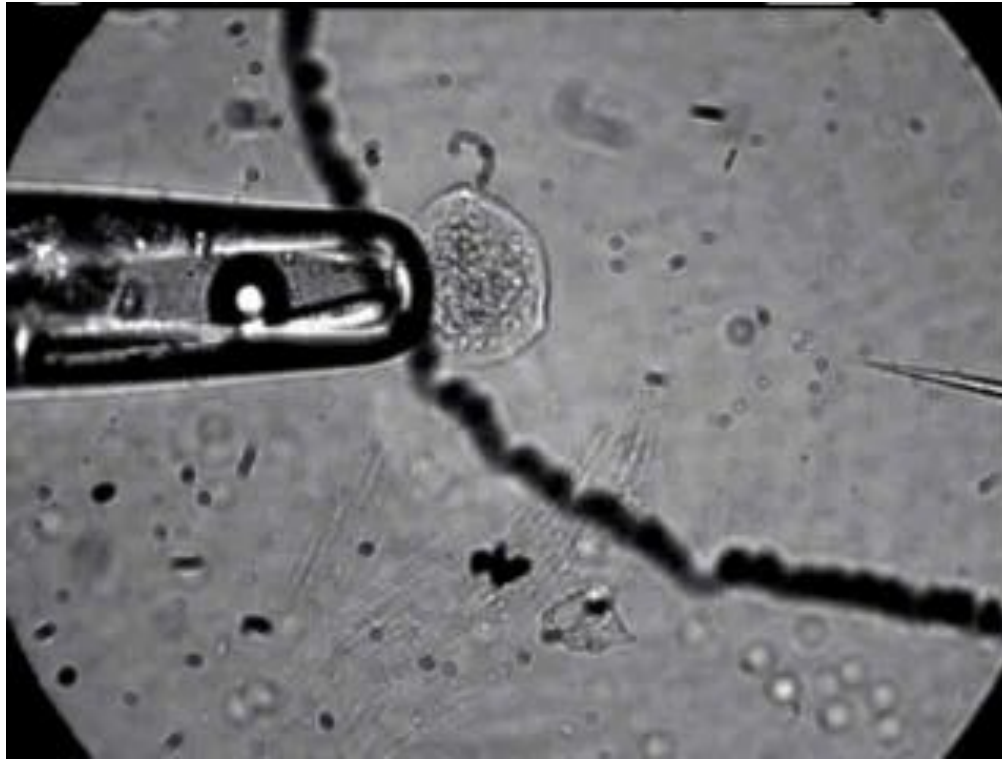


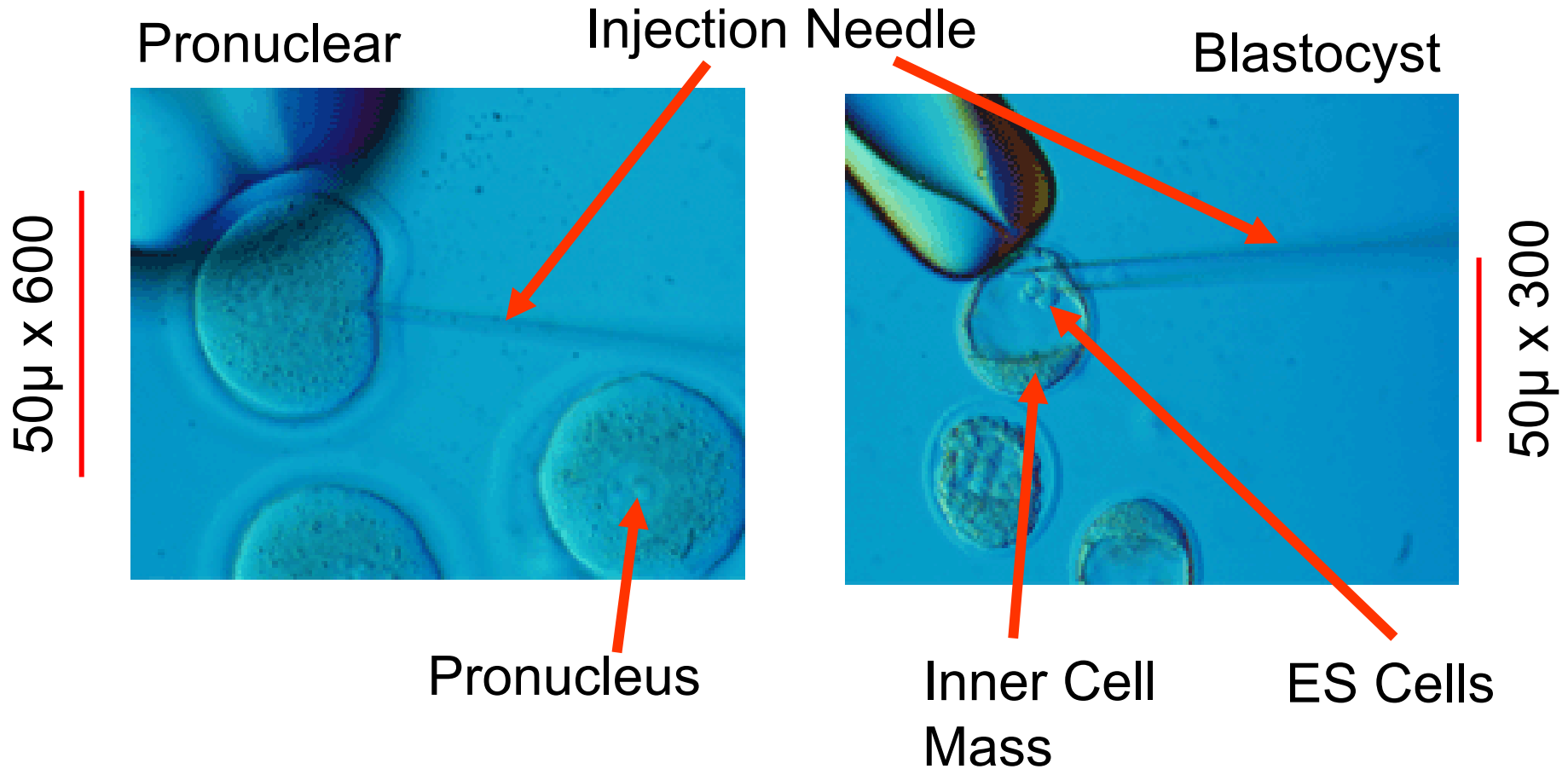
Simple Biomanipulation Tasks with a “Steady Hand” Cooperative Manipulator

Ankur Kapoor¹, Rajesh Kumar² and Russell H. Taylor¹

1: CISST ERC, Johns Hopkins University; 2: Foster-Miller, Inc.



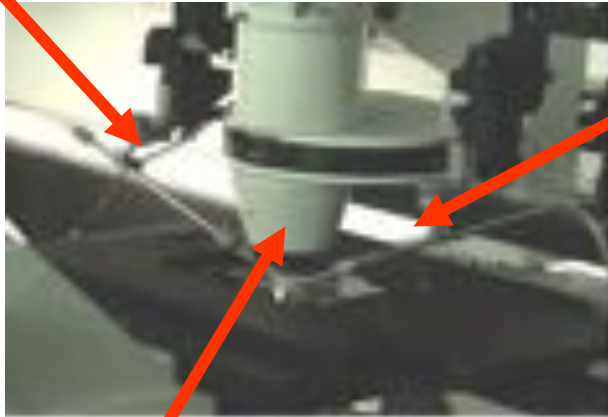
Injections into Cells and Embryos



Conventional Setup

Cell Holder Micromanipulator

Injection Micromanipulator



Microscope & Display (5-400X)

