Section: **Segmentierung, Registrierung**

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Abstract-Title:
ROBOT-ASSISTED 3D ULTRASOUND SCANNING WITH IR NAVIGATION SUPPORTROBOTERGESTÜTZTE 3D-ULTRASCHALLAUFNAHME MIT IR-NAVIGATION

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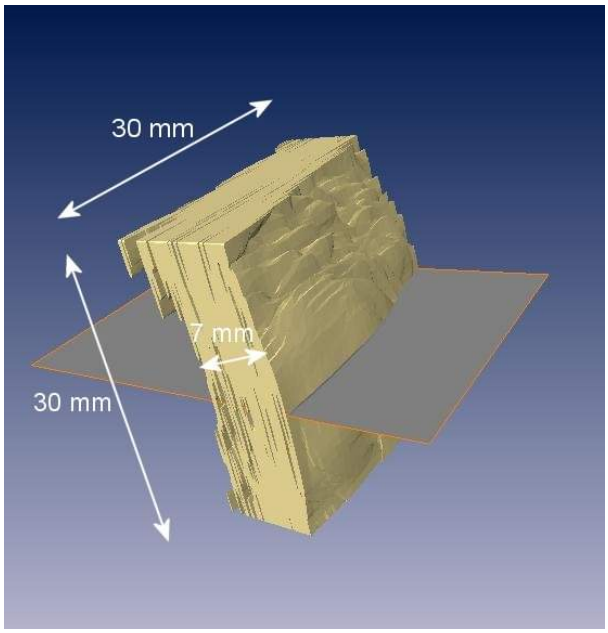
Abstract-Text:
Purpose:
Planning milling paths for robot-based implant bed milling in the lateral skull base - the domain of the RONAF system - necessitates sampling of some pre-operative planning data [Henrich04]. With that data, optimal implant position and individual milling paths can be computed. We present an ultrasound-based method to generate equally suited image data with less cost than with computed tomography (CT). Method:
We generate several implicitly registered image modalities for navigation, using a modified Stäubli RX90 serial robot (CASPAR), an NDI Polaris optical tracking system (OTS), and a Transmit Receive Module II ultrasound probe (Fraunhofer IBMT, St. Ingbert/Germany; integrated in a standard PC). The US system PC is connected with the robot for position acquisition, using two ultrasound probes (center frequency 2,25 MHz, diameter ¼" and 1 MHz, diameter ½"). With this system the unfiltered radio frequency (rf) signals are available for signal processing. We attached a flexible delay line to the transducer. First, the robot performs calibration motions to register the miller and its IR marker in OTS coordinates. Second, the user calibrates a hand-held OTS pointer and samples a cloud of skull surface points already registered with the robot [Stolka06]. Third, the pointer is used to define the scan path to be followed by the robot-held US probe. This path is smoothed by successively removing points until the path deviation exceeds a predefined threshold [Waringo06]. From this data, surface normals are determined by considering a local sample neighbourhood. With an (arbitrarily selected) rotation around the US sensor axis this allows following the scan path, with the robot guiding the probe perpendicularly to the skull surface. This returns an A-Scan, with the upper and lower skull boundaries detectable by thresholding the filtered rf-signal. For matched filtering we use coded excitation chirp signals [Tretbar04]. This creates skull boundary representations for implant position optimization [Waringo03]. Additionally, surface points sampled with the pointer can improve the outer boundary description. Results:
We have described an intuitive user interface for surface and scan path input using an IR pointer registered with the robot. The surface scan is a 2.5-dimensional global map registered to the robot with a precision of < 2.5mm RMS. The ultrasound scan generates a local map consisting of two 2.5D skull surface point clouds. Conclusion:
These maps can be used for CT-free implant position optimization and milling path planning [Waringo04]. The US system can be used as an IR-tracked manual standalone

system as well (SonoPointer®, [Tretbar06]). Future work includes force-controlled contact between probe and skull during the scan. Furthermore, the skull\'s curvature often leads to kinematic singularities, compromising safety and leading to system shutdown, thus necessitating probe orientation optimization. [Henrich04] D. Henrich, Ph. Stolka, "Navigation Principles in Surgical Robotics", MRNV 2004 [Stolka06] Ph. Stolka, D. Henrich, "Improving Navigation Precision of Milling Operations in Surgical Robotics", IROS 2006 [Tretbar04] S. H. Tretbar, Ph.A. Federspil, P.K. Plinkert "Improved ultrasound based navigation for robotic drilling at the lateral skull base", CARS 2004 [Tretbar06] P.A. Federspil, S.H. Tretbar, C. Sittel, P.K. Plinkert "SonoPointer® - a prototype system for ultrasound scanning of skull bone thickness", AORL 2006 (in Press) [Waringo03] M. Waringo, Ph. Stolka, D. Henrich, "First System for Interactive Position Planning of Implant Components", CURAC 2003 [Waringo04] M. Waringo, D. Henrich, "3-Dimensionale schichtweise Bahnplanung für Any-Time-Fräsanwendungen", VDI Robotik 2004 [Waringo06] M. Waringo, D. Henrich, "Efficient Smoothing of Piecewise Linear Paths with Minimal Deviation", IROS 2006

Bild 1/JPG



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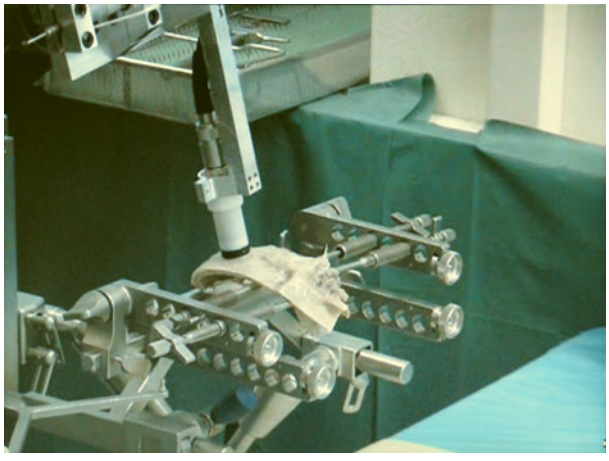

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