Haptic Interfaces to SPM

Daniel Wilhelm
Purdue University
(dwilhelm@purdue.edu)

INAC/NCN SURI Nanotechnology Symposium. August 7th, 2003.

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Overall Goal

- Link haptic device to an AFM
- Feel nanoscopic forces haptically

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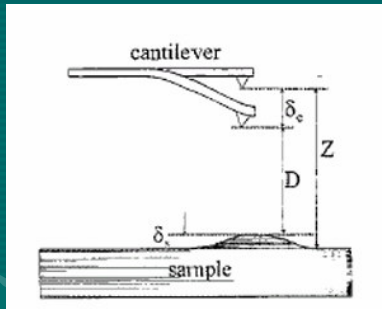
AFM Modeling



$$F_c = -k_c \delta_c \quad (1)$$

$$F_s = -k_s \delta_s \quad (2)$$

$$D = Z - (\delta_c + \delta_s) \quad (3)$$

$$k_c \delta_c = \frac{C}{(Z - \delta_c - \delta_s)^n} \quad (4)$$

$$k_c \delta_c = \frac{C}{(Z - \beta \delta_c)^n}, \beta = (1 + k_c / k_s) \quad (5)$$

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Teleoperation Constraints

SPM

- Material probe properties
- Same probe for topology, forces
- Probe tip size and shape
- Sample or probe movement

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Teleoperation Constraints

Haptic Device

- Mechanical system
- Force actuators
- Position, force sensors
- Local, global control loop

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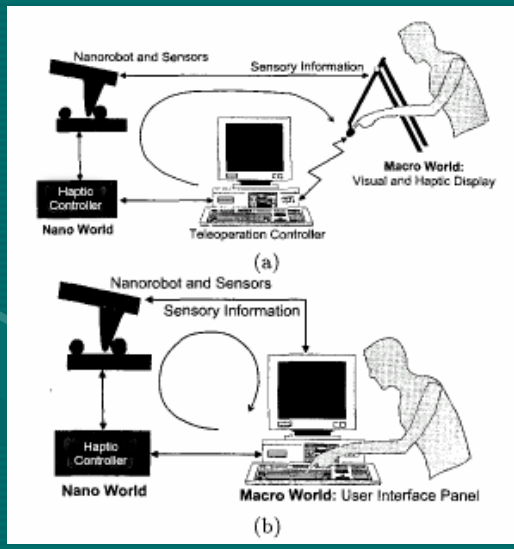
Nanomanipulation



- **Direct control (a)**
- **Semi-autonomous control (b)**

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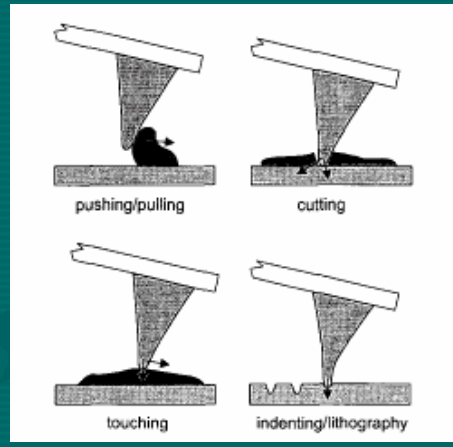
SPM Closed loop Automation

Virtual Brushes

- Pushing/pulling
- Cutting
- Touching
- Indenting/lithography



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PHANToM™ Nanomanipulators

- The NanoManipulator™
- Extensive software support

Limitations

- AFM probe is the haptic tip
- Workspace, possible forces

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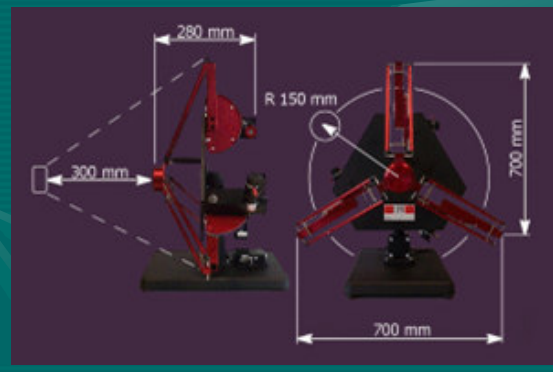
Alternative Nanomanipulators

