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Group 7

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Project title: Steady-Hand Eye Robot Control Algorithm Based on Force-sensing Tool Information

1. Implementing a variable admittance control scheme to increase the robot resistance when the sclera force is increasing a fixed upper level threshold

2. Using the expert’s force-depth variation curve to apply another variable admittance control which helps operator to manipulate the eye

3. Applying these control schemes on the Eye-Robot and performing several experiments with different subjects
Title: Intraocular Robotic Interventional Surgical System (IRISS): Mechanical Design, Evaluation, and Master–slave Manipulation

- Describes the mechanical design of the IRISS
- Discusses the hardware–software interface and the method of control
- Evaluates the performance of the robot both mechanically and in a clinical trial
Key Result and Significance

• Remotely operated and fully automated intraocular robotic system

• Adjustable RCM point aiming at performing safe manipulation

• Designed compatible to clinical requirements

• Simultaneously employ two tools inside the eye

Most significant achievement: robotic retinal vein cannulation
Two methods exist for reducing stress at the eye entry site during surgery:

- Using active software enforcement with visual or force-based feedback control to minimize tool-induced stress

- Physically constraining the surgical instrument about its incision point in the eye
Slave robot with 6-DOF

Master robot with 3 DOF

2 DOF gimbal mechanism

RCM
The data acquisition of the master manipulators and control for the IRISS are implemented on a National Instruments PXI real-time target with sampling rate of 1 kHz.

CAD model of the RCM laser tool holder alignment of the RCM to the incision point with computer-vision guidance by searching the minimal detected area of laser points.
Quantitative Results

resolution of optical joint encoders for each DOF

<table>
<thead>
<tr>
<th>Joint</th>
<th>Count/Rev.</th>
<th>Gear ratio</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>4000</td>
<td>100:1</td>
<td>0.90 mdeg/count</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>2048</td>
<td>588:1</td>
<td>0.30 mdeg/count</td>
</tr>
<tr>
<td>$d_3$</td>
<td>1024</td>
<td>60:1</td>
<td>1.26 μm/count</td>
</tr>
<tr>
<td>$\theta_4$</td>
<td>1024</td>
<td>17:1</td>
<td>20.7 mdeg/count</td>
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</tbody>
</table>

statistical results of precision test

<table>
<thead>
<tr>
<th></th>
<th>RMS</th>
<th>SE</th>
<th>Max.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A</td>
<td>0.027</td>
<td>0.002</td>
<td>0.045</td>
<td>14</td>
</tr>
<tr>
<td>Point B</td>
<td>0.030</td>
<td>0.002</td>
<td>0.047</td>
<td>15</td>
</tr>
</tbody>
</table>

All values are in units of mm.

Point A (at $\theta_1 = 15^\circ$, $\theta_2 = 15^\circ$ and $d_3 = -2.55$ mm).

Point B (at $\theta_1 = 5^\circ$, $\theta_2 = -5^\circ$ and $d_3 = -2.10$ mm).
Surgery tasks performed

- The IRISS was able to perform the following surgical procedures:

1. anterior lens capsulorhexis
2. viscoelastic injection
3. hydro-dissection
4. lens aspiration
5. retinal vein cannulation (requires a tool-positioning accuracy of 10 μm)
6. vitrectomy.
Surgery tasks performed

View of the surgical field through the microscope moments

- before retinal vein cannulation

- during retinal vein cannulation
Assessment

• **Pros**
  - Developing software and hardware components for a remote robotic master-slave retinal surgery
  - Many technical approaches to increase the precision
  - Laser-based RCM positioning
  - Performing many in vivo advanced surgery tasks

• **Cons**
  - They have not attached a force sensing tool to the robot for active force control (sclera or tip) – online sclera monitoring is not possible
  - Surgeons mostly rely on visual or force feedback cues (collaborative controlled robots seem more advantageous)
Conclusion

• Developing an active force control at sclera can still be a novel study

• It would be a great study to compare the sclera safety with the 2 methods mentioned.

• The same studies also can be done on tip force instead of sclera force