

AREA QUANTIFICATION IN NATURAL IMAGES FOR ANALYSIS OF DENTAL CALCULUS REDUCTION IN SMALL ANIMALS

Nilo F. Varela*, Renata S. Alberto Carlos[†], Susana M. Iglesias*, Paulo E. Ambrósio*

*Programa de Pós-Graduação em Modelagem Computacional em Ciência e Tecnologia
Universidade Estadual de Santa Cruz
Rodovia Jorge Amado, km 16, Cep 45662-900, Ilhéus, BA, Brasil
nilofvlgm@gmail.com; peambrosio@uesc.br

[†]Programa de Pós-Graduação em Ciência Animal
Universidade Estadual de Santa Cruz
Rodovia Jorge Amado, km 16, Cep 45662-900, Ilhéus, BA, Brasil
rsacarlos@uesc.br

Keywords: Computational modeling, Image processing, Dental calculus.

Abstract: *Digital image processing face a big challenge when it comes to natural images, because their show many inconsistencies, noise and fake borders. The problem intensifies when we need to identify specific areas in a large image bank where the images were acquired with no defined convention. This paper presents an approach to this kind of scenario that allows images to be processed with a higher level of precision. The context in which this work is inserted is associated with the quantification of periodontal disease in small animals, processing images produced during a treatment cycle. Among the related techniques are, Active Contour for image segmentation and image registration to support a process that reduce the image to a smaller and more significant area.*

1. INTRODUCTION

The periodontal disease, is among one of the most common oral infections in animals, and can harm their health in multiple ways, going from influence on temper all the way to damaging vital organs when the bacteria enters the bloodstream. According to [1], its formation is associated to the calcification of the dental plaque, which are mineralized by elements present on the animals saliva as well as organic sediments.

Usually, the disease is treated preventively by brushing the animal's teeth, and in more advanced cases, an intervention is needed. In that case the animal is sedated and the plaques are removed manually. We must observe some factors about the manual removal, the first being the risk to the animal's health, introduced by the sedation, risk that considerably increases with advanced age, sometimes even overcoming the risk introduced by the disease itself. As an alternative, a gel was created with the purpose of assisting the plaque removal. The gel is applied directly on the animal's teeth during a pre-established amount of days, treating the

disease in a less aggressive way towards the health of a cat or dog. Up to this moment, there are no studies that prove the effectiveness of this product with proper scientific rigor, so under those considerations, a project was started by a partnership between the Postgraduate Program of Animal Science, in the Santa Cruz State University, and the product manufacturer, with the objective of certifying the proposed results of the gel usage.

The study consists in an experiment with 120 dogs, those are submitted to a 90 day treatment. By the end of the process, the results need to be generated by quantifying the amount of plaques present on the teeth at each step of the treatment. Manual measurements was considered but was proven not feasible because of a great difficulty in dealing with agitated animals, that don't allow the measurements to be done properly. Another reason comes from the fact that the disease can cause a inflammatory process on the gums, which can cause pain during manipulation. A solution for this problem would be to sedate the animal, but we already established that this can cause harm to the dog's health.

Facing those challenges, it was decided that images were going to be produced at every step of the experiment to track the evolution of each case, and for that reason, a computational solution was necessary in order to process these images and generate a history with the percentage of the affected area throughout the treatment.

The image acquisition process was executed with no supervision, and as a consequence, the image bank generated was lacking conventions in process, equipment, light conditions and angle, presenting a additional challenge to the natural image processing itself. An example can be seen in figure 1.



Figure 1. Example of images produced during the experiment

This article presents a technique developed to accomplish the digital processing of these images, resulting in an application that can quantify the disease through the produced images, identifying and comparing healthy and affected areas of the teeth, mitigating problems presented by natural images with no conventions.

2. IMAGE SEGMENTATION

Procedure that consist of splitting the image in different segments, or a set of pixels, allowing the identification of objects and edges, like stated in [3]. In this project, the segmentation

consists in isolate the area of the teeth from the rest of the image, so the analysis can be made with the least amount of interference.

2.1 ACTIVE CONTOUR

One of the existing techniques that are applicable to this case is called Active Contour, also known as Snakes, developed in [2]. This technique make use of splines, which are numerical functions that describe curves with a high degree of smoothness. The splines have at least two control points (initial and final points) and two other points to define the tangents (Stoer & Bulirsch, 1980). The Active Contour uses energy minimizing deformable splines, guided by external forces, in this case, by image forces, attracting the curves to features like lines and borders. The Snakes can be used in a wide range of application, like strong border detection, lines, subjective contours and movement tracking, and in this project is used specifically for image segmentation.

The spline position changes in response to the energy, which is composed by: Internal energy, defined by the curve deformation; image energy, given by the image values; and external energy, user input being one of the possible sources.

