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Estimation of breast tumour size, location and pre-processing algorithm for the breast thermal signatures

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ABSTRACT

Breast cancer is the second most cause of the death among the women in society. Thermography is the non-invasive, non-contact imaging modality that can be used for the early detection of breast cancer. This paper proposes the development of the mathematical model using Penne's bio-heat transfer equation, and the estimation of the location and the size of the tumour using Metropolis-Hasting (MH) algorithm. This paper also proposes the pre-processing of the thermal images using RGB max filter and Grab-cut algorithm to extract out the region of interest where the probability of the presence of the tumour is more.

Keywords: *Thermography, Early detection of breast cancer, Breast tissue model, Penne's bio-heat transfer equation, Metropolis-Hasting (MH) algorithm, RGB max filter, Grab-cut algorithm etc.*

1. INTRODUCTION

Thermography is the non-invasive, non-contact, non-radiative, inexpensive method to take the thermal images of the subjects' breast. Thermal images give the temperature distribution of the object. It is proven that the temperature region of the abnormal tissues will be higher than the normal tissues. That means the blood perfusion rate for the tumour will be more as compared to the normal tissues, in that case there will be more generation of heat, and hence the temperature will be comparatively more, through the conduction process the surface temperature of the breast will be more. Hence, the effected surface can be used to calculate the tumour parameters and for the different tumour size, there will be different surface temperature.

With the help of the thermal images and the developed algorithm, thermography can be used as an adjunctive tool for the early detection of the breast cancer.

Figure 1, shows the thermal image taken with help of an Infrared camera. It works on the principle that every object emits the IR radiation, that can be detected by the IR camera, which converts the infrared into the electronic signal, and then to the visual image, which shows the temperature distribution of the respective field of view.

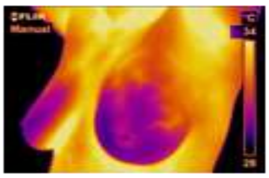


Fig.1Thermal image

2. PROPOSED METHODOLOGY

The two methodologies proposed are as follows.

A. Development of the Breast model

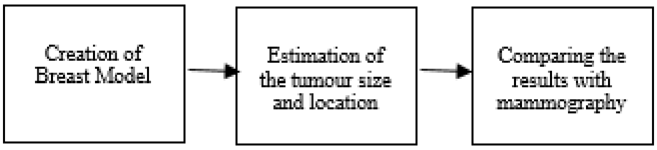


Fig.2 Breast Model development

The Breast tissue model has been created with the tumour inside by solving the Penne's bio-heat transfer equation using Comsol Multiphysics Software as shown in figure 3.

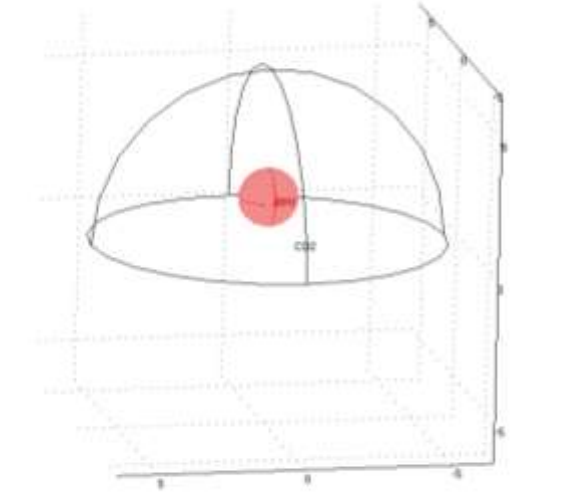


Fig 3. Breast tissue model with tumour

Penne's Bio-heat Transfer Equation:

$$k\left(\frac{\delta^2 T}{\delta x^2}+\frac{\delta^2 T}{\delta y^2}+\frac{\delta^2 T}{\delta z^2}\right)+\omega_b \rho_b c_b (T_b - T) + Q_{met} = 0 \qquad \text{....(1)}$$

Table 1. Bio-heat equation parameters for tissue and tumour [4]

Parameter name	Symbol	Tissue	Tumour
Thermal conductivity (w/m)	k	0.42	0.42
Blood perfusion rate(l/s)	ω_b	18e-8	9e-6
Tissue density(kg/m3)	ρ_b	920	920
Specific heat(J/kg.K)	c_b	3000	3000
Arterial blood temperature(K)	T_b	310	310
Metabolic heat generation rate(W/m3)	Q_{met}	450	29000

The parameters which are shown in table 1 are different for the tissues and tumours.

