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Camera-Based Respiration Monitoring

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Nowadays, the respiratory rate (RR) monitoring of newborns in neonatal intensive care units is based on wired sensors. To reduce false alarms and the discomfort often caused by these sensors, a contactless, camera-based method to measure RR might represent an interesting alternative solution which is being explored in the presented work. However, most of the existing algorithms for camera-based RR monitoring use computationally intensive optical flow computations and are therefore not suited for real-time applications.
In contrast, the proposed approach uses a simple projection-based motion estimation to assess subtle thorax movements in the sub pixel range. These motions are computed for different regions – i.e. blocks – of the image and further classified by their likelihood to contain a true respiratory signal. From the blocks with the highest likelihood, the RR is estimated as the dominant frequency of movement. The proposed algorithm was evaluated on 18 video recordings of 9 healthy adult volunteers breathing at a controlled and varying rate – including apnea sequences – during 4 minutes. For each subject two recordings were performed, one in darkness with a near infrared camera and one with artificial illumination with an RGB camera. The estimated RR was compared to a reference recorded from a thoracic belt and obtained by spectral analysis.
Bland-Altman analysis shows a good agreement (error: 0.0±2.4 bpm) between the reference and estimated RR, both in darkness and illuminated conditions. This was evaluated for more than 63 minutes of recordings (manually excluding apnea sequences) for which the reference RR was in the range of 5 to 25 bpm.
A real-time capable algorithm for camera-based RR monitoring is presented. This preliminary analysis shows promising results on healthy adults. Future work necessitates to improve the robustness against non-respiratory movement, reliable detection of apnea and necessitates an evaluation on a larger database especially including neonatal data.

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Hemodynamic Response to Exercise in Patients with a Left Ventricular Assist Device: In-Sights from Clinical Data and a Numerical Model

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Improvement in physical capacity in patients with a left ventricular assist device (LVAD) implanted remains limited. Understanding the interaction of pump and cardiac response during exercise tests could provide valuable information about current limitations of LVAD patient exercise. Aim of this work was to investigate hemodynamics during exercise in LVAD patients using pump-based monitoring and an individualized computer model.
Pump data from 7 LVAD patients were acquired in an ongoing clinical study using a previously developed data recorder. Estimated pump flow and derived parameters such as heart rate, contractility and relaxation as well as aortic valve opening were continuously monitored during ergometry stress tests and 6-minute walk tests. A hemodynamic lumped-parameter model was used to reproduce patient exercise responses.
At a constant speed the assisted cardiac function lead to an increased pump flow at peak exercise of only +1.2±0.5 L/min (n=6) during physical capacity tests and +1.1±0.7 L/min (n=5) during 6-minute walk tests. Aortic valve opening following exercise occurred in all but one patient. Heart-rate response was absent in the same patient and was in all other patients +17±12 bpm during ergometry tests and +12±7 bpm during 6-minute walk tests. The hemodynamic model was able to reproduce and explain these observed changes in individual patients.
In summary, with current constant-speed pump management, the flow increase during exercise in LVAD-patients is very limited. As more exercise patients get enrolled in the study the combination of continuous pump monitoring and of the hemodynamic model will provide improved understanding of the pump-hemodynamic interaction, especially to develop individual strategies for improving exercise response in the individual patient.

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Textile sensor networks for wound monitoring applications

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With an increasing number of people with chronic wounds like leg ulcera and subsequent high therapy costs, there are medical and economical needs for an improved wound management.
A continuous monitoring based on flexible textile sensors enable objective recordings of important physiological and chemical parameters to determine the health status of the patient. These parameters include pH-value and lactate content of the wound exsudate as well as temperature on the wound edges. Textiles with sensor functions are easily scalable and have a high flexibility. Using biocompatible materials as titanium or chitosan as well as innovative textile production techniques, yarn based sensors can be produced to record the mentioned parameters. A textile sensor network as an interconnection of these yarn-based sensors can be integrated into a wound dressing or used as an additional layer in the bandaging of chronic wounds. This concept improves wound healing control, especially for wounds with a high risk of infection. Furthermore, this integrated textile sensor networks can help to improve the understanding of the wound healing process by analysing important physiological parameters.
In this presentation, the developed sensor yarns integrated into a textile-based sensor network and the working principle are shown.

