WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.9 (3&4): 836-839. 2011 *www.world-food.net*

A rapid quantitative detection method of colorimetric test strip based on machine vision

Youchun Ding and Qiaohua Wang*
*College of Engineering, Huazhong Agricultural University, Wu Han, China, 430070. *e-mail: wqh@mail.hzau.edu.cn*

Received 8 July 2011, accepted 4 October 2011.

Abstract

The traditional method of reading colorimetric pH test strips by eyes is characteristic of low efficiency and large error. This paper presents a rapid detection and quantitative analysis method by using machine vision. In this method the strip images were captured and collected by the USB camera based on Video for Window. Median filter to the original image for preprocessing, the number of test strips and their location information in an image can be indentified with the gradient algorithm by scanning the image from up to down and left to right. When the calculated gradient is larger than that of black background, it can be thought to be the boundary point of test strip. All the points compose the boundary of test strip. The number of test strips and position information of each image can thereby be recognized according to the left and right boundaries. A window is designed with the size of 30×52 and sliding it from up to down in up-down boundary of strip, the RGB sum of all pixels is continuously calculated in the window. The window of minimum RGB sum is discoloration area in a strip. The color distance means the distance between two kinds of color in RGB color space which shows the similarity degree of them. The pH value of the discoloration area can be quantitatively detected by calculating the color distance between the quantified test strip and the standard color card. Multiple pH test strips can be quantitatively detected at the same time by establishing an effective software system with a test error in (-0.095, 0.015) pH unit.

Key words: Machine vision, colorimetric test strip, quantitative detection, pH value.

Introduction

Colorimetric test strip is widely used as a tool for pH test in various fields such as food, water quality, medicine etc. When using the colorimetric test strip to judge the pH value, it has to be compared with the standard color card. The traditional visual qualitative analysis or half-quantitative analysis method, which depends on the naked-eye to read data, has disadvantages of low efficiency, big error as well as poor reliability. Thus, seeking a scientific and practical pH test strip quantitative detection method is particularly important.

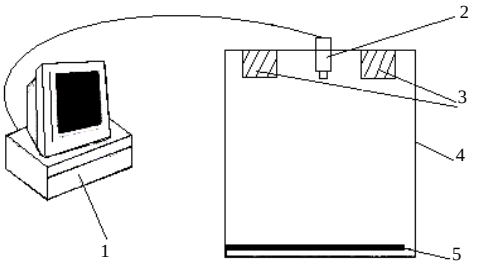
With the continuous development of bio-test strip reader and detection instrument, there correspondingly appears a variety of measurement result analyzers matched to them. Some scholars have made research on the detection of test strip. In order to realize the rapid quantitative detection of sulfite and trace formaldehyde in the food, the test strips can be combined with optical reflector sensor by utilizing specific light source, basing on the dipsticks color difference and different absorption ability of special wavelength [1-4]. By employing the image sensor to obtain biological test strip images and furthermore interpreting them by special test strip analysis instrument, the visual recognition can be applied to analyze the clenbuterol test strip category [5]. Anti-HCV can be detected by using the vision technology to analyze the pixel quantity fluctuation under the condition of positive and negative [6]. On the basis of vision technology and artificial neural network, AFP (α-fetoprotein) test can be realized [7].

The characteristic of colorimetric test strip is mainly embodied in the difference of test strip color. In this paper, VFW (Video for Windows) software development kit was employed with the help of USB camera to acquire images of several colorimetric test strips, meanwhile making quantification of the color strength of several colorimetric test strips and giving rapidly credible and repeatable pH value. By this way, the qualitative and half-quantitative detection is converted to accurate quantitative analysis, therefore, the measurement error caused by human factors can be avoided.

Materials and Methods

Test strip preparation: The solution was prepared with deionized water to get aqueous solution of different pH values of dilute NaOH and H_2SO_4. Some colorimetric test strips were taken with the measuring range between 6.4 and 8.0. A clean and dry glass rod was used to get two drops of detected aqueous solution to drip them on the test strip.

Image system: A machine vision system for image acquisition was set up as shown in Fig. 1, which consisted of a USB 2.0 port camera (Utilize CMOS 1.3 Million Pixel True Color), a computer, a light source box(enclosed and round), a LED annular source and a black stage. The object distance can be regulated by lifting stage.



1. Computer 2. USB camera 3. LED annular source 4. Light source box 5. Stage

Figure 1. The vision system.