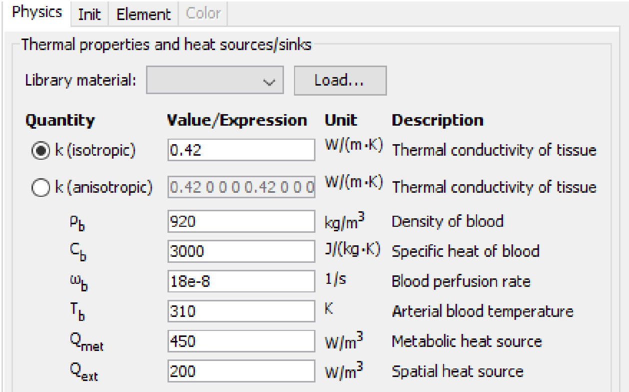


Fig. 4(A) Bio-heat equation parameters for tissue, using in Comsol

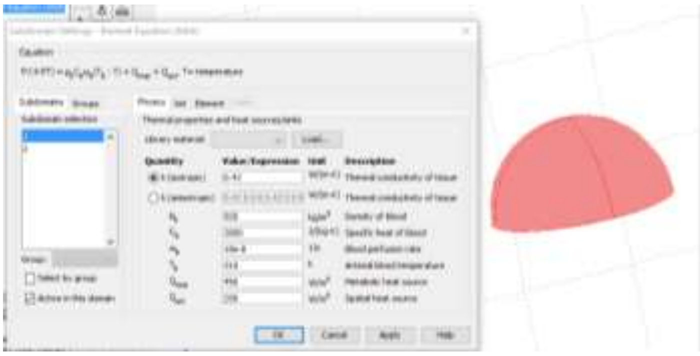


Fig 4(B) Bio-heat transfer to the tissue in Comsol

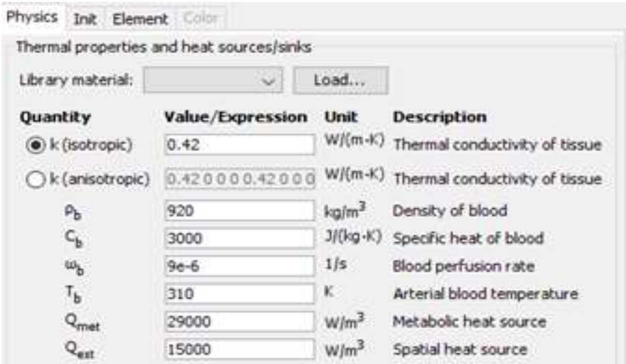


Fig. 5(A) Bio-heat equation Parameters for tumour, using in Comsol

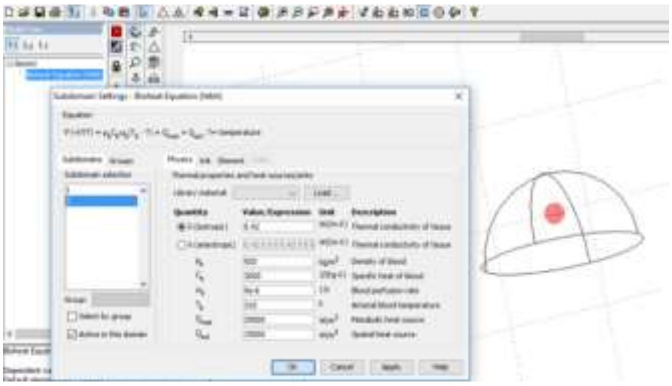


Fig. 5(B) Bio-heat transfer to the tumour in Comsol

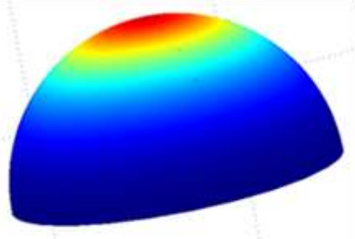


Fig. 6 Breast model after solving the Penne's bio-heat transfer equation

Once the model has been developed, it has been solved using bio-heat transfer equation, and it gave the surface temperatures into the 5*5 matrix format for the particular size of the tumors. The average surface temperature has been taken for the particular size of the tumour. The surface temperature is different for the different size of the tumours.
The Metropolis-Hasting (MH) algorithm has been written to get the tumour size and the location of the tumour in the model.

