ISBN 978-93-84422-63-9
Proceeding of 2016 International Conference on Advances in Software, Control and Mechanical Engineering (ICSCME'16)
Kyoto (Japan) April 12-13, 2016 pp.35-40

The Image Measurement System to Indicate the Gap of Dental Prosthesis Element

Shinn-Liang Chang, Bing-Jiun Tsai, and Wei-Chung, Chen

Department of Power Mechanical Engineering,

National Formosa University, Huwei, Yunlin, TAIWAN

Abstract: *Recently, the development of 3D printing technology makes complex surface design and processing easier, especially applied to the customized manufacture of dental prostheses elements. The applications of three-dimensional printing technology are still in developing. When the dental prostheses element is set in the patient's mouth, poor adaptation between the dentures and the patient's original tooth will make the food remaining in the slit to cause poor breath. More severe cases will lead to the need for removal of the entire teeth. Therefore, this paper aims to develop a device to detect dentures edge adaptation, which is not found currently in industry.*

Keywords: *3D printing, tooth, image processing, measurement.*

1. Introduction

With the breakthrough development of industrial technology and precision machining technology, people began to pursue a more accurate detection technology. In the measurement of the gap between two elements, it proceeds by the contact or non-contact measurement. In this paper, the application of non-contact measurement of single CCD is set up to replace the laser scanning method with simple and fast demand. In [1, 2], laser scanning technology is adopted in the laser-based systems. However, there are some drawbacks, such as shadowing and reflection of certain material quality and surface treatment. Huertas [3] presented a system that takes a grey level image as input, located edges with sub-pixel accuracy, and linked them into lines. Edges are detected by finding zero-crossings in the convolution of the image with Laplacian-of-Gaussian masks. Pentland [4] proposed the depth estimation method (Focal Gradient) - focus gradient method by measuring the value of focus to estimate depth simultaneously at all points. With only one or two images, the sources of information can be used to make reliable depth maps of useful accuracy with relatively minimal computation. Nayar and Nakagawa [5] presented two algorithms for depth estimation. The first algorithm simply looks for the focus level that maximizes the focus measured at each image point. The second algorithm uses a Gaussian model to interpolate the focus measured to obtain more accurate depth estimates. They used the sum-modified-Laplacian (SML) operator which is developed to compute local measurement of image focus. The image sequence and the focus measurement obtained at each image point are used to compute local depth estimates. Subbarao and Choi [6] proposed a new shape-from-focus method which is based on a new concept named Focused Image Surface (FIS). More accurate focused image can be reconstructed from a sequence of images than the traditional methods. The new method has been implemented on an actual camera system, and the results of shape recovery and focused image reconstruction are presented. Shrivakshan and Chandrasekar [7] studied the advantages and disadvantages of various edge detection filters, i.e., Roberts, Sobel, Prewitt, and Laplacian edge detection operators. Senthilkumaran and Rajesh [8] studied the theory of edge detection for image segmentation using soft computing approach based on the fuzzy logic, genetic algorithm and neural network. In [9], Gao, et al. proposed a method which combines Sobel edge detection operator and soft-threshold wavelet de-noising to do edge

http://dx.doi.org/10.17758/UR.U0416014

detection on images including White Gaussian noises. This method is mainly used soft-threshold wavelet to remove noise, and then apply the Sobel edge detection operator to do edge detection on the image.

2. Image Measurement Device

This paper aims to develop the dental imaging measurement system. The components of the prosthesis in the architecture of the system can be divided into image processing and image capture. Image processing is performed by a developed software algorithm while the image capture needs to control the hardware devices. Because the captured image has significant effect on the measurement accuracy, the hardware device needs accurate setting. In this section, the image capture device is briefly introduced.

2.1. Architecture of the Image Measuring System

The developed system in this paper applies the image processing techniques and numerical methods for the detection of dental prostheses gap. The measurement system contains a single CCD (Charge-coupled Device) to capture the gap of dentures, and the denture image data is transferred to the computer through the video capture card. Then, the image processing techniques and numerical methods are applied to calculate the gap size of the dentures. The system architecture is shown in Figure 1.