Image acquisition: The video capture process illustrated in Fig. 2 was followed. A complete test strip image can be obtained by establishing the video capture on the basis of VFW of Windows Platform. Several colorimetric test strips of different pH values on the stage were captured at the same time. The images were stored as 24-bit true color RGB image in BMP format for following image processing.

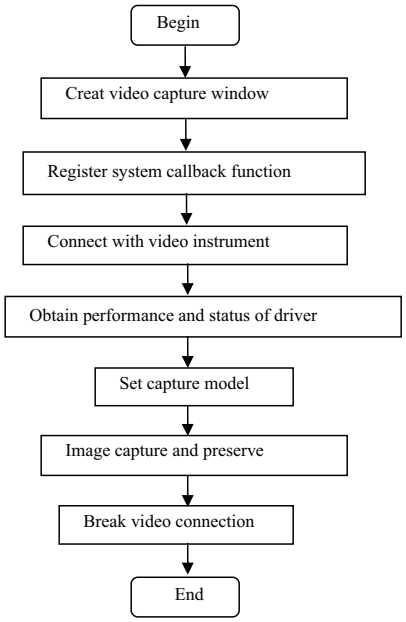


Figure 2. The flow chart of video capture creating.

Results and Discussion

Image processing: In order to effectively inhibit the background and other noises, median filter with simple and fast calculation was used to the original image, which has good ability of noise reduction for many random noises and can filter out additive white noise and long-tailed additive noise as well as protect the detail information of signals.

Test strip number recognition: In order to make quantification of several test strips to obtain their pH values, it is firstly needed to recognize the test strip number on the stage. According to the arrangement rule and imaging environment of test strips, the test strip number recognition algorithm was designed as Fig. 3.

As the edge is the relatively remarkable area of gray change in the image, a high value will be produced when making differential of the gray mutation area. As to the digital image, difference can be used instead of differential [8].

$$\Delta_x f(x, y) = f(x, y) - f(x-1, y) \quad (1)$$

$$\Delta_x f(x, y) = f(x, y) - f(x, y-1) \quad (2)$$

According to the definition of gradient, the gradient amplitude of image $f(x, y)$ is

$$G[f(x,y)] = \{[\Delta_x f(x,y)]^2 + [\Delta_y f(x,y)]^2\}^{\frac{1}{2}} \quad (3)$$

It can be simplified as

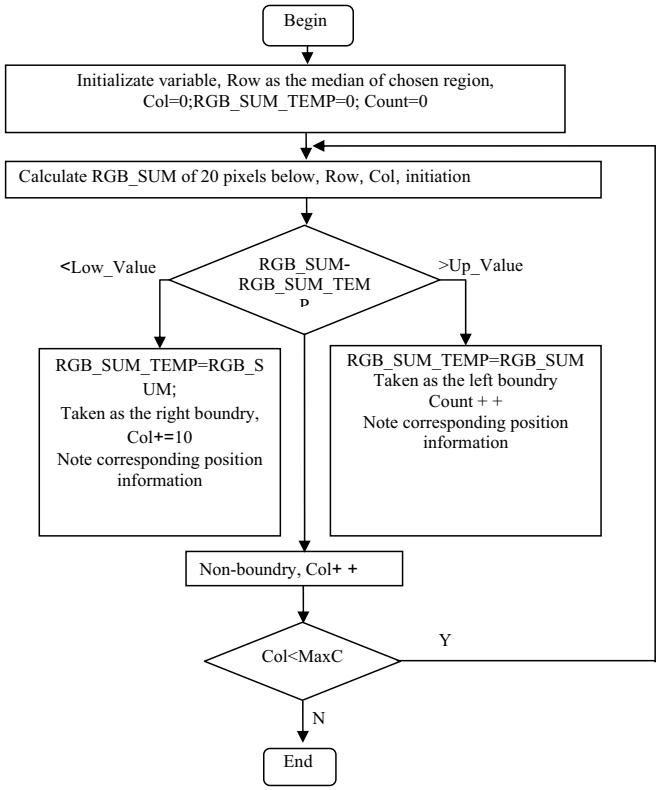


Figure 3. The test strip number recognition algorithm.

$$G[f(x,y)] \approx |\Delta_x f(x,y)| + |\Delta_y f(x,y)| \quad (4)$$

The test strip is set parallel to y-axis, so it can be thought that $\Delta_x f(x, y) = 0$, the gradient is $\Delta_x f(x, y)$, that is, the difference between current column and previous column. The image is scanned from up to down and left to right. When the calculated gradient is larger than that of black background, it can be seen as the boundary point of test strip. All these points compose the boundary of test strip. The number of test strips and position of information can thereby be recognized according to the left and right boundaries.

