Intelligent Automatic Extraction of Canine Cataract Object with Dynamic Controlled Fuzzy C-Means based Quantization

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Article Info	ABSTRACT
	Canine cataract is developed with aging and can cause the blindness or surgical treatment if not treated timely. Since the pet owner do not have professional knowledge nor professional equipment, there is a growing need of providing pre-diagnosis software that can extract cataract-suspicious regions from simple photographs taken by cellular phones for the sake of preventive public health. In this paper, we propose a software that is highly successful for that purpose. The proposed software uses dynamic control of FCM clusters in quantification and trapezoid membership function in fuzzy stretching in order to enhance the intensity contrast from such rough photograph input. Through experiment, the proposed system demonstrates sufficiently enough accuracy in extraction (successful in 42 out of 45 cases) with better quality comparing with previous attempt.

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1.   INTRODUCTION

A cataract is an opacity of the lens or lens capsule, histologically death and disruption of lens epithelial causing opacity. The cataract usually progresses to involve larger areas of the lens and rate of progression is difficult to predict in the speed or the magnitude of the development [1]. The causes of the cataract formation are genetic, secondary to ocular diseases, traumatic, toxic, age-related, radiation-induced, and/or caused by electrocution [2]. The treatment of canine cataract can be injection of eye drops to delay the development or artificial lens insertion by surgery and the surgical methodology may be decided by the age of the dog and symptoms in consideration of postoperative treatment [3]. Surgery is generally recommended when the cataracts cause diminished vision, or for progressive cataracts where vision loss is anticipated [4]. However, an accurate evaluation of the lens is obligatory before its removal in order to achieve the best postoperative result [5].

The cataract for dogs are found usually in the process of regular checkup by veterinarian. However, it needs pet breeder's continuous care and knowledge about the pet's status. As noted in [6], there have been several researches using ultrasonography [7], MRI [8], endoscopic evaluation technique [9] and, if we can extract characteristic features for the diagnosis, even machine learning techniques might be applicable [10] to assist the medical expert.

However, there are many misconceptions about cataracts in society of pet owners in that it is a film over the eye or a type of cancer or can spread from one eye to the other or causes irreversible blindness [1]. Usually a pet dog gives a sign to its owner by expressing unusual behavior or by the change of its body when its health is at risk or having a disease. Without deep knowledge about the pet dog's disease, owners tend to neglect such signs only to make the situation worse [11].

Thus, we have developed a handy pre-diagnostic tool for pet owners that detects cataract-suspicious object from normal cellular phone photographs. The system may not need to be as accurate as the medical doctor's professional analyzing tools like MRI but its role is to draw attention to the public to listen to their pet's complaints for preventive public healthcare.

We have tried various image processing algorithms in conjunction with some artificial intelligent techniques such as ART2 learning, and Fuzzy C-Means (FCM) image to overcome given noise prone cellular phone image analysis [6], [11], [12].

In this paper, we apply dynamic control of FCM in quantization process and trapezoid type membership function in fuzzy stretching for brightness enhancement. When we applied ART2 [6], the software can not discriminate white hair around eyes from cataract in ART2 clustering process thus there was an inaccurate cataract extraction case. FCM was considered as the alternative of ART2 to overcome that problem. However, the static FCM that has predefined number of clusters in quantization process was found too much sensitive to the environment - brightness distribution near cataract region and other region - and time consuming [12]. Dynamic cluster control can be a solution in this environment thus we modified the FCM as such.

2. BRIGHTNESS ENHANCEMENT WITH FUZZY STRETCHING

The input image in this paper is a simple digital camera image that may contain irregular pixel values. The first task of our software is to find the boundary lines of cataract-suspicious object. Then, we nned to enhance the brightness contrast between the "bright" side and the "dark" side.

In this paper, we apply fuzzy stretching for that purpose like we used in [6] but change the membership function from the usual triangle type to trapezoid type that has been successful in many applications where the intensity distribution seems to be irregular [13].

Let X_i^G be the grey value of pixel X_i, then the average intensity value X_m^G is defined as formula (1).

$$X_m^G = \frac{1}{MN} \sum_{i=0}^{MN} X_i^G \qquad (1)$$

where M, N denote the width and length of the input image.

