SORBONNE UNIVERSITÉ

Ecole doctorale SMAER
Sciences **M**écaniques, **A**coustique, **E**lectronique, **R**obotique

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Laboratory : ISIR

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Title of the thesis: *Tangible interface and Human-Computer Interactions for semi-automation in microrobotics*

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Résumé en français

La microrobotique opère dans un environnement physique différent, où les équilibres des forces sont modifiées à cause des effets de la réduction d'échelle. De plus, cet environnement est visionnable uniquement à travers des dispositif de microscopie, aussi bien optique, électronique ou encore à force atomique. Une difficulté supplémentaire apparaît aussi dans les rapport des dimensions des dispositifs robotiques (centimètres) et échantillons (millimètre à micromètre) vs la précision (micromètre à nanomètre) : un exemple à l'échelle macroscopique équivalent à une tâche de micromanipulation serait de placer un carton de déménagement avec une précision millimétrique en utilisant une grue de chantier.
Par conséquent, il est particulièrement difficile pour un opérateur d'interagir directement avec cet environnement intangible, où il a une vision particulièrement de mauvaise qualité et le comportement mécanique n'est pas prédictible. L'objectif de cette thèse est de proposer une nouvelle modalité d'interface qui permettrait à un utilisateur la prise en main naturelle et immédiate d'une tâche de manipulation. L'approche proposée se base sur les techniques de réalité virtuelle et de retour haptique et tactile. La particularité de l'interface est la co-localisation visuel et tactile : il s'agira de pouvoir toucher certain objets de la scène virtuelle et de les manipuler comme s'il s'agissait d'objets réels. Une telle interface a des applications qui dépassent les limites de la microrobotique et aura toute sa place dans le paysage numérique actuel.

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Human interaction with micro-scale is an important challenge in microrobotics. Fields like biology and nanotechnologies, especially for characterization of new materials, for design of micro/nano-systems or analysis of physical micro-scale phenomena present complex challenges beyond the possibilities of automated systems. In those cases, guidance from a human operator is required to carry out the task.

However, this interaction is hardly straightforward. The human operators cannot interact directly with micro-scale because of the scale of treated objects and applied forces. Moreover, the resolution of optical microscopes is limited and the Scanning Electronic Microscope (SEM) do not provide real time images. Systems are sensitive to environmental conditions, for example temperature and humidity. Indeed, the micro/nano scale physics differs from macro world: mechanical behavior is no longer dictated by gravity force and short range forces such as electrostatic, capillary and van der Waals forces dominate [Haliyo-2002]. Consequently, the physics of the micro-scale differs completely from that of the macro-scale perceptible by human. Thus, the understanding of this scale cannot be carried out by simple homothety of macro-scale and requires a special attention. Teleoperation in this case appears to be an interesting and promising solution to supplement human operators perception [Hollis-1990] [Hatamura-1990].

Since 1990s, several force-feedback micro-teleoperation systems are proposed to provide humans a sense of touch and manipulation capabilities at micro-scale. Fore example, in [Sitti-1999] an haptic device is connected with Atomic Force Microscope (AFM) for feeling and manipulating nano objects. [Schmid-2012] presents a coupling of a 3D micro-manipulator with haptic interface. Another micro tele-operation system was developed in [Mehrtash-2011] around a magnetic untethered microrobotic and a haptic device using a bilateral coupling. They allow extending human touch to micro/nano-scales.

Another component for human access to micro-scale is the virtual reality. To work around the poor quality of imaging techniques a novel approach is to create a virtual reproduction of the manipulation task, including digital mock-ups robots, samples and the environment. This virtual scene is coupled to the real one using image processing techniques and allows for a free-flight visualization [Sauvet-2012]. Combining VR and haptic feedback also led to some interesting achievements, such as remote handling of micro-objects inside a SEM between Paris, France and Oldenburg, Germany. [Bolopion-2012].

More recent works at ISIR looked at the interface issue from the user point of view. Motion analysis of an operator interacting with a pick-and-place task led to the development of a natural and intuitive interface, using predictive intention extraction and focus analysis. This interface does not require and device to be held by the operator and uses only a *kinect* camera.

On the other hand, in microrobotics *semi-automation* is new paradigm between full-automation (very hard to achieve in the micro-scale), and manual operation (which requires to user control of the individual degrees of freedom of the robot). It's based on a set of elementary tasks, which all are easy to automate. The user decides on when and how to transition between those tasks and generates set-points and control parameters. This novel approach is hence heavily based on the human/machine interaction and requires a tailored interface.

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The objective of this PhD work consists of design, realization, experimentation and validation of complete remote handling station based on semi-automation and using colocalized virtual reality and haptic/tactile feedback. Especially, a significant difficulty is to co-localize visuals, haptic and tactile cues to represent a scaled-up virtual scene to the user.

Although there are numerous examples in the literature where haptic and tactile feedback are used in virtual reality, colocalization of visual and tactile cues is yet to be achieved. The approach to be investigated here consists in using a fishtank-like 3D display, fitted with a robotic system which places versatile tactile surfaces under the finger of the operator depending on the desired interactions. This work requires significant developments on the hybrid control issues with a good understanding of human perception, on both vision and tactile/haptic modalities, as well as of the sensory-motor system to model and predict the user motions.

Subsequently, a full human interaction scheme needs to be developed based on a microscale remote handling task. In these prospects, design goals will be defined in the context of industrial collaborations and commercial viability concerns.

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