

Augmented Reality Combining Haptics and Vision

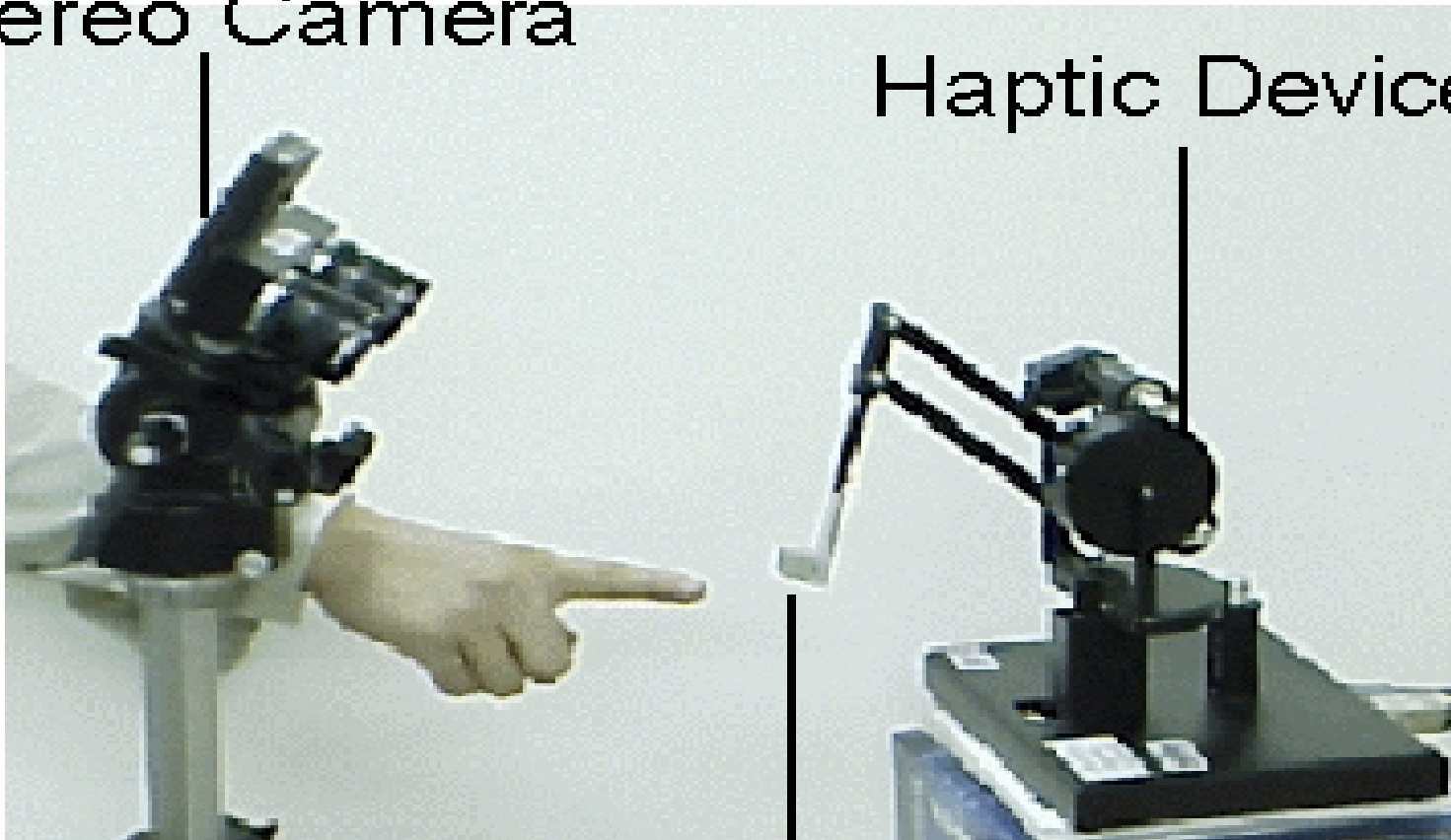
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July, 2003