Test strip discoloration area determination: To get the corresponding pH value of every test strip discoloration area, the position of each test strip discoloration area must first be found. Then quantification of its color feature can be made in accordance with certain calculation. Due to the heterogeneity of test strip discoloration area, the discoloration area has some randomness. Furthermore, the quantification error can be influenced by the size of selected area. In order to get the best region size, two experiments were made in terms of regional window size and the quantification error. The experimental error curve was acquired as Fig. 4 by changing respectively the height and width of window. Fig.4a shows the pH quantization error when keeping invariant the window height and changing the window width. Fig. 4b shows the pH quantification error when keeping invariant the window width and changing the window height. According to the error curve of Fig. 4, it is known that the experimental error is the minimum with the window width 30 and height 52.

Through the experiment, average values of the pH and the corresponding color parameters of test strips were obtained, and some experimental data is shown in Table 1. From Table 1, we can

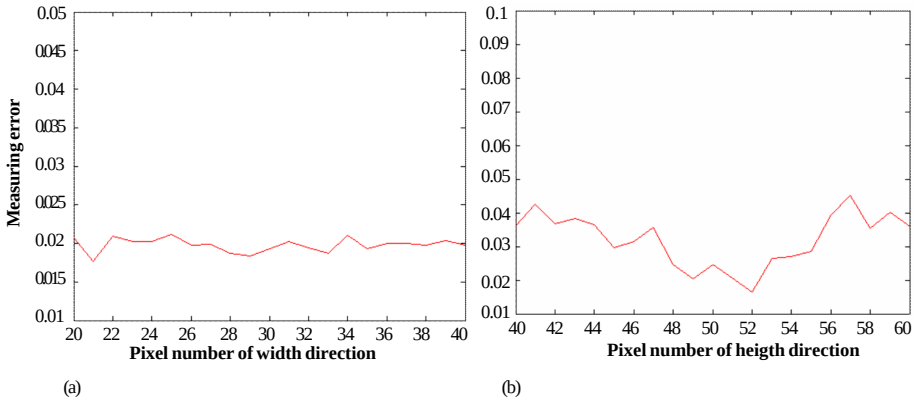


Figure 4. The measuring error curve (a) the window with changing width and (b) the window with changing height.

Table 1. Average values of standard color comparison card.

Color component / PH value	R	G	B	H	I	S	brightness
6.4	172	185	60	114.573	0.545	0.568	146.07
6.7	155	180	58	108.816	0.514	0.557	140.00
7.0	90	150	60	79.107	0.392	0.400	116.40
7.2	50	135	70	16.996	0.333	0.411	106.15
7.5	30	112	90	15.021	0.303	0.612	96.38
7.7	20	100	82	12.383	0.264	0.703	85.80
8.0	17	87	100	351.628	0.267	0.750	83.20
Over 8.0	8	60	82	343.174	0.196	0.84	60.88

know that the higher the pH of solution, the lower the brightness of test strip color. That is to say, the RGB sum decreases with the increase of pH. Thus, a window with the size of 30×52 was designed and slid from up to down in up-down boundary of test strip, the RGB sum of all pixels in the window was continuously calculated, the window of minimum RGB sum is the test strip discoloration area. The line number of this window was preserved.

Test strip color quantification: The pH quantification of discoloration area can be realized by calculating the color distance between the quantified test strip and standard color card. The color distance means the distance between two kinds of color in RGB color space which shows their similarity degree [7, 8]. It is expressed as follows:

$$d_{color} = \sqrt{(r-R)^2 + (g-G)^2 + (b-B)^2} \quad (5)$$

where d_{color} is the difference between color (r, g, b) and color (R, G, B). Firstly the RGB value of test strip discoloration area is extracted and then it is compared with 8 standard color strips of standard color card built in system, their color distances are calculated one by one, and the standard color strip is preserved with minimum distance and proximate color to the test strip discoloration area in the min-1 variable. With the same calculation method, the standard color strip min-2 which is secondly proximate to it can be searched. The reference pH value of quantified test strip can be calculated by making an interpolation operation between pH values of corresponding standard color cards of min-1 and min-2 [9-10].

Quantification software system and test: An effective software system was designed, which can realize rapidly pH quantification of several test strips and auto-detect their pH values. Fig. 5 shows the operation flow chart of software. The software interface is illustrated in Fig. 6.

