Kinect Based Method for the BCCT Quantitative 3D evaluation

Hélder P. Oliveira[1]
helder.oliveira@fe.up.pt
André T. Magalhães[2]
amag1976@gmail.com
Jaime S. Cardoso[1]
jaime.cardoso@inescporto.pt

[1] INESC Porto, Faculdade de Engenharia
Universidade do Porto
Porto, Portugal

[2] Faculdade de Medicina
Universidade do Porto
Porto, Portugal

Abstract

Breast Cancer Conservative Treatment (BCCT) is now the preferred technique for breast cancer treatment. However the surgical outcome depends on several factors, many of them difficult to assess, and this leads to significantly heterogeneous results. These results combined with the limited reproducibility of subjective evaluation, led to the development of objective methods, such as the new computer system named Breast Cancer Conservative Treatment.cosmetic results (BCCT.core). This software is based on comparisons between frontal photographs of the treated and non-treated breasts, using several indices related to the surgical aesthetic result. Although the BCCT.core system presents satisfactory results, there is an important limitation which is the inability to measure three-dimensional (3D) information.

The aim with this work is to develop a simple 3D model of a female torso using low-cost solution, a Kinect sensor device. In the near future, the created model will be used as an updated version of a BCCT.core to obtain a full 3D aesthetic assessment of the surgical outcome. The results obtained are very satisfactory and suggests that this approach could be applied in the BCCT aesthetic evaluation.

1 Introduction

Breast cancer is now considered a public health problem, and it is the most common tumour found in women. It is a very frequent disease and remains one of the most publicized malignancies not only because of its high incidence and prevalence, but also because of the impact that the breast has on women's body, sexual and maternal images. Contrarily to the mastectomy, where the entire breast is removed, in conservative treatment the tumour is removed macroscopically together with a small amount of cancer free breast tissue. Therefore, besides providing a better control of the disease locally, the conservative approach also allows better cosmetic results. Approximately 90% of breast cancers are curable if detected in their initial phase and treated properly. This means that many women are expected to live with the aesthetic results of their local breast cancer treatment for a longer period of time. Therefore, a good aestetic outcome is crucial. However, auditing this problem and developing techniques to improve aesthetic results is a difficult task, especially due to the lack of a standard method to measure the aesthetic outcome.

Until recently, the most common technique used to assess aesthetic results was the subjective assessment performed by one or more observers, who focus directly on the patients or on photographic representations of them. The opinion on the final aesthetic result is graded using one of several existing scales that rank the results, usually by comparing the operated breast with the untreated breast. However, there are some problems regarding the interpretation of the results of the studies which use this type of assessment. For instance, sometimes results are not objective because they are performed by professionals who are involved in the treatment. This lack of objectivity and reproducibility has lead to the introduction of objective methods. These methods consisted of comparing the asymmetry between the two breasts with simple measurements marked directly on patients or on photographs of them. The current methodologies continue to show a significant lack of standardization, not only in the type of assessment used, but also in the factors included in this evaluation and the instruments used for this analysis. The BCCT.core is a computer-aided medical system which aims to overcome the subjectivity and non-reproducibility of existing methodologies. This software aims to be an effective and easy-to-use tool to improve the outcome of breast cancer patient care. The BCCT.core is an automatic system capable of objectively evaluating the overall aesthetic results of BCCT by automatically extracting several features from frontal views of patient photographs. This way, it is possible to capture the factors that have an impact on the overall cosmetic results: breast asymmetry, skin colour changes due to radiotherapy treatment and the appearance of the surgical scar [1]. In a second phase, a Machine Learning algorithm is applied to predict the overall cosmetic result using the recorded features. This tool's approach, while innovative and reproducible, has several points that need to be addressed as often suggested by the users. Some of these points have already been studied, as is the case of the interpretability of the model that relates the aesthetical result to the input measurements [4], and the fact that only frontal view photographs are used, disregarding information from side or oblique views [5]. Therefore, one of the limitations of the software is the lack of the third dimension.

