# Is Kinect Depth Data Accurate for the Aesthetic Evaluation after Breast Cancer Surgeries?

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**Abstract.** The conservative treatment is now the preferred procedure to treat breast cancer mainly due to better aesthetical results obtained. However, the aesthetic outcome is diverse and very difficult to evaluate, which motivates the research on automatic methodologies. The use of three-dimensional (3D) methodologies is increasing; however, the high cost of the equipment and the need for specialised technicians to operate it are import setbacks. Consequently, the search for affordable and easy to perform equipments is highly desirable. This paper studies the application of a Kinect device in this field, addressing issues related to accuracy, resolution and quality of the data. The paper demonstrates a comparative study of state-of-the-art Super-Resolution (SR) algorithms applied to the Kinect depth data, and the importance to improve the quality of images is stressed. The results demonstrate that it is possible to measure volumetric information and that there is agreement between features and the subjective aesthetic evaluation.

**Keywords:** Biomedical image processing, breast cancer conservative treatment, aesthetic evaluation, low-cost solutions.

## 1 Introduction

Breast cancer is the most diagnosed cancer and the main cause of death by cancer in women worldwide. Recent data have shown that breast cancer represented 23% of the total new cancer cases and 14% of the total death by cancer in 2008. Most cancers can be treated when detected in their initial stages. Whenever possible,

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the conservative treatment is preferred as an alternative to the mastectomy, since similar survival rates are obtained but with better aesthetical results [9]. The final aesthetic result and the patients' Quality of Life (QOL) became essential objectives in this type of treatment. However, the results obtained depend on several factors, contributing to very distinct outcomes [5].

The cosmetic evaluation has become essential to the institutions that deal with breast cancer treatment. However, while the oncological outcome of breast conservation procedures can easily be assessed objectively, the aesthetic outcome does not have an assessment standard [2]. Normally, aesthetic evaluation is made directly on the patient or using photographs of them, comparing the two breasts with simple measurements using the Harvard scale, which evaluates into: Excellent, Good, Fair and Poor. This evaluation can be performed subjectively, which includes patient self-evaluation, evaluation performed by a single observer or a panel of observers, or objectively, based on quantitative measurements. In 2007, two approaches have emerged trying to bring some novelty to this topic [1,10]. Afterwards, methods based on 3D information were introduced, which can vary from simple volumetric analyses to more complicated approaches [4,13,14]. The benefits of these methods are known; however, some authors still doubt the potential of current 3D methods [3]. The main drawback of 3D techniques is the need for specific hardware, software and personnel. The high cost and the difficulty of operating the systems on a daily basis hinder their widespread use.

Recently introduced at large scale in the market, essentially driven by computer gaming and home entertainment applications, RGB-D cameras are sensing systems that capture RGB images along with per-pixel depth information, based on active stereo sensing. While sensor systems with these capabilities have been custom-built for years, only now are they being packaged in form factors that make them attractive for the research community. RGB-D devices have great potential, but the acquisition system is limited by its capture resolution. The disparity maps obtained have relatively low-resolution (LR) and may be a limitation when producing a clear model.

This paper studies the use of low-cost devices to aid aesthetic evaluations after breast cancer surgeries. The application of Super-Resolution (SR) methods, the ability to measure 3D information and the correlation with subjective evaluation will be the focus of this work.

## 2 Related Works

There are many possible applications using 3D imaging in breast surgery, such as: evaluating breast asymmetries, measuring breast shape in augmentation mammoplasty or in reduction mammoplasty, and evaluating patients undergoing unilateral breast reconstruction. An objective technique based on a 3D camera to quantify the cosmetic results of Breast Cancer Conservative Treatment (BCCT) was introduced by Losken *et al.* [14]. This technique performed a comparison between the treated and untreated breast by analysing the surface area and volume differences. In the work by Kovacs *et al.* [13], a 3D scanner is presented as promising method to measure the breast volume on dummy models. Catanuto *et al.* [4] present a set of parameters to unambiguously estimate the shape of the natural and reconstructed breasts, using an optoelectronic tracking system, allowing a real-time breathing artifact correction. It is commonly acknowledged that 3D imaging has great potential in a clinical environment, although there are some aspects 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 aspects which physicians want to avoid. Therefore, the search for affordable and easy to use equipment is highly required. The Microsoft Kinect was recently introduced as a promising device that meets the requirements of physicians [15,16].

