Preliminary Study on Sensing Heart Beat by using Digital Image Correlation Method

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Introduction. Digital image correlation method (DIC) is an image based deformation measurement method which has been widely used in experimental mechanics field. Thanks to non-contact and simple surface preparation, DIC method is also extended applied on determining the mechanical properties of the soft materials, and bio-materials. Various applications of DIC methods on the bio-materials have been reported for the last two decades, such as determining the mechanical properties of cells by using florescence particles as random tracing marks [1], determining the mechanical properties of muscle and bone [2], detecting the ventricular volume change before and after surgery [3]. This study is part of a project for developing a system for evaluating the cardiac performance improvement before and after heart surgery, the work presented here is to validate whether the ECG signal can be used to trigger the camera for imaging. For the purpose, a camera is triggered by amplified ECG signal to take two images at a cardiac cycle, and then the DIC method is used to calculate the skin displacement to evaluate whether the proposed system can meet the requirement.

Method and System Description.
In this study, a budget ECG detector is implemented by using an Arduino based ECG module, which is used to detect the tiny electrical signal change for cardiac cycles from skin by attaching three electrodes on the right and left chest, and right lower abdomen; the detected ECG signal is amplified and used to trigger a camera to capture images at different time. According to the working principle, images captured at different status are necessary for evaluating the displacement and the displacement gradient of an object by the DIC method. In general, the maximum left ventricle volume change can be estimated by the volume change of the ECG QT interval. And the maximum left ventricle pressure change can be estimated by the blood pressure change between peaks of the R wave and the T wave of the ECG signal for a cardiac cycle. In this study, the blood pressure causes skin displacement is considered; in principle, it is reasonable to trigger the camera for capturing images whenever the peaks of the R wave and the T wave detected. Unfortunately, the peak of the T wave is not easy to be distinct, and then the S wave is used as the second camera trigger signal.

Evaluating Subject
In this study, a 25 years-old graduate-student, who is 163 cm in tall and 58 Kg in weight, volunteers to be an evaluation subject. An eye-mask is used to protect the volunteer from possible eyes discomfort while exposed to the strong LED light. As shoeing in Figure 1, the volunteer is laying down for taking series images of neck around the carotid artery without artificial random pattern and the chest with the artificial random pattern.

Fig. 1 Taking series images around neck and chest of a volunteer evaluating the displacement by DIC method.

Discussions and Conclusions
Two triggering-modes have been implemented in this study; the first triggering mode is continuous imaging mode, the camera is triggered with ECG R peak detected and then continuously taking 500 images which can be used to reconstruct heart beat history; the second triggering mode is to trigger the camera while R and S peaks of ECG signal are detected, by using this triggering mode, the whole vibration time history is not well described but can determine the surface deformation in more efficient way. Typical results of the U-displacement field around carotid artery and radial artery of the right hand are shown in Figure 2. Please note, in this preliminary study, a single camera is used to evaluate the feasibility; therefore, the obtained displacement is an indicator of the possibility instead of for quantity analysis.

Fig. 2 Typical displacement field around the arteries

(a) carotid artery (b) radial artery

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