International Journal of Smart Home
Vol.10, No.10 (2016), pp.121-130
http://dx.doi.org/10.14257/ijsh.2016.10.10.12

Research of Traffic Statistics in Hospital Outpatient Clinic based on Face Detection

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Abstract

Currently the traffic data of hospital outpatient clinic mainly comes from the hospital management information system, so that the phrase of statistics can only begin after the registration of patients, which lags to a certain extent. This paper firstly makes pre-treatment to the images, and then makes face detection and counting with YCrCb color space algorithm to reflect the traffic of clinic in real time. It is revealed after experiments that, it can help the hospital timely respond to some unpredictable clinic peaks, improve the satisfaction degree of the patients to the hospital, and increase the hospital's economic and social benefits.

Keywords*: face detection, image processing, YCrCb Color Space, traffic statistics*

1. Introduction

Outpatient clinic is a major department of the hospital and a key window facing the society. The quality of work arrangement and services in outpatient clinic represents the overall level of the hospital to a large extent and also determines the patients' satisfaction to the hospital [1]. Along with the continuous improvement of the hospital's information level, the management decision support system based on statistical data has played an increasingly greater role in such aspects as strengthening hospital management, assisting decisions of senior leaders, *etc*. [2], in which process, the traffic statistical data in outpatient clinic takes an important position. Through analysis to the changing rules of outpatient quantity in different times, the manpower and material resources can be dispatched scientifically and reasonably to achieve the optimal allocation of resources, for example, equip sufficient doctors, nurses, technicians and management personnel and ensure rear supply in peak times for smooth implementation of various medical activities.

Currently, the traffic data of most hospital outpatient clinics comes from the hospital management information system, so that the phrase of statistics can only begin after the registration of patients [3] , which lags to a certain extent. Moreover, this data only represents the quantity of patients but not includes the accompanying family members, so it can not reflect the actual person-density in the hospital outpatient clinic. As the management in hospital is featured by concreteness and authenticity, such limitation will easily cause decision failure or work not in place. On account of this, the face detecting algorithm can be adopted to reflect the quantity of persons in a relatively accurate way, to response to some unpredictable clinic peaks timely, and to facilitate early decisions and rapid implementations in treatment for patients. 1

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ISSN: 1975-4094 IJSH

For example, add doctors in outpatient clinic timely, increase triage nurses, provide consultation services related to medicine such as medical insurance, and solve various emergencies in time, *etc*.

2. Domestic and Foreign Research Situation

The theory of face detection is relatively easy, but the influence of other factors shall be considered in actual operation, such as the covering or overlapping of faces in images, the front or side faces, and the influence of complex expressions, *etc*. In certain circumstances, faces may be detected in areas without any faces. To solve these problems, many technological obstacles need to be conquered, including template-based matching, artificial neural network [4], facial feature location [5], support vector machine (SVM) [6], pattern recognition, *etc*.

The researches of face detection overseas are early and among them are those conducted by the MTI Media Lab and Ai Lab, and the Robot Institute of Carnegie Mellon University; there are also researches on face detection methods by Moghaddam *et al* based on facial features, Rowley *et al* based on neural network, and Yullie *et al* based on elastic pattern, as well as researches on eigenface method of Turk *et al* based on PCA technology [7]. Recently, the SVM method based on Statistical Learning Theory stands out and is applied to many areas including face recognition due to its good capacity of generalization. However, the results of these results have strict requirements on the imaging conditions, so their application range is narrow.

Many Chinese research institutes also conduct relative researches on face detection, including Tsinghua University, Beijing University of Technology, Shanghai Jiaotong University and Institute of Computing Technology of Chinese Academy of Science, and certain results have been achieved. Zhou Zongheng *et al* of Computer Department, Fudan University applied K-L transform into the transform of color system coordinate, proposed a new kind of rapid initial face location method based on K-L skin color, and offered the transform matrix and skin color threshold value of K-L color system coordinate. After K-L skin color position, the binary image of face can be obtained, then the small areas will be handled with the theories of mathematical morphology, and finally the face area is confirmed.

