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Concept of a multilayer biopsy needle for magnetic resonance imaging interventions

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Coaxial needles are one of the most used instruments in image guided minimal invasive therapy. For procedures under guidance of magnetic resonance imaging (MRI), the coaxial needle has to be compatible with the imaging system and safe for the patient, which means no or very little magnetic attraction / heating / electric charging, as well as acceptable artefacts in the images. Most coaxial needles used in high-field MR interventional procedures produce large susceptibility artefacts due to the material selection (stainless steel, NITINOL). Thus, a precise placement in the target structure can be difficult. To overcome this issue, needles made from ceramics or carbon fiber were presented by other groups but are prohibitive due to the very high costs and their limitated applications. We present a coaxial needle concept based on cost saving MR compatible plastics that provides a thin wall structure with increased stability for use in MR interventions. For the needle core a PEEK round profile was selected (PEEK Filament Victrex, 1.75mm diameter). PEEK offers hardness and form stability that is important to produce a sharp needle tip. For the hollow outer needle, three layers of tubes (Polyimide Vention medical tubes, 1.842, 1.918, 2.019mm) were arranged coaxial into each other in a cascade according to the expected bending strain. Each layer has a wall thickness of 0.0318mm. The layers were joined using glue (Loctide 4902). The outer diameter of the final hollow needle is 2.39mm, inner diameter is 1.76mm. Minimal wall thickness is 0.0318mm on distal end and maximal 0.127mm on proximal end. The final prototype was tested in mechanical performance. Bending stiffness and puncture force were evaluated in a phantom setup and compared to standard needles. The multilayer coaxial needle shows comparable mechanical performance to common needles, but is fully MR compatible.

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Integration and evaluation of 6 DoF input devices for computer-assisted planning in maxillofacial surgery

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Virtual planning of maxillofacial interventions comprises the measurement of parameters necessary for quantifying the intraoperative correction of bone segments' positions (e.g. upper or lower jaw). Beside functional issues like chewing and swallowing, aesthetic aspects are particularly relevant. Therefore, the surgeon has to fine-tune functional planning parameters to find out an optimal solution for the specific patient. Virtual planning systems support this task by offering tools for interactive adjustment. As sophisticated manipulation comprises all 6 degrees of freedom (6 DoF), an ordinary mouse device with 2 DoF could be unsatisfactory for this purpose.
In this work we present a generic interaction software module for utilizing 6 DoF input devices in MITK (Medical Imaging Interaction Toolkit) and evaluate two different 6 DoF interactors:
- Space Navigator (3DConnexion, Boston, USA)
- Custom-build electromagnetic tracked freehand interactor prototype
The input devices may be used for interacting with any 3D scene in MITK including rotation, zooming, panning and camera movement.
For evaluation purposes a typical planning scenario, representing the precise positioning of bone segments for manidbular reconstruction, was build up. Six test persons used both input devices and the traditional computer mouse to perform this planning task. Overall, the Space Navigator was best suited for the observed planning scenario.
Quantitative results show that all test persons were able to find a rough approximation rapidly using the 6 DoF interactors (on average in 15 s). On the other hand fine-tuning the segment's orientation was rather time consuming (>100 s) because the visual angle and the zoom settings had to be modified several times. Therefore, we plan to refine the interaction model to be customized for specific planning tasks e.g. by restricting the movement to certain degrees of freedom depending on the visual angle or by utilizing the interactor's buttons to confirm specific planning steps.

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Modular three-dimensional magnetic camera dedicated to magnetic manipulation instrumentation systems

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We present a three-dimensional magnetic camera based on monolithic three-dimensional Hall sensors integrated in CMOS technology. The device is aimed at supporting the development, installation, calibration, and maintenance of magnetic manipulation instrumentation systems. It also paves the way to new research and development activities in the field of magnetic navigation. Preliminary experimental results obtained in the electrophysiology lab at the University Hospital Basel illustrate the capability of our device to map the magnetic field generated by the Stereotaxis Niobe® navigation system. Our modular magnetic camera concept enables precise placement of magnetic sensors at different points within the volume of interest. This flexibility facilitates adaptation of the measurement to e.g. increase the spatial resolution locally by augmenting the amount of magnetic sensors placed in a given volume. The presented magnetic camera renders possible new research activities related to automatic localization of interventional instruments, such as catheters within magnetic navigation systems. The automatic magnetic localization of a catheter requires integration of a miniaturized magnetic sensor within the tip of the catheter and precise mapping of the control magnetic field with a magnetic camera, in order to not only better control but also locate the interventional instrument. In addition, we plan to use this modular magnetic camera to investigate possible cross sensitivity between clinical control and localization devices provided by different manufacturers, e.g. between the control system Stereotaxis Niobe® and the localization system Biosense Webster Carto®. The Carto® system uses small pick-up coils integrated within the catheter and an AC magnetic field generated underneath the patient that is superimposed to the control magnetic field of the Stereotaxis Niobe®. Even though permanent magnets should in theory not distort the AC magnetic field, our magnetic camera allows us to quantify any possible distortion that could stem from system non-idealities and potentially lower the localization accuracy.