Vision + Haptics

Stereo Camera

Haptic Device



Passive Haptic Object

Outline of the Talk

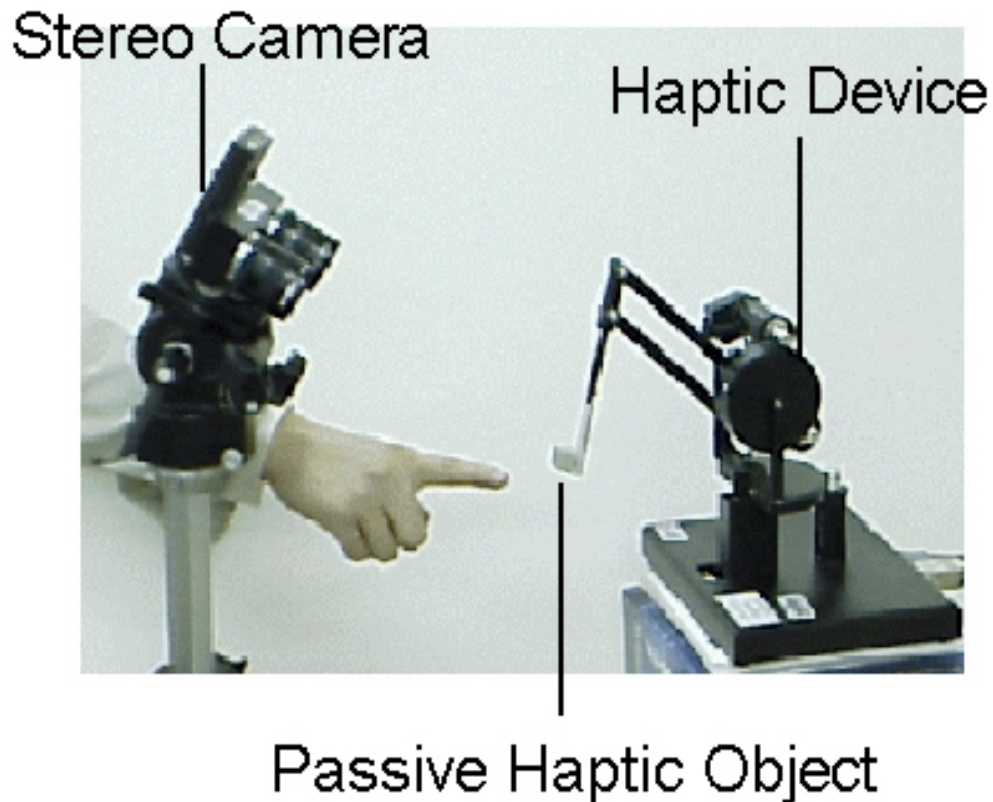
- Motivation
- System Framework
- Implementation Details
- Experimental Results
- Short Videos and Conclusion

Cons of Constant Contact

- Prevents feeling of new tactile sensation
- Limited workspace of haptic device
PHANTOM 1.0A: 13 cm * 18 cm * 25 cm
- Constant reminder of “a virtual world”

Our Solution: Combining Vision

- Project Goal:
integrating force feedback and tactile feedback



Advantages of Our System

- Combining force feedback and tactile feedback



- User-friendly
- Immersiveness

Modular Framework

- Three modules
Vision, Haptic device, augmented reality
- Vision: Tracking the user's fingertip
- Haptic device :
Meeting the user and Interaction rendering
- Augmented Reality
Scene configuration
Vision/Haptics 3-D registration