Novel approaches to human or scene scanning have been performed using the Kinect device. Zollhofer *et al.* [21] presented a methodology using the colour images combined with depth maps to create a high-quality personalised avatar, combining non-rigid-registration and fitting models on facial reconstruction. In [6], the authors describe a method to scan a human body using a single Kinect, moving the device freely around the object, by aligning depth and colour scans. Henry *et al.* [11] built 3D dense maps of indoor environments for the robotics field, employing a joint optimisation algorithm and combining visual features plus shape-based alignment. The possibility of using such apparatus is well received by clinicians in favour of expensive solutions. Still, this acquisition system may pose difficulties due to its own limitations. The disparity maps obtained have relatively LR, which may obstruct the construction of reliable models.

## 3 Performance Tests

This work proposes the use of depth data, acquired with a low-cost device, in contrast to the current 3D techniques applied in the aesthetic outcome evaluation. However, the disparity map information obtained is relatively weak in terms of resolution and for that reason a study is required to evaluate its quality.

### 3.1 Database

Currently, the database includes data from 65 patients acquired during several sessions by an expert on breast cancer. For each patient the data include several depth frontal images acquired with the Kinect device and the height of both nipples (distance between the medial projection of the nipple and the sternum measured with 2 rulers) obtained manually by the physician (see Fig. 1).

Manual ground truth annotation was performed, defining the breast contour delimitation and nipple position, in the type of data where their detection is facilitated. While breast contour was directly annotated over the depth information, nipple position was initially marked in the corresponding RGB patient data. After a correct alignment of depth and colour information [12], the position of the nipples was superimposed over the depth-map image (see Fig. 2).

Subjective evaluation for the aesthetic result is also provided based on the Harvard scale. Ideally, the overall aesthetic assessment should correlate coherently with a significant number of expert assessments. This evaluation panel was

**Fig. 1.** Nipple height measurement

(a) (b) (c) (d)

**Fig. 2.** Kinect data ground truth annotation

planned; however, it was not possible to achieve a final assessment decision by the end of this work. In order to provide the subjective evaluation, an expert in the field of breast cancer, voluntarily provided his evaluation.

### 3.2 Super-Resolution

The goal of SR is to apply signal processing techniques to increase the spatial resolution and recover details that are present in LR images [17], normally referred as a 3-step process: (1) image registration, (2) image interpolation and (3) image regularisation. Usually, SR methods were not designed for depth images; however, more recently, presumably due to the wide spread use of depth sensors, researchers have been developing techniques for the specific use of SR in this type of images [20]. In theory, multi-image based methods are able to achieve a substantial increase in detail, but require strict conditions to perform adequately. Most single-image based methods employ stochastic approaches and the inclusion of a priori knowledge. While achieving very good reconstructions, they also take high computational load and may see their performance restrained by the quality of the training dictionaries used.

Four state-of-the-art SR algorithms were applied in order to understand the impact of SR application in this work. The respective identifiers for each program, author, year, paper and number of images used are shown in Table 1. The performance of each SR method was evaluated for a scale factor of 2. Either single or multi-image based approaches are used according to the nature of the method. Since we do not hold HR depth images from the scene, the images acquired were the ground truth. Images were then downsized with a scale factor of 2, and then subjected to SR methods so that the final spatial resolution matches the original. Images were downsized assuming a loss of integer pixel information for every 2 pixels. Therefore, no interpolation that could have impact on the outcome was presented. Methods were compared based on the Peak Signal to Noise

Ratio (PSNR) value. All experiments were conducted with Matlab R2011a, running on an Intel R i5M450 (@2.4 GHz) with 4 GB of RAM. Results from the application of SR methods are summarised in Table 1 and Fig. 3.

**Table 1.** Performance Overview

| Program | Info | # of images | Exec. Time (s) | PSNR (dB) - $\mu$ ($\sigma$) |
|---|---|---|---|---|
| #1 | Yang'10 [19] | single-image | 444.42 | 40.1 (1.3) |
| #2 | Vandewalle'06 [18] | multi-image | 3.00 | 46.0 (0.8) |
| #3 | Dong'11 [8] | single-image | 380.99 | 51.4 (1.2) |
| #4 | Dong'09 [7] | single-image | 7.35 | 40.1 (1.0) |

