Haptic Interfaces to Scanning Probe Microscopy (**ABSTRACT**)

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Recent advances in the past thirty years have brought nanotechnology into the mainstream, allowing scientists and engineers to develop theory and products at atomic scale. One major breakthrough was the invention of Scanning Probe Microscopy (SPM), a technique that allows nanoscopic objects to be viewed at macroscale. However, this technology was primarily developed for the visual senses, neglecting other critical sensory functions responsible for optimal human functioning.

The majority of human-computer interface research has focused on visual perception even though several other senses also provide frequently-used feedback [1]. However, many haptic research devices such as the PHANToM (SensAble Technologies) and the Delta Haptic Device (Force Dimension) have been commercialized, leading to increased interest by industrial and academic sectors. The addition of haptic force feedback to traditional ocular SPM approaches was shown to be more intuitive, increase productivity, enable new types of experiments, and allow for finer control of the SPM probe [2, 3, 4]. By modelling the cantilever and surface force feedback variation with an approximate model (e.g. a spring), a nanoscale object can be haptically modelled. Further, Lederman et al. proposed that spatial tasks are best represented visually while properties of materials are best perceived haptically, and SPM-scanned surfaces are often composed of many unique materials [5].

The overall goal of this research is to give an operator control of an Atomic Force Microscope (AFM) teleoperatively using the nanoManipulator (3rdTech) system (Fig. 1). This goal requires three phases: a training phase where the software adapts to each user's perceptual capacity, a controller phase where a passivity controller is added to allow teleoperative control, and an experimentation stage where the software and AFM are engineered to work in tandem. At this date, the first phase is nearing completion.

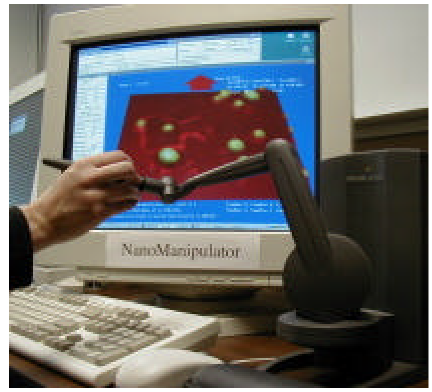

Figure 1. The nanoManipulator system (photo courtesy 3rdTech).

To allow for perceptual constancy among operators, a quantitative training procedure was developed after several experimental iterations. Two homogeneous surface stimuli (***S1*** and ***S2***) were presented separated by ***z***-axis distance ***D***, each surface having unique stiffness ***k***. The haptic output force is determined by Hooke's law (F=-***k***Δd); experimentally, an inverse correlation between ***k*** and the operator's effected Δd (penetration depth) was established (Fig. 2). Thus, the goal of training was to determine Δ***k*** experimentally between ***S1*** and ***S2*** when ***D*** is held constant such that at all surface

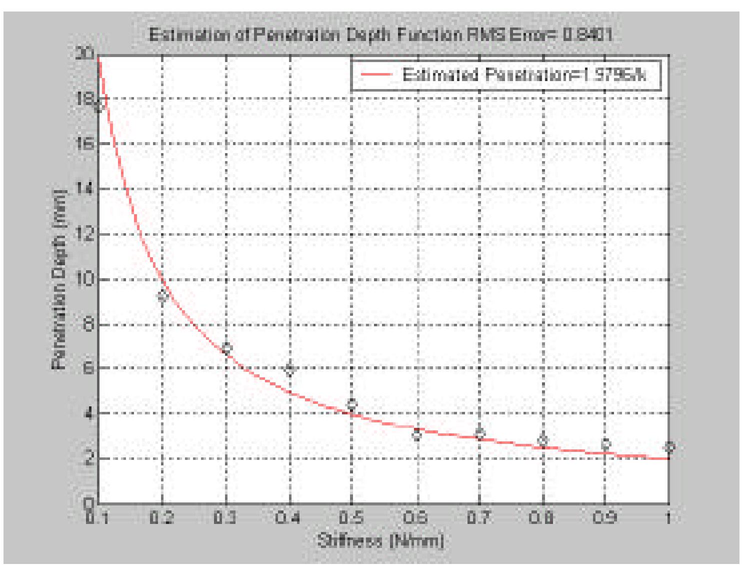

Figure 2. Inverse correlation between stiffness (*k*) and penetration depth (Δd).

points, the user-controlled Δd is also constant. By using user-specific perceptual configurations, an operator will feel the multimodal, displaced surfaces as one continual surface at constant height. Through application of this technique and the remaining two phases of integration, an operator will be able to manipulate any nanoscopic specimen as if it were a macroscopic object, an important goal that will make the nanoscale more approachable to scientists.

References:

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