Vision Subsystem

- Hand Segmentation
- Fingertip Detection
- Fingertip Tracking

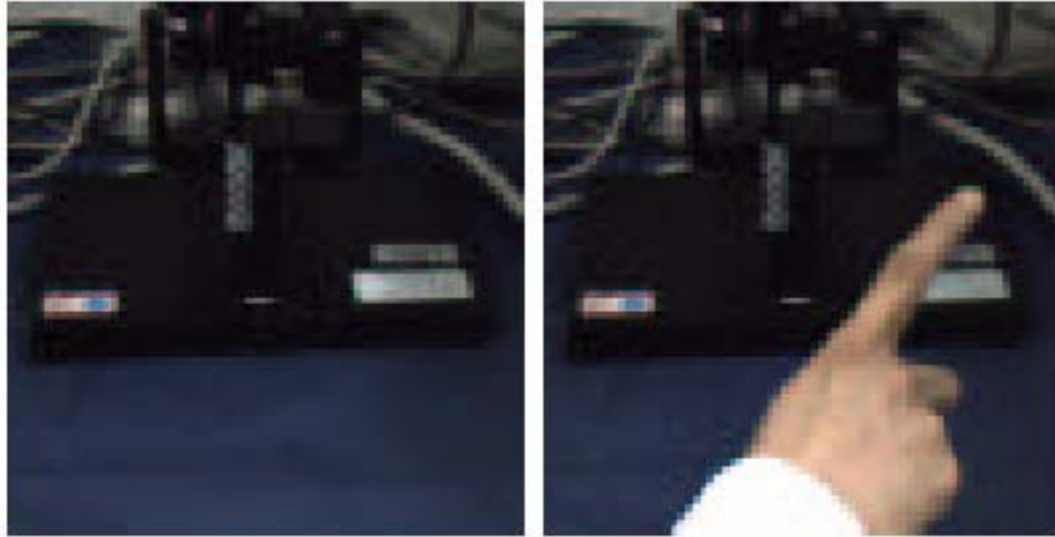
Segmentation of Hand

- Appearance Model: Hue Histogram
- Classification Criterion: histogram matching

$$HI(Measure, Model) = \frac{\sum_{i=1}^n \min(Measure_i, Model_i)}{\sum_{i=1}^n Model_i}$$