Analysis of outpatient traffic is of great significance to the hospital management and is also one of the important embodiments of quantitative management concept [8]. The traditional statistical methods enjoy priority in most hospitals currently. Among them, the frequently used is the analysis of historical outpatient traffic data in HIS retrieved through seasonal indexes analysis to time sequence data, for example, the study of reasonable allocation of outpatient resources of Ge Liang and Mi Yiqun based on outpatient traffic monitor (*Chinese Hospital Management*, 2014 (09)). In addition, the application idea and model of data mining into patient traffic analysis are also of certain research significance and exploration value. However, there are rarely any papers or researches about the outpatient traffic statistics with face detection technology. Therefore, this paper aims to propose a method to make real-time statistics of outpatient traffic with face detection technology.

3. Algorithm

3.1. Face Detection with YCrCb Color Space

As the color representation model applied in CCIR601 coding scheme with studio quality standard as the objective, the color space YCrCb (YUV) is widely applied in such fields as color display of videos [9]. This space can be slightly influenced by brightness variation, can distribute independently in two-dimension, and well restrict the skin color distribution area. The CrCb component of color image based on color space YCrCb is

sensitive to brightness, and the skin color presents little difference under CrCb component. The image based on RGB color space under the component of person can not distinguish the skin color from the background. To avoid the influence of brightness, the color model of YCrCb is selected and color space conversion is conducted to the input color images, *i.e*. from the RGB space with high correlation to the color space YCrCb with irrelevant color components. The conversion formula is as follows:

Formula 1

After statistics to a large number of skin color samples, it is found that the distribution of skin colors in CbCr space presents good clustering feature. The statistical distribution satisfies 77<Cb<127 and also 133<Cr<173.

Skins of different races have large difference, but the difference in chrominance is far less than that in brightness. On the two-dimensional chrominance plane, the skin color area is concentrated, so it can be described in Gaussian distribution. According to the Gaussian distribution of skin color in chrominance space, the probability of each pixel in the color image in the skin area can be calculated after it is converted from RGB color space to YCbCr space [10], *i.e*. obtain the similarity with skin color according to distance of this point from the centre of Gaussian distribution and convert color image to gray image to make the gray level of each pixel correspond to the similarity of that point to skin color. The similarity computation formula is as follows:

$$p(CbCr)=\exp[-0.5(x-m)^{\wedge}\tau C^{\wedge}(-1)(x-m)]$$

Formula 2

Wherein, m is the average value, m=E(x), C is covariance matrix, x=(CbCr)^ţ, the 2D Gaussian model G (m, V2) of the skin color can be represented as:

$$m=(\overline{Cb},\overline{Cr})$$

$$\overline{Cr}=\frac{1}{N}\sum_{i=1}^{K}Cr_i$$

$$\overline{Cb}=\frac{1}{N}\sum_{i=1}^{N}Cb_i$$

$$V=\begin{pmatrix}\sigma_{CrCr} & \sigma_{CrCb}\\ \sigma_{CbCr} & \sigma_{CbCb}\end{pmatrix}$$

Wherein, $\overline{Cr},\overline{Cb}$ are the average values corresponding to Cr and Cb, and V is the covariance matrix.

After the color image is converted to gray image of similarity through Gaussian model, proper threshold values can be selected and then the skin color area and non-skin color area can be divided. The skin color model is based on statistics and similarity computation is needed to each pixel, so the speed is not so fast. Of course, in the real skin color detection, the $[-0.5(x-m)^{\wedge}\tau C^{\wedge}(-1)(x-m)]$ in formula 2 can be directly used for determination to increase the detection speed.

3.2 Gray Processing and Pre-Processing

The built-in gray processing function rgb2gray [11] of MATLAB is used to make gray processing to the images; for the image pre-processing part, the open operation is adopted to eliminate the desultory points; in the screening of face candidate regions, as some head parts are overlapped and some heads are connected with the clothes, the closed operation is first adopted to break the connections and then hole filling is conducted to lay a

foundation for confirmation of face area. Open and closed operations actually refer to the erosion and dilation to the images, and there are two methods to represent gray erosion operation, which are respectively one-dimensional and two-dimensional ways:

$$f\theta b = \min\{f(s+x) - b(x) \mid (s+x) \in D_f, x \in D_b\}$$
$$(f\theta b)(s,t) = \min\{f(s+x,t+y) - b(x,y) \mid (s+x),(t+y) \in D_f \text{且} (x,y) \in D_b\} \quad \text{Formula 3}$$

