Proceedings of the 26th Annual International Conference of the IEEE EMBS
San Francisco, CA, USA • September 1-5, 2004

# Fundamental Theoretic Research of Thermal Texture Maps Ⅰ

## ---Simulation and Analysis of the Relation between the Depth of Inner Heat Source and Surface Temperature Distribution in Isotropy Tissue

Zhigang Shang, Guotai Jiang
School of Life Science & technology , Tongji University, ShangHai, China
E-MAIL: jianggt@public3.sta.net.cn

*Abstract*—**Thermal Texture Maps is a new technology that can locate the inner abnormal heat sources of human by thermography analysis, and a great deal of application examples in clinic to early detect breast cancer with it shows its effectiveness. But the current explanation for its principle is hard to comprehensive and did not illuminate clearly the relation between the inner heat source and surface temperature distribution. In this paper, the temperature fields caused by the point heat source in isotropy tissue are simulated in different conditions, including different heat source intensities, different heat transfer coefficients and different heat depths and so on. The variation of surface temperature with the heat source depth change is discussed especially. The analysis result of simulation data shows that there lies the special relation between the heat source depth and the surface temperature distribution.**

*Keywords*—**Thermal Texture Maps, surface temperature distribution, depth of heat source, isotropy tissue, point heat source**

### Ⅰ INTRODUCTION

Temperature is the most important life character. The heat abnormality generally means there is some disease under the region where local surface temperature is higher or lower, so the small change of surface temperature could be taken as valuable information in medicine diagnosis. As a noninvasive approach, Thermography that display the surface temperature distribution as thermal infrared image has been largely applied in early cancer detection, vessel disease diagnosis, metabolic disease diagnosis and TCM.

To the question of how to noninvasive measures the inner temperature field only using the skin surface temperature, many researchers have done much work. It is thought as the most possible way to solve it by using the reasonable bioheat transfer model and the surface thermal infrared images. Z.Ren, J.Liu introduced a method to solve this problem with boundary element method[1]，but the unknown and complex distribution of heat source, heat transfer medium and vessel in body make it seems impossible to get the exactly solution by solving inverse problem. There are few study reports about the reasonable way to measure noninvasive inner temperature field so far.

Thermal Texture Maps (TTM) is a new technology that avoids solving the inverse problem of heat transfer equation. Considering the symmetry of normal body temperature distribution, TTM can locate the inner abnormal heat sources and the metabolic status by thermography analysis. H.Qi provided a thermal-electric analogy method that can estimate the depth of heat source and can know inner metabolism activity of human body in TTM research[2].Through a deal of application examples in clinic, this method has been applied in early detect breast cancer and has been proved great effectiveness and high sensitivity. However, the current explanation for its principle is hard to comprehensive and did not illuminate clearly the relation between the inner heat source and surface temperature distribution. There are many fundamental theoretic research should be done.

In order to understand clearly the relationship between the surface temperature distribution and the depth of inner heat source, in this paper, the temperature fields caused by the point heat source in isotropy tissue will be simulated in different conditions, including different heat source intensities, different heat transfer coefficients and different heat depths and so on. The variation of surface temperature with the heat source depth change will be discussed especially.

## II METHODOLOGY

### *A heat transfer model*

In the classic Pennes bio-heat transfer equation:

$$\rho C\frac{\partial T}{\partial t}=\nabla\cdot(K\nabla T)+w_b C_b \rho_b (T_a - T_\upsilon)+Q_m \tag{1}$$

Tissue conductivity K, blood perfusion $W_b$ and metabolic rate $Q_m$ are the most important thermal coefficient which generally varied with space and time. In this paper, taking the blood perfusion effect and metabolic heat product as a integrated heat source, we only consider the heat transfer in steady status in isotropy tissue and the x-y coordinate which vertical to the surface, so (1) could be simplified as:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=\frac{-Q}{K} \tag{2}$$

Boundary condition is:

$$-K\frac{\partial T}{\partial n}|_\Gamma = a(T-T_f)|_\Gamma \tag{3}$$

where n is the normal direction of boundary $\Gamma$, $T_f$ is the environment temperature , a is the heat exchange coefficient between subject and environment. Set a and $T_f$ as constant.

### *B. FEM solving*

The functional of (2) is

$$J=\iint_D\left[\frac{K}{2}(\frac{\partial T}{\partial x})^2+\frac{K}{2}(\frac{\partial T}{\partial y})^2-QT\right]dxdy+\oint_\Gamma a(\frac{1}{2}T^2-T_f)ds \tag{4}$$

We use the finite element method (FEM) to solve the variation of (4) with the boundary condition (3), so we can get the node temperature in mesh grid model, which show in Fig.1

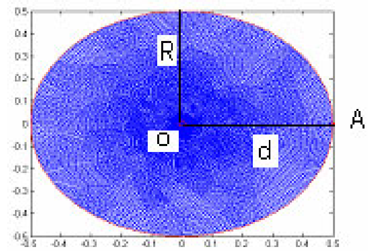



Fig.1 mesh grid

In Fig.1, R=0.5,is the radius of the circle region , d is the heat source depth, that is the distance between the heat source position and position A.