The developed program is based on the application of Microsoft Visual Studio 2015. The software features are mainly contained read image, image processing, computed geometry characteristics, and the output of measurement results.

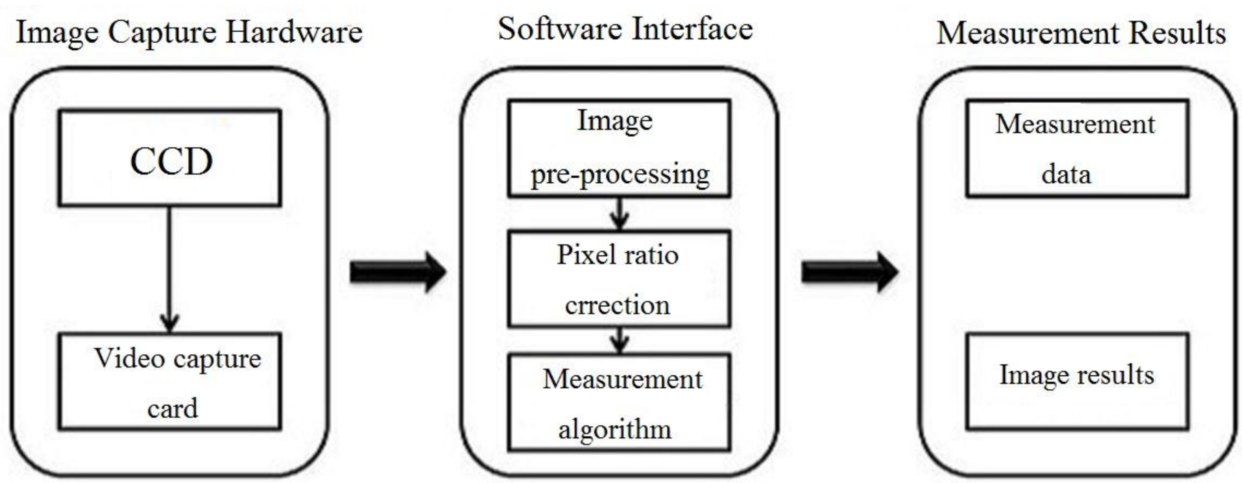

Fig. 1: Architecture of Machine Vision System.

The execution procedures of the developed measurement software got the digital images of dentures gap from the video capture card and then loaded into the measurement program to detect the gap size. The boundary contours are obtained to facilitate the calculation of dentures gap. The image processing steps are shown in Figure 2.

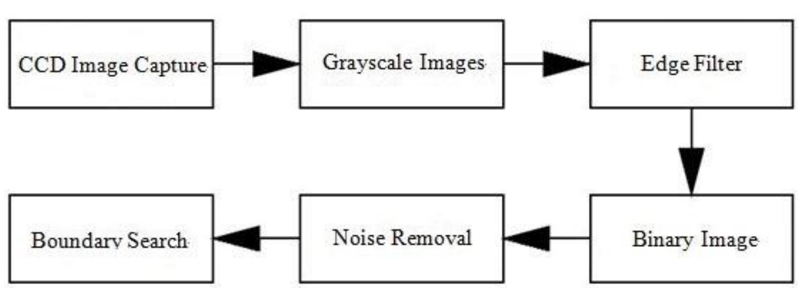

Fig. 2: Flow Chart of the Image Processing.

2.2. Equipment of Image Measuring System

The measurement system developed in this paper is divided into image capture and computation. The image capture part includes CCD camera, lens, CCD stent, video capture cards, and the light source components. Each element of the above models and specifications are listed as follows:

1. CCD camera:

   The SENTECH STC-N63CJ-B 1/3" interline transferring CCD of colour cameras is applied. The image resolution is 768 (H)×494 (V) pixels.

