color space models are dependent on external illuminations.

Although many works have been done in this domain, still there exist an ample amount of room for making a computer vision-based analytical method reliable, portable, fast and cost-effective at the same time.

III. The Proposed Method

A. Sample Preparation

For performing the experiments, samples are prepared by using Copper (II) Sulphate salt and distilled water. Copper (II) Sulphate is chosen as sample color remains stable and monochromatic for couple of days after dilution. We have prepared eleven samples of Copper (II) Sulphate solution with molar concentration of 0.0M, 0.1M, 0.2M, 0.3M, 0.4M, 0.5M, 0.6M, 0.7M, 0.8M, 0.9M and 1.0M. 10mL of each sample is transferred to eleven identical test tubes as shown in the Fig.1.

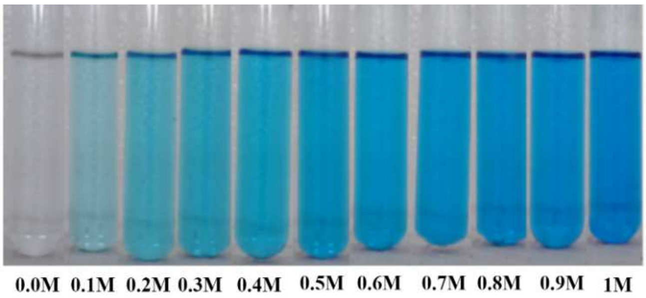

Fig. 1. Snapshot of the liquid samples with their respective molar concentration level.

B. Experimental Arrangements

The experimental arrangement of the proposed method is illustrated in the Fig.2. It consists of a cuboid chamber which is isolated from ambient light. The camera module, light source and liquid sample are introduced suitably inside the chamber as shown in Fig.2. The outer surfaces of the chamber have been coated with black paint to block the ambient light, whereas the inner surfaces are laminated with white card board paper to ensure uniform diffusion of light. The white card board also act as white background for the images taken by the camera. The camera module is fixed at one end of the chamber with the help of a support. The light source is placed just above the camera module along with a diffuser so that light incidents over the samples uniformly all around. The light source is made up of white light emitting diodes. Only one sample of liquid is introduced inside the chamber at a time with the help of a customized test tube holder. The Raspberry Pi model B is used as the image processor. The display, connected to the Raspberry Pi, shows the captured images and estimated color information of various samples.

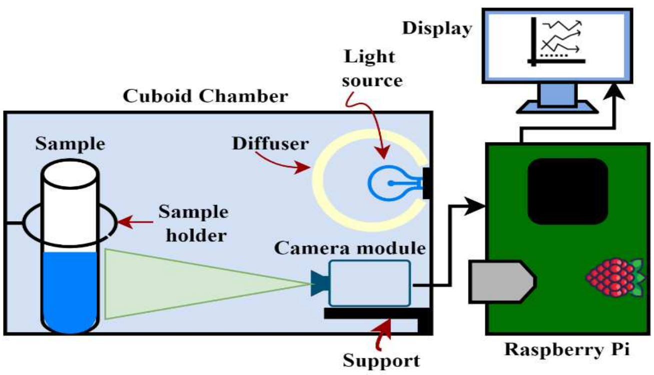

Fig. 2. Block diagram of the proposed method for estimating concentration of chemical solutions.

C. Image Processing Method

The complete image processing method is illustrated with the help of the flowchart shown in the Fig. 3. After initialization of the camera module, parameters such as resolution, exposure compensation and white balance are locked. The camera captures the original image at 1024×768 pixels. The size of the original image is reduced to 400×300 pixels in order to reduce computational load. Then, a rectangular region of interest (ROI) from the image is selected manually by mouse input or touch input (in case of touch screen display). The ROI represent the sample area of the image. A gaussian filter over the ROI is applied in order to remove noise from it. The RGB color space of the ROI is then converted to LAB color space. The entire image processing tasks are performed with the help of python programming language with OpenCV library.

D. Experimental Observations

At the time of observations, the chamber is illuminated with the help of the light source. The measured illumination level is 1700 lux. The illumination level is measured with the help of a standard lux meter (HTC LX-103 Digital Lux Meter). The camera module is at a distance of 15 cm from the sample. The resolution of the camera is set at 1024×768 pixels, exposure compensation at '0' and white balance is kept in 'sunlight' mode because it represents colors closest to natural scene. The samples are placed in the test tube holder one by one and image processing program determines the values of L, A and B components of the recorded images one after an-other. Fig.4 shows the variations of L, A and B components with change in concentration levels.

