Special Issue of International Journal of Computer Applications (0975 – 8887)
on Electronics, Information and Communication Engineering - ICEICE No.1, Dec 2011

Estimation of Electrolytes in a Flame using Photographic Images

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ABSTRACT

The paper proposes a novel technique for the detection of alkali metals such as sodium; potassium etc. which is carried out by the digital photographic technique. Various samples of known concentration are prepared. The samples are aspired in a flame photometer. The flame images are captured using a consumer grade digital camera of known resolution. The images are captured and post processing techniques are developed using appropriate software to identify the change in colour. Correlation between the colour and the concentration is developed using various analytical techniques. The results are promising.

Keywords:

Electrolyte Estimation, Digital Photography

1. INTRODUCTION

Measuring the concentration of electrolytes such as sodium, potassium etc. in a solution is very important. One of the conventional and simple method for determining sodium and potassium in biological fluids involves the technique of emission flame photometry. This relies on the principle that an alkali metal salt drawn into a non-luminous flame ionizes, absorb energy from the flame and then emit light of a characteristic wavelength as the excited atoms decay to the unexcited ground state. The other widely used method is electrodes and electrolyte method. The electrodes are placed in the electrolyte solution and the current passing through it is measured and the concentration is predicted. However, the above mentioned techniques are analog and also the whole process is manual, so the accuracy of the system is not good and manual errors are involved. Also the response time is more.

Digital cameras are more popular now days. When sample is burnt in flame, colour of flame changes with respect to the concentration. So if images of the source are captured and post processing is carried out, it is possible to predict the amount of electrolytes in a flame by correlating it with colour values.

Ping Wah Wong Tretter *et al* presented the importance of the digital photography for the image acquisition. If the images are captured directly in digital form, they can be easily transmitted for processing, storage and display, either through a local network or through the internet. This digital photography is useful in capturing the flame images [1].

Sharma, G. Vrhel *et al* describes the basics of color science, color input and output devices, color management, and calibration that help in defining and meeting these requirements [2].

Anagha Panditrao *et al* have proposed a low cost non-contact temperature measurement technique using consumer grade digital still camera. The images of various visible heat sources are captured. Using colour image segmentation, source zones are identified. The colour temperature correlation is established by applying various analytical techniques [3].

The study reveals that, it is possible to correlate the percentage of electrolyte with the colour. If the technique is established, the human errors involved in the present flame photometric method will be reduced. Direct digital data is available for processing which will improve the accuracy and results in faster response. It is also possible to design an online display system.

2. EXPERIMENTAL DESIGN

Measurements of monovalent alkaline metals (Li, Na, K) in water solutions are commonly used in various fields of science and techniques. Such researches are carried out with the purpose of controlling quality of reagents and preparations, water used in technological processes, environment protection and medical analysis [4].

The basic block schematic of the proposed technique is shown in Figure 1. The samples are prepared by mixing the accurate amount of electrolyte salts with the distilled water. Table I shows the Amount of salt needed to prepare the known concentrations of the electrolyte solution samples. This sample of known concentration is aspired in the flame. The sample is allowed to burn in the flame. The photographs of steady flame are captured using a consumer grade digital camera of known resolution. The images are captured in manual mode by varying camera settings or shutter speed. To observe the colour change in the flame, various image processing techniques are used. Various colour zones are observed in the flame. These colour zones are separated by developing image processing algorithms. Change in colour is correlated with concentrations using various analytical techniques

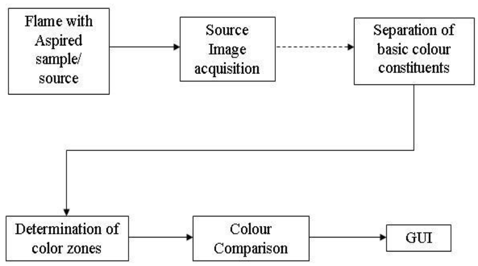

Figure 1. Block Schematic of the Proposed System

Table I: Solutions of Known Concentrations

Sample	Concentration (mEq/L)	Amount of salt needed (gm)
NaCl	135	7.89
	140	8.19
	145	8.48
KCl	3.5	0.26
	4.5	0.33
	5.5	0.41

The photograph of experimental setup is shown in Figure 2. Images of source with various samples are captured using camera DSC-S60.

