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DIMENSIONAL ANALYSIS OF AXISYMETRIC TISSUE EXPANDER

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Abstract – This paper presents a methodology to measure automatically a membrane expansion over an axisymetric tissue expander. A mechanical model is developed in order to simulate the expansion process. Vision Computer techniques are applied to make the expanded membrane three-dimensional reconstruction. Consequently, it is possible to obtain the main information, which consists in the membrane quantity expanded. This research may support plastic surgeons in select the best expander, according to the necessary amount of tissue required in the surgery process.

Keywords: tissue expander automatic measurement, biomechanical, computer vision.

1. INTRODUCTION

Tissue expander is a silicon balloon used for skin expansion. It has a wide range of applications in plastic surgeries. It is used mainly because it is possible to obtain better results when compared with any other similar surgery process. Burns are the main use, but there are others such as breast reconstruction. One of its principal advantages is the possibility to have, near the damaged skin area, a similar expanded skin, with the same properties.

Expansion process is not only a surgery process, it involves also psychological and social aspects. Patients will have to put up with deformations in their body for a period not less than two months. In some cases, it is necessary more than one expansion at the same time in different places. That is the reason why it is so important to study the effective skin expansion. With a better surgery plan resulted from this knowledge, maybe it is possible a time reduce. It is worth to say patients will need to deal with theirs low self-esteem during the expansion process, as they will not match with social concepts of beauty.

In this application field is essential to know the amount of skin that the expander can enlarge. However, hand-performed measurements are used in this surgery process. Surgeons make use of measuring tapes to evaluate expanded skin. Then, it takes surgeons feelings and backgrounds into account when choosing the expander for expansion process.

Some works were proposed to evaluate expander's characteristics and possibilities. Most of them considered simple algebra formulations what makes it occurs in errors. Even with these errors, they could reach their purposes. But by now, with all this technology advances, it is necessary a more accurate result. So it will be allowed to surgeons to have extra information when making their choice.

Herrera (1986) proposed a measurement model that consisted in analysing both the damaged and its boundary skin areas. At first, the surgeons specify the boundary skin and later take picture of both the damaged skin and its boundary. In order to find out the area, the region is supposed to be a group of well-known geometric elements (triangles, rectangles and circumferences) [2]. However, this method is under great errors, once the region can't be totally defined like small geometric elements. This is a way to estimate the amount of healthy skin necessary to be expanded. In his approach it is not verified the real area expanded.

Hammond *et al.* (1992) proposed an analysis in which some parameters describing expander shape were defined. These parameters are the point of maximal projection and the percentage of upper pole deformity. They were used to indicate the expander size, based on the evaluation only of the expander lateral profile [1].

Our research purposes a prototype to simulate the expansion effect allowing the evaluation of shape changes and applying measurements automatically. We analyse volume and area obtained by the expansion process. Making use of this model, it will be possible to compare the data furnished by manufacturer and the real one, which is obtained in surgery process, having in mind that the accomplished tests involved silicone membranes. Sharing surgeons' proceeds, a profile measurement will be made to compare with the hand-made one. In a later research, we will extend the proposed methodology to estimate the tissue amount necessary to substitute the damage skin. In the future we intend also former this methodology for skin.

2. METHODOLOGY

Based on Hammond et al. (1992) model, our mechanical model takes not only the lateral view in account. Our experimental prototype consists of a platform to support the tissue expander covered by a thin elastic rubber (or silicone) membrane. Points are marked on this membrane. During the inflation process of expander, two digital pictures are taken in each instant. The inflation is made with small liquid volume quantities. Digital camera is placed in two different positions: upper and frontal one. In the figure below, it is possible to observe an overview of the experimental model.

As the main point of the research is the analysis of the expansion process, we decided to monitor the whole process. In this way, pictures are taken within specific periods during the process.

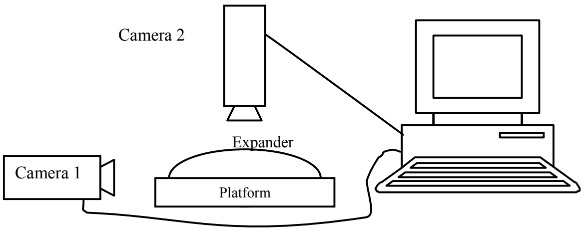

Fig. 1 – Overview of the model.

Computer Vision techniques were applied to match some marked points over the membrane, in order to look for the membrane expansion properties. It is possible by the membrane surface 3D-reconstruction. For this, an algorithm was made involving the following processes:

(1) Pre-processing and segmentation of the image, which consists in the image threshold. The result of the segmentation process is two main components: the background and the marked points.
(2) Recognition of each marked point. The marked points are the basis for the reconstruction process, and for that reason must be distinguished.
(3) Marked points mapping. In this process the position of the marked points, in both frontal and top pictures, are correlated.
(4) 3D-reconstruction. The surface reconstruction is based on a spline modelling, using the marked points.

