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# REAL-TIME SIMULATION OF AFM TIP-SURFACE COHESIVE INTERACTIONS

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The manipulation of nano-objects requires specific instruments as Atomic Force Microscopes (AFM). Despite qualities and performances of these devices, many physicists complained about the lacks of adequate man-AFM interfaces, since the experimentalist can not control the AFM tip during the sample scan [1] or feel in real-time the results of his actions on the sample surface [2]. Since the information we can extract from a nano-scene is complex and above all, a-priori foreign to our common sense and daily experience, an efficient communication of human perception/action processes and the physical actions and behaviours in the nano-world is a non-trivial task. Several works as those of [3,4,5] deal with the implementation of a multi-sensory AFM-human operator interface allowing the experimentalist to see, to hear and to touch the nano-objects in real-time during the manipulation. The first stage of these works was to enrich the conventional instrument by adding a force-feedback device allowing the user to feel the forces applied to and returned by the AFM tip. Thus, the architecture of the developed instruments was a conventional teleoperator architecture composed of a force feedback manipulator, signal transmitters and AFM.

The work presented here aims to a similar objective: allowing the experimentalist to act on and feel the nanoworld phenomena during the manipulation by the use of multisensory representations including the force feeling. Nevertheless, keeping in mind the differences between the human world and the nanoword, we assume that simulation is an imperative layer to adapt in real time the specificities and the information between human and nano worlds. Thus, a crucial challenge is to have at our disposal minimal models of the nanoscene, able to be simulated in real-time, which could be inserted between the user's multisensory interfaces and the real nanoscene.

In this context, our paper presents a minimal model able to simulate in real-time the complex phenomenon of approach-withdraw interaction that appears between an AFM tip and a sample surface in contact mode. This interaction is a cohesive interaction presenting a hysteretic behaviour as shown in approach-withdraw curve (fig.1). Figure 2 illustrates our minimal model equivalent to the physical elements: the piezo-actuator controlled in Oz position, the cantilever, the tip, the sample surface and the tip-surface interaction.

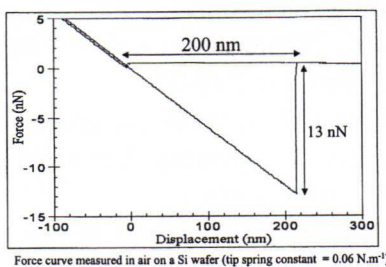


Fig.1 The observed approach-withdraw interaction curve

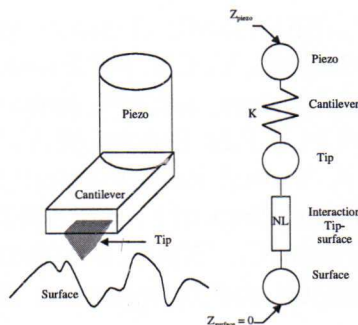


Fig.2 Minimal model of the AFM piezo-tip-surface

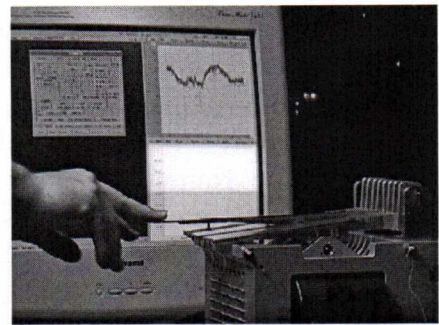


Fig. 3 Feeling the approach-withdraw interaction

The real-time simulation of this model produces the correct approach-withdraw curve, with hysteresis phenomenon, and thus without any element in the model which exhibits explicitly memory function. The force applied on the tip during the approach-withdraw procedure is transmitted to the experimentalist in real time through the virtual model and a Force Feedback Gestural Device, making thus possible a human haptic perception of the approach-withdraw interaction (Fig.3).

In order to validate the results of this minimal real-time model, we developed a Simulink model presented in fig.4, respecting the functional principle of each component of a real AFM. This simulation uses as input data the physical parameters that characterise a silica sample surface and returns two results that correspond to the observation of the real AFM functionality: a tip-surface interaction curve corresponding to Lennard-Jones potential, and an approach-withdraw force curve. The results of this study match with the practical results already obtained by physicists [6] and prove the validity of our approach in modelling the tip-surface cohesive interaction.

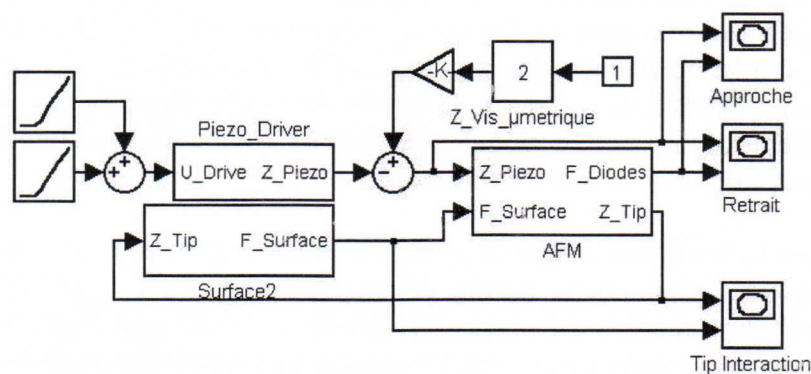


Fig. 4 Simulink model of AFM

The minimal model presented has been easily designed and implemented in real time by means of the Cordis-Anima modelling and simulation system [7]. The work presented here plays the role of a test bed for a generic use of this simulation, necessary to design minimal real-time models and to insert them in the new nanomanipulation instruments. That is a first step in the designing of the instrumental complete chain composed of force feedback nano-feeler, simulation, multi-sensory nano-manipulator, real nanoscene, which allow scientists to manipulate nano-objects in real time and to avoid the classical trials et errors methods.

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