Real-time 3D Vertebrae Shape Completion in Robotic Ultrasound

Project Management and Software Development
for Medical Applications

General Info

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Project Abstract

Back pain affects millions of people globally, and spinal injections have emerged as a hopeful treatment option, delivering anti-inflammatory medications to specific spinal areas. However, concerns about radiation exposure from X-ray fluoroscopy used for needle guidance have led to a search for safer alternatives, especially for pregnant women undergoing epidural injections [1].

Ultrasound imaging offers a radiation-free alternative. It provides real-time imaging during needle insertion and has been found to be as effective as fluoroscopy for guidance. Despite this, challenges like limited visibility, artifacts, noise, and differences in tissue appearance between ultrasound and fluoroscopy have slowed down the widespread adoption of ultrasound in spinal interventions.

Background and Motivation

For spine injections, Ultrasound (US) imaging could potentially constitute a radiation free alternative to the predominantly used modality of X-Ray Fluoroscopy. US has the advantage that it is non-invasive, real-time, cost-effective and widely available.

However, the visualization of the spine in US scans is limited due to the acoustic shadowing effect causing shadow below bone structures. As a result, only the upper parts of the vertebral components are visible and the lower, such as vertebral body remains invisible. At the same time, high inter-operator variability and a lack of repeatability of current US image acquisition impair the implementation of US specific real-time algorithms for spine.

To tackle the problem of limited visualization, a potential solution is to reconstruct the missing anatomical details. 3D Shape Completion, a thoroughly researched area in computer vision, offers viable solutions. Recently, point cloud-based methods like VRCNet have gained prominence in this field [2]. These techniques, adapted for vertebrae shape completion, have proven effective in generating lifelike and precise shapes.

Volumetric data is useful to the clinicians to visualize and inspect the full shape of the vertebras. 2D ultrasound images with corresponding tracking information of the US probe pose is needed, in order to spatially align the images into a 3D volumetric shape. This has the potential to improve US spine interpretation and treatment planning.

This opens the way to automation of the procedure, and use of robotic platforms for manipulating the US probe [3]. Automating US imaging acquisition can reduce operator-dependency and increase accuracy.

In this project, we want to develop a robotic US system for autonomous spine scan with real-time vertebrae shape completion for improved 3D volume visualization.

Please send the completed proposal to ardit.ramadani@tum.de, lennart.bastian@tum.de and tianyu.song@tum.de. Please note that this proposal will be evaluated by the BMC coordinators and will be assigned to a student only in case of acceptance.

Student's Tasks Description

- Setup the robot with attached US probe.

- Acquire US image stream in real-time over ROS.

- Record real-time robot trajectory.

- Adapt an existing 3D vertebrae shape completion algorithm for real-time results

- Visualization of completed vertebrae shapes in live ultrasound sweep

Technical Prerequisites

Good Python Programming level

Experience with ROS (Robot Operating System)

References

[1] Esteban, Javier, et al. "Robotic ultrasound-guided facet joint insertion." International journal of computer assisted radiology and surgery 13 (2018): 895-904.

[2] Pan, L., Chen, X., Cai, Z., Zhang, J., Zhao, H., Yi, S., & Liu, Z. (2021). Variational relational point completion network. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition* (pp. 8524-8533)

[3] Tirindelli, Maria, et al. "Force-ultrasound fusion: Bringing spine robotic-us to the next "level"." IEEE Robotics and Automation Letters 5.4 (2020): 5661-5668.

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