Haptic 3D micromanipulation

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Introduction

How can human touch be extended to enable manual exploration and manipulation of micro and even nano-structures? This is one of the key questions driving our research. M. A. Srinivasan of MIT, USA and UCL, UK, with support from TUM-IAS, Germany, has developed a micromanipulation system with a haptic interface to enable manual exploration, manipulation, and assembly of micro-structures. In collaboration with A. Schmid of UCL, London, S. Thalhammer of Helmholtz Zentrum, Munich, and R. Yechangunja of Yantric, Inc., USA, he has demonstrated manual grasping and moving of 10 to 100 µm sized objects with direct haptic feedback of the gripping force in real-time, so that the objects can be placed in three dimensions with nanometer precision [1].

Setup Description

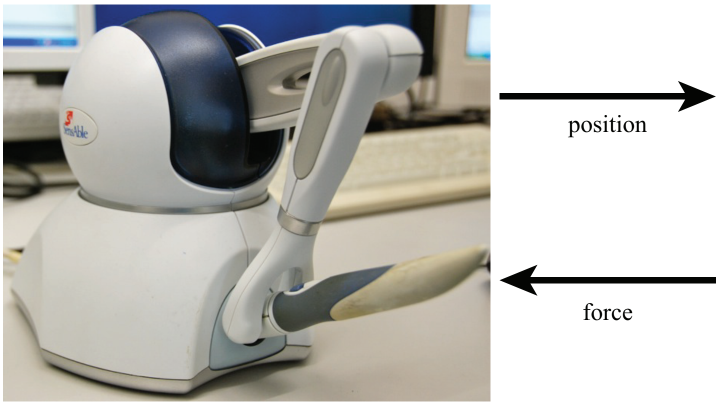
Our Master-Slave micromanipulation system consists of an haptic interface (Master), taking human position commands and displaying interaction forces and the robotic micromanipulator (Slave). The devices are connected through a controller PC. A stereomicroscope at the slave end enables visualization of the micro-objects.

Slave system:

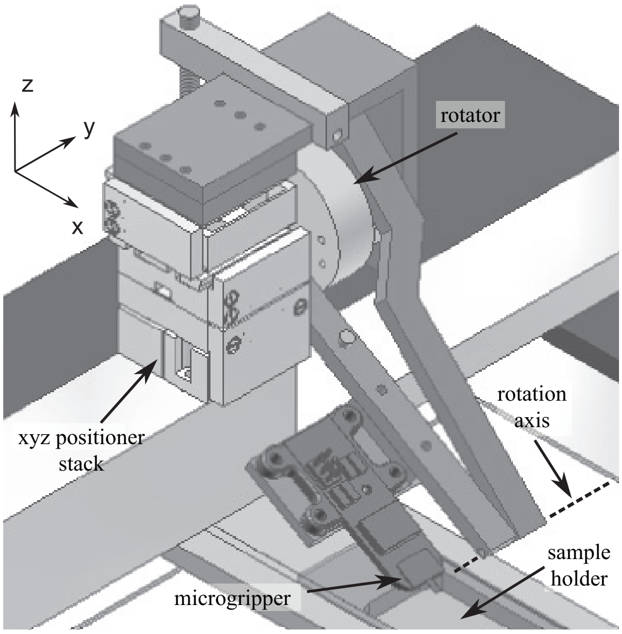
For the micromanipulator a force-sensing microgripper with 100µm opening is mounted onto two attocube's ANPx101/NUM and one ANPz101/NUM for xyz positioning. Additionally an ANRx101/NUM rotator can adjust the tilt angle. Using the ANC350 controller box, the positioners are run in closed-loop mode with the control command continuously updated by the master commands.

Master system:

The demanded 3D-position is read by the Phantom haptic interface (in the centimeter range), scaled down and sent to the controller (micro/nanometer range). On the slave side, the force measured by the microgripper in the micro-Newton range, is scaled up to the Newton-range and exerted on the operator's fingers through the haptic interface.