Embryos/Cells

Limitations of Conventional Methods

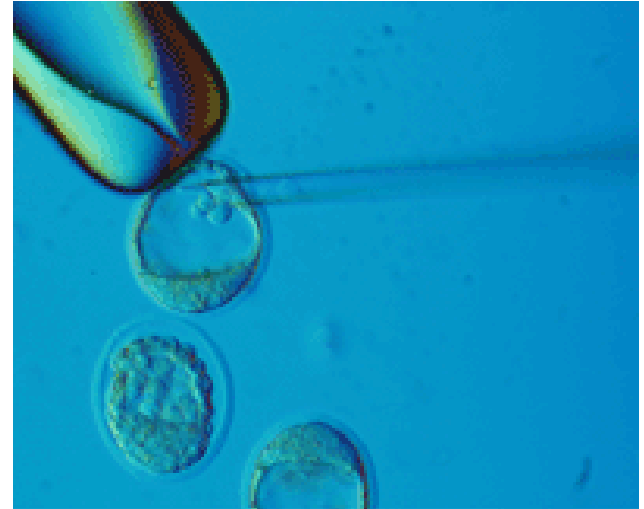
- **Operator training & retention**

- Up to 1 year to become skilled
- Skill loss from turnover

- **Success rates**

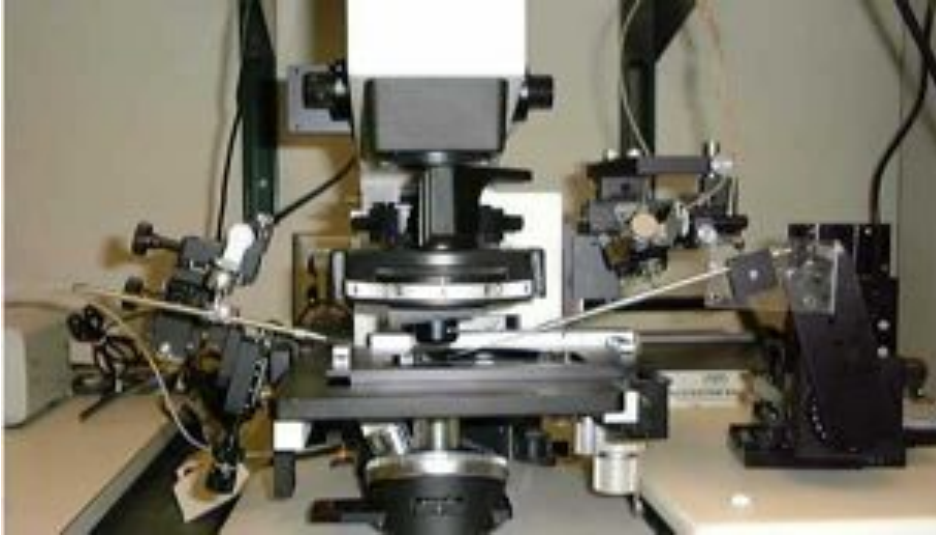
- Injection Phase – 40-70%
- Implant Phase – 40%
- Desired Gene in Offspring – 10-20%
- Overall – 1-4%

