KONTINUIERLICHES AUTOMATISIERTES VERFOLGEN DES PATIENTEN FÜR 3D-NAVIGATION MIT ULTRASCHALL

CONTINUOUS AUTOMATED TRACKING OF THE PATIENT FOR 3D-NAVIGATION WITH ULTRASOUND

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The generally used methods of patient-to-image registration include interactive allocation of anatomic and external landmarks. These methods include fixation of the patient and invasive manipulations with attaching fiducials directly on the skull. We propose a new approach to avoid patient discomfort and streamline the registration procedure. Our approach is based on the automatic recognition and allocation of specific areas on the occipital surface of the skull with the help of ultrasound sensing. These areas are then used as anatomic landmarks for registration. We are presenting first experimental results from a prototype, constructed to reduce the difficulties and sources of potential errors during the referencing procedure for 3D-navigation.

The time-of-flight of the ultrasound signal is measured to acquire a 3D-surface to be input into matching and referencing algorithms. This surface (called also data-surface) is then registered to another surface, obtained by segmentation of preoperative CT-images in DICOM format (called also model-surface). The strategies for processing the acquired and available data and the application of basic and accelerated versions of the iterative closest point (ICP) algorithm for optimization of the registration computing process are addressed. Digital signal processing (conditioning, averaging and filtering) as well as the registration algorithms are implemented under Lab View and Mat Lab software environments. The general issue of maintaining good coupling for signal transition in ultrasound scanning has been approached by the mechanical setup. The need to avoid interaction with the device has lead to increased challenges for coupling. A mechanical feeder was constructed and mounted on the ultrasound transducer to provide a constant feed of gel for maintaining a reliable coupling.

The mechanical implementation takes advantage of the physics of ultrasound to ensure precise measurement of 3D-surfaces (ΔX = 20.3 µm, ΔY = 0.063 µm, ΔZ = 39 µm).

The ultrasound transducer is positioned stepwise in the X-Y plane with the help of stepper motors and motion control software under Lab View environment. The (X,Y) coordinates are determined relatively to a logical initialization point by counting the steps of revolution of the motors.
The Z-coordinate is determined on basis of the ultrasound echo signal transit-time measurement targeting at the occipital bony surface of the human skull. The possible range of inclinations between the measured surface and the ultrasound beam is determined theoretically and proven experimentally. Based on this the limits of precision and achievable ranges of measurement have been determined as a starting point for real applications. Experimental measurements have been performed on phantom and cadaver objects.

The proposed method will allow fully or partially automated registration and will eventually eliminate human errors or imprecisions coming out of peculiarities like shifting of soft tissues and repositioning of landmarks. We review the current status of the project and discuss implications for the development of clinical tools to be used in conjunction with intraoperative navigation.

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