Feasibility of interactive gesture control of a robotic microscope

Abstract: Robotic devices become increasingly available in the clinics. One example are motorized surgical microscopes. While there are different scenarios on how to use the devices for autonomous tasks, simple and reliable interaction with the device is a key for acceptance by surgeons. We study, how gesture tracking can be integrated within the setup of a robotic microscope. In our setup, a Leap Motion Controller is used to track hand motion and adjust the field of view accordingly. We demonstrate with a survey that moving the field of view over a specified course is possible even for untrained subjects. Our results indicate that touch-less interaction with robots carrying small, near field gesture sensors is feasible and can be of use in clinical scenarios, where robotic devices are used in direct proximity of patient and physicians.

Keywords: gesture control; motorized surgical microscopes; gesture tracking; assistance in surgical intervention; touch-less interaction; medical robotics

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1 Introduction

Interaction with robotic assistance devices is particularly interesting in medical applications, where physicians are typically confronted with a number of different tools and instruments they need to control. One example are robotic cameras and microscopes. For example, operating microscopes are frequently used in neurosurgery, where the physician sits close to the patient’s head, looking at the surgical field through a microscope while performing precise surgery, e.g., along nerves. Given the small field of view, the clinical scenario typically involves frequent manual adjustments, i.e., grasping the handles and moving the microscope to the next region of interest. Clearly, removing the instruments from the surgical field, placing them outside and manually positioning the microscope interrupts the surgical workflow.

System setup

We propose a setup where the sensor is embedded in a surgical microscope. A clear advantage is the unobstructed view on the surgical field. However, the sensor needs to be small, which holds true for the LMC. The device primarily consists of two cameras and three infrared light emitting diodes illuminating the scene. It is intended to track finger motion in a range of 25 to 600 mm above the device. Given that all processing is done on a computer, the device is small and lightweight, measuring just 75 mm by 25 mm by 6.2 mm. Another advantage is the high temporal resolution. The software interface provides information on hand
gestures and can be configured to track different points, e.g., the centroid of the hand, or a finger.

To assess the feasibility of tracking and gesture control we have realized a simplified setup consisting of a UR5 (Universal Robots, Denmark) robotic arm, a USB microscope, and the leap motion controller. A second robot (ABB IRB120, Sweden) is used for some experiments evaluating the tracking performance by moving a hand phantom with adjustable fingers. A computer with an Xeon E3-1225v3 CPU and 16 GB RAM running Windows 8.1 Professional is used to process the LMC data and to control the UR5. Figure 1 shows the setup.

The LMC defines a coordinate frame with the x axis along the long centerline, the z axis along the short centerline, and the y axis normal to form a right hand system (see Fig. 2). For the purpose of our experiments, the height of the microscope with respect to the base plane was not changed. The LMC and the microscope were aligned and placed into an adapter and mounted to the tool flange such that the orientation of the coordinate axes was aligned. We did not need to obtain the actual transformation, i.e., particularly the translation, as all motions are relative to the last position of the microscope.

3 Experimental evaluation

In our analysis we were primarily interested in the possibility to track motion for interaction with a robotic microscope. We studied two different scenarios. First, the actual microscopy setup was used, but the motion was mimicked with the hand phantom mounted to a second robot (compare Fig. 1). Second, a pattern denoting a corridor for a target trajectory was printed, and 14 test persons were asked to move the center of the microscope image along the pattern. The center was highlighted by a cross-hair and the motion was solely controlled by moving the hand.

In the first experiment, the trajectories of the robot representing the microscope and of the robot moving the hand are compared. This is evaluated by calculating the root mean squared error (RMSE)

$$\text{RMSE} = \sqrt{\frac{\sum_{j=1}^{n}(err_j)^2}{n}}$$  \hspace{1cm} (1)
of the difference in the xy-plane between both TCP positions $TCP_{pos}^{UR5}$ and $TCP_{pos}^{IRB120}$

$$\text{err}_j = \left| \left( TCP_{pos}^{UR5} \right)_{xy} - \left( TCP_{pos}^{IRB120} \right)_{xy} \right|_2.$$ (2)

In the second experiment the quotient

$$p_{\text{quote}} = \frac{\Delta_{\text{outside}}}{\Delta_{\text{total}}}$$ (3)

between the total moved distance $\Delta_{\text{total}}$ and the distance $\Delta_{\text{outside}}$ moved outside the course is calculated for evaluation. In addition the time of the subjects to finish the course is measured.

During the experiments the room temperature was constant at approximately 22 degrees Celsius and the LMC and the UR5 robot worked under normal operating conditions.

### 4 Results

#### 4.1 Motion tracking

We measured the motion tracking performance for squares of edge length 50mm and 100mm at speeds ranging from 5mm/s to 20mm/s. An example of a resulting trajectory is shown in Fig. 3. The RMSE between the TCP positions is displayed in Table 1. The LMC was mounted with its longer centerline and hence its x-axis is parallel to the y-axis in the image. In the data this is represented by higher errors in y-direction of the example trajectory. Besides, the results are pretty straightforward with RMSE increasing for higher speeds and squares.

<table>
<thead>
<tr>
<th>speed (mm/s)</th>
<th>edge length (mm)</th>
<th>RMSE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>50</td>
<td>6.8183</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>6.9378</td>
</tr>
<tr>
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</tr>
<tr>
<td>20</td>
<td>100</td>
<td>13.9469</td>
</tr>
</tbody>
</table>

#### 4.2 Microscope survey

The survey was completed by 14 untrained participants with one to three tries with the majority completing two tries. The results are displayed in Tab. 2. An example of a resulting trajectory is shown in Fig. 4. Clearly most of the subjects delivered very good results for not being familiar with the system before. Only two participants could not achieve comparable results. The data shows a pretty steep learning curve with most of the participants improving their results in a second run either in accuracy of their movement or in speed. In at least one try 9 of 13 achieved results of $p_{\text{quote}} < 0.1$. As with motion tracking we achieved a sampling frequency greater than 100Hz.

### 5 Discussion

Our results indicate that the general tracking performance of the LMC using the standard software interface has to
be carefully considered when using the device in clinical scenarios. The RMSE for robot hand motion was between 6.8mm and 13.9mm but some delay in the control is definitely measured here, too. Following the course, most test persons performed well with 9 of 14 having a $P_{quote}$ below 0.1 in at least one try. The results for both, the robotic hand motion and the human trajectory following indicate that the errors are small enough to realize interactive motion control.

Currently, few motorized microscopes are available, with their practical advantages being questionable. We have shown that interactive gesture control of a robotic microscope is feasible. Embedding the sensor in the device would avoid extra setup effort and line of sight problems while adding no extra complexity to the workflow.

**Author’s Statement**

Conflict of interest: Authors state no conflict of interest. Material and Methods: Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The conducted research is not related to either human or animals use.

**References**