Let X_l^G, X_h^G be the lowest and highest intensity value of the image, the maximum and minimum differences from the average are defined as formula (2)

$$D_{max}^G = \left| X_h^G - X_m^G \right|, \; D_{min}^G = \left| X_m^G - X_l^G \right| \qquad (2)$$

And then the adjustment rate $adjustment^G$ can be determined as following;

$$
\begin{aligned}
&if \, (X_m^G > 128) \; then \; adjustment^G = 255 - X_m^G \\
&else \, if \, (X_m^G \leq D_{min}^G) \; then \; adjustment^G = D_{min}^G \\
&else \, if \, (D_{max}^G > X_m^G) \; then \; adjustment^G = D_{max}^G \\
&else \; adjustment^G = X_m^G
\end{aligned}
\qquad (3)
$$

Since the shape of the membership function is trapezoid, we need to find 1/3 and 2/3 points as following;

$$
\begin{aligned}
&I_{max}^G = X_m^G + adjustment^G \\
&I_{min}^G = X_m^G - adjustment^G \\
&I_{min \, mid}^G = \frac{1}{3}(I_{max}^G + I_{min}^G) \\
&I_{max \, mid}^G = \frac{2}{3}(I_{max}^G + I_{min}^G)
\end{aligned}
\qquad (4)
$$

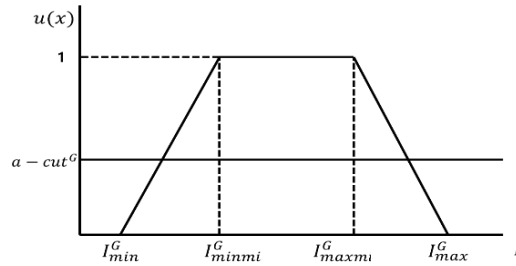Then the membership function for the fuzzy stretching as as shown in Figure 1.

Figure 1. Trapezoid Type Membership Function

The upper limit value (β) and the lower limit value (α) are defined as the highest and lowest X_i among pixels that have higher membership degree than the cut point (α-cut^G) as following;

$$if\ (I_{min}^{G} < 0)\ \alpha - cut^{G} = ((I_{min}^{G} / \alpha) + (I_{min}^{G} / I_{max}^{G})) / 2$$
$$else \qquad \alpha - cut^{G} = 0.5 \tag{5}$$

Then the final stretched value of the pixel is computed as following;.

$$f(I) = \frac{I - \alpha^{G}}{\beta^{G} - \alpha^{G}} \times 255 \tag{6}$$

3.   DYNAMIC CONTROLLED FUZZY C-MEANS IN QUANTIZATION

FCM Algorithm is an unsupervised clustering method that has been widely used for ultrasound image analysis where pixels with the same features is grouped into the same cluster. Using FCM algorithm, the colors in the image are segmented depending on the number of clusters that is usually predefined line we used in [12].

From [12], we experienced that the quantization process was not sufficiently correct in that some objects were incorrectly grouped due to the predefined number of clusters. The shape of the canine cataracts may variate according to the different species in size of the eyeball and hair thus we need more adaptation in this quantization process.

Thus, in this paper, we change the number of clusters dynamically based on the accumulated error rate of membership degree.

Thus, the FCM used in this paper works as following;

Step 1: Initialize the number of cluster c ($2 \leq c < n$), exponential weight m($1 \leq m < \infty$), and the membership degree $u^{(0)}$

Step 2: Compute the central vector v_{ij} as Equation (7) for$\{v_i | i = 1, 2, ..., c\}$

$$v_{ij} = \frac{\sum_{k=1}^{n} (u_{ik})^{m} x_{kj}}{\sum_{k=1}^{n} (u_{ik})^{m}} \tag{7}$$

Step 3: Compute the distance d_{ik} between the kth pattern x_k and the central vector of the ith cluster by the Equation (8).

$$d_{ik} = d(x_k - v_i) = \left[\sum_{j=1}^{l} (x_{kj} - v_{ij})^2 \right]^{1/2} \tag{8}$$

where l denotes the number of pattern nodes. Then, v_{ik}, the new membership degree of kth pattern in ith cluster is computed as Equation (9).

$$u_{ik}^{(r+1)} = \frac{1}{\sum_{j=1}^{c} (d_{ik}^r / d_{jk}^r)^{2/m-1}} \quad for \; I_k = \phi$$

$$or \; u_{ik}^{(r+1)} = 0 \quad for \; all \; classes \, i, \, i \in \tilde{I}_k \tag{9}$$

$$I_k = \left\{ i \mid 2 \leq c < n; d_{ik}^{(r)} = 0 \right\}, \tilde{I}_k = \{1, 2, ..., c\} - I_k$$

$$AND \; \sum_{i \in I_k} u_{ik}^{(r+1)} = 1$$

Step 4: Compute the difference between the new and the previous membership degree as shown in Equation (10). Also, in this step, accumulate the differences based on the number of clusters c. If the difference is larger than the error threshold (ε), then go to Step 2.

$$\Delta = \left\| U^{(r+1)} - U^{(r)} \right\| = \max_{ik} \left| u_{ik}^{(r+1)} - u_{ik}^{(r)} \right|$$

$$if \; (k > \varepsilon_t) \; k = \Delta + k \tag{10}$$

Step 5: Determine the number of clusters c as shown in Equation (11).

$$if \; (c > 20) \; N_c = \sum_{j=0}^{n} \Delta N_j$$

$$N_e = \sum_{c=10}^{20} N_c \tag{11}$$

where c is the initial number of clusters and j is the real number of the clusters. ΔN_j is the accumulated differences and N_c is thus that of initialized c.