Now, more than ever, it is important not only to compare results after the treatment, but also to predict cosmetic results before the procedure has taken place. A more accurate and objective tool to predict surgical outcomes to guide the patient and surgeon in the decision-making or planning process is using 3D imaging and surgical simulation. A simulation model also allows patients to visualise the possible outcomes of different surgical options. Several research groups have recently made attempts with 3D approaches [2, 3]. It is generally accepted that 3D imaging has great potential in clinical environments, although there are factors that may influence its use in the near future. The high cost of the equipment and the need for specialised people to operate it are some of the downsides. Moreover, almost all currently used techniques based on 3D models do not try to predict the aesthetic result for a more informed choice of treatment. At the same time, they are not suitable for the automatic evaluation of the aesthetic result after the surgery. Consequently, low cost and easy-to-use equipments are highly desirable.

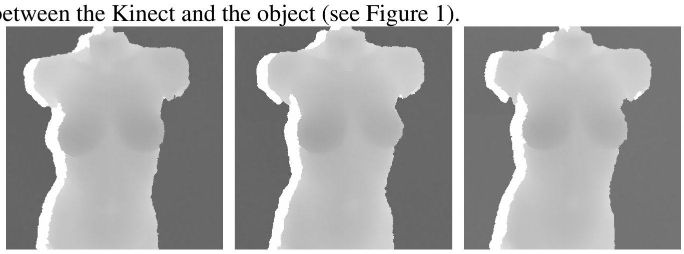
The aim with this project is to obtain simple 3D models or volumetric information from the data, and compare this information with the reference measurements that physicians collect daily. Using a Kinect sensor device, it was possible to generate a disparity map of the scene. In the near future, the created model will be used in an updated version of the BCCT.core to obtain a full 3D aesthetic assessment of the surgical outcome. Including the measurements extracted from the 3D model, it is possible to improve the global assessment result. Furthermore, this system is less complex than other systems used today, especially because the pictures are taken with a single equipment and no calibration procedure is required.

2 Kinect based method

The Kinect is hardware developed for the X-BOX console. This device has one RGB camera and a depth sensor based on an infrared laser projector combined with a monochrome CMOS sensor. This sensor captures video data in 3D under any ambient lighting conditions. It is a very recent and low-cost platform, and its use is increasing as an alternative to other more expensive 3D technologies. Using this device, it is possible to obtain a disparity map in colour or gray scale. The pixel colour or gray scale represent specific depth information, but the conversion to metric distances is not proportional. Calibration equations must be used to convert the raw data generated by Kinect, which is represented in 2048 levels. There are few different equations to calibrate Kinect and all of them have been tested, but the one that provided the best results was $d_m = (d_r/2048)^3 \cdot 9216$, where d_r is the raw data from the Kinect and d_m represents relative real distance.

We started by applying this approach to the female phantom torso in order to validate our methodology. After the Kinect collected the data, it generated a disparity map which was used to make measurements, namely

the distance between each nipple and the chest wall. The Kinect device collected data in three different occasions, to assess the accuracy of the measurements. Some differences were found, including: the rotation of the phantom, the translation of the Kinect device, and also the distance between the Kinect and the object (see Figure 1).



(a) (b) (c)

Figure 1: Different disparity map generated.