- Skin color model
Single Gaussian model of hue distribution
- Accuracy: 98%

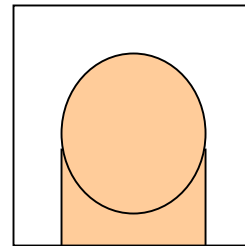
Segmentation Example



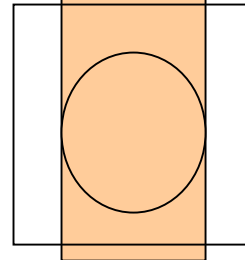
Fingertip Detection

- Geometrical Properties of Fingertip

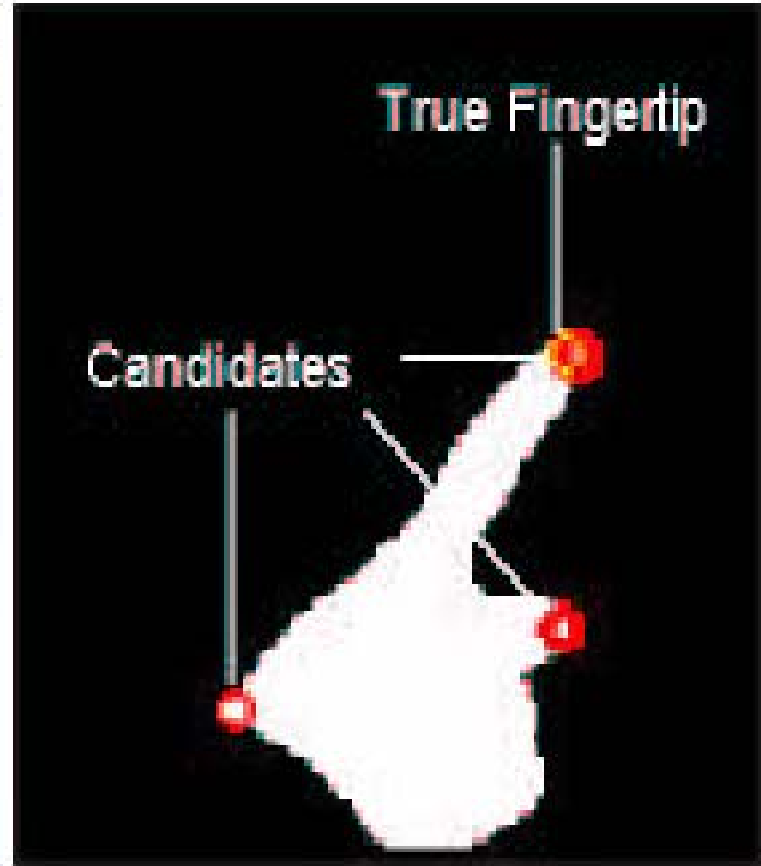
True Fingertip



False Fingertip



Fingertip Detection Example