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Smart device based application for minimal invasive spine surgery using mobile tracking

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In orthopaedic spine surgery pedicle screw systems are used for stabilisation of the spine after injuries or disorders. Almost all surgeries are realized with an open procedure, which is very traumatic because of an extensive muscle dissection during surgery. With an alternative percutaneous operation method surgeons are faced with huge challenges compared to an open surgery, but it`s less traumatic and the patient benefits with a faster rehabilitation and less traumatic injuries. One of the big challenges this method is, that the screw positions relative to each other are not visible for the surgeon. That`s why the required rod dimensions for the stabilizing connection between the screws can just be estimated by the operator without an open view on the operating field. Because of these facts, a smart device based system for rod shape assignment has been invented. For this system an application for a smart device has been developed, which integrates a localizer module to get the position data of the pedicle screws with help of rigid bodies placed on top of the downtubes intraoperatively. With the recorded position data it is possible to calculate the correct shape of the rod, which fits to the current pedicle screws situation. In this work the latest state of the rod assignment method and first results of the system accuracy will be shown. In addition prospects of an augmented reality implementation into the application and a method for pedicle screw placement with navigated ultrasound are being presented.

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Sonographic measurement for patient-specific hip rotation using smart devices

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Total hip replacement is a very common surgical procedure in orthopedics and is performed very effectively all over the globe. The longevity of the implant relies mostly on the correct alignment of the components. The most critical component is the positioning of the acetabular cup which defines the functional performance of the entire endoprosthesis. The positioning of the acetabular cup is commonly referenced against the anterior pelvic plane which defines a reference for the anteversion and inclination angles which set the basis for a correct alignment of the implants. Current state-of-the-art procedures are based on Lewinnek's inclination and anteversion angles which define a „safe zone" of the implant. Lewinnek's assumptions though are only based on measurements when the patient is lying flat on the operating table and possess only a horizontal pelvic plane. The pelvic plane differs in standing and supine position, additionally the main functional pressure on the implant requires its highest performance in a standing position. With the known pelvic inclination, it is possible to readjust the position of the cup implant with respect to the individual posture of the patient. Taking into account the fact that there is no general rule how to place the cup implant for every patient, a system was developed to receive patient-specific and personalized data. A cost-effective navigated ultrasonography-based system has been developed for measuring the patient-specific hip rotation. In this system the ultrasound probe is tracked with an optical localizer implemented on a hand-held mobile device. The system was tested by taking preoperative measurements in 20 osteoarthritis patients in standing and supine position to determine the individual pelvic rotation.

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Joint depth and color camera for positioning of the acetabular component in total hip replacement

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We present a preliminary evaluation of a prototype, portable localizer for intraoperative measurements in navigated total hip replacement (THR). Our system combines a color camera and a Time-of-Flight (ToF) depth camera to detect the instruments that are used to introduce the acetabular cup and to determine their orientation in a predefined reference frame. As a mobile tool, it is also capable of determining its own pose with respect to patient's anatomy, by means of inside-out optical tracking, augmented with inertial cues. In contrast to the marker-based optical localizers, which are the current standard in computer-assisted surgery, our prototype does not require any patient- or instrument-mounted markers The prototype is composed of a miniature ToF camera, coupled with a smartphone with built-in color camera and intertial sensors. The orientation of the cup is measured based on the axis of acetabular impactor. In order to define an appropriate reference frame for this measurement, the system is with two patient-specific orientations of the anterior pelvic plane (APP): first, measured pre-operatively in standing position and the second, in supine position, measured on the operating table, immediately before THR. The system uses an assumption that the position of the pelvis does not change significantly during the procedure. All measurements of the APP are taken noninvasively, with a smartphone-navigated ultrasound probe.
The prototype was tested in terms of angular accuracy, with actual instruments used for THR. As a reference system, we used a marker-based optical localizer. Since our tracking method is based purely on the shape and appearance of the instrument, we also evaluated its reliability under various lighting conditions. According to the first test, the indications of our prototype proved to be in agreement with those of the reference system. For more specific evaluation, further tests will be performed in clinical setup in the future.