An important property of Active Contours, is that the spline generate smooth shapes even in images with a high level of noise, and its dynamic behaviour make it stand out from the other solutions for contour delimitation, keeping itself active and minimizing the energy during all the process, allowing the interaction with external forces in real time, like user interventions for manual spline adjustments.

3. IMAGE REGISTRATION

With images acquired with no methodology, the data suffer from lack of conventions and alignment, and some techniques were considered to mitigate this problem. One of these techniques is the Image Registration, and according to [6], is applied in cases where we have multiple images of a single object, usually produced with different equipment and angles, and we have the need to make these images geometrically aligned so they can be properly analyzed. One of the image registration methods consists in the insertion of recognizable objects, that are positioned in the image where strong features can be seen. The same objects are placed on the second image on top of equivalent features. After the objects are placed, a transformation matrix is calculated in order to align the corresponding objects, and finally, this matrix is applied to the image, finalizing the process.

Besides the method described, there are other ways of image registration, defined by [6], like curve alignment, surface alignment among others.

4. TECHNIQUE

Since the project deals with natural images, is expected that the data may contain noise, inconsistencies and may eventually be incomplete, for that reason, pre-processing routines were defined as a preliminary step in order to achieve a higher degree of precision on subsequent steps. Among those we have : Conversion to gray scale, Gaussian Blur (Shapiro & Stockman, 2001) and contrast enhancement.

Given that fact that not all teeth are equally visible across all the images, for this project the analysis were limited to the canine tooth, which are the most consistent in terms of visibility.

The first step is isolate the area of interest from the rest of the image, in a way to allow the analysis to occur with the least amount of interference as possible. The Active Contour was the method of choice for image segmentation, however, when used in isolation, the image inconsistencies will reduce the quality of the segmentation, producing undesirable results, and besides that, the Active Contour requires the initial spline position before it can carry on with the calculation, and the lack of conventions prevents that position to be automatically defined. As a solution to this problem, the area of the image was reduced by using a mask. This mask is nothing more than a black and white image, representing an approximation of a canine tooth silhouette, as seen in the Figure 2, and with that, we can use the mask to encapsulate the area of interest, excluding most of the external noise. And as a second purpose, the borders of this mask can be used as an initial position for the splines, considerably reducing the manual process of the analysis.



Figure 2. Mask used to isolate the canine tooth

The mask represent the canine tooth, however, it is only a approximation, which means that the image will most likely not fit the mask perfectly. To solve this problem, the image registration method was applied, where four reference points were positioned in the image as well as in the mask, like seen in Figure 3, and those points were used to transform the image in a way to align it to the mask as much as possible.

After isolating the area of interest, a first Active Contour pass is executed, as stated before, using the mask border as initial spline position. That first pass aims to remove small portions of the image that are not part of analyzed tooth. In the Figure 4, in the center, we can observe the initial spline position represented by a blue line, and in red, the splines after 200 iterations.

With the area considerably reduced, the quantification itself can take place. For the presented application, the healthy area corresponds to the most clear areas of the tooth, and a color sample must be defined as reference. The lower extremity of the canine tooth is in constant abrasion with food, and as a result, the region is usually more polished and free of strong plaques. Using the points previously positioned, as shown in Figure 3, the average point is calculated