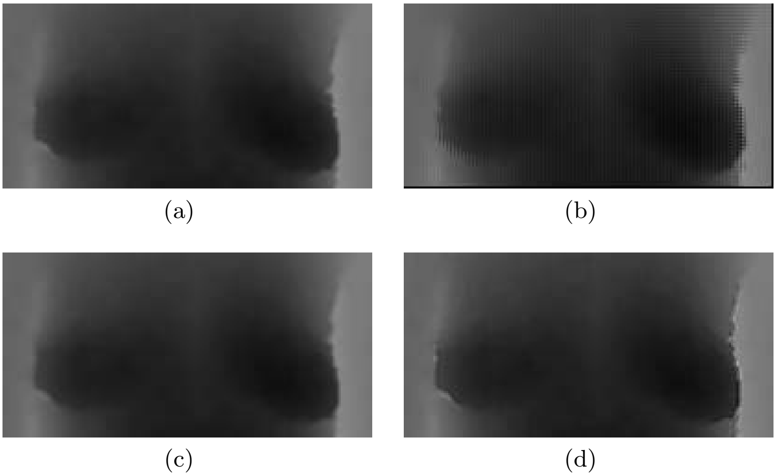
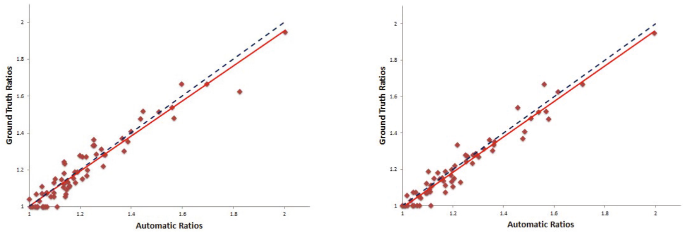


**Fig. 3.** SR output "zoomed" images (example of patient #7). (a) Original; b) Output of program#2; c) Output of program#3; d) Output of program#4. (The output obtained by program#1 was not included due to its poor results, both in terms of execution time and PSNR).

The average PNSR value obtained for each program and the respective standard deviation were demonstrated. The medium execution time to produce a single image was also made available. From these results, it is clear that program#3 provides the best results. Albeit the processing time was not the desired, this program presents clear reconstructions above the remaining contenders.

### 3.3 Nipple Height Detection

The use of 3D data enables a more complete understanding and renders a much more reliable aesthetic assessment. However, captured information must be objectively processed and present consistency. Furthermore, the use of enhanced images provided by SR on depth images may improve the performance to match with real metrics. This work only focused on the detection of nipple height (depth value of the chest plane relatively to the nipple value), comparing this measurement with the real metrics acquired by a medical expert (see Section 3.1). Additionally, and based on the results obtained in Section 3.2, nipple height was also computed in SR resolution images ($\times 2$ the initial resolution) obtained with program#3. It is possible to calculate the height ratio between right and left nipples, and verify if they are compatible with real metrics provided (see Fig. 4).




(a) Low Resolution Images (b) High Resolution Images

**Fig. 4.** Scatter plot of depth height ratios. Red line is the trendline for graph data. Blue dashed line represents the ideal trendline.

The results presented in Fig. 4 can make clinical experts approve the use of the data acquired with a Kinect device to evaluate the aesthetic outcome. Smaller or too similar breast shapes may interfere with the data. It is also important not to disregard the errors introduced by the physician during manual measurement. Comparing the results obtained with LR and SR images, the second provided better results, although they are not significant. With LR images it was possible to obtain a 0.92 correlation, while the value for SR images was 0.95.

### 3.4 Correlation with Subjective Evaluation

In the aesthetic outcome evaluation, individual features are normally compared with subjective evaluation to understand the importance of each feature to the final classification. In this study, the nipple height obtained with LR and SR images was used, providing a correlation score of 0.26 and 0.27 respectively. Values obtained are very similar, and the importance of SR images is not conclusive. Correlation values are very low; however, they are consistent with results obtained in previous work [16], which proves that a single feature is not enough for the global evaluation of aesthetic outcome.

## 4 Conclusions

This work presents a study about the application of low-cost devices on aesthetic evaluation assessment. The paper emphasises the importance of improving the quality of images obtained with Kinect device by applying SR methods.

Through the experimentation sets with SR methods, the general standard deviation throughout the experimentations on the set of patients is very satisfactory with values to be around plus or minus 1 dB. From the general results it is possible to detect the potential of using SR methods to enhance image resolution, before proceeding to further processing. Two programs recorded an average PSNR value above 45 dB, one of which even recorded an average value above 50. This is a very satisfactory reconstruction as confirmed by visual inspection.

With the processing of the 3D data acquired using a low-cost apparatus, it is possible to detect features and to extract information on the breast shape (namely the nipple height). The results achieved are interesting and they demonstrate the use a Kinect device to measure relevant volumetric information in comparison with measurements performed by the physician. With regard to the correlation of nipple height with subjective evaluation, although results are within the expected range, they are inconclusive and require further validation, particularly by creating new models combining 2D with new 3D features.

In the future, the extraction of new 3D information will be studied, namely volume and surface area. The importance of using SR images was not proven, probably because improvements are produced only in $xy$ resolution. Improvements on depth resolution could be interesting and may provide better results.

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