3D Breast Parametric Model for Surgery Planning - a Technical Review

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Abstract

Breast cancer is the most common cancer among females. Two main approaches are used as treatment: mastectomy, in which the cancerous breast is completely removed; and conservative treatment, in which the tumour is removed with margin of healthy tissue. To improve surgical approaches resulting less damage to dynamic shape of breast, it is worth to study the breast model to enable specialists having full comparison between the results of different treatments. The aim of this work is to study 3D reconstruction based on passive and active sensors. Also, it is aimed to study state of the art about parametric models to obtain breast shape. Such parametric model can enhance surgeons experience in order to perform better surgeries and patients to be more confident about the breast shape after treatment.

1 Introduction

Nowadays, breast cancer is the most widespread cancer among women accounting for near 23% of all cancers and nearly 13.8% of cancer deaths in women; however, this issue is curable if it is detected in early stages. Based on diagnosing time, there are various treatments to remove tumours. [1].

Surgical methods determine the amount of breast tissue that should be removed, which to finally result in distorted breast shapes [2]. In Lumpectomy (which is known Breast Cancer Conservative Treatment or BCCT), just the tumour and a thin layer of healthy tissue around it are to be removed. It is essential for the patients to undergo a period of radiotherapy to ensure that all cancerous cells are removed perfectly [1]. However, in mastectomy total tissues of the breast are evacuated, which is resulted in huge loss of body. Howsoever, the success of both methods is near equal [1].

Based on treatment, the breast is distorted due to tissue removal. Almost all patients feel unpleasant after surgery since the breasts are symbol of feminine. Obtaining complete and parametric 3D model of the breast has the advantage of breast shape prediction. Following a complete reconstruction, both surgeons and patients can intercept the changes that are caused by surgery. The result would enable the prediction of the shape of the breast. In this paper, we aim to review state of the art about breast 3D reconstruction and further, the parameterization of 3D models.

2 Human Body Reconstruction

Reconstructing 3D model of human body has enhanced measurement, evaluation and planning that are required for treatments. Unfortunately common human body reconstruction methods lack accuracy and are incomplete. Moreover they require expensive device which are not available in all clinics. For instance, proposed method in [3] provides accurate body shape reconstruction, however it requires laser scanners that costs a lot. In the other research reported in [4], it is proposed to perform body reconstruction with low-cost IR sensors; but their model had lacked in accuracy in medical diagnosis applications.

In 2011, Cui et al. [5] proposed a method to perform the reconstruction of human body by using one Kinect. Since they were not able to handle non-rigid movements, the reconstructed limb model such as arms and legs were poor in quality. In another work doje by them recently in [6], they proposed a method that indicates they have coped with the problem by using global rigid and non-rigid alignments. They also improved the depth data quality by applying super resolution techniques on the model. At the same time, Weiss et al. [7] reconstructed human body by fitting the parameters of SCAPE in [8] that predefined model to depth data and image silhouettes.

3 Breast 3D Reconstruction

The idea of using 3D breast models in BCCT aesthetical evaluation motivated researchers to propose methods for breast reconstruction.

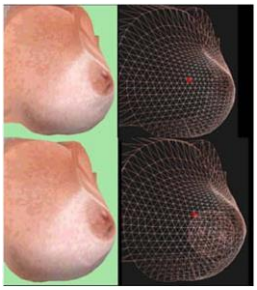

Figure 1- Blaniuk et al. virtual reality approach [12]

Catanuto et al. [9] carried out a research on a set of parameters by which they determined the shape of breast; for both healthy and treated breast using an optoelectronic tracking system. They reconstructed patient's perspective self-view to present divergence angle. On the other hand they used colorful map indicating flat regions or curvatures for introducing other features. They also used a real-time breathing artifact correction automatically to make the method more robust.

Eder et al. [10] studied the 3D evaluation protocols to analyze asymmetry via the differences between both breasts. They used a 3D scanner to reconstruct the breast and finally showed that the current method could assist surgeons both in pre-operative planning and breast reconstruction optimization after plastic surgeries.

Henseler et al. [11] proposed the usage of multiple stereo camera system to reconstruct breast model without human interaction. Using a stereo photogrammetry consisting of 8 cameras located on 4 pods two by two, they constructed breast models from dummy torso in both Figure 2-a and Figure 2-b.