- **Time**



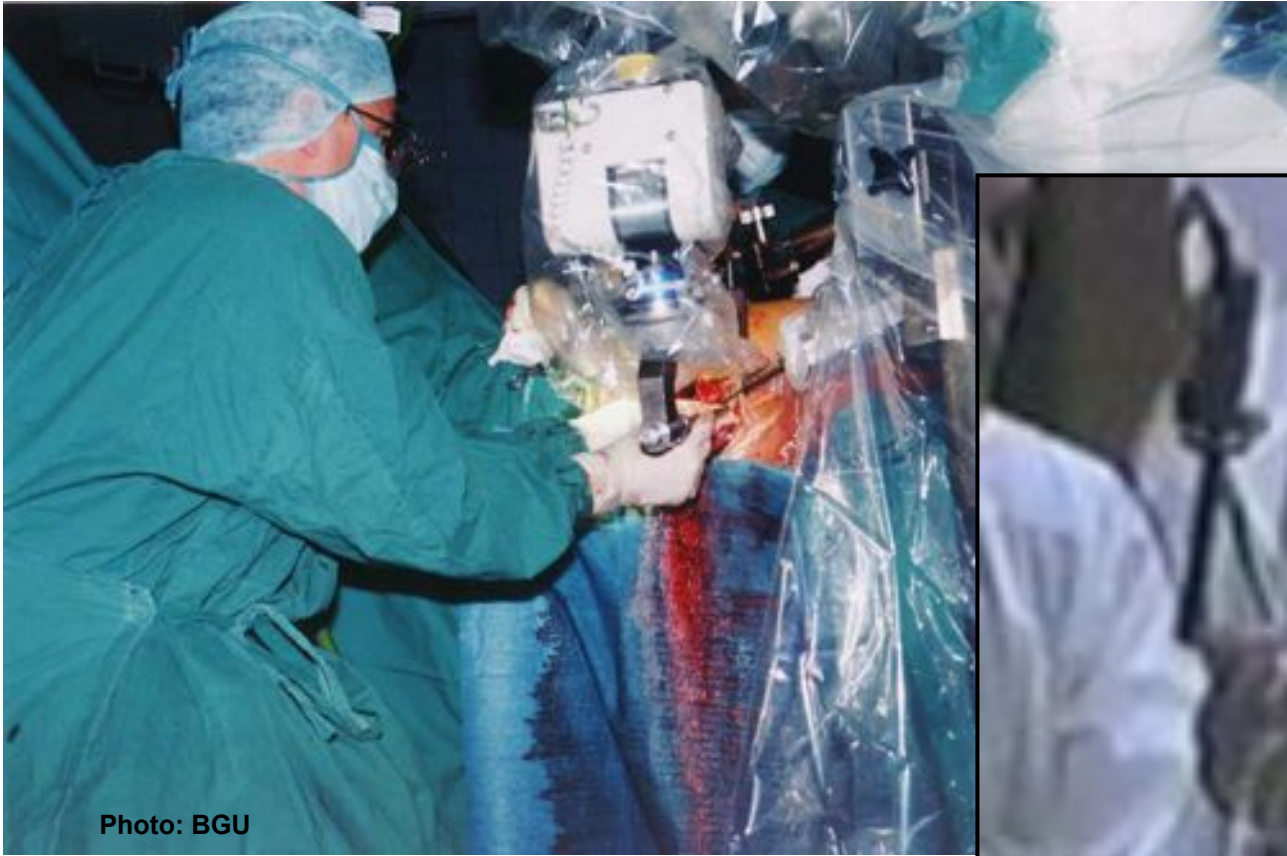
50 μ x 300

Related Work

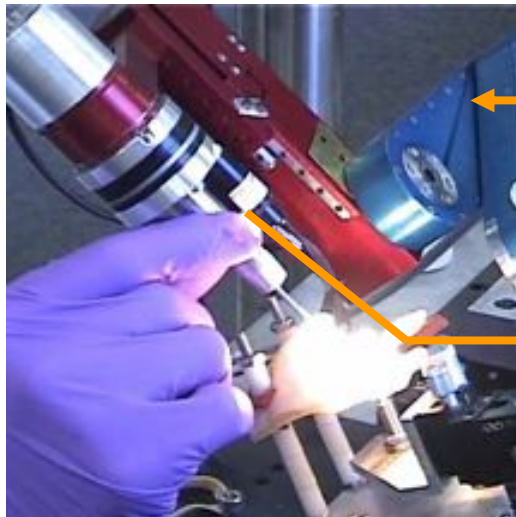


- **Su and Nelson**
 - S. Yu and B. Nelson, “Microrobotic Cell Injection”, ICRA, 2001
- **Taylor *et al.***
 - Taylor, R.H., et al., A Steady-Hand Robotic System for Microsurgical Augmentation. International Journal of Robotics Research, 1999. 18(12).
- **Kumar *et al.***
 - R. Kumar, P. Berkelmen, P. Gupta, A. Barnes, P. Jensen, L. Whitcomb, and R. H. Taylor. Preliminary experiments in cooperative human/robot force control for robot assisted microsurgical manipulation., *Proceedings of ICRA 2000*, pp610-617, April 2000.