2. Lens:

   The magnification range of zoom lens is 0.6X ~ 5X; aperture is f 1 to f 1.8.

3. Video Capture Card:

   EURESYS Picolo series, i.e., Picolo Junior 4 is applied, which can receive four input video sources in the format of colour image or greyscale images.

4. Light source:

   The lens has four LCD segments of white ring light source.

5. CCD support:

   The size of CCD support is D250mm * W180mm * H410mm.

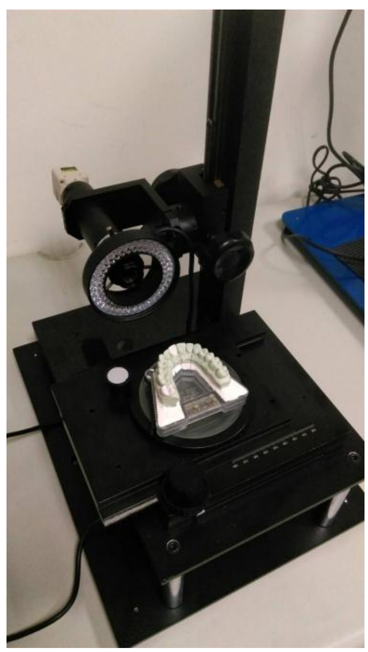

Fig. 3: The Developed Image Measuring Machine for Teeth Manufactured by 3D Printing.

3. Digital Image Processing

Traditional film and images taken by the camera are belonging to the analogy image. Through the digitized operation, the analogy image is converted into a digital image. In each sampled image point, a value is assigned to represent the intensity and the corresponding position. Each has a value to indicate its colour. The smallest unit of these image elements is known as picture elements, or pixels.

3.1. Greyscale and Binary Images

A greyscale has only the brightness information of the image without colour information. Colour image is composed of three primary colours, i.e., red (R), green (G), and blue (B). Each primary colour has its own brightness, and therefore need to be quantized the luminance values, generally classified as 0 to 255, where 0 is the darkest, 255 is the brightest, shown in Figure 4.

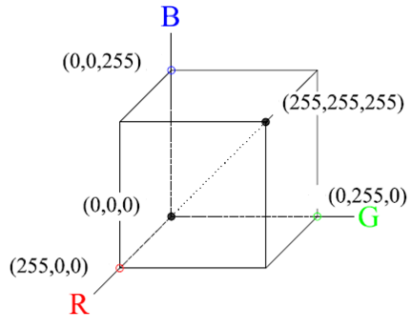

Fig.4: RGB Colour Cube.

The figure shows the RGB colour cube with black origin (0, 0, 0) and white vertices (255, 255, 255). A line is drawn through these two points; this line then has the same RGB value. In this paper, the RGB values of every pixel are averaged to be the greyscale. The greyscale image is then transferring into binary image. The binary image is constituted by 0 and 1, which represents the black and white colour respectively. Then, there are only two colours existed in the image for the further image calculation and judgment as shown in Figure 5. In order to convert the greyscale image into binary image, a threshold value should be defined. In this paper the average greyscale value is selected as the threshold value shown in Eq. (1).

$$I = \frac{\sum_{1}^{m}\sum_{1}^{m} G}{m \times n} \tag{1}$$

In the equation, m is the number of horizontal image pixels, n is the number of vertical image pixels, and G is greyscale value for each pixel.