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Microsystembased functionalization of sensor catheters

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The hot bar method is used to join a flexible interposer with copper wires inside the catheter wall. These copper wires with a diameter of 150 µm were integrated during the extrusion process of a polyethylene catheter with a diameter of 3 mm and a wall thickness of 1 mm. The wires will be used as signal and power lines. Because the copper wires located inside the catheter wall, the polyethylene material above the copper wires has to be removed for joining the interposer copper lines. The material ablation was done by a femtosecond laser. The advantage is a very good anisotropic profile and a precise material removal. A combined flexible flat cable (FFC) structure at a flexible printed circuit (FPC) with the sensors was used to connect the copper wires inside of the catheter wall. The solder material is deposited and melted on the copper lines of the interposer. The copper wires inside of the catheter wall and the copper lines of the interposer are positioned to each other with the help of a tacky solder flux. Detailed knowledge about the heat sensitive handling with the polyethylene catheter has to obtained before start the joining procedures. For the setup of the final joining procedure, there were used different types of test vehicles. Therefore the hot bar is placed at the back of the polyimide layer. The investigated parameters of the hot bar are stamp temperature, stamp force and time. After the setup analysis of the sensor test vehicle, the optimal joining parameters are discovered and the flexible interposer and the copper wires inside of the catheter wall could be joined. Finally, nondestructive (ultrasound, x-ray) and destructive methods (tweezer pull test, microsection) are investigated to evaluate the joining quality and quantity of the sensor catheter.

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Packaging of µLEDs to flexible polyimide substrates

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Recent developments in the field of optogenetics have created a demand for advanced engineering tools to stimulate neuronal activity using light. The generation of distinct, microscale stimulation patterns requires the integration of multiple light sources into flexible substrates used to manufacture neuronal interfaces. A common polymer substrate base material used for this purpose is polyimide. The thinness and flexibility of the material presents a challenge to mounting rigid LED light sources. Here we developed a packaging technology to mount and passivate 50 µm thick SMD µLEDs (190 x 190 µm², C470UT190-0314-31, Cree) to optically near-transparent thin-film polyimide foils fabricated from PI-2611 (HD-MicroSystems). The BPDA/PPD polyimide PI-2611 is characterized by low moisture uptake as well as similar thermal expansion as metallic thin-films. The electrical connectorization of the µLEDs is achieved by aerosol jet (AJ) deposition of UT DOTS Ag25TE silver ink. Mounting is achieved by epoxy resin (E8074, Resin Designs, LLC). The resin is underfilled using a pin transfer technology. Backside passivation is then achieved by a 2 µm parylene C thin-film (Spacialty Coating Systems, SCS).

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The development of an expert system as a virtual physiotherapist in the domestic environment

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Physiotherapy is more successful if the conventional therapy is intensified at home by self-reliant exercises. At home the therapeutic expertise is not available to the patient. Therefore, an expert system is proposed that provides a virtual therapist. This system should guide, correct and motivate the patient. Expert systems consist of three main components: the knowledge base, the inference component and the dialog component. The proposed technical realisation of this framework includes an artificial intelligence, sensors for movement detection and a visual interface for the patient. This work focuses the development of this artificial intelligence. The first step is to collect the necessary medical knowledge. In addition to the literature studies, targeted interviews with leading specialists are also conducted. The medical knowledge is translated into rules and features. Multivariate static methods are used for the selection of features which are sufficient to classify the correct execution of exercises. The next step is the development of suitable measuring principles for the movement detection. EMG sensors, acceleration sensors and 3D cameras were investigated. The results indicate that 3D-optical systems like Microsoft Kinect meet the requirements. The knowledge base is the input for the inference component. The task of this component is to simulate the decision-making process of the physiotherapist in the evaluation of a therapeutic exercise. Therefore, the method machine learning is used. The dialog component communicates with the user. The main goal of this component is to maintain the patient's cooperation and increase his motivation. Therefore, the patient’s behavior was analyzed by using the SORCK model. As a result, a gaming and gratification component is incorporated. The proposed concepts are the framework for the virtual physiotherapist which combine established technical solutions with new classification algorithm. The results of the parameter identification for the movement detection are presented.

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Instrument calibration for a camera based surgical navigation system

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In a current research project we develop a surgical navigation system where a camera mounted on a navigation instrument is used as measurement device. The navigation instrument, e.g. pointer, is located relative to the patient by computing the transformation of the camera to the patient. When the camera is mounted to an arbitrary instrument the required transformation of the camera to the instrument’s tool center point (TCP) is unknown and needs to be calibrated. In this abstract we present a flexible mounting system and a calibration procedure for TCP computation. The mounting system is produced by selective laser sintering from polyamide PA12. It consist of a L-shaped base module that guides a jaw plate. A thread screw is used to press the jaw plate against the L-shaped base module and clamps it to the instrument. The camera is connected to the base module with integrated magnets so that it can be covered with sterile foil without damaging it. The calibration transformation, i.e. the transformation from the camera to the instrument’s TCP, is computed by a camera based procedure. A calibration body with checkerboard pattern and ArUco markers in the white checkerboard squares (ChArUco) is used for this purpose. Rotationally symmetric pivot points with varying radii are manufactured and mounted on the calibration body to define positions that can be touched by the instruments tool tip during calibration. The transformation from the camera to one pivot point is determined by estimating the camera location relative to the checkerboard pattern in 30 different orientations (pivoting). Accuracy measurement are done with three reference instruments with known TCP. The results show a precition of the calibration transformation below 0.5 mm. The clamp mount was tested on different instruments with diameters from 2 mm to 20 mm and could be clamped without displacement.