The maximization method is used when the gray value erosion is defined, *i.e*. obtain the maximum value that can be achieved in push-up structure when it is under the signal. Here we use the reflection of structure element to obtain the minimum value of push-up structural element exceeding the signal when the signal is limited within the domain of structural element, so as to define the gray value expansion. The gray scale expansion is the dual operation of gray corrosion operation, and the gray scale expansion of structure element b (x, y) to target image f(x, y) can also be expressed by two methods, which are respectively one-dimensional and two-dimensional ways:

$$f \oplus b = \max\{f(s-x) + b(x) \mid (s-x) \in D_f, x \in D_b\}$$
$$f \oplus b = \max\{f(s-x,t-y) + b(x,y) \mid (s-x),(t-y) \in D_f, (x,y) \in D_b\} \quad \text{Formula 4}$$

With the two morphological algorithms, *i.e*. erosion and expansion, to primary gray value, we can define the secondary computation – gray open and gray closed operations. The two operations are dual operations and they can both be described by the filling concept. The formula is:

$$f \circ b = (f\theta b) \oplus b \quad \text{Formula 5}$$

Open operation is usually used to remove small (relative to the structural elements) brightness details, but keep the overall gray level and the big brightness characteristics unchanged. As the initial erosion operation will make the image darker at the same time of eliminating small brightness details, the afterwards expansion process is used to increase the whole strength of image but will not introduce the details that have been eliminated.

According to the definition of duality, the closed operation for gray value is defined as follows:

$$f \bullet b = (f \oplus b)\theta b \quad \text{Formula 6}$$

The closed operation to gray value is of expansibility, and the filtering results always stay at the top of original images.

3.3 Confirmation of Face Area

Due to the similarity between background and skin color as well as the light reflection or other reasons, disturbance will be caused to the confirmation of face area, so certain measures shall be taken to remove the non-face area. The following methods can be adopted:

(1) Label the connection area with bwlabel function, calculate the area of labeled area, then calculate the area with the longest side of labeled area, compare the two areas and obtain the area filling rate. If the filling rate is larger than 0.5, then keep this area as the candidate area. L=bwlabel (BW,n), return an L matrix with the same size as BW which contains the category labels indicating each connection area in BW, and the values of these labels are 1, 2 and num (quantity of connection areas). The value of n is 4 or 8, which means that the area is found based on 4 or 8 connections. The default value is 8.

4-connected or 8-connected is the basic concept in image processing: 8-connected means that a pixel is considered as connected with other pixels when it is connected with them in up, down, left, right, top left, lower left, top right or lower right corners; 4-

connected means that a pixel is considered as connected with other pixels when it is connected with them in up, down, left and right sides but considered as not connected when it is connected with them in top left, lower left, top right or lower right corners.

[L,num] = bwlabel(BW,n), wherein what returned by num is the quantity of connected areas in BW.

(2) Make further judgment on the basis of candidate area in last step, then make labeling to the connected area again with the above method, and keep the area with the ratio of over 0.3 as the candidate area again.

(3) Confirm the face area further with the screening of candidate face areas (the judgment rules are as follows):

1. If the target depth-width ratio is larger than 0.8 but smaller than 2.0, then it is not considered as the face area and will be deleted.

2. If the target area is too large or too small, it is not considered as the face area and will be deleted.

3.4 Framing to the Face Area

The face area has been determined in the last step. To make the result more intuitive, the confirmed face area is framed for labeling and then it just needs to output the quantity of faces.