- Delta Haptic Device™
- The ARM™



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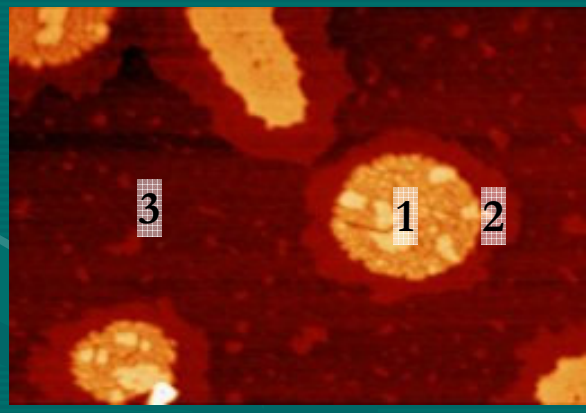
Motivation: Mica



1: Protein

2: Halo

3: Mica

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Experiment Physical Set up

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Psychophysical Study

1. Determine detection threshold
2. Collect penetration depth data
3. Reaffirm perceptual continuity

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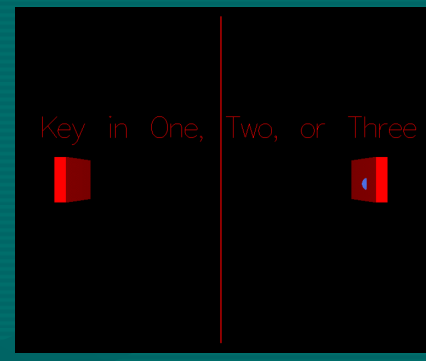
Software Visual Aspects



- Collect penetration depth data
- User applies force +x, +z

- Collect psychophysical data
- User motion restrained

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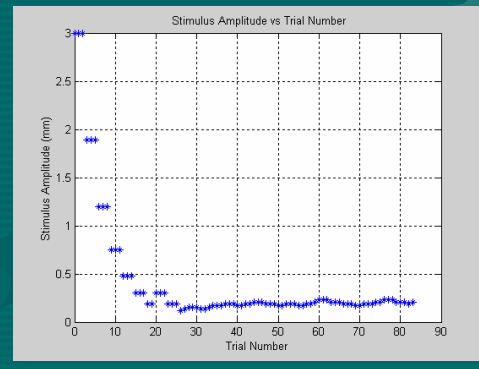
Determine Detection Threshold

Three-Interval Forced Choice

adaptive procedure




```
>> reversals
input file name dkw0.4exp1.txt

JND =
    0.3303

std_JND =
    0.0997

JND for this subject is 0.330314 mm
```

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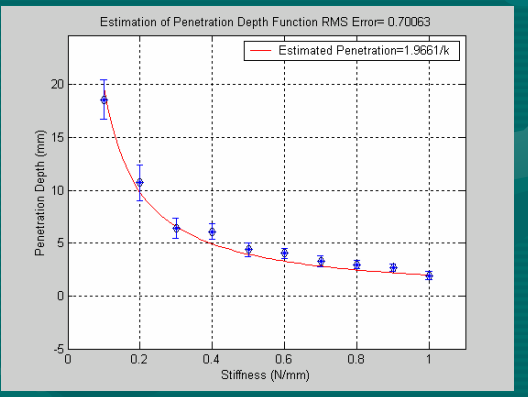
Collect Penetration Depth Data



- Ten trials
- Constant-stiffness surface

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Reaffirm Perceptual Continuity

Perceptual Scenarios:

- Mostly correct (d' positive)
- Equally correct/incorrect (d' zero)
- Mostly incorrect (d' negative)

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Acknowledgments

- **INAC/NCN SURI Program** staff
- **NASA/NSF** for program funding
- **Haptic Interface Research Laboratory** members,

especially

Prof. Hong Tan
Laron Walker

By thought and reason great ones had their turn.
Now, with my hands, some new things I shall learn.
- Tammy Gordin

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