Researchers Propose AFM-based Virtual Nano-hand for Stable Nanomanipulation

The atomic force microscopy (AFM) is a promising tool for manipulating nano-objects to fabricate nano-structures or nano-devices. However, there are still some challenges facing the development of an AFM-based robotic nanomanipulation system, such as the uncertainties associated with AFM tip and nanoparticles, the single point force and interaction between the tip and nanoparticles, and the parameter calibration of models being used.

To overcome the severe bottle-neck in AFM-based robotic nanomanipulation system, scientists from the Shenyang Institute of Automation proposed a concept of the virtual nano-hand (VNH) strategy for automatic and stable nanoparticle pushing without monitoring the dynamic interactions between the tip and nanoparticles. The VNH strategy is like a mimic of a human hand to flick a ball with multi-fingers alternatively, which prevents the tip from slipping away from the particle and stably hobbles the manipulated particle throughout the whole pushing process.

The concept of the AFM-based VNHS is illustrated in Fig. 1. In the traditional target-oriented pushing (TOP), the single AFM tip is always programmed to strike the center of the nanoparticle being pushed [Fig.1 (a)]. However, this method can easily cause nanoparticles to be lost during the process of pushing, due to the uncertainties with the tip positioning. Another traditional nanoparticle pushing strategy, double-tip pushing [Fig.1 (b)], can make nanoparticle pushing more stable but not flexible. In the strategy of virtual nano-hand pushing, [Fig.1 (c), (d)], the single AFM tip mimics multiple tips by quickly touching different points for stable pushing of the nanoparticle or nano-rod, respectively.

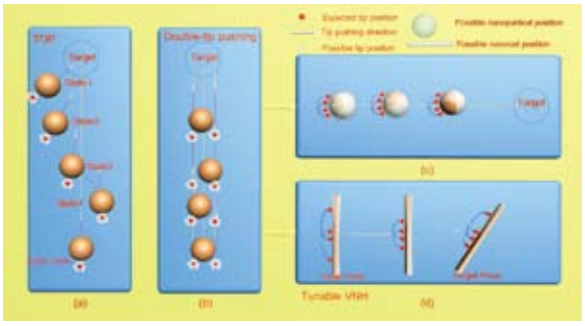

Fig.1. The concept of VNH. (a) Conventional target oriented pushing (TOP). (b) Real double tip strategy. (c)-(d) AFM-based virtual nano-hand strategy.

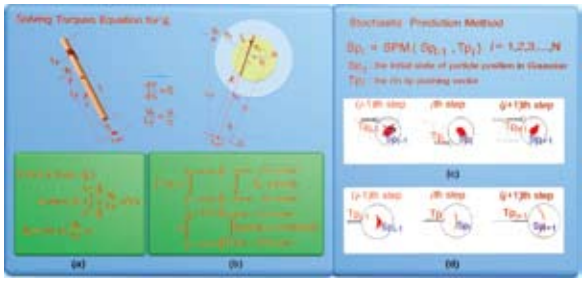

Fig. 2. The kinematics models of nano-objects and the probabilistic prediction method based on Monte-Carlo algorithm for the position distribution. (a) The static torques self-balanced for nano-rod pushing. (b) The torques for nano-sphere pushing. (c) The probabilistic prediction for the uncertainty distribution of particle position in TOP strategy. (d) The probabilistic prediction in VNH strategy where the uncertainty distribution can be described by beta function.

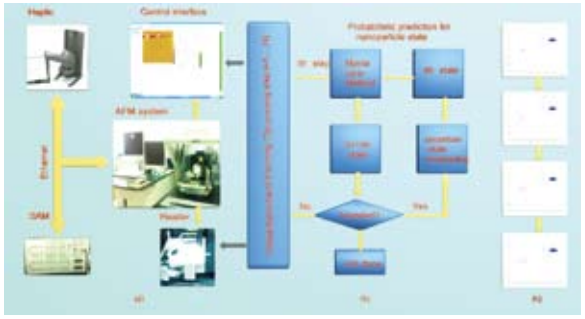

Fig. 3. Applications of the VNH strategy in AFM-based nanomanipulation system. (a) Current AFM-based nanomanipulation system. (b) VNH strategy predictor to evaluate the adopted tip pushing trajectory. (c) Simulation results of the predictor for the probabilistic distribution of the manipulated nanoparticle positions.

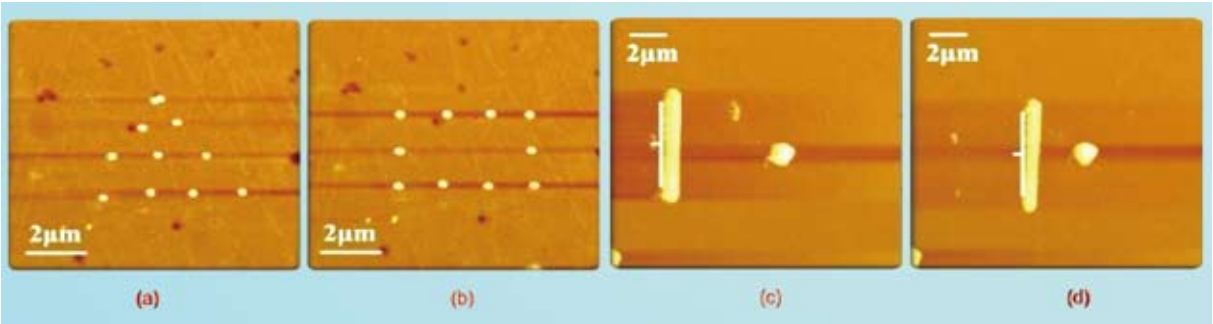

Fig. 4. Nanoparticles pushing results using the upgraded AFM-based nanomanipulation system. (a) - (b) Nanoparticles pushing results. Every particle pushing is planed using the tested multi-point VNH strategy. (c) Before nanorod pushing. (d) After nanorod pushing. VNH strategy can easily maintain the orientation of the nanomanipulated object.

The VNH was designed based on a probabilistic prediction method (PPM) developed for dealing with the uncertainties in the nano-particle pushing. One of the advantages of VNH strategy is to assist the operator to perform nanoparticle transfer stably, efficiently, and effectively. Ultimately, the VNHS can intensify the AFM-based robotic nanomanipulation system so that the only thing an operator needs to do is specify the manipulation task.

Their work has been published as a cover story of *IEEE Nanotechnology Magazine*. The research was supported by the National Natural Science Foundation of China and the CAS/SAFEA International Partnership Program for Creative Research Teams. (Images by WANG Zhiyu from the Shenyang Institute of Automation)