Phantom haptic interface (MASTER)



micromanipulator (SLAVE)

Figure 1: *Haptic interface (left) and positioner arrangement for the micromanipulator (right).*

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Results

For validation of the tracking behavior and the force measurement capabilities of the manipulator, it was employed in a model scenario: to approach a glass slide from above. Performing an operator controlled, oscillating movement in y-direction (Fig. 2a) the gripper was carefully moved downwards (Fig. 2c) while the measured force of the gripper sensor (Fig. 2d) was scaled up and presented to the operator. This force was caused mainly by friction of the tip touching the glass surface. In Fig. 2e it can be seen how this force increased. With decreasing height, this force increases , which can be observed in Fig. 2e.

The 3D manipulation capabilities are assessed by performing the task for stacking four 45 µm diameter polystyrol beads into a two-layered pyramid. The resulting structure is shown in Fig. 3. Each bead was lifted up from the ground, moved to a target position, precisely put down and released. The human operator commanded the opening of the gripper through the Phantom device while the measured force was scaled up and displayed to the user on the device. This gives the operator a direct “feeling” for the bead.

Summary

The major purpose of the presented teleoperation setup was to build a tool for human experimenters which provides them with direct and intuitive capabilities to explore and assemble micro-structures. The applied gripping force on the object could be controlled through a haptic feedback loop. This does not only prevent fragile objects from damage but actively helps reducing adhesion during contact manipulation.

Our human-in-the-loop system gives scientists a versatile tool for micro-assembly and characterization at hand.

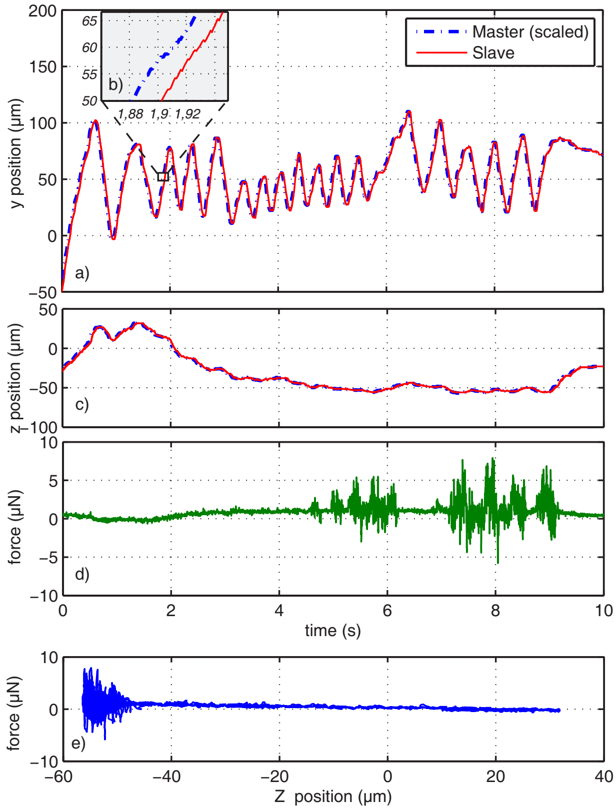

Figure 2: *Tracking behavior and force measurement during surface approach: a) y position of oscillating gripper (slave) compared to scaled master position with b), zoomed view on position trajectory, c) z position of gripper and master, d) measured force, e) measured force over z position.*

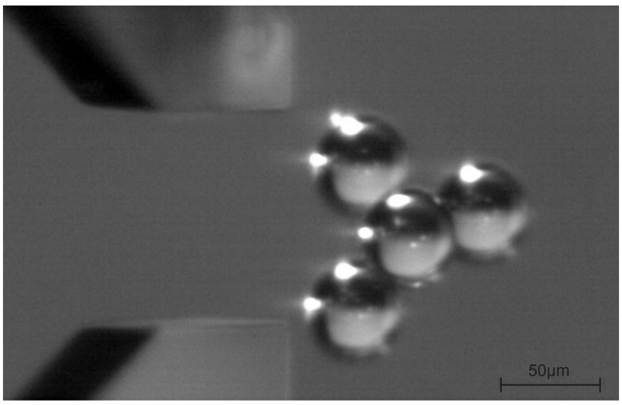

Figure 3: *Microscope image of a pyramid of four 45 µm beads as a result of 3D assembly done using the microgripper whose tips are also visible in the image.*

References

[1] A. Schmid, R. Yechangunja, S. Thalhammer, and M. A. Srinivasan, Proceedings of the IEEE Haptics Symposium, 517-522 (2012).

All images and data are courtesy of A. Schmid and S. Thalhammer.