Fingertip Tracking

- Kalman Filter
- Search for fingertip in a local area
- 3-D coordinates calculation

Augmented Reality Module

- 3-D registration

$${}^H \vec{P} = {}^H_C R \quad {}^C \vec{P} + \vec{t}$$

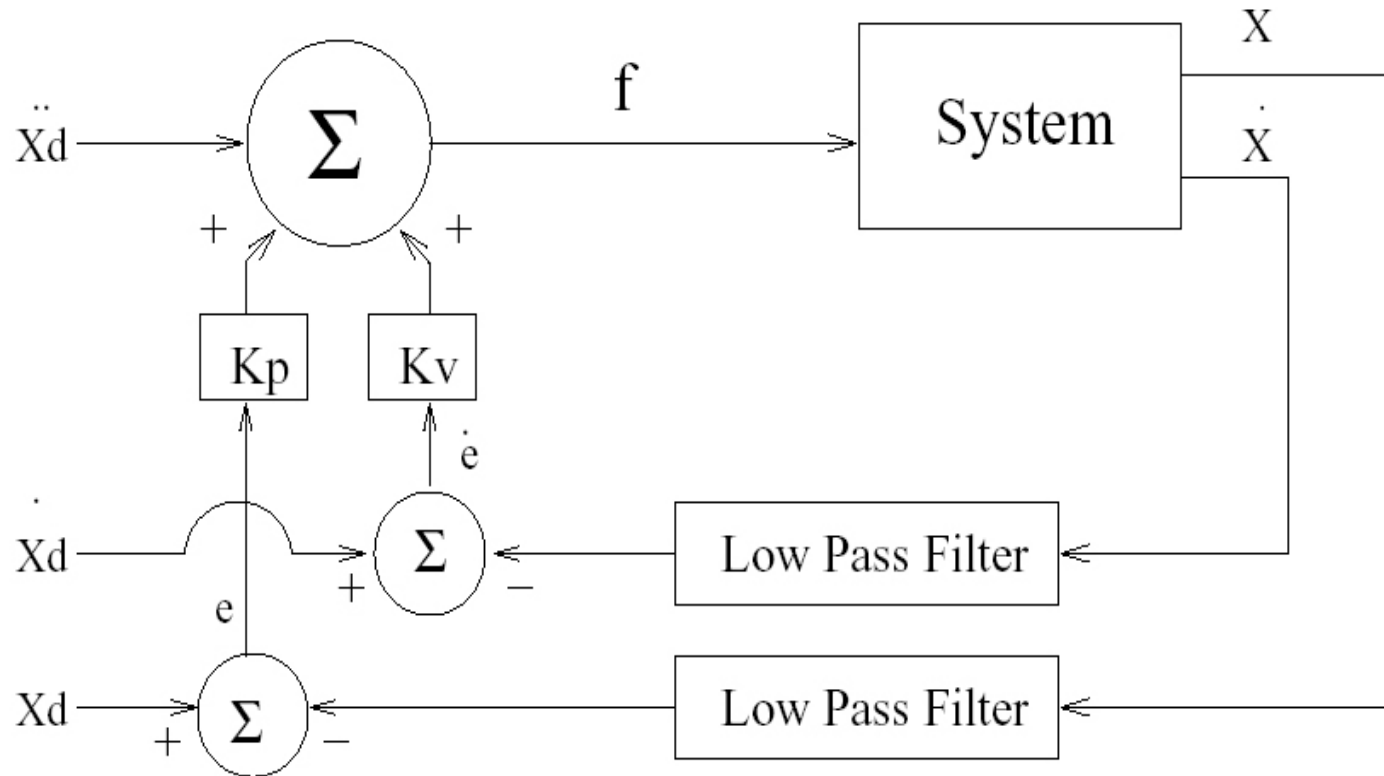
- Calculate R and t
Optimal solution of absolute orientation
- Precision: 0.5mm