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Medical localizer based on Apple iPhone and iPod devices

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Medical navigation plays great role in computer assisted surgery (CAS) providing intraoperative localization of medical instruments. Several different optical localizers are available on the market as multiple-camera standalone specialized systems. These devices are usually expensive and difficult to use for the user. Our aim was to develop a single-camera, easy-to-use, portable, and low-cost medical localizer based on Apple iPhone and iPod. We decided to use these devices because of their high performance, reliability and good optical parameters of their cameras. In our approach we use iOS localizer app to detect two rigid bodies on the camera image and to determine their position in 3D device's coordinate system. Set of two Rigid Bodies (first acting as a reference and second attached to the tool) allows us to estimate position of an instrument regarding to position of the reference. Moreover, our localizer can be embedded into another CAS application providing specialized measurement system for a given medical procedure. The prototype was preliminary calibrated, tested and evaluated in terms of measurement accuracy and repeatability. In the testing procedure, we took measurements of two Rigid Bodies placed at a known distance from several different points of view and for various distances between the camera and the Rigid Bodies. The standard deviation of the measured distance in first validation trials was 1.37 mm and 2.27 mm for iPhone 6 and iPod Touch, respectively. Due to the promising results of this evaluation, we plan to perform more specific tests in clinical setup in near future.

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Integration of electronic components into medical plastic parts by injection molding

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Two ongoing trends will play a crucial role in the development of innovative medical products in future: 1. Realization as single use devices made of plastics to reduce manufacturing costs and avoid necessity of resterilization; 2. Integration of electronic components even in small medical mass products to realize smart functions such as sensing parameters or device tracking. We performed a comprehensive study on the challenges to insert electronic components into plastic parts unmediated within the injection molding process. This avoids a separate assembly step, however leads to a critical thermal and mechanical strain for integrated electronic parts. The study was performed on a test system comprising an electronic test piece and a test injection mold. The sophisticated electronic test piece contains passive (e.g. resistors, capacitors) and active (e.g. photodiodes, operational amplifier, temperature sensors, microcontroller) electronic components on a FR-4 printed circuit board (PCB). The arrangement allows a differentiated consideration of damages of individual parts and component classes. The test injection mold was designed supported by injection molding simulation. The test mold allows insertion of the electronic test piece in different orientations so that next to the variation of process parameters (e.g. injection speed, pressure, temperature) various melt injection directions could be realized and their influence on the integrity of the test piece investigated. Different thermoplastics relevant for medical devices were processed. The damage analysis comprises microsection studies to look for form fit and shear off of electronic parts, function tests of single electronic components, and microcontroller data analysis. The results allow profound statements of mechanical and thermal loading capacity of relevant electronic components within the injection molding process. This serves as a basis for recommendations for action regarding the design of electronic pieces and the choice of process parameters for a successful processing of electronic components by injection molding.

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Monitoring of Daily Physical Activity in Patients with Implantable Blood Pumps Using a 3-Axial Accelerometer

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Monitoring of daily physical activity is an important tool to assess health status both in normal and pathologic conditions. Such monitoring can be particularly useful in patients with a left ventricular assist device (LVAD) implanted. This study aims at the validation of activity detection based on accelerometer data and at its first application to monitor post-implant patient activity.
A 3-axial accelerometer was embedded in a previously developed recording device for LVAD data, which is placed in the patient's shoulder-bag. The measured signals (sampled at 10Hz) allowed a binary classification of activity/rest based on device position and acceleration magnitude. For validation, during ambulatory visits the accelerometer data were compared to notes recorded in a protocol including the time course of active and resting periods. Once validated the post-operative course of total daily activity (min/day) was also analyzed.
Validation was performed with 17 datasets from 11 patients and resulted in a sensitivity of 96.3±3.1% and a specificity of 93.6±6.8%. To investigate the postoperative course, activity data were recorded in 7 patients within the first 200 days post-implant (at an average length of 152 days). At post-operative days 50, 100, 150, 200 average daily physical activity was 60, 77, 88, 65 min/day. Two rehospitalizations due to the occurrence of adverse events were correlated with a drop in detected activity.
In conclusion, activity derived from the accelerometer can be useful for monitoring LVAD therapy and for closed-loop feedback control of blood pumps. Combined with hemodynamic pump monitoring, it provides a comprehensive picture of the interaction between LVAD and the remaining cardiac function during daily living.