Project16

VR Guided Surgery
SDF based guidance and safety

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**Project Summary**

**Mastoidectomy Procedure**
- Require high precision
- Preserve important structures

**Volumetric Drill Simulation** [1]

**Signed Distance Field** [2]

**Goal:** Evaluate the effectiveness of feedback modalities based on SDFs to improve situational awareness on virtual drilling.
Paper 1 detail

- **Title**: Virtual Reality for Synergistic Surgical Training and Data Generation
- **Authors**: Adnan Munawar, Zhaoshuo Li, Punit Kunjam, Nimesh Nagururu, Andy S. Ding, Peter Kazanzides, Thomas Looi, Francis X. Creighton, Russell H. Taylor, Mathias Unberath
- **Journal**: Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization

**Relevance**
- Description of skull surgery simulation.
- Detailed description of software architecture.
- Description of the clinical task.
- Key to providing a seamless integration of our SDF-based feedback mechanisms with the current simulation.
Technical Approach(1)

• **Asynchronous Multibody Framework Plus (AMBF+)**
  - Generate relevant data in real-time
    (e.g RGB stereo images, depth, and object pose )
  - Propose a plugin to customize the environment
Technical Approach(2)

• **Anatomy Loading**
  – input sliced CT volume
  – Generate voxel grid anatomy in the simulation

• **Stereo display and VR support**
  AMBF+ has support for Virtual Reality(VR) Head Mount Display(HBD) by generating a pair of stereoscopic images.

• **Haptic device**
  CHAI3D’s finger proxy collision algorithm [3] to provide haptic feedback by simulating the collision with the surface of the volume.
Experiment 1

- **Goal**: Evaluation of state-of-the-art pose tracking algorithms with data produced by the simulation.
- **Algorithm**: ORB SLAM V3.
- **Analysis**: Calculate selected algorithm's precision under two conditions (Camera movement & tools movement)

- **Results summary**:
  - The analyzed pose tracking algorithm is not robust to camera motions.

<table>
<thead>
<tr>
<th></th>
<th>Translation Error (mm)</th>
<th>Rotation Error (deg)</th>
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<tbody>
<tr>
<td>Moving camera</td>
<td>40.97 ± 22.40</td>
<td>8.44 ± 3.07</td>
</tr>
<tr>
<td>Moving drill</td>
<td>8.1E-1 ± 9.1E-1</td>
<td>3.2E-3 ± 3.6E-3</td>
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</tbody>
</table>
Experiment 2

- **Goal**: Evaluation of deep learning-based depth estimation algorithm.
- **Algorithm**: Stereo depth network STTR.
- **Analysis**: Calculated a depth estimate of the selected network.

**Results summary:**
- The trained depth network generalizes to changes in the anatomical structure. (Even when training on a single anatomy)
- The resulting depth maps have an error 1.98mm.
Critical Review

• **Pros:**
  – Paper does a good job at demonstrating the utility of the simulator's data for testing a development computer vision algorithms.

• **Cons:**
  – Paper lacks experiments that proves the training/educational value of the simulated environment.

• **Key Takeaway:**
  – Our work complements this paper by building tools that will make the simulation a better training tool for residents.
  – Evaluate the usefulness of the simulation as surgical training tool.
Paper 2 detail

- **Title:** Image-Guided Mastoidectomy with a Cooperatively Controlled ENT Microsurgery Robot
- **Authors:** Christopher R. Razavi, Paul R. Wilkening, Rui Yin, Samuel R. Barber, Russell H. Taylor, John P. Carey, and Francis X. Creighton
- **Journal:** Short Scientific Communication—Otology and Neurotology

**Relevance**
- Description of the clinical task.
- Baseline for the robot aided mastoidectomy
- User study design
Technical Approach

• **5DOF cooperative Robotic ENT Microsurgery System**
  – Enhanced operative precision with dampening of tremor

• **Forbidden Regional Virtual Fixtures**
  – Demarcate surgical workspace boundaries and prevent motion into undesired areas
Experiment

- **Task:** Drilling on right temporal bone model phantom while being assisted by virtual fixtures.

- **Virtual fixtures:** After an image registration procedure, 3 intersecting planes were used to delimited the regions where the drill could move safely.

- **Protocol:** Untrained user performed the drilling experiment 5 times while being assisted by the virtual fixtures.

- **Evaluation:** Success of the procedure was evaluated by fellowship-trained neurotologist who was not present during the experiment.
Critical Review

• Pros
  – Successfully demonstrated the feasibility of the robot system and the virtual fixture assistance.
  – Increase safety and reduce task completion time

• Cons
  – No quantitative discussion about the assistance.
  – No comparison with other control

• Key Takeaway
  – User study design
  – Baseline for the robot aided mastoidectomy
Conclusion

• AMBF+ is a flexible simulation environment that can potentially be used to benchmark computer vision algorithms and develop surgical skills.

• Assistive robotic tools such as virtual fixtures can make a big difference on a procedure to improve safety and develop situational awareness.
References

