Tele-Nanorobotics 2-D Manipulation of Micro/Nanoparticles Using AFM

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Controlled action at a distance, teleoperation, has been used since the earliest times to extend man's reach into hostile or distant places. Telerobotics systems for operating robots in hazardous environments, outer space or deep sea have been a recent hot topic in the field of teleoperation. Besides of these kinds of applications, there is a new emerging application area of such systems which we call "Tele-Nanorobotics". Since man cannot sense or manipulate directly in the nano scale world, one solution is teleoperation between macro and nano worlds. This kind of application has become possible by the invention of Scanning Tunneling Microscope and Atomic Force Miscoscope which can provide atomic size 3-D topology images. Although the nano scale imaging technologies are being established, nano scale manipulation and fabrication technologies are still in their early infancy. Therefore, the aim of this study is to construct a direct teleoperation system which will enable teleoperated manipulation of nano scale objects with sizes in the range of 10 nm - 5 micrometer.

The overall structure of the Tele-Nanorobotics system is shown in Figure 1. An open-hardware and open-software home-made Atomic Force Microscope (AFM) is constructed. It consists of sensor-integrated XYZ positioning stage, micro-fabricated piezoresistive cantilever, deflection measurement electronics using Weastone bridge and amplifiers, top-view Optical Microscope for rough imaging, acyrylic isolation chamber, and vibration-free table.

Previously, 0.484 micrometer size latex particles are scattered and deposited on a silicon substrate. The aim of the nano-robotics system is to push or pull the particles in order to position them on the silicon substrate, which means 2-D particle assembly. After initial alignment and other calibrations, cantilever scans the user-defined area and gets 3-D topology image. During the imaging scanning, since the particles are semi-fixed on the substrate, tapping-mode type of intermittent contact AFM imaging is utilized for not changing the particle positions.

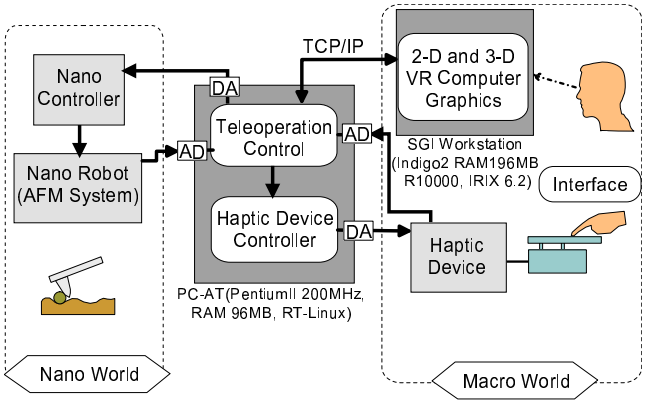

Figure 1: Overall structure of the Tele-Nanorobotics system.

Scanned image is transferred to the Virtual Reality user interface. This interface consists of a 3-D computer graphics display, 1-DOF haptic display, and mouse. Operator directly controls the XYZ position of the cantilever tip through this interface. User selects the most convenient perspective and magnification in the visual display, and can feel the scaled nano scale forces on his/her finger in real-time. Since the AFM scanning takes time and the same tip is used for both imaging and manipulation, on-line pushing of the particles cannot be seen during pushing operation. However, real-time force feedback increases the dexterity of the operator since he/she can sense the forces on the tip. Particles are pushed in the AFM contact mode where the cantilever behaves as a simple XYZ micro/nano manipulator with a one finger gripper. After desired pushing operation, the moved particle area is scanned again, and the image is updated off-line for confirming the manipulation.

Using this system, mechanical, adhesional and tribological properties of the micro/nano objects can be understood, 2-D nano devices and memories can be constructed, and biological object manipulation can be realized. This kind of tele-nanorobotics systems are one of the indispensable components of the future nanotechnology research and applications.