The images or photographs of flames without and with aspired samples are captured. The camera characteristics are studied. Numbers of photographs are acquired in manual mode by varying the shutter speed. The samples are also prepared for known concentrations of different metals like sodium, potassium, lithium etc. Various samples are aspired and flame photographs for all the samples are captured. Figure 3 shows the images of flames without aspired sample and with sodium, potassium and lithium as aspired sample respectively.

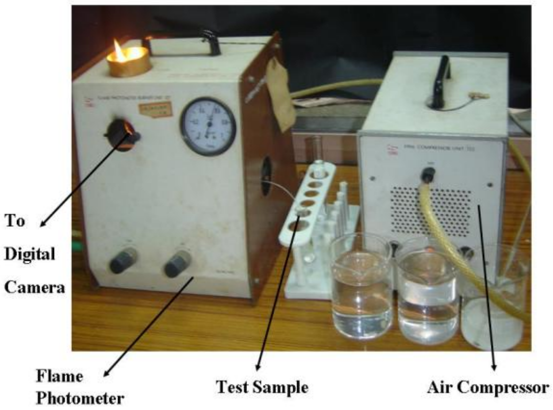

Figure 2. Setup Photograph

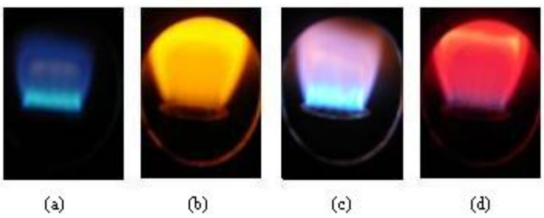

Figure 3. Flame Images Without and With Aspired Sample

3. IMAGE PROCESSING

An image consists of various colour components, which can be represented into various colour models. The image can be characterized with Red, Green and Blue (i.e. R, G and B) colour components. After capturing the images, to find out the colour change with respect to change in concentration, various image processing algorithms are developed.

The flame colour changes with the concentration. In the image processing, the colour components of the images are identified and grouped into RGB colour model. Different colour zones are observed in a flame, based on the percentage concentration. To differentiate various flame zones, segmentation is carried out. Basic image processing flow is shown in Figure 4. The image is stored at a known location. The image is then resized and segmentation is applied. After the segmentation, colour change in the flame is determined, as colour change varies with the concentration.

The processing is carried out using MATLAB version 7.1

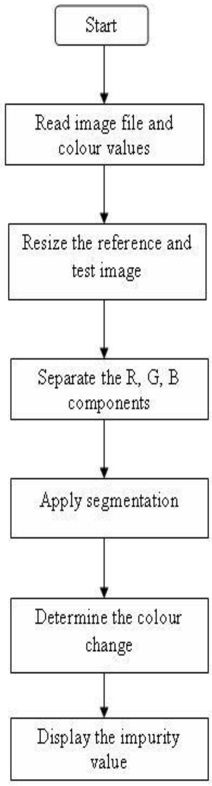

Figure 4. Basic Image Processing Flow Chart

In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image.

A flame consists of many zones based on the RGB components. In the present work, it is observe that, the zone colour changes as the sample concentration increases. Hence to separate the colour zones, segmentation technique is applied.

There are two approaches to perform Image Segmentation, the first one is to find points of rapid changes in intensity/color (edge detection), connect them to give boundaries. The second one is to find regions of constant intensity (color). Clustering means the combining the image pixels having same colour values.

Figure 5 shows basic image segmentation flow chart.