Augmented Reality Module

- Scene Configuration
- Virtual plane (n, d)
- Button (p, n, w, h)
- Passive objects

Haptic Device Subsystem

- Control Law



Gravity Compensation

- Torque of gravity of PHANToM parts

$$\tau_g = \begin{pmatrix} 0 \\ g(m_a l_1 + 0.5 l_1 m_c + m_{be} l_5) \cos \theta_2 \\ g(0.5 m_a l_2 + m_c l_3 - m_{df} l_6) \sin \theta_3 \end{pmatrix}$$

- Force to compensate gravity

$$F = (J^b{}^T R^T)^{-1} \tau$$

Interaction Simulation

- Overall force control

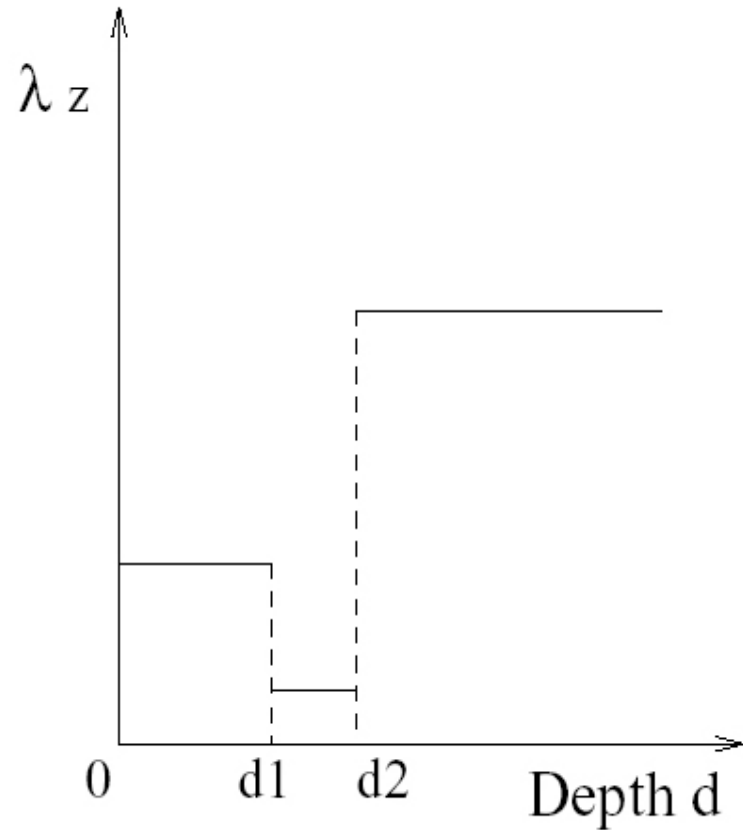
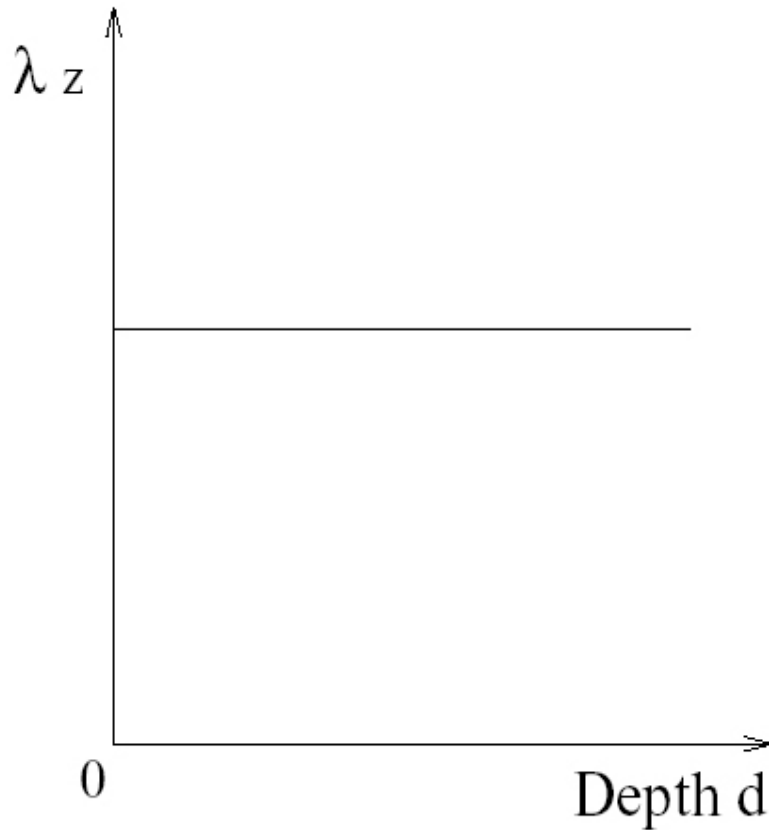
$$F = F_{GC} + \Lambda_{gain} f$$