In his paper, we explore the number of clusters between 10 and 20 and then determines the final number of cluster of the given data as the one which minimizes N_e. And repeat the procedure of FCM until no more significant changes exist.

The effect of this dynamic control of FCM quantization is demonstrated as Figure 2 compared with static controlled scheme.

(a) After Fuzzy stretching   (b) Quantization by Static FCM [12]

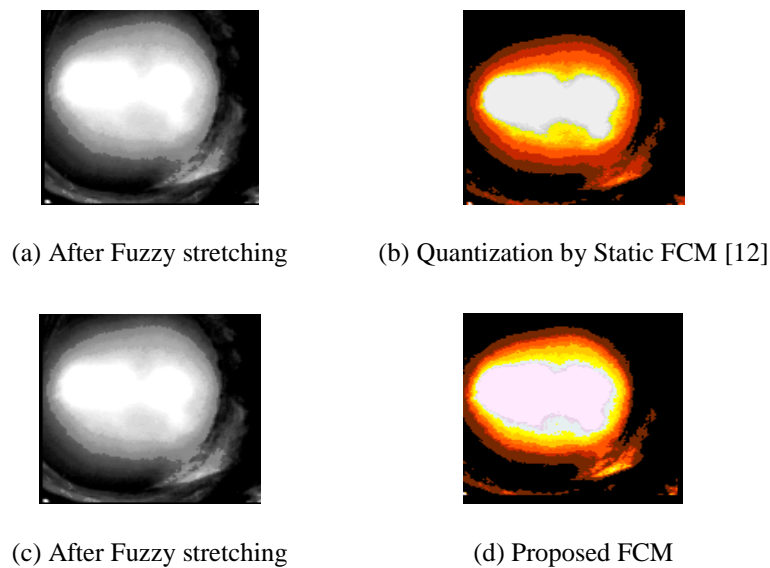(c) After Fuzzy stretching   (d) Proposed FCM

Figure 2. The Effect of Dynamic FCM in Quantization

In Figure 2, the static FCM had the number of clusters as 15. One can find the clear difference in extracting cataract candidate region.

After quantization, we apply average binarization and morphological operators such as erosion and expansion. Small objects in the region of interest(ROI) are removed as noise and a sufficiently big (over 3/5 of ROI in size) candidate object is chosen as the probable cataract as shown in Figure 3.
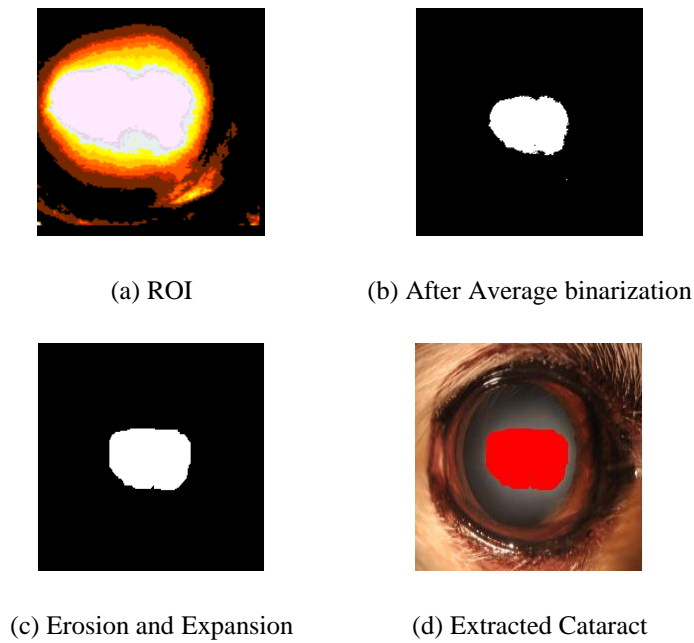

