# Haptic Interface for Cardiac Cell Exploration Using AFM

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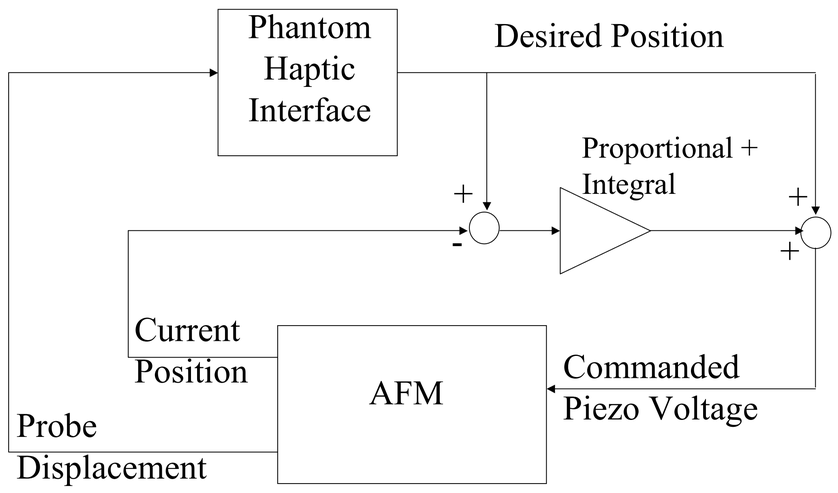
## Atomic Force Microscope (AFM)

The AFM enables mechanical interactions on the nano scale
- Microfabricated probe with tip radius of a few nm
- Mounted on 3-axis piezoelectric actuator
- Optical sensing of probe deflection measures contact force

Haptic interface control of AFM
- User commands AFM tip position and feels contact force with haptic stylus
- Provides productive interface, enables new experiments, and builds intuition [1][2]

## Implemented System

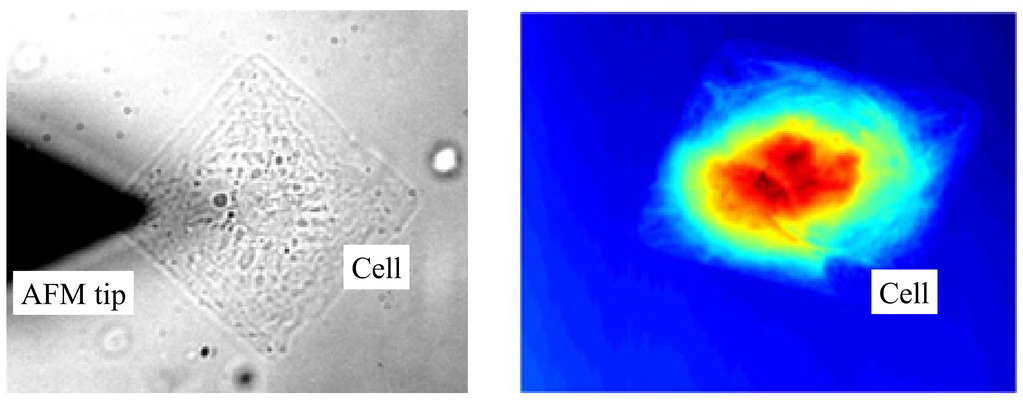
- Asylum Research model MFP-3D AFM, resolution ~few nm X-Y, ~0.1 nm Z
- Sensable Technologies Phantom 1.5 haptic interface.
- Phantom stylus position sent as position command to AFM piezoelectric actuator controller
- AFM probe deflection sent to Phantom controller as force command
- Force feedback gain ~$10^7$



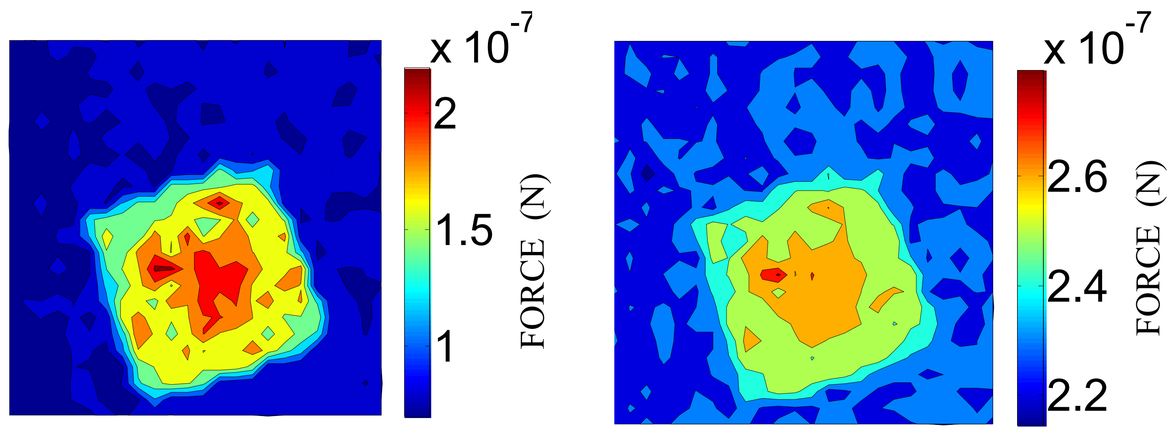

*Control scheme for AFM + haptic interface.*

## Cardiac Cell Interaction

Mechanics are central to the function and development of cardiac cells; haptic interface allows biologists and tissue engineers to interact with them mechanically for the first time
- Substrate with microlithographed pattern of 50 x 50 μm square island of fibronectin
- Single cardiac myocytes on island can be probed in vivo in real time with AFM