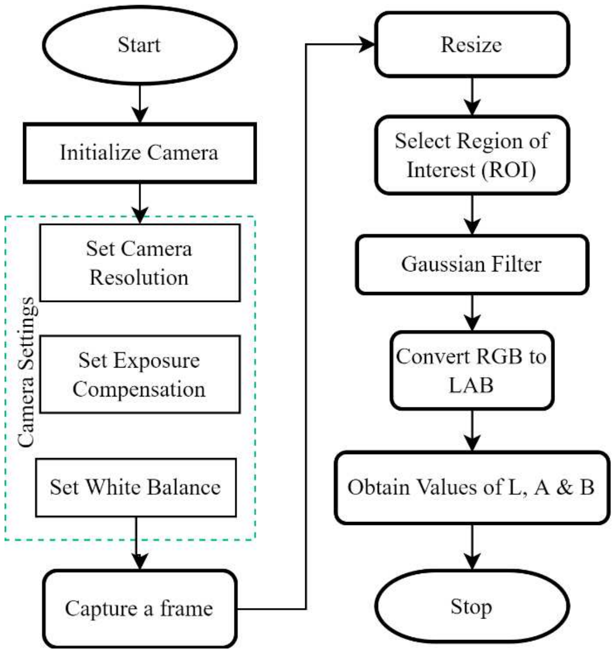

Fig. 3. Flowchart of the image processing method for estimating LAB color information of a given colored chemical solution.

Then, to observe the effects of exposure compensation level, we have recorded the values of L, A and B components for each of the samples at different level of expo-sure. Fig. 5 shows the variation of L, A and B components with respect to change in concentration under exposure level of 0, 5, 10 and 15.

To observe the effect of intensity of light over the samples, we have recorded the values of L, A and B components for each of the samples at different level of illumination. Fig. 6 shows the variation of L, A and B components with respect to change in concentration under illumination level of 200 lux, 700 lux, 1200 lux and 1700 lux. The illumination level of the light source is controlled with the help of a potentiometer connected in the controlling circuit.