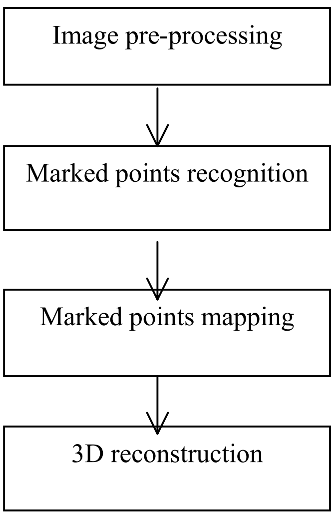

Fig. 2. Computer Vision System.

A morphological operation (4-connectivity concepts) is used to recognize marked points. It consists in assessing the four direct neighbors of each pixel (smaller picture element) of the image. Two pixels are connected if they are adjacent to each other and have the same color value. Another approach consists in the 8-connectivity operation. It is useful to obtain the membrane profile perimeter. In this one, all the eight neighbors are evaluated in order to find out which of them has the same value [3]. To segment the points, it is worthy to say that a 4-connectivity operation achieves a worst result than the real expected one. By the other side, an 8-connectivity operation may reach a better result than the real one, but the computer processing time doesn't justify its use.

Using some functions, different colors classify all marked points. Then, it is possible to calculate each marked point coordinates.

Using these points, we developed a methodology to make the expander three-dimensional reconstruction. The reconstruction is possible by the use of top and frontal views (Fig. 3). An oval expander is used as it matches with the axisymetric profile we want to. Letting P(X,Y) to be the point coordinates in the expander top view, and P(X,Z) its coordinates in the frontal image.

Taking these points as the spline basis, it is possible to obtain the profile of the expansion. A spline is used for the results obtained when compared with a simple polynomial structure.

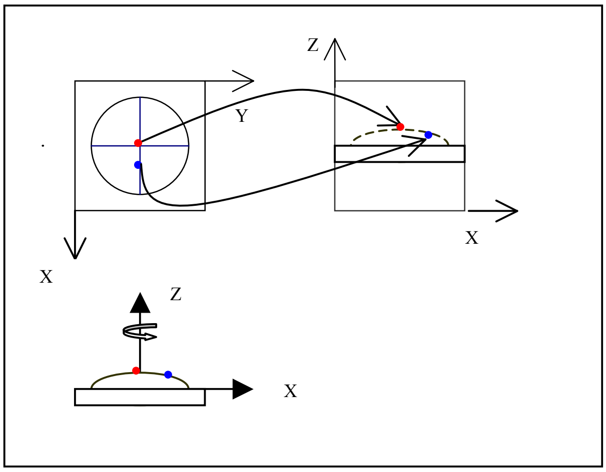

Fig. 3 – 3D-reconstruction.

After the 3D-reconstruction process, using a spline curve, we obtain the membrane profile and surface area. These data are important to predict the expander capability.

3. RESULTS

In Fig. 4 we can observe the experiment digital image taken by a CCD camera. In this paper we show the results obtained over this particular image. All the Computer Vision techniques were developed in Matlab software.

A size adjustment of the image was necessary because of time processing and memory also. In this reported case, cropping was applied to use part of image as it can be seen in Fig. 5. It is worth to say that Matlab works with axis in a different methodology, axis center is at upper left pixel. So from this pixel, downwards we have the number of lines growing from up to down. Columns have the same characteristics of a normal axis.

Fig. 4. Digital image before processing – real size.

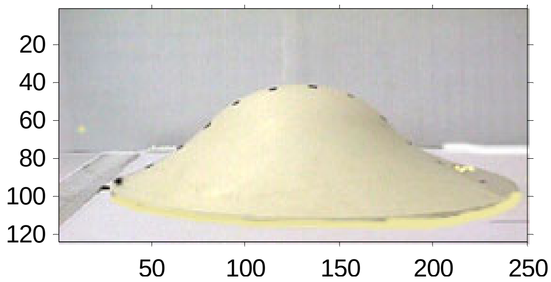

Fig. 5. Digital image before processing with appropriate axis.

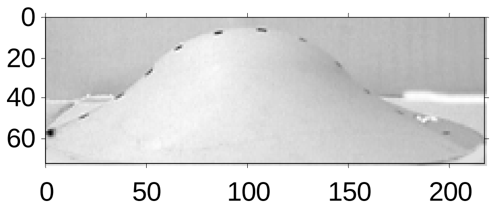

Fig. 6. Image after cropping.

The digital image is a RGB one. Although it is necessary to change it to binary one, before this it is necessary to obtain a greyscale image. The image histogram is obtained in order to choose the appropriate value for binarize the image (Fig. 7). After the threshold process we obtain the result showed in Fig. 8.

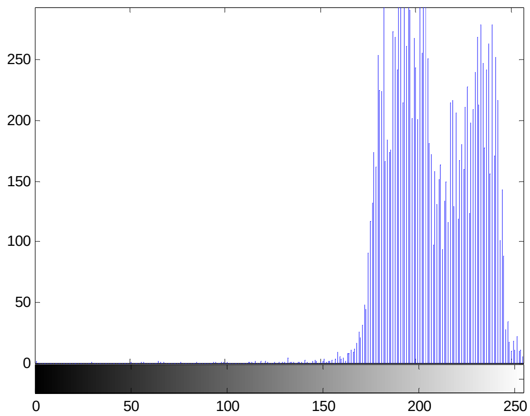

Fig. 7. Image histogram.