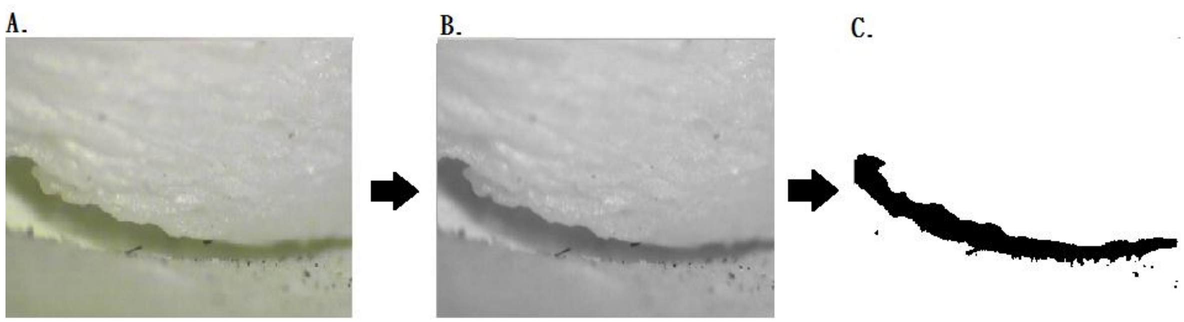

Fig.5: (A) Original Gap Image (B) Greyscale Image
(C) Binary Image.

3.2. Noise Removal and Edge Filter

The image after binarization process may produce a solitary point (or so-called noise). It causes difficulty and errors in the process of pattern recognition. In this paper, the isolated points appear on the graph as single dark spot whose adjacent edges are all bright spots. It means that there are eight bright spots around the dark spot in the process of image search. This dark spot will be changed into a bright spot to remove the isolated point. Here the tooth edge is the main target to find the gap; the graphical gradient (boundary) is strengthened to enhance the edge filtering.

3.3. Comparison Edge Detection

In this paper, a new developed comparison edge detection method is applied to calculate the boundary profile of dentures. A horizontal template of 5×1 and a vertical template of 1×5 are used. Two types of vertical template shown in Figure 6 are used to search along the vertical direction of the picture with point y_i as a dark spot and stored in another new image. The templates for the horizontal direction search are shown in Figure 7. The point x_i is searched to be the dark point. The proposed method is more suitable to detect the gap boundary because it has thinner boundary than the boundary got by the other method.

Type 1		Type 2
0	y_{i-2}	255
0	y_{i-1}	255
255	y_i	255
255	y_{i+1}	0
255	y_{i+2}	0

Fig.6: Vertical Edge Comparison Template.

	x_{i-2}	x_{i-1}	x_i	x_{i+1}	x_{i+2}
Type 4	255	255	255	0	0
Type 3	0	0	255	255	255

Fig.7: Horizontal Edge Comparison Template.

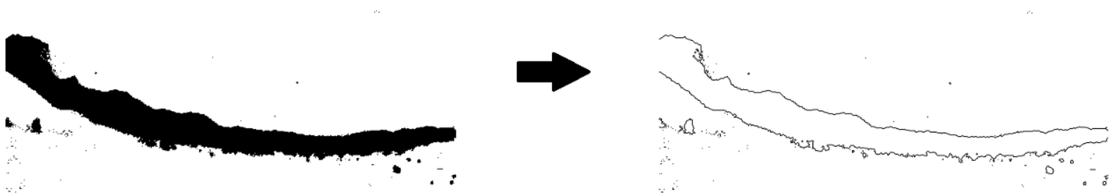

Fig.8: Gap Image by the Comparison Edge Detection.

4. Pixel Correction

In the image, the pixel coordinate represents the position of each pixel. The algorithms in image processing are developed to calculate the distance of pixels and then converted into the actual size of dentures gap. Here the pixel arithmetic is adopted to calculate the dentures gap size and error. In order to transfer the distance of digital image into the corresponding distance, the ratio between the pixel distance and actual size must be determined. P_m shown in Eq. (2) is defined as the ratio.

$$P_m = \frac{actual\ distance}{pixel\ distance} \tag{2}$$

In calibration experiment, a Japan Mitutoyo 200 mm standard measuring scale shown in Figure 9 was used to correct the resolution of pixel. The image of Figure 9 is taken at the specified condition and shown as Figure 10. The distance between A and C in the image represent 0.1 mm. The ratio between the pixel distance and actual size can be easily calculated by Eq. (2).

