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ScienceDirect

Physics Procedia 63 (2015) 189 – 194

Physics Procedia

43rd Annual Symposium of the Ultrasonic Industry Association, UIA Symposium 2014

Real time target tracking in a phantom using ultrasonic imaging

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Abstract

In this paper we present a real-time ultrasound image guidance method suitable for tracking the motion of tumors. A 2D ultrasound based motion tracking system was evaluated. A robot was used to control the focused ultrasound and position it at the target that has been segmented from a real-time ultrasound video. Tracking accuracy and precision were investigated using a lesion mimicking phantom. Experiments have been conducted and results show sufficient efficiency of the image guidance algorithm. This work could be developed as the foundation for combining the real time ultrasound imaging tracking and MRI thermometry monitoring non-invasive surgery.

Peer-review under responsibility of the Ultrasonic Industry Association

Keywords: ultrasound image guiding, robot, real-time

1. Introduction

Focused ultrasound surgery (FUS) is developing rapidly as a completely non-invasive medical intervention alternative. Application of FUS in the treatment of fibroabdoma of uterus has passed the FDA clearance in 2004 and the sonication of bone metastasis has obtained a CE mark (Chen, 2005). Other tumours are under preclinical (prostate, kidney) or clinical (brain, breast, liver) evaluations.

However, the requirement for motion management during FUS treatment is recognized. Motion of the target object due to breathing, peristalsis, heartbeat or discomfort caused by FUS ablation is critical during FUS interventions. To prevent ablating surrounding normal tissue rather than target lesion, several approaches exist based on using physical constrains to minimize target's motion. However, it is not comfort for patients to hold their breath for too long (Dawson et al., 2001).

There are several treatment control methods which might solve this problem. The forms of treatment control include gating (Korreman et al., 2005) (the treatment is only applied during a certain range of the breathing cycle), triggering (the treatment is applied for a certain time period as soon as a certain phase of the breathing cycle has

Peer-review under responsibility of the Ultrasonic Industry Association
doi:10.1016/j.phpro.2015.03.031

been reached) or adaptive methods, where the beam follows the motion. The last method is favorable since the treatment is not interrupted and minimal duration of intervention is achieved with a maximum accuracy possible.

Typically MRI images provide best guidance to focused ultrasound surgery because of its good soft tissue contrast, temperature monitoring (Yea et al., 2005) and tissue coagulation detection. However, MR image acquisition time is slow, therefore it is not preferable for real-time monitoring when the target object is moving (Bock et al., 2004). Ultrasound, with real-time imaging, more cost effective than MRI, is a promising alternative.

In this paper, the feasibility of ultrasound-guided tracking was investigated in order to compensate for involuntary patient movement. Ultrasound scanner was used to image the target as real time visual servoing to guide a robot's motion. The real time ultrasound image tracking guided focused ultrasound ablation control was realized.

The ultrasound tracking system consists of an ultrasound imaging probe which is 7.5MHz, a 6-DOF industrial robot, a single-element arch FUS transducer (1MHz), and a computer workstation with software to process video. The system layout is illustrated in Figure 1.

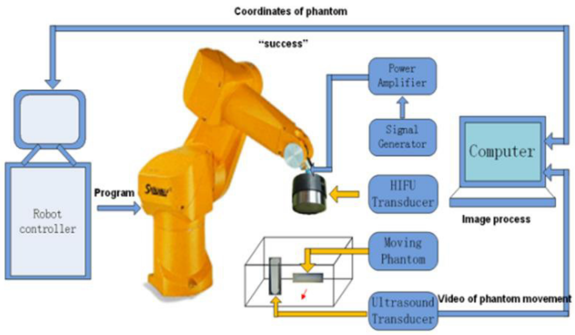

Figure 1. Imaging and tracking system, red arrow points the movement direction of the tumor phantom.

The ultrasound probe acquires the continuous images of the tumor phantom in motion. Calculated coordinates from the image processing workstation are transferred to the robot control workstation which will guide the FUS transducer moving along with the phantom in real-time.

The working procedure of the software is shown in Figure 2. Selected image processing algorithms have been developed here to extract the contour of the target, and identify the moving phantom section of the target simultaneously in real time. Phantom with known geometry is used to verify the system.

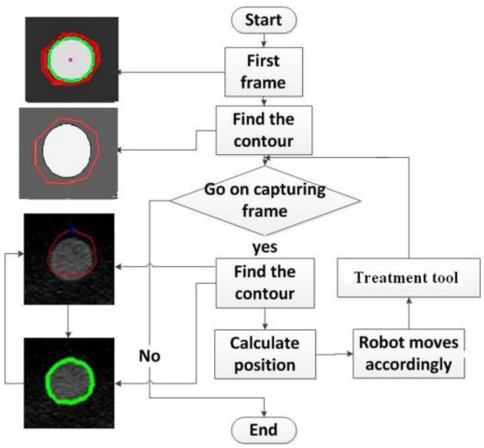

Figure 2. The whole programme procedure