

ESTIMATING THE HEIGHT OF A BREAST ABNORMALITY THROUGH COMPARISONS BETWEEN SIMULATED TEMPERATURE PROFILE AND THERMOGRAM

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Abstract. Although, the dimensions of a tumor are a very important characteristic, its height could not be evaluated by infrared images. This paper describes a method to estimate this by comparisons between the simulated temperature profile calculated with CFD commercial software and the thermogram of the patient's breast. The simulations were performed using substitute geometry of external breast prosthesis. A volume with the same dimensions of the abnormality described in the patient's ultrasound examination was designed by software inside the chosen surrogate geometry. For this, the third dimension was supposed. The nodule height was not measured in this examination. The referred software evaluated the breast temperatures profiles using parametric analyses and the Finite-Volume Method into the supposed geometry. Many temperature simulations were performed varying the supposed height of the nodule. These profiles were compared with the patient's infrared image. The height of the abnormality was taken from the temperature profile that gives the best approach to the patient's infrared image.

Keywords: breast cancer, infrared images, numerical simulation, parametric analysis.

1. INTRODUCTION

From the last two decades, the breast thermography has achieved an average sensitivity and specificity around 90%. According to Ng (2008), an abnormal thermogram is reported as the significant biological risk marker for the existence of or for the development of a breast tumor. A combination of clinical examination, mammography and IR imaging may provide the greatest potential for breast conservation and survival. Thermography may have the potential to detect breast cancer 10 years earlier than the traditionally golden method – the mammography (Ng, 2008).

Infrared thermal imaging shows promise to be a noninvasive and effective adjunctive modality for early breast cancer screening. Widespread clinical adoption of breast thermography, however, is still hindered by its poor sensitivity to deeper or smaller tumors (Keyserlingk, Ahlgren, Yu, Belliveau, and Yassa, 2000, Head and Elliott, 2002, Ng, 2008).

This paper describes some of the results of the efforts of the Federal University of Pernambuco (UFPE) to estimate one of the three dimensions of abnormalities in the female breast due to breast cancer, i.e, its height. Infrared (IR) images have been taken at the Clinical University Hospital of Federal University of Pernambuco (UFPE). A breast model in computer aided design (CAD) was developed based on a breast external prosthesis. The abnormality was substituted by a volume with the same dimensions described at the ultrasound examination of the breast and an estimated height. A computational program, which was developed using the Matlab[®], varied the height of the abnormality. The result was compared with the abnormality location described on the ultrasound examination.

2. METHODOLOGY

Infrared (IR) images have been taken from a volunteer. These images were used in the present work. The protocol used to obtain the patient thermograms was approved by the Ethical Committee of the UFPE and registered at the Brazilian Ministry of Health. In these image acquisitions, a previously developed protocol was used. It was described by Araujo (2009).

The ultrasound examination of the patient's breast indicated a solid nodule with regular contours inside of the left breast, Birads 3, located at 3h, i.e. at the junction of the external lateral quadrants, 1.5 cm from the areola and 0.7 cm from the skin surface. The given dimensions were 0.6 cm x 0.4 cm. The third dimension was not measured at the ultrasound examination. This work intends to give a new method to estimate this height value.

The surrogate geometries were obtained by Viana (2010). In order to do so, seven external breast prosthesis donated by Ortho Pauher Company were scanned by a coordinate measuring machine (CMM) that is located at the Mechanical Engineering Department from UFPE. The CMM has its calibration certification emitted by a lab of the Brazilian Calibration Network (INMETRO). The points obtained by the CMM were manipulated by a computational fluid dynamic (CFD) pre-processor to design the tridimensional surrogate geometry.

One of them is showed on Fig. 1. The surrogate geometries chose by the examiner closest to the patient breast was the surrogate geometry number 1 and number 2. The volume of the first geometry was 204117mm³, and the other was

213335mm³, i.e. the second one was about 4.5% bigger than the first, but its shape was closer to the patient's breast. In the near future, the real geometry of any patient will be used. So that, there were performed tests with both surrogate geometries to verify with one get a simulated profile closer to the patient thermogram. To check this, the maximum temperature at the point of the patient skin just above the abnormality was chosen.