Fig.9: Glass calibration scale.

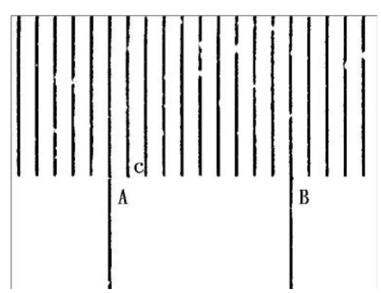

Fig.10: Pixel correction mode.

In this case, the distance between A and $\overline{C}$ is 0.1mm and the corresponding pixels are 32. The ratio P_m is then calculated as 0.003125. If the distance $\overline{AB}$ is checked, it has 318 pixels. The corresponding length and error are 0.99375 mm and 0.00625 mm, respectively.

Until now, the traditional intraoral camera can only take the image but does not have the function of measurement. The developed measurement program shown in this paper could combine with the commercial oral camera to improve its application. The image signal got from intraoral camera is transmitted to a computer through USB interface and measured by the developed measured software. This instrument can be applied to measurement the denture gap efficiency.

5. Conclusion

In this paper, the device and computation algorithm are developed successfully to indicate the gap of dentures. The comparison edge detection is proposed to obtain a thinner boundary. It helps to identify the boundary precisely. Then, the gap of dentures can be precisely indicated. The measurement error is about 0.006mm, less than the required 0.01 mm in dental operation.

6. Acknowledgements

The authors wish to thank MOST 104-2218-E-010-004-A project for the financial support.

7. References

[1] D. W. Manthey, K. N. Knapp, and D. Lee, "Calibration of a laser range finding coordinate measuring machine ," *Opt. Eng.* , Vol. 33 , No. 10 , pp.3272 -2379 , October 1994 .

[2] C. Bradley and G. W. Vickers, "Free–from surface Reconstruction for machine vision rapid prototyping", *Opt. Eng.*, Vol. 32, No. 9,pp.2191-2200, September 1993.

http://dx.doi.org/10.1117/12.145064

[3] A. Huertas, "Detection of Intensity Changes with Sub-pixel Accuracy using Laplacian-Gaussian Masks," *IEEE Trans. On Pattern Analysis and Machine Intelligence,* Vol. 8, No. 5, pp. 651-664, September 1986.

http://dx.doi.org/10.1109/TPAMI.1986.4767838

[4] A.P. Pentland, "A New Sense for Depth of Field," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 9, No. 4, pp. 523-531, July 1987.

http://dx.doi.org/10.1109/TPAMI.1987.4767940

[5] S.K. Nayar and Y. Nakagawa, "Shape from Focus: An Effective Approach for Rough Surfaces," *IEEE International Conference on Robotics and Automation*, Vol. 2, No. 10, pp. 218-225, 1990.

http://dx.doi.org/10.1109/ROBOT.1990.125976

[6] M. Subbarao and T. Choi, "Accurate Recovery of Three-Dimensional Shape from Image Focus," *IEEE Transaction On Pattern Analysis and Machine Intelligence*, Vol. 17, No. 3, pp. 266-274, March. 1995.

[7] G. Shrivakshan and C. Chandrasekar, "A Comparison of various Edge Detection Techniques used in Image Processing," *International Journal of Computer Science Issues,* Vol. 9, No 5, pp.269-276, September 2012.

[8] N. Senthilkumaran and R. Rajesh, "Edge Detection Techniques for Image Segmentation and A Survey of Soft Computing Approaches," *International Journal of Recent Trends in Engineering,* Vol. 1, No. 2, pp.250-254, May 2009.

[9] Wenshuo Gao, Lei Yang, Xiaoguang Zhang, and Huizhong Liu, "An Improved Sobel Edge Detection," *2010 3rd IEEE International Conference on Computer Science and Information Technology*, Vol. 5, pp. 67 - 71, 9-11, July 2010.