Metropolis-Hasting (MH) algorithm:

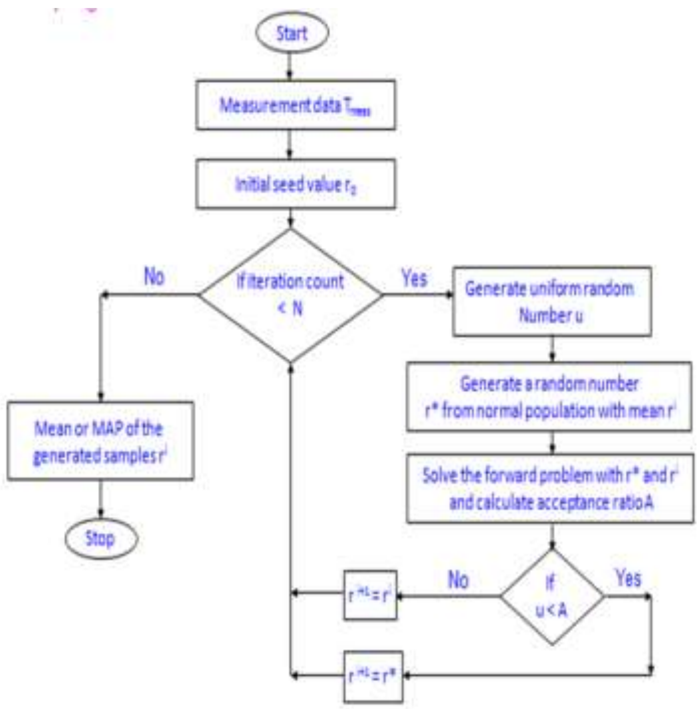


Fig. 7 MH algorithm flowchart

In the Metropolis-Hasting algorithm, the sequence gives the approximate distribution of random samples, and it is used to get the set of random variables from a probability distribution.

In the above figure 7, the measured data have been fed as an initial seed values in MH algorithm, then, the condition has been given that if the number of iterations is more than the set value, the algorithm will be stopped and will give the mean values, else it will continue, and will generate the uniform random samples. Further, the acceptance ratio will be calculated, and then again the number of iterations will be checked, and the algorithm will be continuing, until the average value will be calculated.

B. Development of image pre-processing algorithm

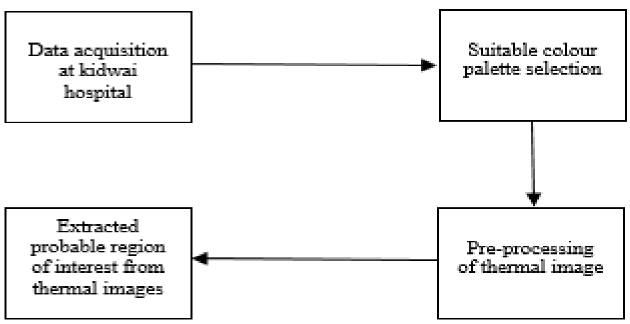


Fig. 8 Image pre-processing methodology

The thermal images and the mammogram data had been collected through various subjects. The high contrast color palette was selected. Then the pre-processing algorithm was developed using python with open cv.

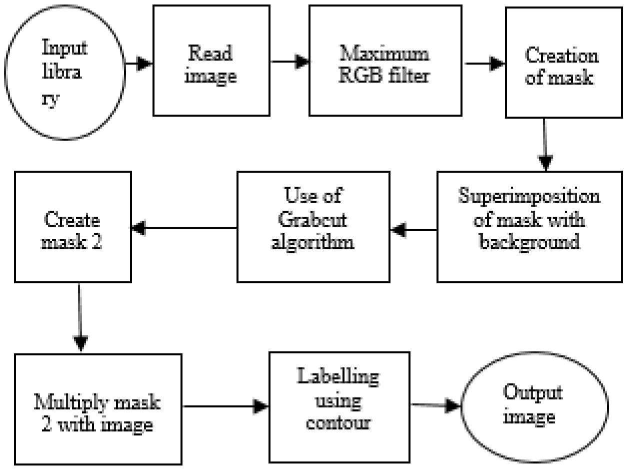


Fig. 9 Pre-processing flowchart

The high contrast thermal image was taken as the input image,
The image then converted into the RGB color format, with the help of RGB max filter.

RGB max filter:

The filter holds the maximum and minimum intensity channel, the filtered thermal image shows only three colors. i.e. red, green and blue.

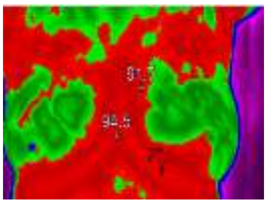


Fig. 10 Image after RGB max filter

Figure 10 shows the image with red, green and blue colors, using RGB max filter.
The mask was created and was superimposed with the background. Further, the Grab-cut algorithm has been used to extract the probable region, where the tumour cells will be present.

Grab-cut algorithm:

It makes the bounding box around the object for the segmentation. It estimates the distribution of the colors in the image. Each color has the different energy levels, based on that parameter, it gives the graph cut segmented image.