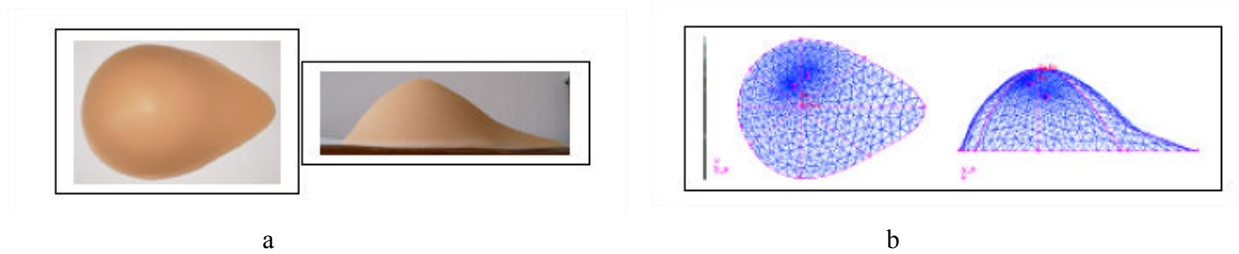


Figure 1. An example of breast prosthesis (a) and the correspondent meshed surrogate geometry (b).

To this article, the nodule was a volume with elliptical bases. The length of the longer diameter, D_1 , was 0.6 cm and the other diameter, D_2 , was 0.4 cm. A cylinder with elliptical bases was designed with the same dimensions of the solid nodule described on the ultrasound examination. The initial height was 0.1cm. The first geometry that represents the nodule is showed on Figure 2.

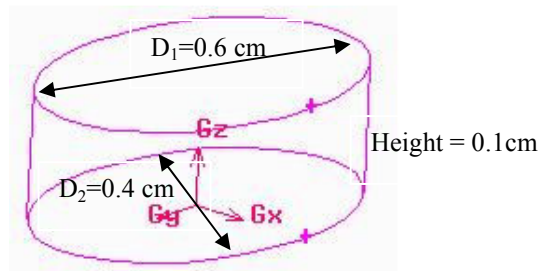


Figure 2. Representation of the first nodule.

PARAMETRICA is software developed in Matlab[®] by Santos (2009) and was used to estimate the nodule height. The main purpose of PARAMETRICA is to make automatic temperature simulations. In order to do this, it was used a commercial computational fluid dynamics (CFD) software, the Fluent[®], which has a pre-processor, the Gambit[®] that made the meshed geometry. The implementation of the PARAMETRICA was based on a file, called *journal*, which records all the commands performed by the Fluent[®] and the Gambit[®]. At first, the *journal* file was obtained iteratively. Shortly thereafter, the parameters of interest were modified such that symbols were inserted in its place. Meanwhile, Gambit[®] was rebuilding the meshed geometry with the desired parameters modifications as shown in Figure 3.

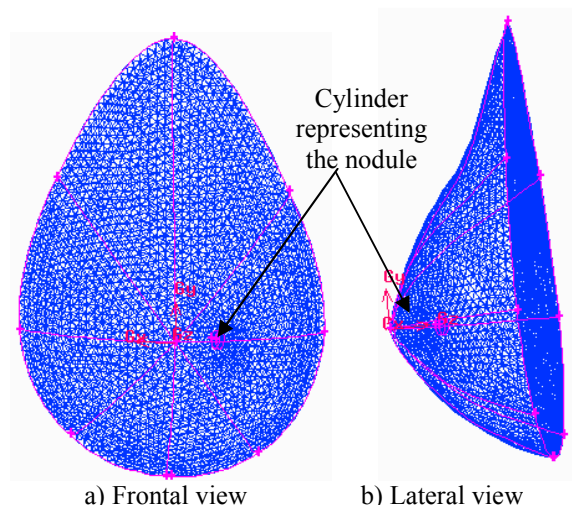


Figure 3 1 dimensional surrogate geometry of the patient breast with mesh.

An output file, with extension *.neu*, was delivered containing all coordinates of each node of the mesh. Afterwards, PARAMETRICA started Fluent[®] in order to proceed to temperature simulations.

The geometry used to represent the nodule in this article was a volume referred before because it is the closest to the real geometry. Generally, the ultrasound examinations describe the position and size of the nodule but, in many cases, some details are missed. In this work, the ultrasound exam described the nodule location and two dimensions of the nodule, but there was not details regarding to the third dimension. So that, the purpose of this article is to estimate the nodule height with the aid of the PARAMETRICA. In order to do so, the height was modified at each cycle of the program. To ensure that the nodule did not exceed the limits of the breast, PARAMETRICA used a routine that performs the tests of this parameter before doing the simulation. The .neu file was used in this routine. That nodule whose height was out of the breast was discarded. By passing the test, PARAMETRICA starts Fluent[®] to perform temperature simulation. The temperature profiles were storage in files. The file name contains some information such as the tumor's type, patient's name, height and location of the tumor, as shown in Figure 4.