4. Experiment

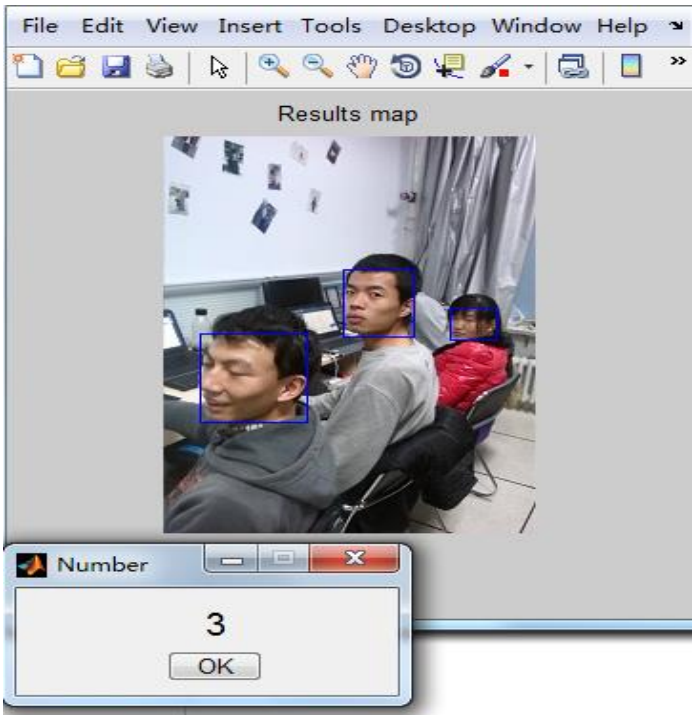

Figure (1)

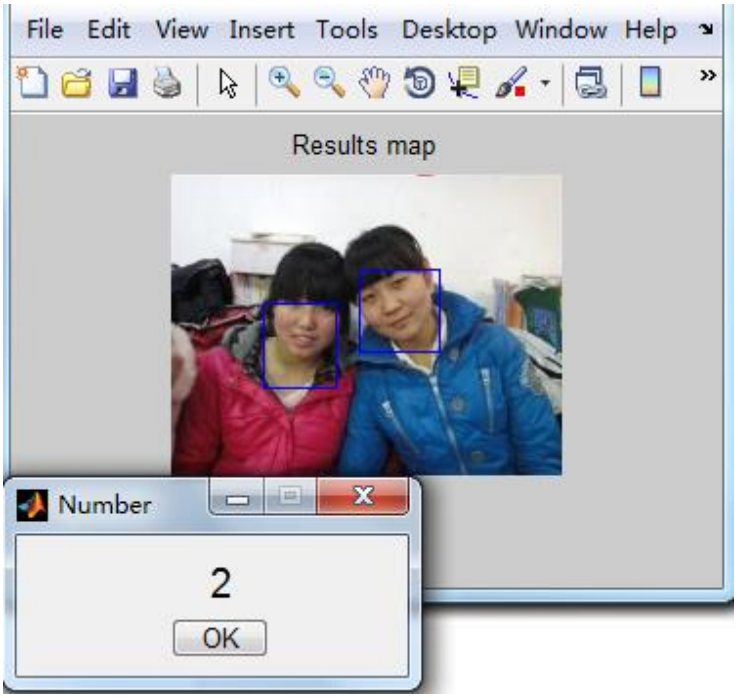

Figure (2)

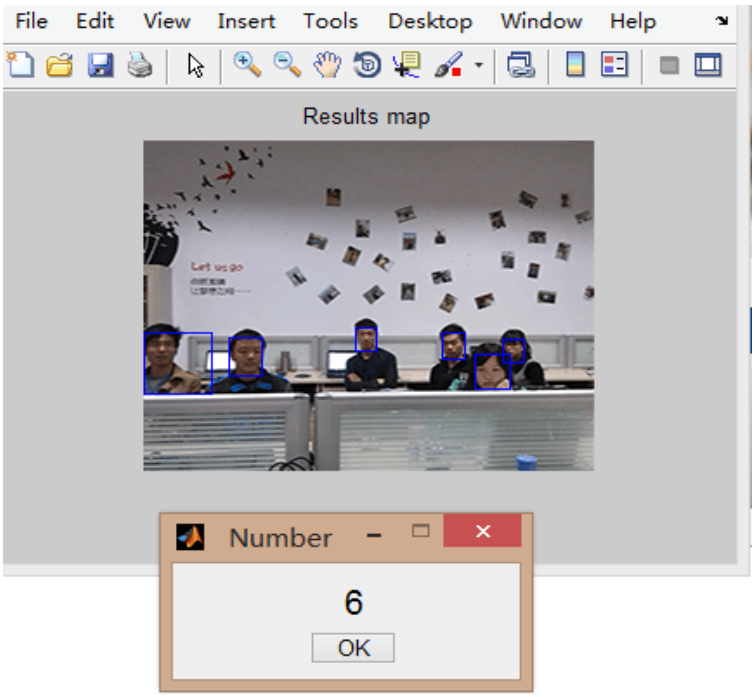

Figure (3)