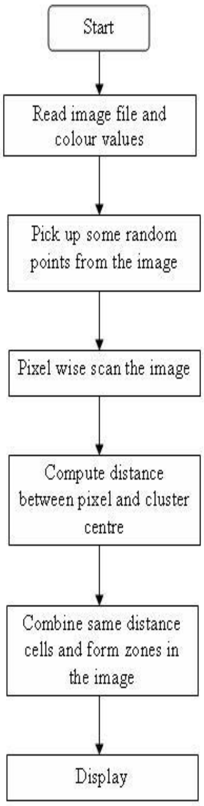

Figure 5. Flow Chart for Basic Image Segmentation

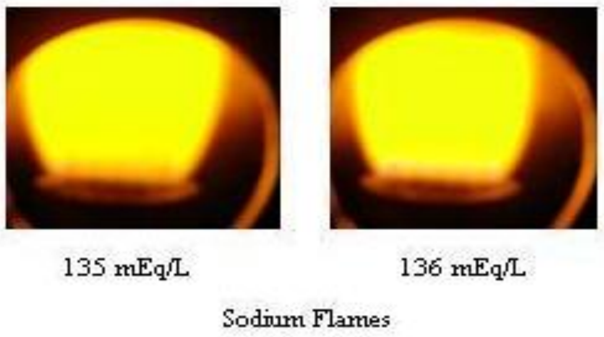

Figure 6 (a)

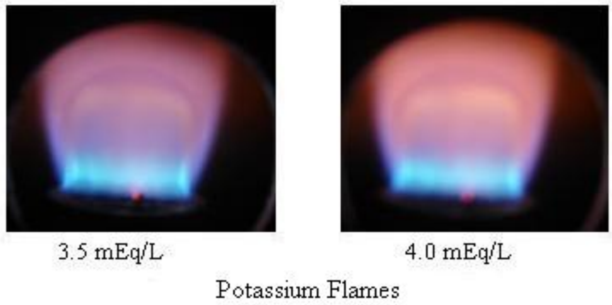

Figure 6 (b)

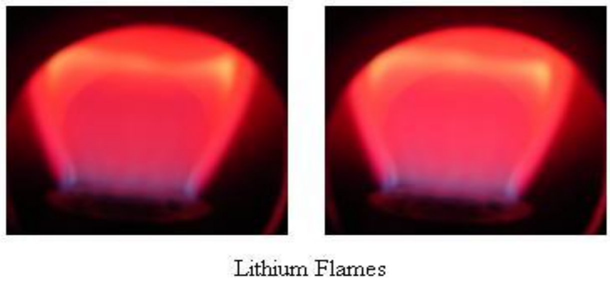

Figure 6 (C)

Figure 6. Sample flame images.

4. RESULT AND DISUSSION

A. Image acquisition

Since human body contains the 135-145 mEq/L of sodium and 3.5-5.5 mEq/L of potassium. Hence sodium solutions in these ranges are prepared. Figure 6 shows the some sample flame images, when sodium, potassium and lithium is aspired in the flame.

B. Processing

After aspiring the sample of known concentration in the flame, flame colour changes. When sodium is aspired in the flame, the flame colour changes to amber. Table II shows the sample values for Flame image with and without aspired sodium sample.

Table II. Sample Values for Flame Image

Before Aspired Sample			After Aspired Sample		
RED	GREEN	BLUE	RED	GREEN	BLUE
Sodium Sample					
35	46	91	255	184	0
36	47	92	255	185	0
34	47	91	255	187	0
31	48	91	255	189	0

33	52	94	255	189	0
Potassium Sample					
35	46	91	131	89	139
36	47	92	130	88	138
34	47	91	131	88	141
31	48	91	134	89	144
33	52	94	136	89	141
Lithium Sample					
35	46	91	252	40	78
36	47	92	255	43	81
34	47	91	255	43	81
31	48	91	255	44	81
33	52	94	255	42	79

It is observed that the blue colour is dominant before aspiring the sample which changes with varying contribution of red for sodium and lithium and varying contribution of red and blue for potassium.

C. Image Segmentation

Edge detection is a well-developed field on its own within image processing. Region boundaries and edges are closely related, since there is often a sharp adjustment in intensity at the region boundaries. From the edge detection, the boundaries of RED, GREEN and BLUE components are identified. Figure 7 shows the basic edge detection of RED, GREEN and BLUE components.

Segmentation could be used for object recognition, occlusion boundary estimation within motion or stereo systems, image compression, image editing etc. The segmentation is done for separating various colour zones in the image so as to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Figure 8 shows the basic Flame Image Segmentation.