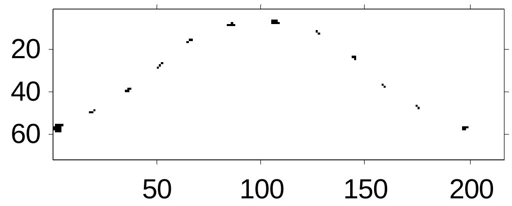

Fig. 8. Threshold image.

After this, with a binary image, morphological operations and others concepts are used to match the points. These concepts consist of mathematical ones to find out inertial moment from each point. As can be observed below, these points are classified by different colours according to its position.

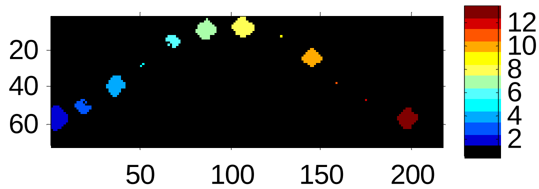

Fig. 9. Classified points.

With the classified points and its inertial moment, it will be possible to construct a profile line. A spline curve was chosen as the most appropriate for the experiment purposed. In Fig. 10 we show part of the profile spline, used to model and reconstruct the membrane surface.

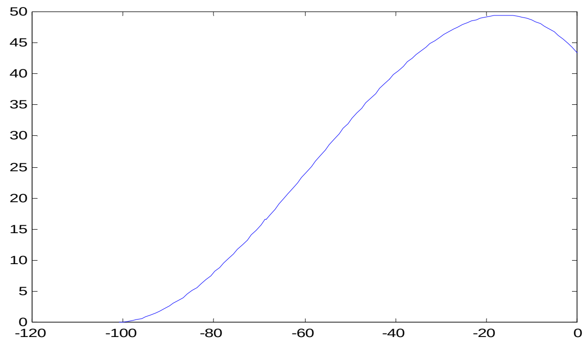

Fig. 10. Spline used to model the membrane surface.

In order to construct the membrane surface, a rotation of this spline was necessary. In Fig. 11, we can observe surface created by the rotation around a "imaginary" axis.

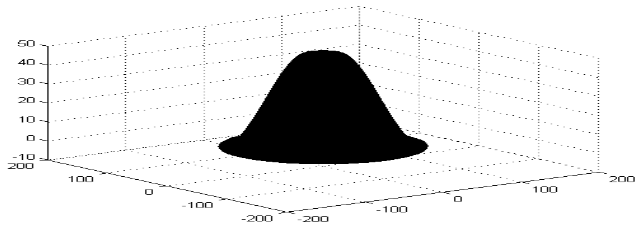

Fig. 11. Surface based on spline

As mentioned before, surgeons make use of tape measure to analyse the tissue increase during the expansion process. So, with a specific purpose to compare this methodology with an automatic one, we analysed the profile and get its measurement.

The results obtained in our methodology use pixels quantities. In order to establish the corresponding measurement in centimetres, the Adobe Photoshop Software was used. For attesting this methodology a rule was put together with the experiment, as it is in fig. 12.

Fig. 12. The top image of the experiment.

The upper rule is a 30cm one. Taking measurements in Adobe Photoshop based on this rule, we get that 1cm is equivalent to 6.9 pixels. Comparing pixel area units to metric area units, the following relationship is obtained: 1 cm^2 is equivalent to 804.4853 pixels.

The first analyse with this relation was with the area before the expansion. In the purposed method we obtained the circle area before the expansion, and after it we can observe the profile perimeter and the surface area.

To obtain the membrane profile, an 8-connectivity system was developed and applied. The result is shown in the Table 1.

For the surface area, we used an integration to analyse it and the results are also in Table 1.

The tape measurement results are limited to the area, considering the measurement of the circle diameter of the membrane before the expansion, and to the profile perimeter after the expansion.

Table 1. Methods Comparison.

	Purposed		Tape–Measurement	
	Before	After	Before	After
Profile	-	28.52cm	-	29cm
Area	455 cm^2	610.332cm^2	452.38cm^2	–

4. CONCLUSION

In this paper we present a model to obtain the geometry and shape of a membrane submitted to an axisymetric expansion. The purposed model uses the concepts of the following sciences: Biomechanical, Metrology and Computer Vision.

Generally, many medical techniques don't worry about accurate measurements. They use qualitative measurements and sometimes some quantitative ones. The Metrology in Medicine has not yet a great role. In this field, it is important to make measurements automatically in many applications. The use of Computer Vision techniques has improved diagnoses so that doctor has more conditions to find out diseases earlier as cancer, for example.

The difference from Herrera (1986) research to ours is the automatic measurement system and also the three-dimensional reconstruction, which will allow evaluating the area after the expansion, analysing if it reached the necessary expansion, or not.

It is necessary to state that until the present we use only membranes to evaluate the methodology. In the future, we will apply it on biological membranes (skin). According to the results, the purposed methodology will be the support to a quantitative model to estimate skin properties.

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