- Object gain matrix

$${}^H \Lambda_{gain} = {}^H_O R^T \quad {}^O \Lambda_{gain} \quad {}^H_O R$$

- Adjust gain along the normal to the surface

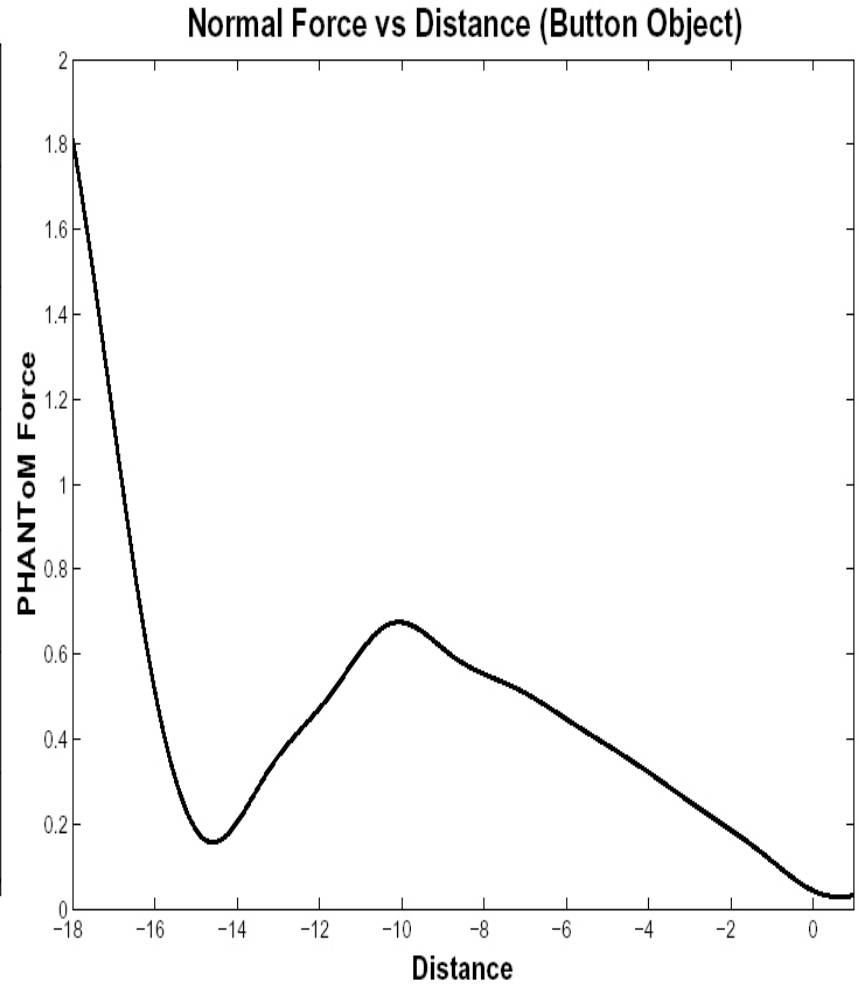
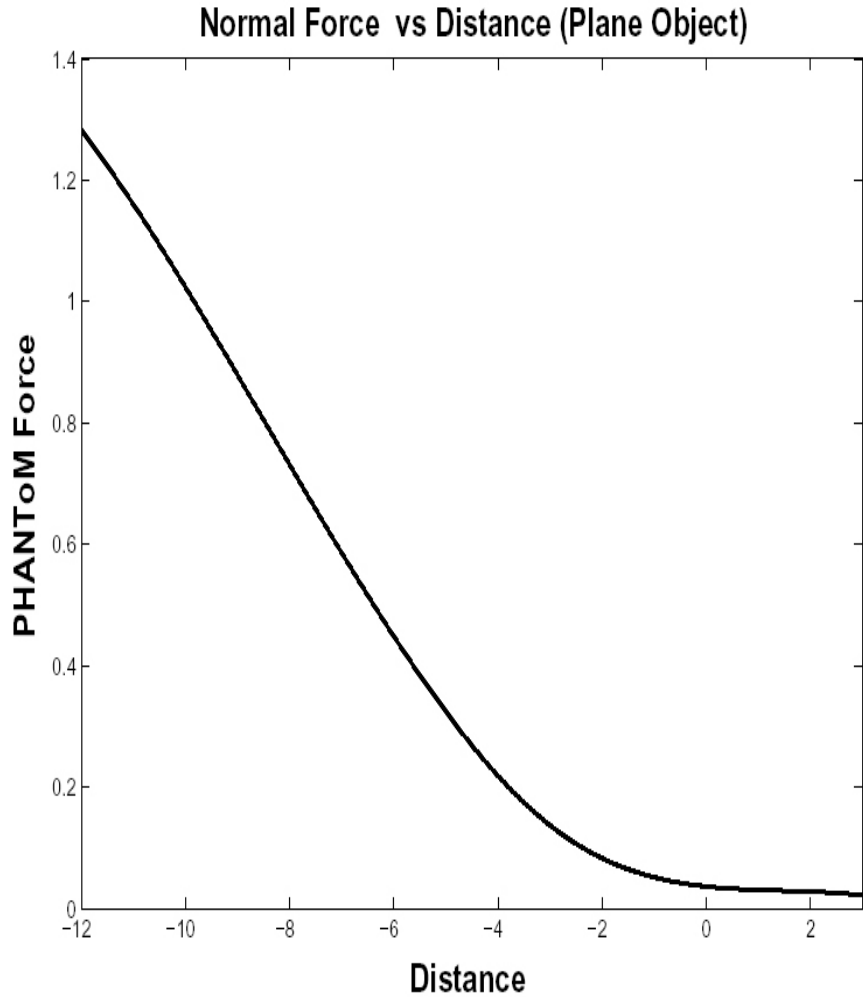
Model the Interaction