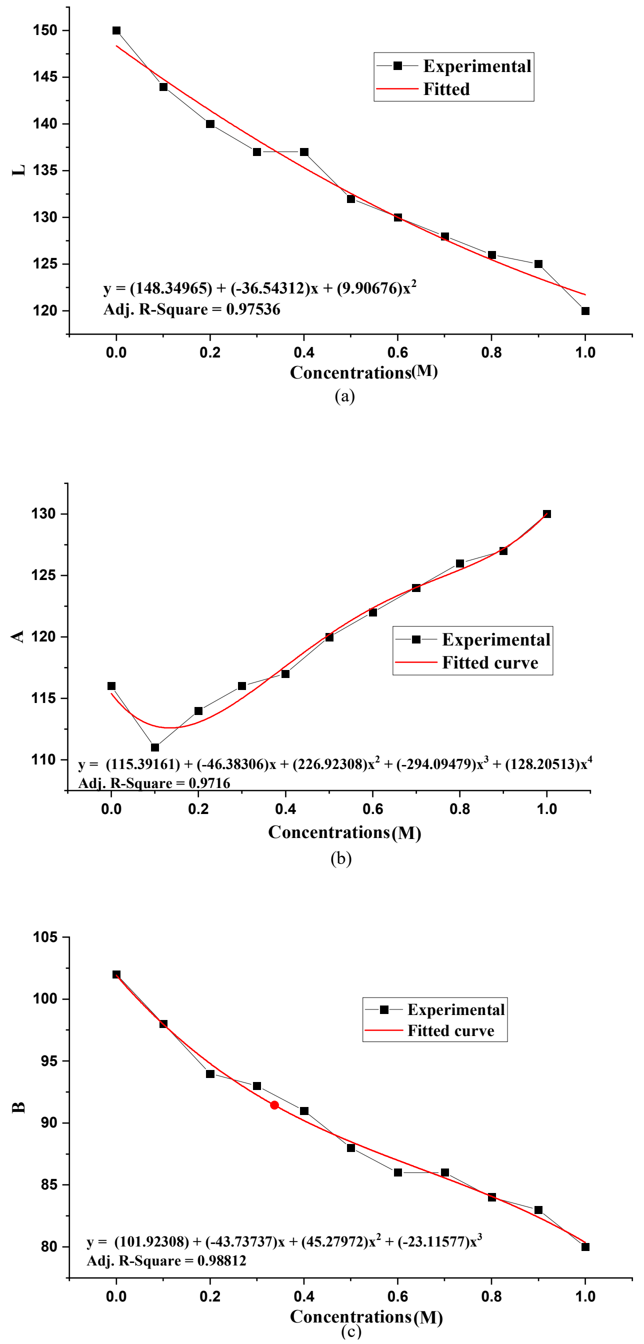

Fig. 4. Scattered plot showing variation of LAB color space with change in concentration of samples (a) L- component (b) A- component (c) B- component.

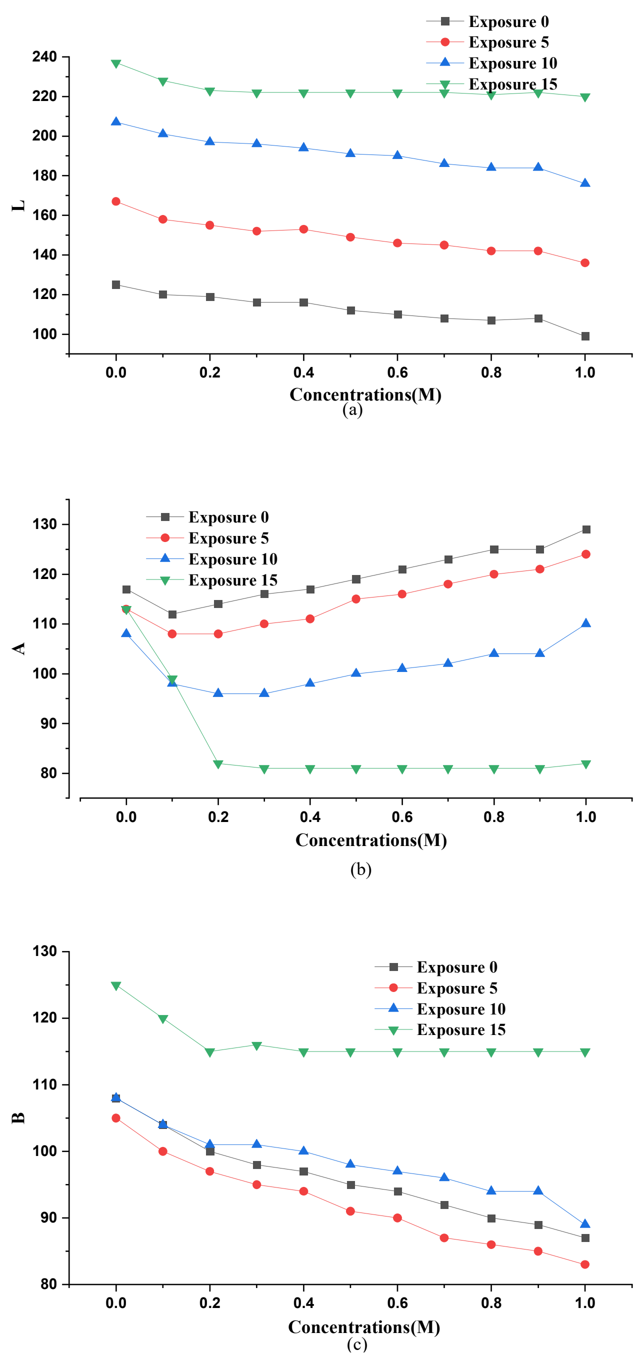

Fig. 5. Scattered plot showing variation of LAB color space with change of concentration at different exposure levels (a) L- component (b) A- component (c) B- component.

IV. RESULTS & DISCUSSIONS

Based on the experimental observations, the relationship between the concentrations of eleven liquid samples and corresponding values of L, A and B components of the LAB color space are obtained as shown in the Fig. 4(a), 4(b) and 4(c) respectively. The responses shows that the values of L and B- components of the LAB color space decreases non-linearly with the increase in concentrations of the samples. On the other hand, the A- component of the LAB color space increases non-linearly with the increase in concentration level of the samples. In this case, we find that a second order polynomial function fits well with the experimental values of L-components in the 0.0-1.0M concentration range of the samples. Similarly, for A and B- components, a fourth order and third order polynomial functions are fits well with the experimental data in the same concentration range. These polynomial functions can be used in estimation of Copper (II) Sulphate concentration.