Cooperative force guiding of surgical robots

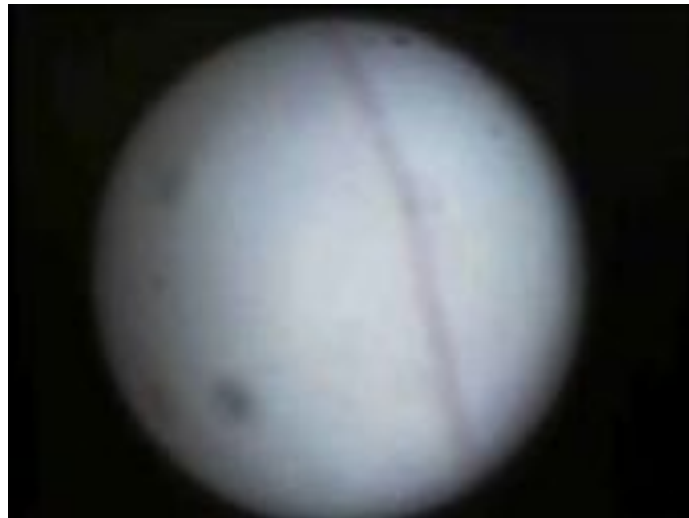


Steady Hand Guiding for Microsurgery

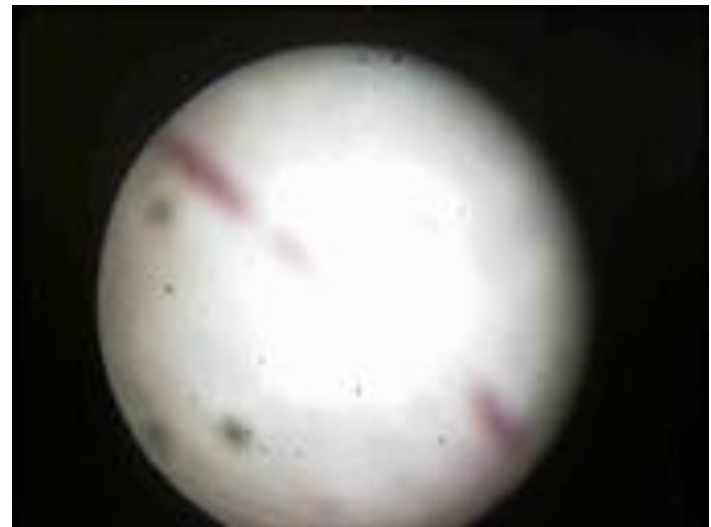


K_v

Handle
force

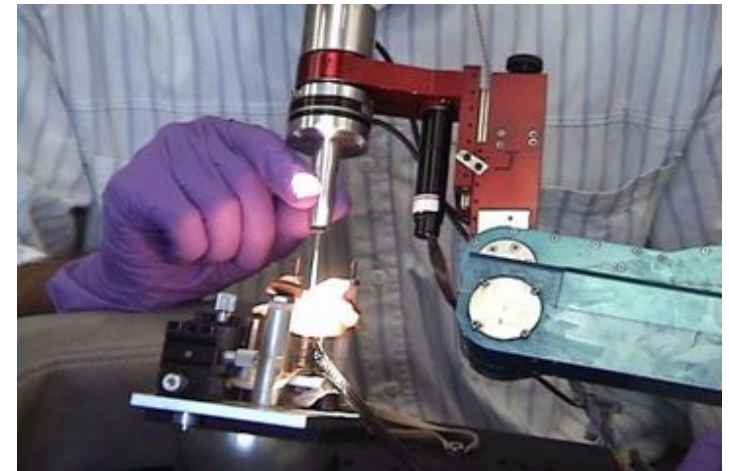
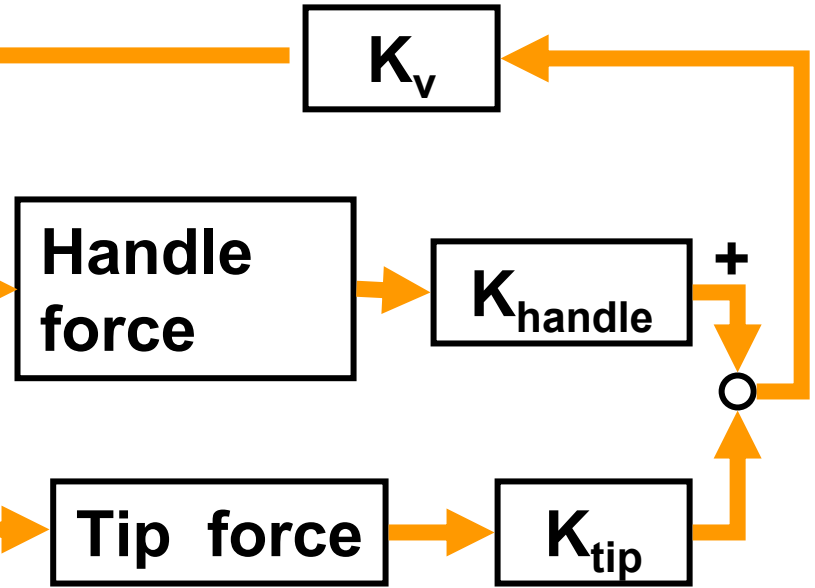
