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Problems of heart geometry reconstruction in IR-monitoring of cardiosurgery procedures

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Abstract

This paper presents the image processing techniques for geometry reconstruction of the shape of the heart during IR-monitoring of cardiosurgery procedures. This is very important especially for ADT and TSR thermal imaging techniques where the series of thermograms are analyzed and following this the parametric images are visualized. For in vivo experiments on animals (performed according to all legal regulations and permission of the Local Ethics Commission for Experimentation on Animals at the Medical University of Gdansk, Poland) the pigs have been studied due to the closest to human physiological and anatomical structure of the heart muscle and the circulatory system. Optimised solutions of instrumentation have been analysed during such experiments as: evoked heart stroke, CABG, OP CABG procedures and some other. Non-invasive measurements have been also already applied to clinical cases.

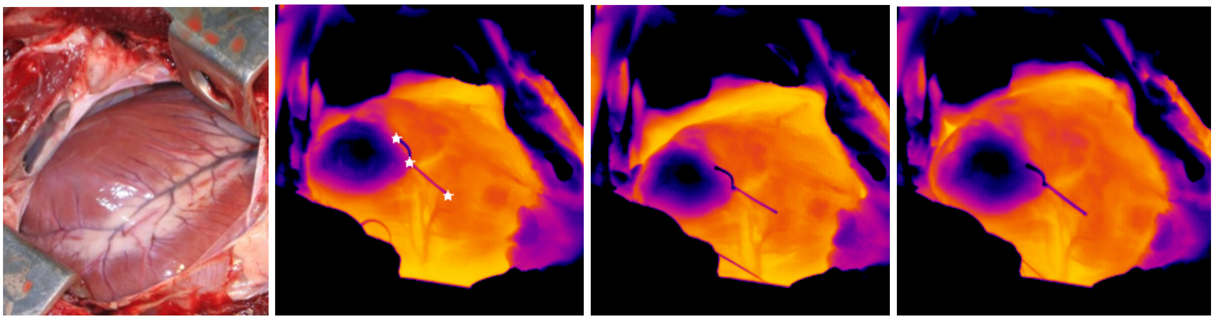
1. Introduction

Among many unsolved problems in medical diagnostics one of the most difficult is evaluation of the state of the heart muscle during cardio-surgery interventions. Non-invasive monitoring of treatment procedures, e.g. by observation changes of tissue properties during coronary artery by-pass grafting (CABG) would be of the highest importance for appropriate choice of cardiac protection and following prevention of post-surgery incidents. The aim of this work is to discuss problems of effective inspection of the state of the heart during cardio-surgical open chest interventions and to propose effective tools for monitoring the heart muscle state. Thermal state of the heart is monitored by simple registration of IR radiation emitted by the observed surface of the heart while thermal properties of the heart muscle are calculated from active dynamic thermography (ADT) experiments based on external thermal (usually optical or cold air) excitation [1].

2. Methods

Each pixel in the recorded series of thermal images shows the temperature changes at a specific point on the surface tested. Single excitation and registration of transient temperatures at the position x-y allows identification of the structure “in depth” on the basis of the equivalent thermal model and for all pixels, resulting in a 3D image of the object tested. Additionally visible light digital camera may be applied for continuous observation of the surgical interventions. Visual and IR images may be matched. Such procedure may be important for necessary precise localisation of the heart muscle position. Usually external markers are applied for holding the picture stable in time.

In our case the temperature of each pixel is recorded to calculate the thermal time constant specific to each pixel (correlated with the blood flow). The parametric image of the time constants then enables the tested surface to be visualised, owing to the high degree of correlation with the depth of the affected tissue.



a) b)

Fig. 1. *Photograph (a) and series of a heart thermograms (b) during ADT IR-monitoring recorded at different moment in time (t1, t2 and t3 respectively), visible different placement and shape of the heart, locations of white stars indicated characteristic point on the heart surface for further analysis*

Table 1. *Characteristic pixel location changes according to Fig.1. (white stars - coded as P1, P2 and P3)*

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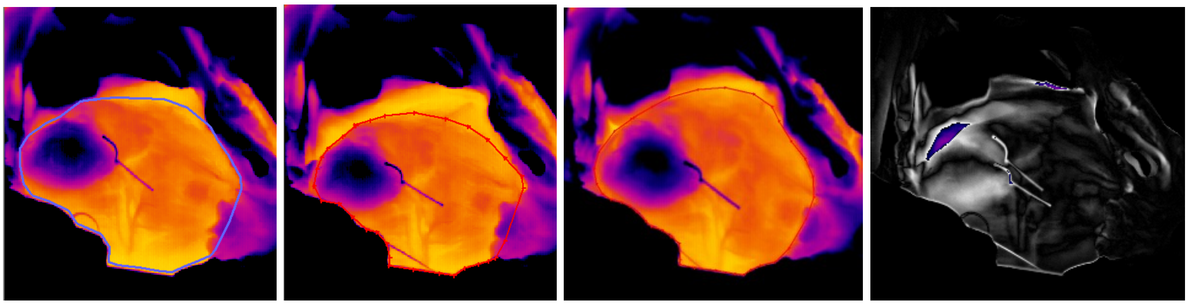
	Thermogram number						Differences					
	t1		t2		t3		t2-t1		t3-t1		t3-t2	
Point	x	y	x	y	x	y	Dx	Dy	Dx	Dy	Dx	Dy
P1 (upper left)	100	106	100	128	106	126	0	22	6	20	6	-2
P2 (middle)	110	124	114	142	120	140	4	18	10	16	6	-2
P3 (lower right)	139	148	146	162	150	163	7	14	11	15	4	1

If we measure a circumferential length (Fig.2) of the heart surface for this three thermograms the results are as follows: for t1 thermogram is equal 503, t2 = 466 and for t3 = 516 pixels. So, during this in-vivo on pigs experiment beating heart changing not only the position but also the shape.



a) b)

Fig. 2. *Series of a heart thermograms during ADT IR-monitoring according to Fig.1.-(a), fusion of the first and the second thermogram - visible different placement and shape of the heart*

2.1. Image processing

The manual image registration is based on defining corresponding points in the template and the transformed images. It is difficult to do this for a sequence of transient thermal images of the heart because of a large volume of data to be processed. Global and local geometry transformation methods (free from deformations) were investigated to solve the problem of changes of the heart shape and position. In the case of global geometry transformations the affine and elastic transformations (i.e. polynomial expressions) were analysed. The developed software enables the registration of series of images and the application the global affine and elastic geometry transformation as well as the local Delaunay [2] triangulation and image morphing to following images. Local geometry transformations with the Delaunay triangulation and the morphing transformation are based on triangle generation inside an image plane - for the template and for the target images. Then, triangles are compared and transformed into the initial form (locally by affine transform). As a result, the image part covered by each triangle is copied to the output (transformed) image. The morphing transform (used in this study) is based on the line segment comparison between template and transformed images.

3. Conclusions

Application of modern IR-thermography equipment, image processing methods can improve the quality of differentiation and evaluation of indicated regions of tested living organs. Still, this requires additional processing to improve the quality of parametric images. First, the image-to-image registration should be performed, which eliminates image blurring and improves SNR of one-dimensional signals extracted from image sequences. Since thermography is based on surface measurements it is relatively simply to use surface markers (e.g. reference signs on the tissue surface with a special pen or a marker and then normalize all images in the series to the frame of reference - usually to the initial image). The parametric images can be also co-registered with simultaneously captured visual images.

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