## III RESULTS

We have simulated the temperature fields caused by the point heat source in isotropy tissue in different conditions, including different heat source intensities, different heat transfer coefficients and different heat depths and different boundary shape. Here we only give the simulation results with the different heat source depth as examples:

(1) d=0.5

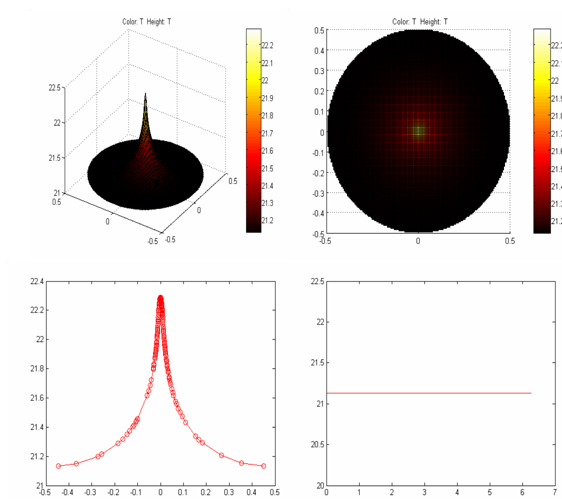


Fig.2 results example 1 d=0.5

(2) d=0.2

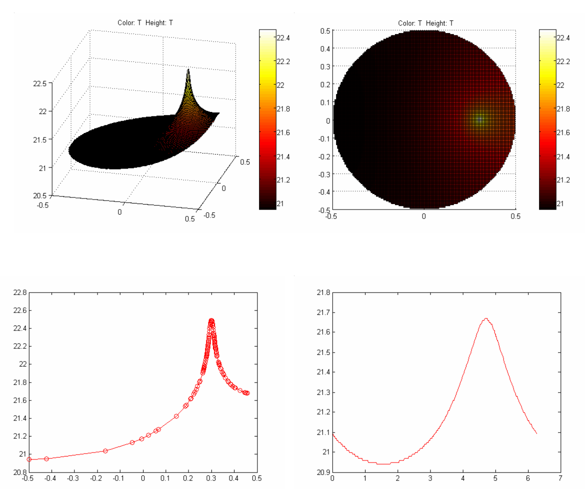


Fig.3 results example 2 d=0.2

In the Fig.2 and Fig.3, the top subplots are the different view of the temperature field distribution, the bottom left one is the temperature distribution (Tio) from heat source position to outside along the radius direction, and the bottom right is the temperature distribution (Tcs) of the whole circumference boundary.

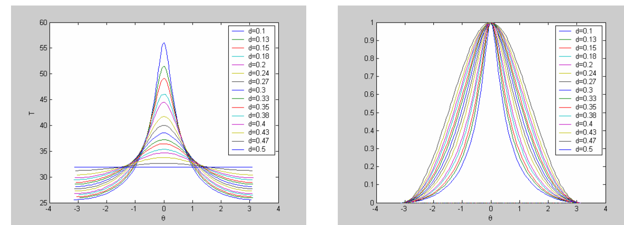
## Ⅳ CONCLUSION

(1). The temperature distribution (Tio) from inner to outside and the surface temperature distribution (Tcs) are gauss curves.

(2). The normal direction of the highest surface temperature point is the radius direction of the corresponding heat source.

(3). With the variance of heat source depth d, the amplitude and the σ value of Tcs change correspondingly. Fig.4 shows the original boundary temperature distribution Tcs and its symmetrized and normalized result. There is a special relationship between the area that enclosed by Tcs and the heat source depth d.

(4). After made a great deal of computation, we found the value of σ is fixed as the boundary shape fixed, the different heat source intensities only change the amplitude of Tcs. Compared with the heat depths, the effect to the Tcs caused by the different heat transfer coefficients is smaller and unapparent.



(a) (b)

Fig.4 Tcs (a) original (b) normalized

## Ⅴ DISCUSSION

In above simulation and analysis, we only consider the effect of single point heat source, which is different widely with the actual human body. But in fact the skin surface temperature distribution is the superpose result of many different heat source. The preliminary result indicates that there lies the special relation between the heat source depth and the surface temperature distribution. On this base, the relationship between them in complex condition of multi heat source, anisotropy tissue will be studied step by step in future.


## ACKNOWLEDGMENT

This study is supported by NEC San-ei Instruments Ltd.


## REFERENCES


[1].Z.Ren,J.Liu,C.Wang,etal, Boundary element method(BEM) for solving normal or inverse bioheat transfer problem of biological bodies with complex shape,Journal of Thermal Science,Vol.4,pp.117-224,1995

[2] H. Qi, P. T. Kuruganti, and Z. Liu. Early detection of breast cancer using thermal texture maps. In IEEE Symposium on Biomedical Imaging: Macro to Nano, Washington, D. C., July,2002. IEEE.

[3].H.H.Pennes, Analysis of Tissue and Arterial Temper-atures in the Resting Human Forearm, Journal of Applied Physiology, Vol.1, pp.93-122,1948.