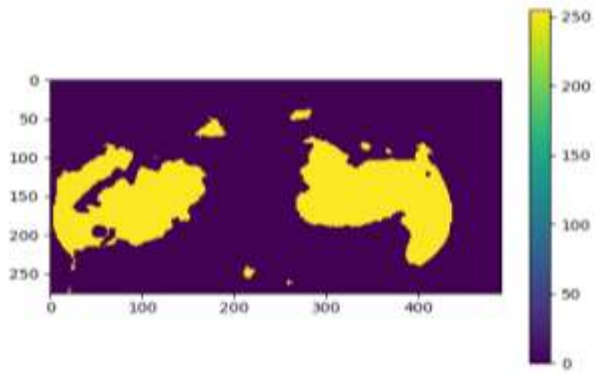


Fig. 11 Probable ROI extraction using grab cut algorithm

Figure 11 shows the probable region of interest extraction using the Grab-cut algorithm. The scale shows the minimum to maximum intensity values.

3. RESULTS

A. The results of the breast tumour model show that the increase in the size of a tumor increases the surface temperature as represented in table 2.

Table 2. Surface temperature with different tumour size

Tumour size(m)	Surface temperature(K)	Location		
		x	y	z
0.0025	304.286	0.0582	0.0704	0.0339
0.005	304.6128	0.0649	0.0628	0.0466
0.0075	304.8692	0.0640	0.0507	0.0289
0.01	305.2897	0.0626	0.0541	0.0289
0.0125	305.6439	0.0641	0.0534	0.0282
0.015	307.0416	0.0636	0.0554	0.030
0.0175	308.7254	0.0632	0.0542	0.0301
0.02	311.6512	0.0639	0.0538	0.0264

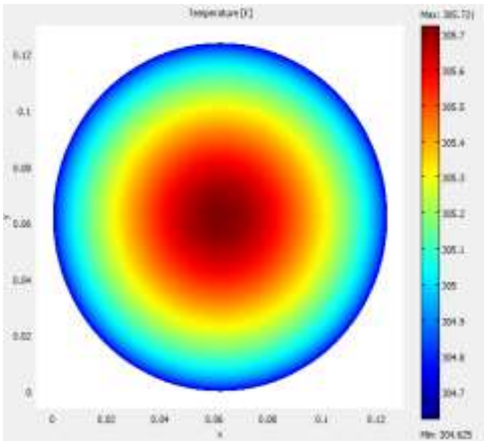


Fig. 12 Output as surface temperature measurement for certain radius and location

Figure 13 shows the plot between the radius of the tumour and the surface temperature. As it can be seen that the surface temperature increases when there is an increase in size.

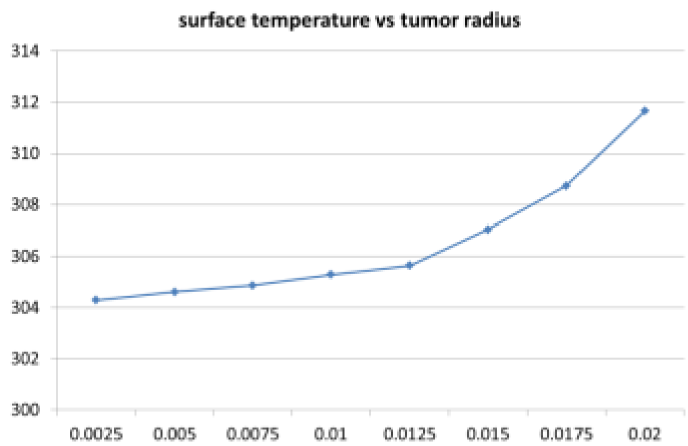
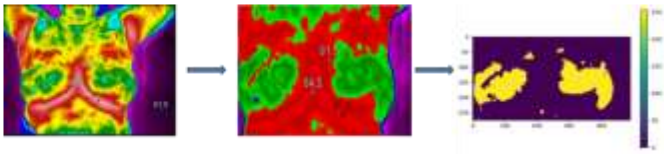


Fig. 13 Plot between the radius of the tumour and surface temperature

B.) Results for the image pre-processing algorithm is shown below,



Input image RGB image Output image

Fig. 14 Image pre-processing algorithm

4. CONCLUSIONS

An algorithm has been developed to identify parameters of tumour in human female breasts from cancerous skin surface temperature. Tumour size and location were estimated using MH algorithm from surface temperature measurement of the breast. This shows practicability of using this methodology by medical professionals in the diagnosis of a breast tumour.
Through this model, the region of interest can be extracted out where the probability of the presence of tumor is more.

5. FURTHER SCOPE

With the help of this model and the thermal images, the actual size and the location of the tumour in the patients' breasts can be found.

6. ACKNOWLEDGEMENT

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