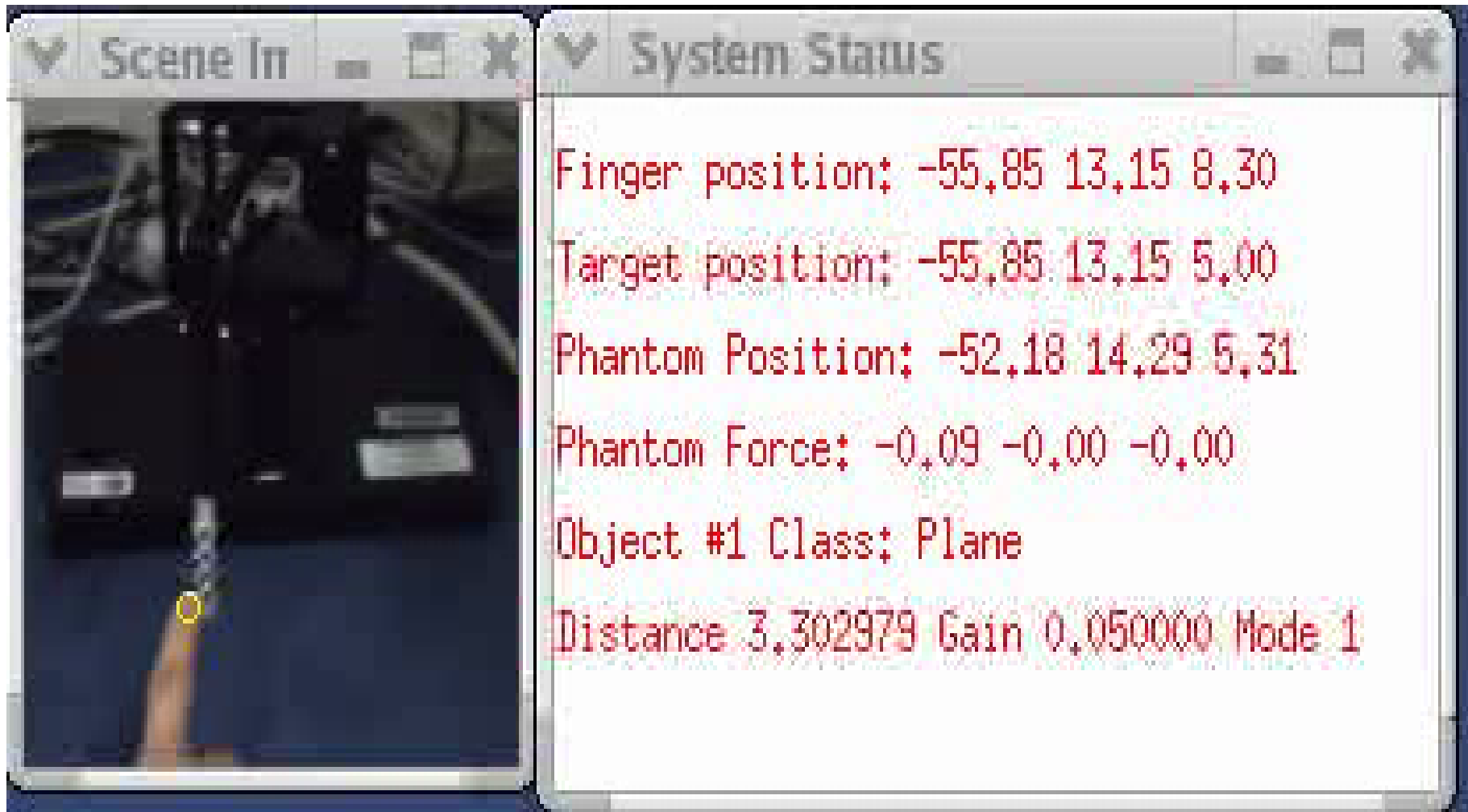
Experimental Results

- Implementation on average PC
- Around 12 fps
- Multiple objects

Interaction Simulation Results



A Short Movie



Conclusion

- Combine vision to resolve the problem of constant contact
- Modular framework incorporating force feedback and tactile feedback
- Key problems: visual tracking, 3-D registration, interaction rendering
- Further research: HMD, richer interaction

- Thanks
- Comments/Questions ?
- Acknowledgements:

The authors thank Jake Abbott for his assistance with PHANToM control. The work was supported in part by the Johns Hopkins University and National Science Foundation Grant #EEC-9731478.