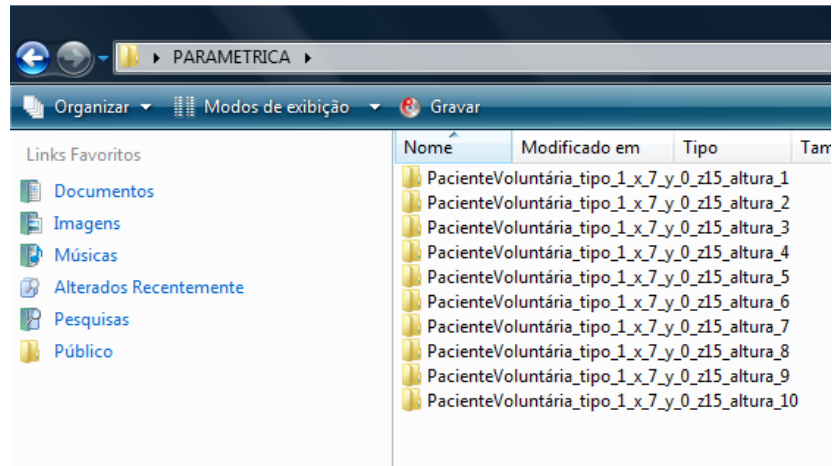


Figure 4 Files created by PARAMETRICA to storage temperature profiles.

Afterwards, temperature's profiles were compared with patient's thermogram. Tumors' height was that one whose temperature's profile matched patient's thermogram with the smallest error. Temperature on thermogram was measured by QuickReport[®], proper software from Flir Systems.

4. RESULTS

Figure 5 shows the patient's thermogram with the region of the solid nodule highlighted. The maximum temperature measured on this region was 33.1°C. It can be observed in the first image that the region near nipple is hotter on the left breast than on the right one. This fact is due to the presence of the tumor.

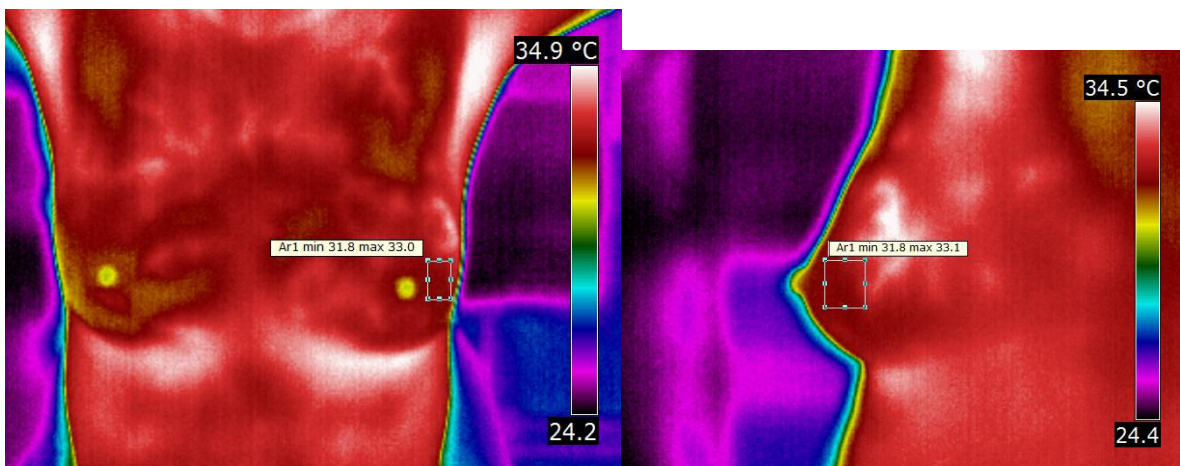


Figure 5 Patient's thermogram with the region of the solid nodule highlighted.

In order to compare the influence of the tumor's height on the calculated temperature, the graphic displayed on Figure 6 was done showing with the simulations results. The temperatures were measured on point on the surface just above the nodule.

