Robotics and Navigation in Medicine (Project)
Summer term 2018
Deadline (demonstration): July 13th, 2018
Deadline (report): September 14th, 2018
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Medical Technology | Science | Systems

Group Project: Image Guided Robotic Transcranial Magnetic Stimulation

Transcranial magnetic stimulation (TMS) is an effective medical procedure for diagnostic and therapeutic purposes. Typically, the TMS procedure involves a physician placing the magnetic coil to stimulate a specific cortex. It is, however, important to compensate for any patient motion. In this project, you will develop a motion compensation system using ROS/C++ by essentially tracking a head using a camera and moving a coil attached to a robot accordingly.

For this, you will use an RGBD camera (Microsoft Kinect v2) to track the head motion without using any markers. You will also need to program and control the robot (UR3) to keep the coil at the target position relative to the head. Additionally, you need to calibrate the camera and the robot, in order to update the robot poses relative to the tracked head.

Project Groups: The project work should be conducted in groups of five students. We will form the groups based on the information provided in the registration form by the 16th of April. (Note: To be assigned to a project group you need to submit the registration form either via e-mail or manually to our office (E3.087) by the **10th of April**.)

The lab will be available to you during your lab times as well as by appointment starting the 2nd of May.

Requirements: The following requirements are **mandatory** and need to be fulfilled in order to successfully complete this project.

- Submit a project plan inlcuding a sketch of the necessary interfaces between the components of the motion compensation system, tasks assigned to each group member and a weekly time plan by the **2nd of May**.
- Submit **weekly reports** starting in the first week of May. These reports should include the contribution of each team member, the progress achieved in each part of the project as well as any problems you may have encountered. Team members not mentioned in more than three of the weekly reports will be considered inactive and excluded from the project.
- Develop a motion compensation system using a robot to closely follow head movements tracked with help of an RGBD camera.
- Present your motion compensation system between the **9th and 13th of July**.
- Describe your results and choices in a scientific paper consisting of approximately 5 pages due by the **14th of September**.
- State and explain every assumption made.
- Provide sources for all formulas you use.

Consultation Hours: You may consult the teaching assistants during lab times (to be announced) or by appointment.

Recommendations: Remember to test scripts concerning the robot in the simulation environment available via Stud.IP before running them in the lab. You may use the UR3 or the UR5 during development. However, you will have to use the UR3 during the final presentation.

Consider the following exercises as suggestions on how to solve the motion compensation problem. You can always find alternative solutions as long as you keep the above requirements.

Task 1: Robot Kinematics
The robot works in the joint space, however, you will need to compensate the head motion in Cartesian space. Therefore, it is important to convert the joint positions to a robot pose in Cartesian space and vice versa. Please solve and implement the solutions to the following:

a) Direct Kinematics,
b) Inverse Kinematics.

Task 2: Calibrations
Typical RGBD cameras provide depth images which still need to be converted to a 3D scene (point cloud). This 3D reconstruction from depth images requires depth camera's intrinsic parameters. Additionally, the transformation between RGB and depth cameras is required, so that the images from one camera can be mapped to another. Lastly, in order to navigate the robot based on the tracked poses from the camera reference frame, you will need to calibrate the camera and the robot relative to each other. Please implement the solutions to the following:

a) Kinect intrinsic calibration,
b) Kinect extrinsic calibration (i.e., RGB-camera to depth-camera calibration),
c) Kinect-robot (hand-eye) calibration.

Task 3: Head Tracking
Perform marker-less head pose estimation from Kinect RGBD data. You can record different head poses utilizing a styrofoam head phantom which may be attached to a robot's end effector. Feel free to utilize available open source libraries to help you with the head pose estimation, but remember that you need to be able to explain every part of your system during the final presentation.

Task 4: Motion Compensation
For the complete motion compensation system, you will need to combine the individual components from tasks 1 to 3 for robot navigation.

a) Consider path planning for the initial placement of the coil in close proximity to the head (optional).
b) Consider trajectory planning for a moving target.
c) Update the robot pose using your calibrations and the results obtained for head tracking.

Bonus Points: You may receive up to 10 bonus points that will be added to the points you obtain in the written examination for

- active participation during lab sessions,
- regularity of weekly reports,
- quality of your final presentation and the subsequent discussion,
- quality of submitted software (reasonable structure, sufficient commenting, performance during final presentation),
- plausibility of chosen algorithms and quality of their implementation/incorporation into your work,
- your ability to critically evaluate results,
- creativity and implementation of additional features,
- content and completeness of the final report including list detailing contributions of each author,
- and quality of writing (structure, appropriate use of figures and tables, no grammar or spelling errors).