Visual SLAM for Robotic Surgery

Background

Robotic surgery is an exciting and upcoming paradigm in minimally invasive surgical interventions with the potential to increase accuracy, reduce trauma, allow partial autonomy, and enable new operating techniques that would otherwise not be possible with conventional surgical methods. This interdisciplinary surgical approach has aspects involving robotics, control theory, sensor design and fusion, and environment perception. The overall success of a robotic surgery system is highly contingent upon each subsystem operating robustly and effectively.

Despite the potential advantages, there are numerous obstacles for the successful application that still need to be overcome. One particularly challenging limitation is the reduced field of view of the operating site. In minimally invasive surgery the operating site is only visible with an endoscopic camera inserted through a minimal incision into the patient. Navigation of the surgical instruments, inspection of the surgical site, and overall orientation estimation inside the patient has to be performed using information gained from the endoscopic camera. The overall accuracy and safety is thus contingent on augmenting the robotic surgery system with additional visual information extracted from the endoscopic camera.
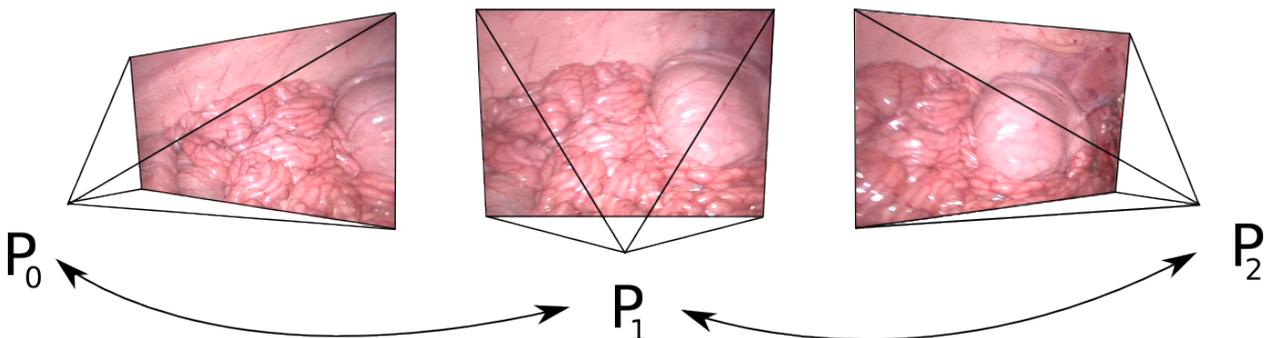
Description

An important improvement to the functionality of the surgical robot system is to extract pose information about the robot relative to the patient. The absolute pose of the surgical robot relative to the patient cannot be observed directly due to the highly dynamic nature of the operating environment, the reduced field of view, and inaccurate robot kinematics, so that it instead needs to be estimated from the available sensor information.

Visual Simultaneous Localization and Mapping (VSLAM) refers to the process of estimating the robots pose while simultaneously creating a map of its environment. In this thesis techniques from VSLAM will be applied the surgical context using the robot's endoscopic camera. In this thesis methods will be investigated for robustly estimating the camera's pose relative to an unstructured operating scene. Special attention will be paid to motion estimation strategies that are robust to changes in the scene. Efficient data structures will be developed that will allow 3D geometry from the scene to be inferred.

Tasks

- Implementation of pose estimation strategies suitable for rigid surgical scenes (appropriate features and matching strategy).
- Optimization of the methods for partly deformable scenes.
- Visualization of the 3D pose over time.
- Qualitative evaluation using prerecorded in-vivo and quantitative ex-vivo data sets.