(a) ROI   (b) After Average binarization

(c) Erosion and Expansion   (d) Extracted Cataract

Figure 3. Extracting Cataract by the Proposed Method

4. EXPERIMENT

The system is implemented in Visual Studio 2013 C# with Intel(R) Core(TM) i5-3330U CPU @ 1.80GHz and 4 GB RAM PC. 45 real world dog eye photographs having cataract taken by cellular phones are used in this experiment. Figure 4 demonstrates a snapshot of the implemented system.
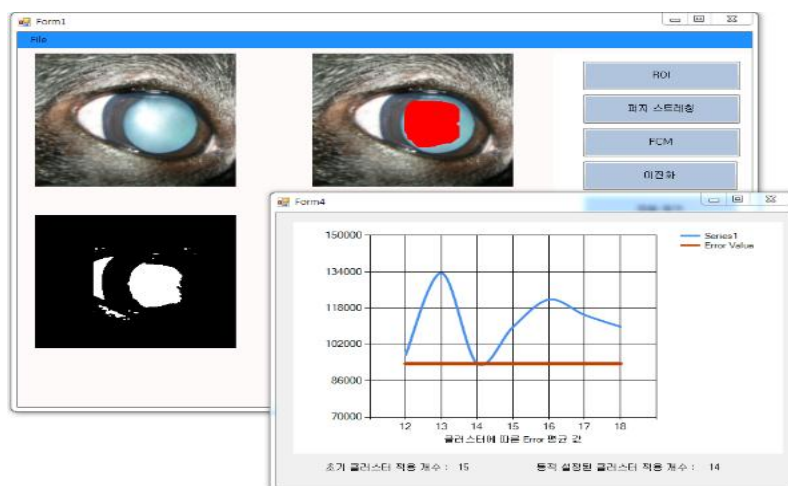

Figure 4. Snapshot of the System Output

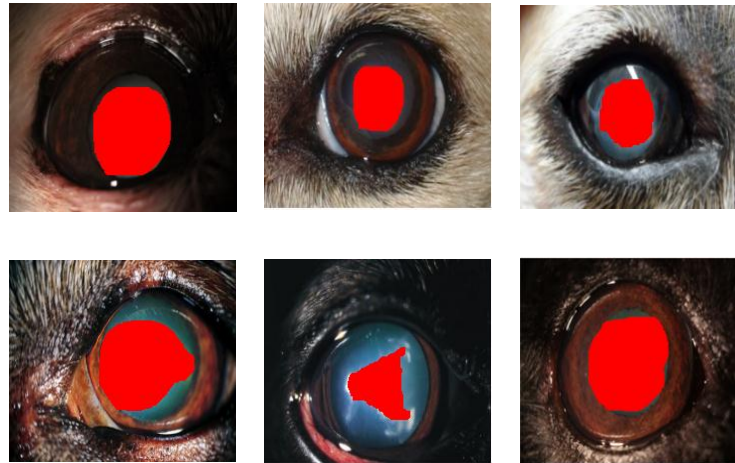Several real examples of extracting cataract suspicious regions are demonstrated in Figure 5.

Figure 5. Cataract Extraction Examples

Table 1 summarizes the performance result of the proposed method comparing with previous attempt [12].

As one can see from Table 1 and Figure 6, the proposed method is much better in successful extraction rate and the quality in general. A veterinarian is involved in this experiment to evaluate and verify the quality of the system. Three failed cases of extraction does not meet the size constraint in this experiment.

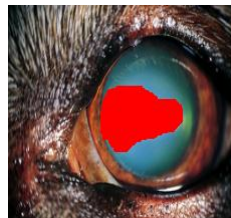Table 1. Cataract Extraction Performance

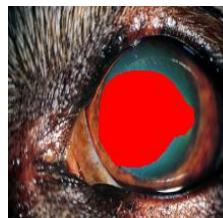|	Previous [12]	Proposed
Success	36 / 45	42 / 45

(a) Previous

(b) Proposed

(c) Previous

(d) Proposed

Figure 6. Performance comparison in Cataract Region Extraction

5. CONCLUSION

Like human, dogs also develop cataracts with age among many other causes. It can cause blurred vision and eventually entire lens diffusely can become cloudy, and all functional vision may be lost.

However, since the patient is a dog who has very limited capability of complaining its abnormalities to human, we need a pre-diagnostic tool for the pet owners who have limited knowledge of animal diseases.

In this paper, we propose a computer vision based software to extract canine cataract from digital camera photographs automatically. This effort has been done by our team for many years with different technical algorithms involved [6], [11], [12].

Intelligent control of FCM clusters in quantization and careful trapezoid type membership functions used in fuzzy stretching are keys of successful result in this experiment.

Since this pre-diagnostic function for knowledge-limited pet owners without professional equipment does not have to meet the rigorous standard in accuracy, the proposed method is verified as effective for casual pet dog owners to see if the dig has cataract problem as early as possible. We expect that similar vision based methodology can be applied to extract glaucoma and give pre-diagnosis of abnormality as soon as possible.

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Doo Heon Song received a B.S. degree in Statistics & Computer Science from Seoul National University and M.S. degree Computer Science from the Korea Advanced Institute of Science and Technology in 1983. He received his Ph.D. Certificate in Computer Science from the University of California in 1994. Form 1983-1986, he was a research scientist at the Korea Institute of Science and Technology. He has been a professor at the Department of Computer Games, Yong-in Songdam College, Korea, since 1997. His research interests include ITS, machine learning, artificial intelligence, medical image processing, cognitive, and game intelligence.