4 Breast 3D Parametric Model

Sole reconstruction could be used in order to perform measurement, but using a complete parametric model, all measurement, prediction and planning would be available. Highlighting the necessity of a tool for both surgeons and patients to predict results of the surgery, Balaniuk et al. [12] combined both virtual reality approaches and soft tissue modeling methods to simulate reconstruction or augmentation surgeries using 3D tools. AS shown in Figure 1, both distorted and implanted breasts are modeled. Kovacs et al. [13] also introduced their work on to measuring breast volume by 3D scanner. They studied scanner-related factors and tested the most favorable imaging technologies on dummy models to guarantee that the method is reproducible.

In another research to reconstruction of human body, predefined models (known as avatar) are implemented that equipped with scaling parameters. In Figure 3, three avatars are considered as initial model; male, female and child. Determining the initial model, the reconstruction continues to change scaling parameters to fit the captured data on a correct avatar [14]. Also the proposed method is not automatic in detection of the initial avatar.

In none of the above mentioned methods, it was proposed a complete 3D parametric model. Besides, they are not either accurate enough or require expensive devices to be used in clinics.

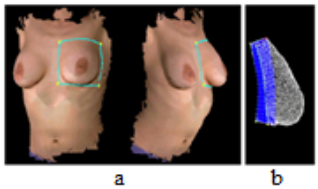

Figure 2- Application by Hensler et al. [11] Segmented breast on 3D model and c) Breast segment with "chest wall"

5 Conclusion

Common 3D reconstruction methods have some difficulties in implementation due to high cost devices, requiring expert personnel and computation complexity; hence they have not proposed a complete breast parametric model. Having a complete parametric model, surgeons will be able to plan for required treatments. Moreover the breast shape would be predicted before performing any surgery. Based on planning and prediction facilities, specialists are able to improve both the effectiveness and the cosmetic result of the surgeries. Not only surgeons, but also patients can benefit from the pre-operative outcomes of breast shape prediction. The parametric model can play important role to improve the patient's quality of life by filling the gap between pre and post-operative outcomes.

In terms of hardware devices, common 3D reconstruction sensors require expert personnel. It is essential to propose such method which can be performed even without skilled staffs. Regarding the cost, the proposed method would be equipped with low-cost devices that are accessible by all clinics. Moreover, it is aimed to perform more accurate reconstruction to result models appropriate for medical diagnosis applications.

6 Research Milestone

Future research can be concentrated on employing different methods to reconstruct the parametric model of the breast. Considering both the advantages and disadvantages of previously researches, we tend to introduce a method which can be used in breast surgery planning and prediction.

Methods such as [15] used low-cost active sensors to perform the reconstruction; however they have not modeled the breast completely. Continuing the research done in [15], we aim to perform the complete 3D reconstruction by utilizing low-cost devices. Keeping the cost in mind, dissimilar to methods such as [14], we will propose a complete automatic method in order to ease the process of scanning for non-expert personnel. The novelty of current research is to perform complete 3D reconstruction together with planning and prediction which will be done automatically.

The trend is continued to relate the model to parameters which control the shape of the breast. Rigid model is converted to alive and elastic model which is altered based on any tissue removal. Although parametric reconstruction has been performed in some parts of human body in previous works, it has not been proposed on breast yet, thus we tend to specify breast characteristics in the reconstructed model. Mentioned parameters provide the facility for the surgeon to track the breast shape changes as any part of tissue is removed.

Computation complexity is an important factor to reduce the cost. The proposed method in either reconstruction or parameterization requires common hardware which can be obtained without significant cost.

Finally study would be resulted in a planning application to be applied by surgeons and specialists. Both planning and prediction are considered to assist the surgeons in the package. The patient's breast is scanned with appropriate scanning device. It will then be modeled in reasonable time. Proposing a user-friendly application is the second aim of the current task to ease the interaction between the surgeon and specialists with the computer.

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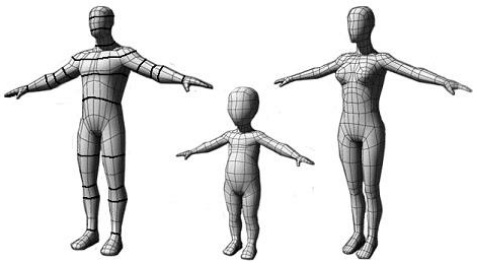

Figure 3- Three type of avatars used in [14]. Scaling parameters are used to fit the reconstructed model to the manually selected avatar