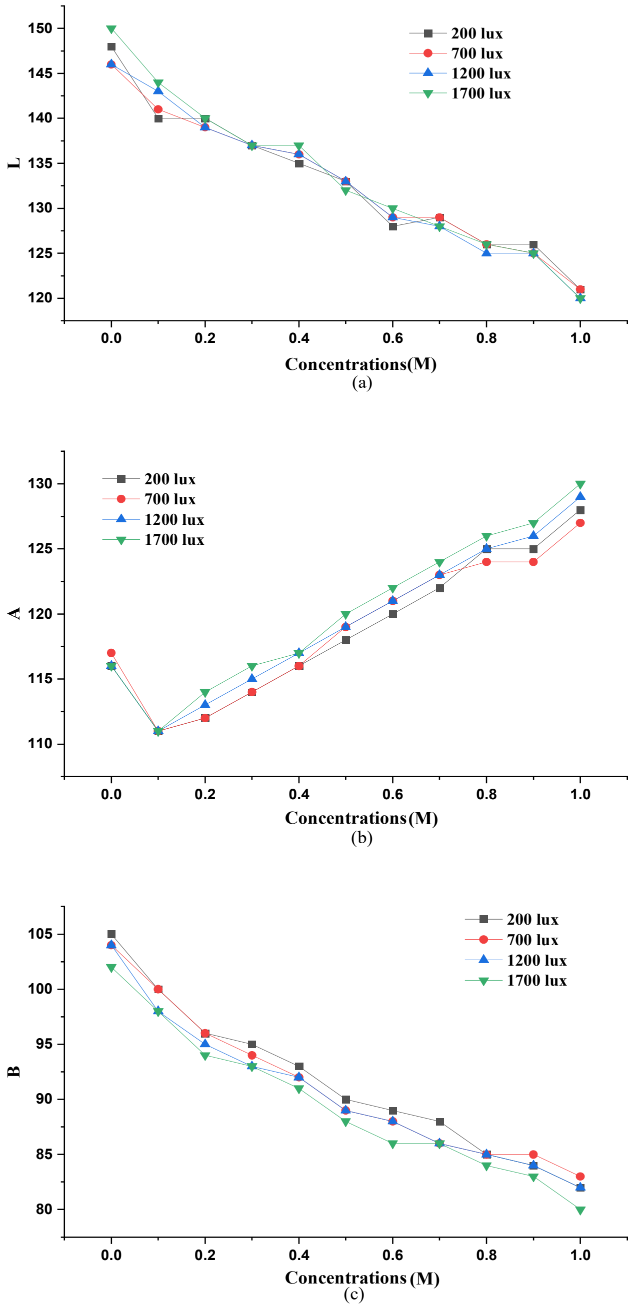

Fig. 6. Scattered plot showing variation of LAB color space with change of concentration at different illumination levels (a) L- component (b) A- component (c) B- component.