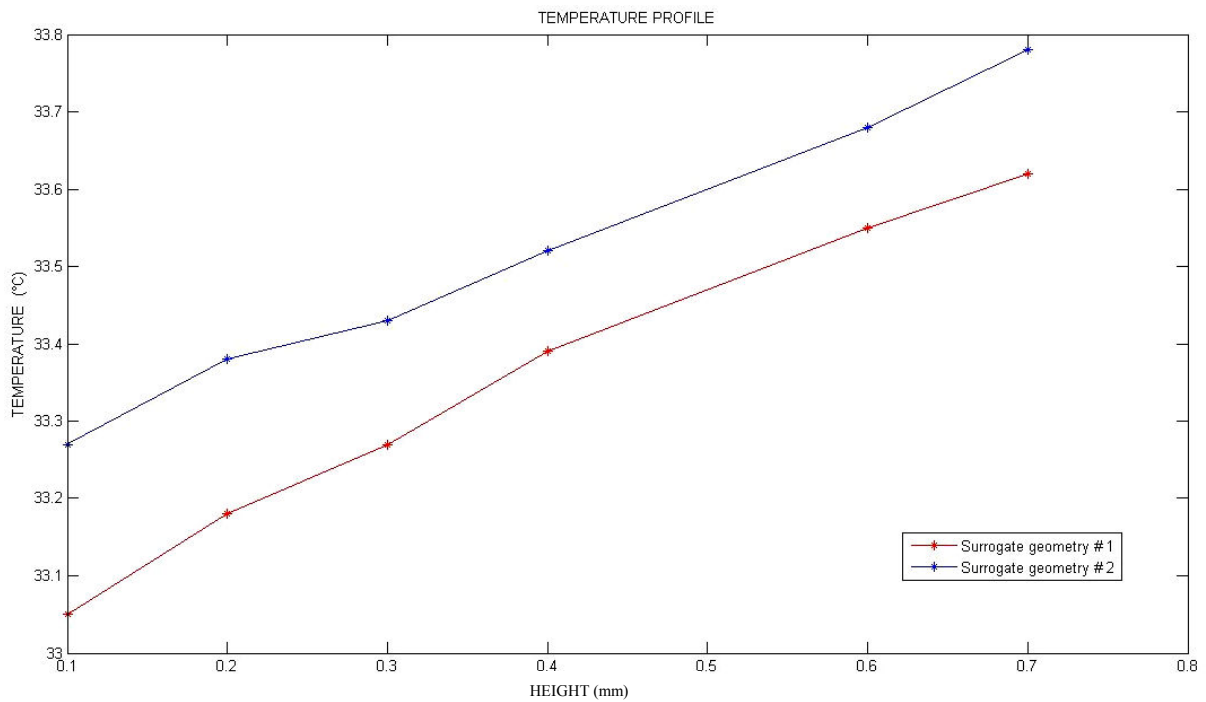


Figure 6 Graphic comparing the results of the simulations on surrogate geometry #1 and #2.

The geometry number 2 has a volume greater than the geometry number one. Although this, the temperature measured at the chosen point is always higher in the second geometry. Probably this fact is due to its shape. As shown in Figure 7, the upper region is thinner on the geometry #2 than in the geometry #1 so that the heating on the surface due to the nodule was higher on the geometry #2.

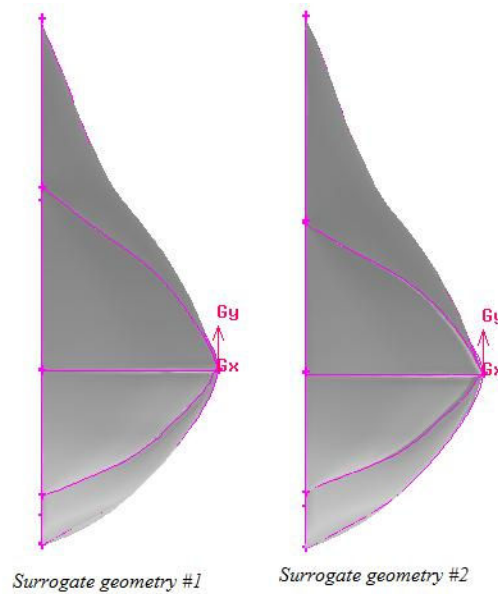


Figure 7 Surrogate geometries #1 and #2.

As shown on Figure 6, the simulation with the temperature that get closer to that one measured on the thermogram was 33.18°C. This simulation was made with the geometry #1, and the height was 0.2 cm. Figure 8 shows the temperature profile of this simulation with the region of the abnormality highlighted. The difference between the maximum temperatures of the simulated profile and the thermogram was 0.08 °C, which gives a percentage error of 0.24%. Figure 9 shows the simulated profile of surrogate geometry #2 whose tumor' height is equal to 0.2 cm.

