A METHOD FOR COMPUTER GENERATED PROSTHESES

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Abstract: Nowadays, most of the internal human body prostheses are designed on the basis of the patient external anatomy and generic forms. The lack of the use of knowledge of the internal body shape often produces misadaptation of prostheses, causing a discomfort for the patient. Here we propose a method that allows the modeling of an optimum prosthesis form from anatomy reference obtained with CT-scans.

The principle of our method is that : logical contours of the prosthesis are directly drawn by the practitioner on CT-images with control points that are automatically connected by B-spline curves. In order to both improve the user-friendly aspect and to reduce the interaction between the tool and the specialist, many techniques from the image processing domain and computer graphics area will be used. Once each slice logical contour is defined, an especially adapted contour-tracking algorithm produces a prosthesis surface representation. Then, it is possible to display the result before sending it to a stereolitography machine to produce a sample.

Introduction

Most of the prosthesis makers use external anatomy and generic forms in order to design prostheses that will be set within the body. This often results a poor matching between the prosthesis and the human body. This sometimes causes more serious problems such as painful discomfort.

With the help of both computed tomography [1] and rapid prototyping, some systems have been already made which produce an acceptable result. Generally, the Marching Cube algorithm [2] is used to construct the bone surface, then it is send to a rapid prototyping system to produce a sample of the skeleton. So the specialist can use it to shape a prosthesis.

Even if it is quite simple to model a form in this way, because of the hands 3D movements natural ease, there is a disadvantage of this method for it doesn't allow for a view of other structures apart from bone. We propose here a way for designing a prosthesis directly from CT-scan by drawing logical contours.

Materials and Methods

Our method can be divided in 3 stages, a drawing stage, a reconstruction stage and finally a visualisation stage.

First of all, a drawing stage is needed to create a form by the practitioner. It's a highly interactive stage because of the subjectivity of the form, so the user has to contribute by setting control points by clicking on the screen image. The more the points are informative, the less the points are needed. It seems to us that the easiest and most logical way to design the prosthesis is that the user defines the intersections between the theoretic form and each scan. We call these intersections the logical contours.

In our solution, one logical contour is created by putting a set of consecutive points on the scan image. Between two consecutive points a B-spline curve (Hermitian cubic) is drawn, which is defined by the two ends and their tangent. The logical contour results from connected curves. Each point tangents is computed automatically and we impose a G(1) continuity, but one may also step in. In order to reduce the user interaction, we have implemented some image processing tools. If required, some points may be joined to structure like bone, and tangents fit perpendicular to the gradient vector. Furthermore, because of the likeness of two neighbouring scans, a logical contour can be made directly from the contour computed before by matching each old point in the new image. In doing this, one has just to adjust some points.

Once all the logical contours has been set, we have to link them in a reconstruction stage. In our case the problem is simplified because we already know which ones must be connected, so there is no branching problem. Furthermore two successive contours are very similar. Many methods are available [3,4,5] to solve this, but our method seems to be the most appropriate one.

First, each logical contour is sampled with a given accuracy to obtain a sequence C of N sorted points ($P_0..P_{N-1}$). Let V_{REF} be a reference vector. We define an angle sequence S ($T_0..T_{N-1}$) where T_i is the angle between V_{REF} and the P_i tangent, $0 \leq i \leq N-1$. S is a discrete function that is shape representative as we can see in Figure 1.

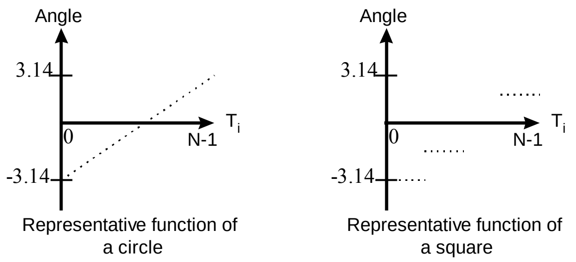

Figure 1: Two example of angle sequence

Let C_i and C_{i+1} two sequences of respectively M and N points, the main idea of our algorithm is to match the function S_i with S_{i+1}. It is made by searching a minimal-cost path in a graph M*N. In order to avoid some artefacts, we also take into account the distance between the points in the graph.

We deduce with the minimal path the surface prosthesis as a set of facets that able both to watch the prosthesis in the visualisation stage, and to make a STL file that will be processed by a stereolitography device in order to produce a sample. This sample may still undergo manual modifications for better results.

Results

We experiment our method on a patient who has already undergone a prosthesis setting in the aim of filling a thoracic cavity (figure 2).

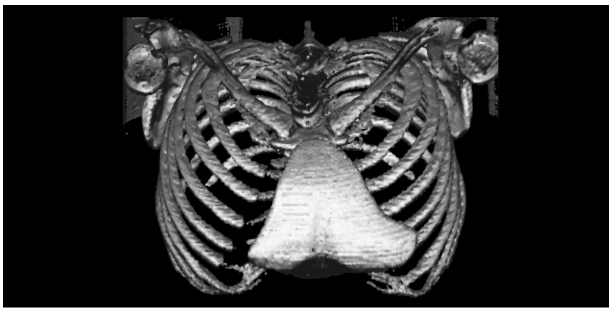

Figure 2: Old patient prosthesis

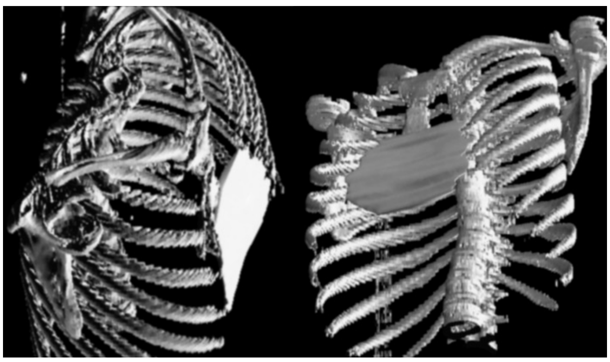

Figure 3 : New patient prosthesis

The use of classical methods based on external shape has provided a poor matching between the thoracic hole and the prosthesis, with now a visible big bump on the skin surface. Thanks to our method, we have designed a new prosthesis in less than half an hour. Figure 3 shows a simulation of the new prosthesis within the patient. All the computation have been made on a Silicon Graphic Octane with two 175Mhz R10000 processors.

Discussion

We must keep in mind that the accuracy of the shape is limited by many parameters such as the acquisition method of the scanner, or the interpretation of the CT-scan by the user. Although, this method can be applied up to a quite good accuracy, and it is greatly more superior than classical methods.

Conclusions

We propose here an easy method that allows to increase significantly the accuracy of internal prosthesis compared to conventional techniques. It can be applied in various fields like in plastic surgery or in cranioplasty.

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