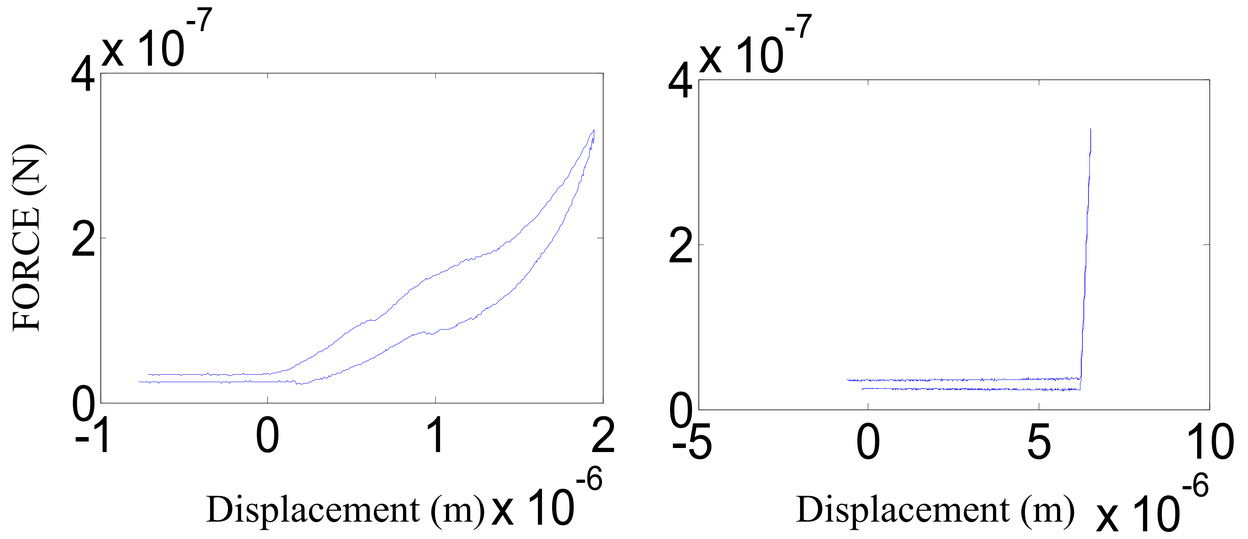

*Optical (left) and AFM (right) image of cardiac cell grown on square micropatterned substrate.*




*Force volume slices showing increased force due to cell nucleus in the center.*

## Virtual cell palpation

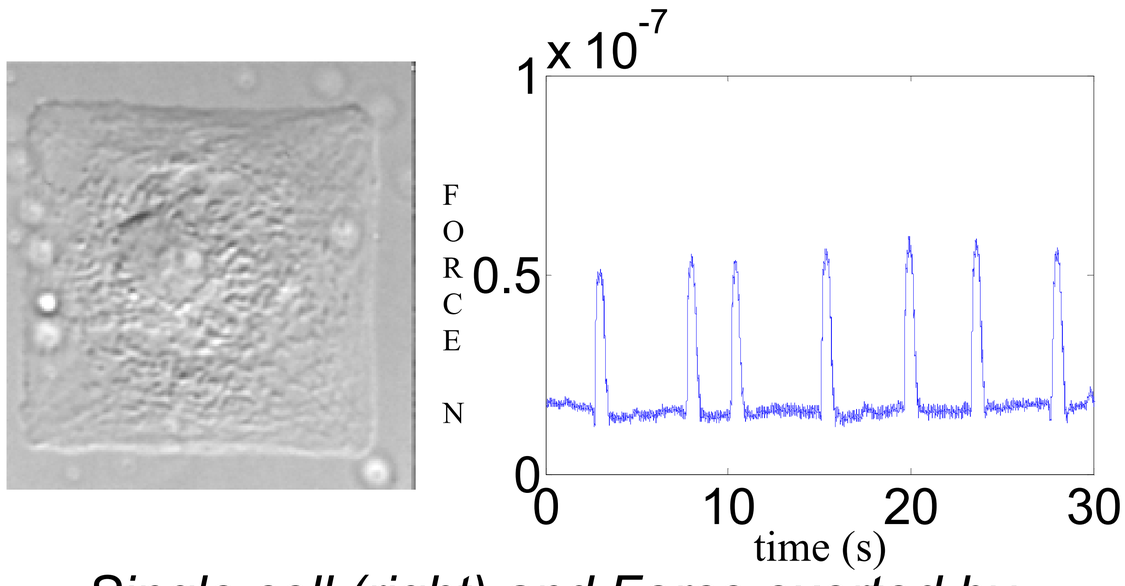
Goal: Create accurate virtual model of cell shape and stiffness for off-linehaptic exploration
- Collected AFM force-displacement data in tapping mode at a 25x25 grid of points over the cell surface (automated collection, no haptics).
- Rendered the measured force at the depth input from Phantom.
- Tri-linear interpolation to smoothly transition between data points, depth subsampled to 100 points.
- Users feel the same stiffness interaction as if directly connected to the AFM.
- Visual rendering based on the AFM height map allows both visual and haptic interaction.




*Force-displacement curves with probe over cell nucleus (right) and cell substrate (left).*

## Real-Time Haptic Interaction

Goal: Allow users to feel interactions between AFM probe and cell
- Cell contraction induced with epinephrine
- User lowered AFM tip onto cell surface
- Beats readily felt by user through haptic interface




*Single cell (right) and Force exerted by beating (left)*

## References

**[1]"*Tele-Nanorobotics Using Atomic Force Microscope*", M. Sitti and H. Hashimoto, IEEE Intl. Conf. On Intelligent Robots and systems, 1998**
**[2]"*Controlled Manipulation of molecular samples with the nanoManipulator*", M. Guthold et.al., IEEE Trans. On Mechatronics, Vol. 5, No. 2, 2000**