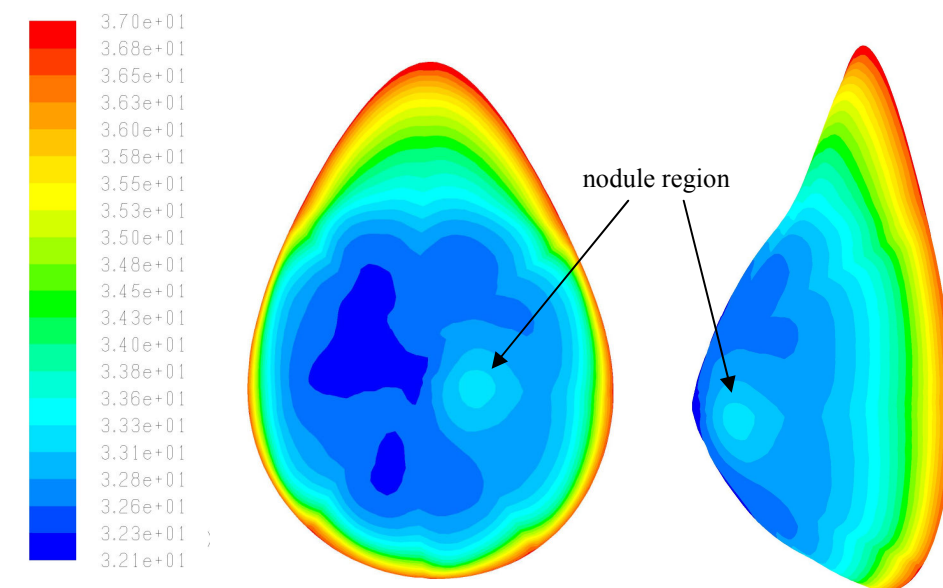


Figure 8. Simulated profile of surrogate geometry #1 with the region of the solid nodule highlighted. Temperature scale, frontal view, lateral view.

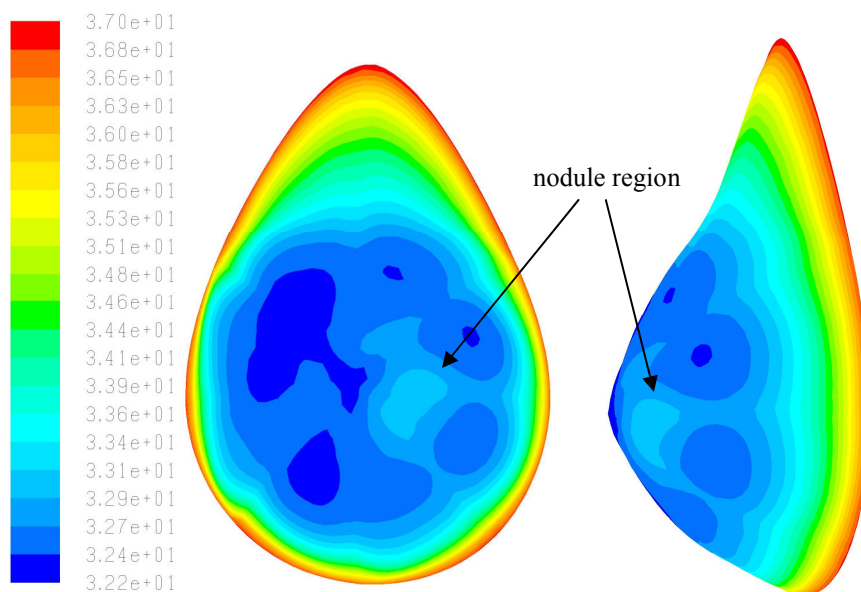


Figure 9 Simulated profile of surrogate geometry # 2 with the region of the solid nodule highlighted. Temperature scale, frontal view, lateral view.

4. CONCLUSIONS

Once height of the abnormalities is not given on ultrasound examinations, the method described in this article is a good approach to estimate this dimension. The PARAMETRICA could be used to estimate the distance of the abnormality from the skin surface.

In a near future, it will be possible use of the real patient's geometry in numerical simulations. Software is been developed at Fluminense Federal University (UFF) in cooperation with UFPE. It will be able to reconstruct the tridimensional geometry of the patient's breast by the use of their infrared images. So, the estimated height obtained by the procedure shown in this work can return more precise value for the tumor height.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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7. RESPONSIBILITY NOTICE

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