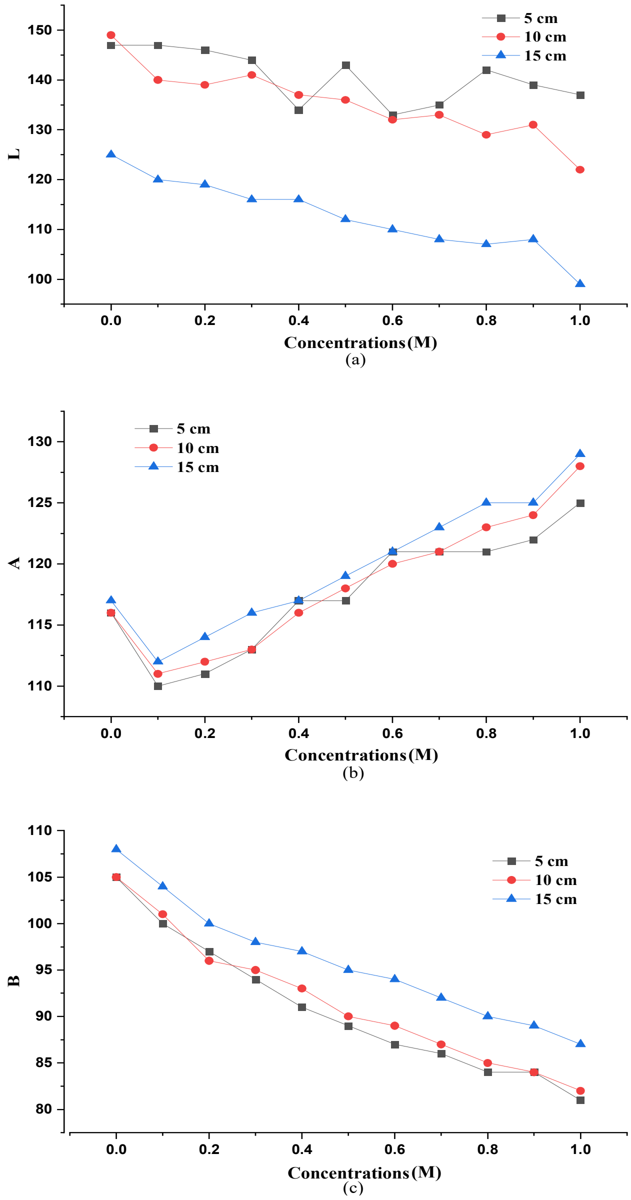

Fig. 7. Scattered plot showing variation of LAB color space with change of concentration at different distances between camera and sample (a) L-component (b) A- component (c) B- component.

A. Effect of Exposure Compensation

Since the exposure compensation controls the amount of light received by the camera sensor, it is very crucial to investigate the effect of this particular camera parameter. From the Fig. 5(a), 5(b) and 5(c), it is seen that amount of exposure has large effect on each of the components of LAB color space. With each increase in exposure level, the values of L, A and B- components get amplified. However, over expo-sure leads to deterioration of the response curve in each component of the LAB color space.

B. Effect of Illumination

The effect of external illumination on the determination performance is investigated within the range of 200 – 1700 lux. From the Fig. 6(a), 6(b) and 6(c), it can be observed that the effect of external illumination is very less in the range 200 – 1700 lux as compared to the effect of exposure compensation. The L-component is the less effected one than the A and B- components of the LAB color space.

C. Effect of longitudinal distance between camera and sample

The effect of longitudinal distance between the camera sensor and the sample is also studied. The effect on L, A and B- component can be clearly observed from the Fig. 7(a), 7(b) and 7(c) respectively. All the components are affected by the longitudinal distance between the camera sensor and the sample. This is due to the fact that the number of pixels covered by the ROI increases as the distance between the camera sensor and the sample decreases. Hence, it is mandatory to keep a fixed distance between camera position and sample position for stable performance of the system.

Table-I shows the comparison of different computer vision-based methods reported in the literature along with the present method.

TABLE I. COMPARISON OF VARIOUS VISION BASED TECHNIQUES

Reference	Imaging Device	Color space	Merits	Demerits
[1]	Scanner	RGB	Precise, rapid and low cost.	Can't provide real-time analysis.
[3]	Digital camera	LAB	Simple	High cost of imaging device, absence of real-time analysis.
[4]	CCD Camera	RGB	Improved sensitivity, economical and portable.	Manual extraction of color intensities using third party software.
[5]	Smartphone's Camera	RGB	Cost-effective, compact, portable and easy to use.	Proper uniform lighting is not observed.
[10]	Scanner	HSV	Simple and inexpensive.	Not portable and time consuming.
[14]	Smartphone's Camera	Gray	Accuracy is enhanced by using imaging box.	Manual extraction of color intensities using third party software.
Proposed method	Raspberry Pi camera	LAB	Low cost, portable and real-time measurability.	Automatic selection of ROI is not available currently.

V. CONCLUSION AND FUTURE SCOPE

In this paper, we have demonstrated a vision-based method that has the potential of becoming a rapid, portable and cost-effective method for the estimation of concentration of a colored chemical solution. The development of the python program for image analysis has been done without relying on commercial software. The use of the Raspberry Pi as an image processor has made the system very compact and portable. The components of the LAB color space have shown good correlation with the concentrations of the samples. Future direction of the work will focus on investigation on calibration, repeatability, uncertainty of measurement and effect of temperature on the measurement.

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