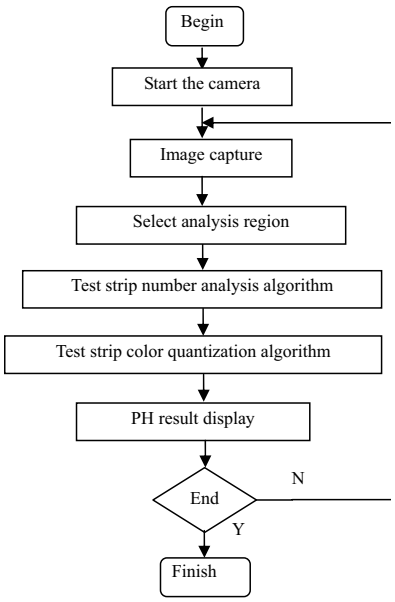


Figure 5. The operation flow chart of the software.

To verify the effectiveness of detection algorithm, we take solutions of different pH values for detection and recognition. Some recognition results are shown in Table 2. In Table 2, the mean error is -0.04, the error standard deviation is 0.055, the error between detection result and expected value is -0.04±0.055 pH unit, which can be accepted by users. The error is mainly caused by the standard color card and the interpolation operation.

Table 2. Recognization results.

Standard pH	6.4	6.7	7.0	7.2	7.5	7.7	8.0
Recognized pH	6.38	6.68	7.0	7.18	7.48	7.6	7.9
Error	-0.02	-0.02	0	-0.02	-0.02	-0.1	-0.1
Standard Deviation				±0.055			

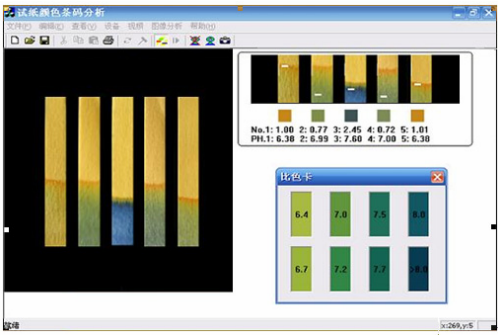


Figure 6. The software interface.

Conclusions

1. By utilizing the USB camera based on VFWPH value of multiple test strips can be read at the same time.
2. The detection method with test strip number recognition algorithm and color quantification algorithm has the advantages of high accuracy, repeatability, simple operation, low cost, rapid field detection and quantification.

Acknowledgements

This work was supported by the Fundamental Research Funds for the Central Universities (Program No. 2009JC001 and 2010JC007).

References

[1]Fang, Y. J., Wang, H. Y., Zhou, H. Y. and Gao, Z. X. 2005. Using the test strip and optical reflector sensor for the detection of trace formaldehyde. Chinese Journal of Analysis Laborator **24**(2):1-4 (in Chinese).

[2]Fang, X. Y., Gao, Z. X. and Fang, Y. J. 2005. Using the paper strip and optical reflector sensor for the determination of sulfite in food. Modem Preventive Medicine **32**(11):1532-1534 (in Chinese).

[3]Guo, Y. 2006. Vision Based Method in Biologic Strip Analyze System. Jilin University (in Chinese).

[4]Zhao, Y., Yang, C., Chen, F. and Xiao, S. 2009. Development of a novel portable color analytical reader for colloidal metalaxyl gold test strips. Chinese Journal of Scientific Instrument **30**:2175-2179 (in Chinese).

[5]Lin, C.-S.,Wu, C.-Y., Hsu, H.-C., Li, K. M.-C. and Lin, L. 2004. Rapid bio-test strips reader with image processing technology.Optic-International Journal for Light and Electron Optics **115**:363-369.

[6]Chuang, L., Hwang, J.-Y., Chang, H.-C.,Chang, F.-M. and Shiang-Bin Jong, S.-B. 2004. Rapid and simple quantitative measurement of α-fetoprotein by combining immunochromato graphic strip test and artificial neural network image analysis system. Clinical Chemical Acta **348**(8):87-93.

[7]Health, M., Sarkar, S., Sanocki, T. and Bowyer, K.W. 1998. Comparison of edge detectors: Amethodology and initial study. Comput Vis Image Understanding **69**(1):38–54.

[8]Onyango, C. M. and Marchant, J. A. 2001. Physics-based colour image segmentation for scenes containing vegetation and soil. Image Vision Comput. **19**:523-538.

[9]Sharma, G. and Trussell, J. H. 1997. Digital color imaging. IEEE Transactions on Imaging Processing **6**(7):901-932.

[10]Venkateswarlu, N. B. and Raju, P. S. V.S. K. 1992. Fast ISODATA clustering algorithms. Pattern Recognition **25**(3):335-342.