Table（1）

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	43,523	20,369	34,421	33,236	32,717	33,126	36,337	41,226	34,109	30,207	55,112	56,341
2014	45,125	21,743	35,563	36,461	37,959	35,311	38,908	43,812	41,116	35,677	55,922	54,882

During January 2013 and December 2014, this algorithm was used in a hospital to make statistics of the outpatient patients and their family members and the details can be seen in Table (1) /person times

Table （2）

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	13,511	12,809	15,611	15,116	16,255	16,982	17,316	19,433	17,517	14,574	17,593	18,371
2014	14,955	13,567	15,881	16,391	17,201	17,722	18,394	19,333	17,768	15,944	17,977	18,109

Table （2） shows the monthly report of patient statistics based on hospital information system during January 2013 and December 2014. /person times

Table（3）

Item	Evaluation Times (person times)			Satisfaction Percentage (%)			Comparatively Satisfied (%)			Not Very Satisfied (%)			Dissatisfied (%)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Clinical Environment	319	389	462	35.78	40.37	47.19	30.13	33.56	39.12	20.69	18.34	10.47	13.40	7.73	3.22
Guiding Service	334	356	489	32.38	38.68	38.84	32.29	37.89	39.68	23.78	20.28	15.19	11.55	3.15	6.29
Queuing Time	309	398	492	30.23	29.45	37.47	32.39	34.29	36.30	25.39	24.38	20.11	11.99	11.88	6.12
Registration Service	348	384	474	33.17	34.89	37.12	32.14	34.28	37.29	20.28	18.28	17.28	14.41	12.55	8.31
Consultation Service	328	389	478	35.89	36.63	36.93	31.23	33.38	37.21	19.28	18.35	15.29	13.60	11.64	10.57
Examination &Test Services	350	376	469	30.82	33.28	36.19	34.21	35.17	37.38	18.69	17.37	18.27	16.28	14.18	8.16
Other Services	328	372	428	29.19	33.27	36.28	35.25	36.14	38.20	13.29	14.28	10.29	22.27	16.31	15.23

Satisfaction survey was conducted to the outpatients in this hospital during the clinic peaks in November of 2012, 2013 and 2014 [12], and the results are shown in Table(3).

The experiments in Figure （1） and Figure （2） show that the algorithm is of universal applicability. It has good identification to the head images captured by the general cameras, it has few requirements to the external conditions such as light, and it has certain identification to the biased side images of heads. Table （1） shows the experiment results in hospital outpatient clinic based on this system, while Table （2） reveals the statistical data from HIS for comparison. During the two years of experiment in hospital, several small peaks in stream of people were successfully predicted and timely response was carried out, such as add medical guide nurses temporarily and equip more doctors thus reducing the inefficient routes and waiting time of patients or their family members, increase tables and chairs in waiting area, guarantee supply of hot water, provide free newspaper and brochures for the prevention of common and frequently-occurring diseases, add cleaning workers to create a comfortable and neat clinic environment, strengthen onsite investigation, solve the problems encountered by patients, coordinate the tensions between doctors and patients, *etc*. The above measures provide patients more convenience on one hand and placate their family members on the other hand, so that the negative emotions of family members produced from the process of seeking medical assistance will not be transferred to patients. In Table （3）, it reveals that the implementation of this system enhances the satisfaction of patients to the hospital.

5. Summary

This paper studies a statistical method to the traffic in hospital outpatient clinic based on face detection. With high real-time, this method can help hospital managers acquire statistical data dynamically, implement management planning and arrange human power and material resources based on the quantity of patients and family members. In this way, the clinic services can be improved, the satisfaction to hospital can be increased, and the economic and social benefits of the hospital can thus be enhanced. Therefore, it is of high application value.

Acknowledgements

This work was supported by Hebei North University (No.Q2014002,No.ZD201301,No. ZD201302,No.ZD201303,No.Q2014005,No.Q2014008) .

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