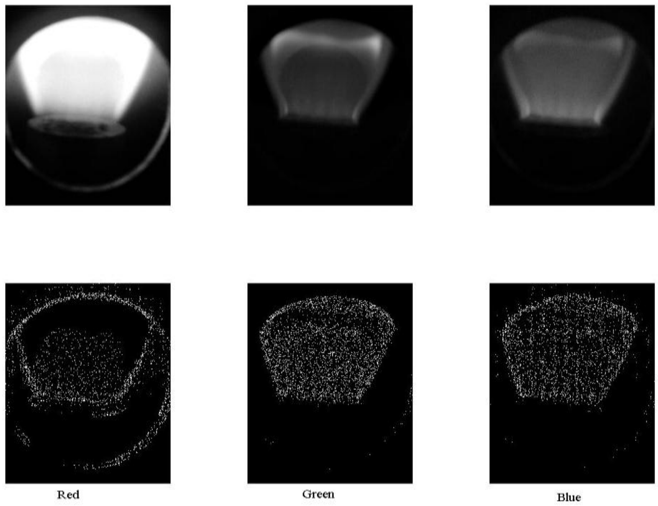

Figure 7. Edge detection

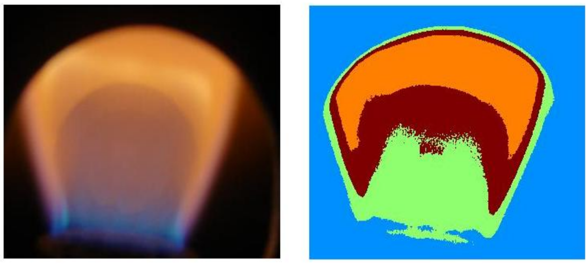

Figure 8(a)

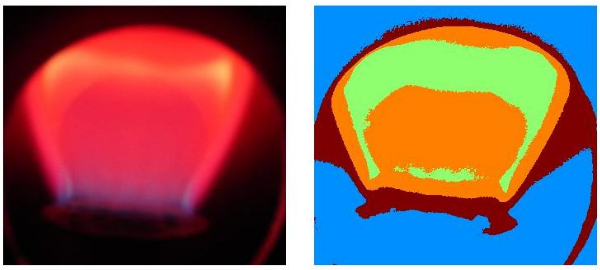

Figure 8(b)

Figure 8. Images Before and After Segmentation

The colour zones are separated. The colour values and the respective concentration values are tabulated using spread sheets.

D. Analytical Techniques

To formulate the correlation between colour values (R, G, B) and concentration, following 'Best Fit Techniques' techniques are used.

- **Least Square method**

The "least squares" method is used to calculate the best linear fit and coefficients to predict the concentration. The equation

$$y=m_1x_1+m_2x_2+\ldots+b \quad (1)$$

is used as there are multiple independent variables. Least squares method is often applied in statistical contexts, particularly regression analysis. Least squares can be interpreted as a method of fitting data. The best fit in the least-squares sense is that instance of the model for which the sum of squared residuals has its least value, a residual being the difference between an observed value and the value given by the model.

- **Polynomial fit**

Polynomial equation establishes relation between dependent variable and independent variable at various powers (like quadratic, cubic etc.). Polynomial fit is one method for modeling curvature in the relationship between a response variable Y and a predictor variable X. To do this, high-order terms are included in the regression model. Often, the response variable Y is expressed as a result of multiple degrees (second, third, etc.) of predictor variables X. The equations are in the following form:

$$Y = b_0 + b_1x + b_2x^2 + e. \quad (2)$$

The correlation is formulated using both the methods. Analysis of variance (ANOVA) is carried out. The method giving minimum standard deviation (SD) is selected.

The correlation between colour and percentage concentration is established which can be displayed with proper GUI.

5. CONCLUSION

In the proposed technique, the correlation between colour and percentage concentration is established and results are promising. No moving parts and minimal human interface with the total digital process, improves the accuracy significantly. The operating cost is negligible. It is possible to design continuous monitoring system. Image segmentation improves the prediction, so more numbers of zones with appropriate equations are worked out to enhance the applicability of the technique. The digital photography technique has a good potential for electrolyte estimation in a flame.

6. REFERNCES

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