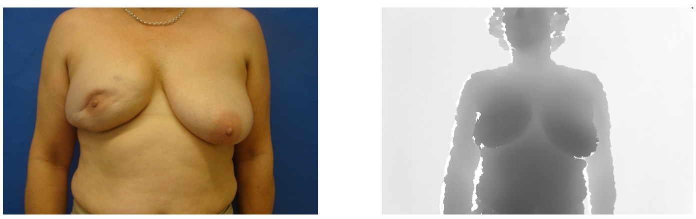
To evaluate the quality of the disparity map, an attempt was made to compare the depth information with measurements taken from the 3D model generated with a laser scanner [6]. Those measurements represent the height of each breast achieved by measuring the distance between the nipple and the chest. The measurements obtained were $4.3cm$ and $3.7cm$ for the right and left nipple respectively. However, the values obtained with the Kinect pertain to a certain reference, and for that reason it was not possible to work with real metric values. In contrast, we can work with relative distances and with ratio values in both scenarios: the real phantom and the disparity map. Therefore, the real ratio between the nipples was 1.162. In the disparity map, two different approaches were used: in the first, the fiducial points were manually identified, and in the second those points were found automatically, using *min/max* functions. The ratio values obtained from the disparity map are presented in Table 1 - without rotation compensation (there are several acquisitions for each period):

Table 1: Ratio values obtained with the Kinect using the female phantom.

Acq. #	No rotation compensation				Rotation compensation			
	Auto		Manual		Auto		Manual	
	μ	σ	μ	σ	μ	σ	μ	σ
1	1.067	0.008	1.190	0.126	1.152	0.062	1.315	0.320
2	2.043	0.062	3.585	0.837	1.108	0.050	1.360	0.144
3	1.637	0.022	3.055	0.426	1.148	0.100	1.107	0.061
MSE	0.137		0.435		0.017		0.057	

By comparing the ratio values obtained with the Kinect device and the value obtained with the reference model (1.162), it is possible to observe large discrepancies between the values. In the first acquisition, the phantom does not present too much rotation. Therefore, the ratio, both for manual and automatic labeling, is similar to the measurement performed using the reference model. The other results are different from the reference measurements because there is some rotation and this has to be compensated. This is needed because only *z-axis* is known, for that reason we have to assume that patients' body is parallel to camera plane. For that reason, rotation compensation was implemented based on value points extracted from the abdomen, assuming that that region has a similar shape on both sides, separated by a vertical line between the breasts. By looking again at Table 1, it is possible to compare the result with and without compensation by observing the Mean Square Error (MSE) related to the measurement made on the reference 3D model. It is easy to observe that the approach using automatic measurements and rotation compensation presents very satisfactory results.

The same scheme was applied to a database of 42 patients subjected to mastectomy and immediate reconstruction (see Figure 2).



(a) (b)

Figure 2: Patient photograph and generated disparity map.

After the disparity map of all patients is generated, the process mentioned above was repeated to compute the ratio and estimate volume differences between the patient's breasts. Afterwards, this ratio was compared to another ratio, obtained manually by the physician, of the height of both nipples (distance between the medial projection of the nipple and the sternum measured with 2 rulers). The obtained results, in terms of MSE error, are presented in Table 2.

Table 2: Kinect measurements with patients (The range of ratios ratio found for the 42 patients was [1; 2.522]).

MSE	No rot. compensation		Rot. compensation	
	Auto	Manual	Auto	Manual
	0.062	1.030	0.056	0.436

By looking at Table 2, it is possible to state that the results are also very satisfactory, namely for the automatic procedure with rotation compensation, especially because the tests were made with patients. Although results are only preliminary, there is a potential for the use of this low-cost and user friendly infrared laser projector, to obtain 3D images (disparity map), particularly because it will be possible to introduce volumetric information in the aesthetic objective evaluation made after breast surgery.

3 Conclusions

In conclusion, it is possible to state that 3D capabilities have a high clinical potential. However, currently used 3D techniques face two major problems: they are expensive and require specialized operators. Because of that, the 3D modeling solutions used today are not advantageous, and therefore are not commonly applied.

In this work, a low-cost solution - a Kinect sensor device - was used to extract 3D information from patients or from a female phantom torso. The results obtained until now can be considered very satisfactory, not only with the female phantom torso, but mainly with real patients. It was possible to detect the volumetric differences in the breasts using the disparity map generated by the Kinect. The results were very similar to the reference measurements performed manually by the physician, and for that reason we believe that this approach has great potential for aesthetic evaluations after breast surgery.

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