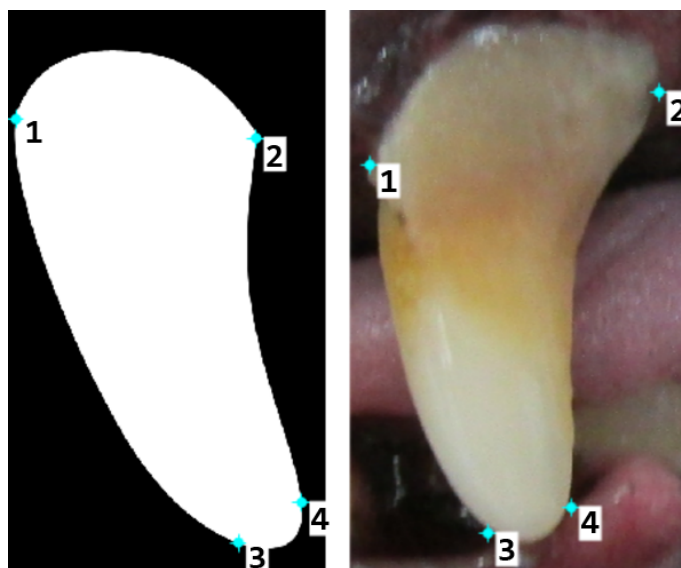


Figure 3. Reference points created to assist image registration

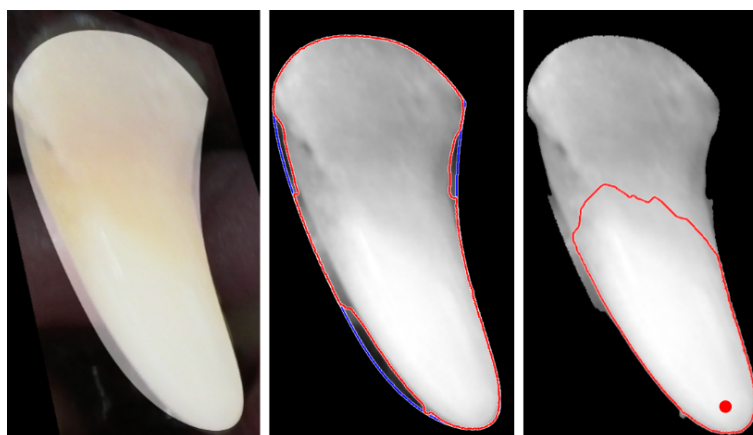


Figure 4. Processing routine. From left to right: Image registration, first Active Contour pass
second Active Contour pass

between points three and four, and is represented with a red dot in the same Figure. A sample is taken from the average, defining a healthy pixel value.

From this point on, all the pixels in the image are analyzed, and the difference between its value and the healthy value is calculated, if this difference is lower than an established threshold (20 for this particular case), the pixel is assigned the healthy group. By the end of the process, a second Active Contour pass is executed, running 50 iteration and using the border of the healthy group as initial spline position. That is a way to smooth the area and reduce an eventual noise generated by the detection. At this stage is already possible to utilize to whole area and the healthy area to calculate the final percentages, for both healthy and affected zones.

5. CONCLUSIONS

The use the technique developed in this project has proven itself as an advance on the disease measurement, because the manual procedure, in addition to the problems previously described, is not capable of generating numerical data, and is a totally empirical process, in counterpart, the computational solution generate data that is more consistent and capable of deeper analysis.

The presented results were validated by professional veterinary, and the technique was considered capable of successfully quantifying the state of the disease in the animal's teeth. A complete study on one of the canine tooth is shown in Figure 5, accompanied by a histogram in Figure 6, that represents the analysis of the results.











Day	1	14	35	63	84
					
					
Healthy area	49,70%	36,37%	35,52%	34,82%	71,15%

Figure 5. Study of one canine tooth

Even though considered effective, the application requires a certain amount of manual process, harming the practicality of the system when dealing with large image bases, but future developments will be made to further automate the application.

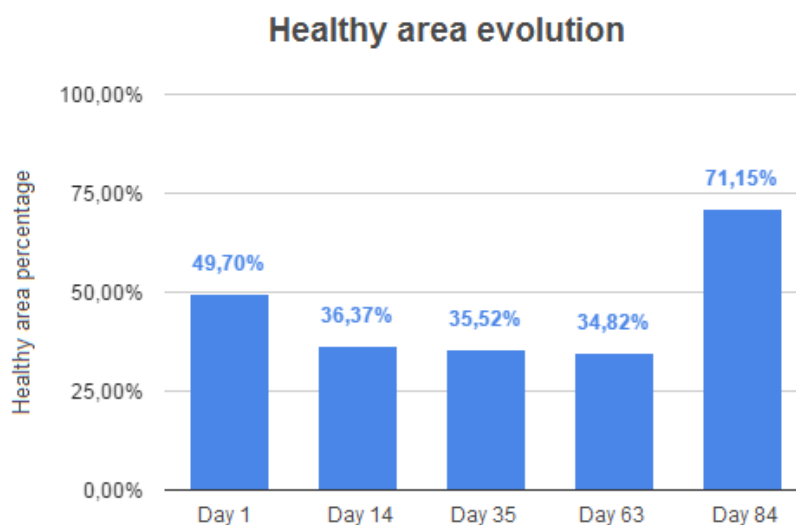


Figure 6. Histogram showing the evolution of the healthy area

References

- [1] Dos Santos, N., S. and Alberto Carlos, R., S. and Albuquerque G., R. (2012), “Doença periodontal em cães e gatos - revisão de literatura”.
- [2] Kass, M. and Witkin A. and Terzopoulos D. (1988), “Snakes: Active contour models”, *International Journal of Computer Vision*, vol 1, 321-331.
- [3] Mahmood, N., H. and Rusli, A., H. (2014), “Segmentation and Area Measurement for Thyroid Ultrasound Image”, *International Journal of Engineering and Advanced Technology*, vol 3, 303-307.
- [4] Shapiro, L. G. and Stockman, G. C. (2001), “Computer Vision”, pag 137, 150. Prentice Hall.
- [5] Stoer, J. and Bulirsch, R. (1980), “Introduction to numerical analysis”.
- [6] Wyawahare, M., V. and Patil, P., M. and Abhyankar, H., K. (2009), “Image Registration Techniques : An overview”, *International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol 2, 11-28.