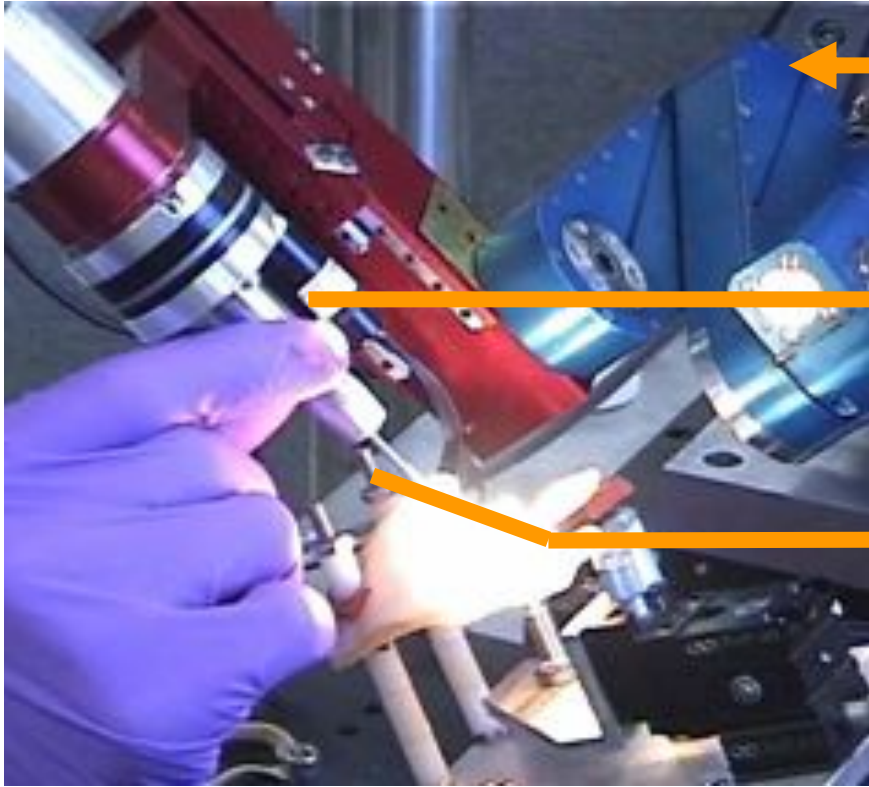


Free hand motion



Steady hand motion

Steady Hand Force Scaling



More Generally: Cooperative Control & Virtual Fixtures



“Intelligent” task-based control

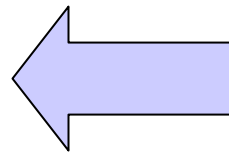
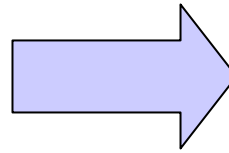
Human Interaction

Vision

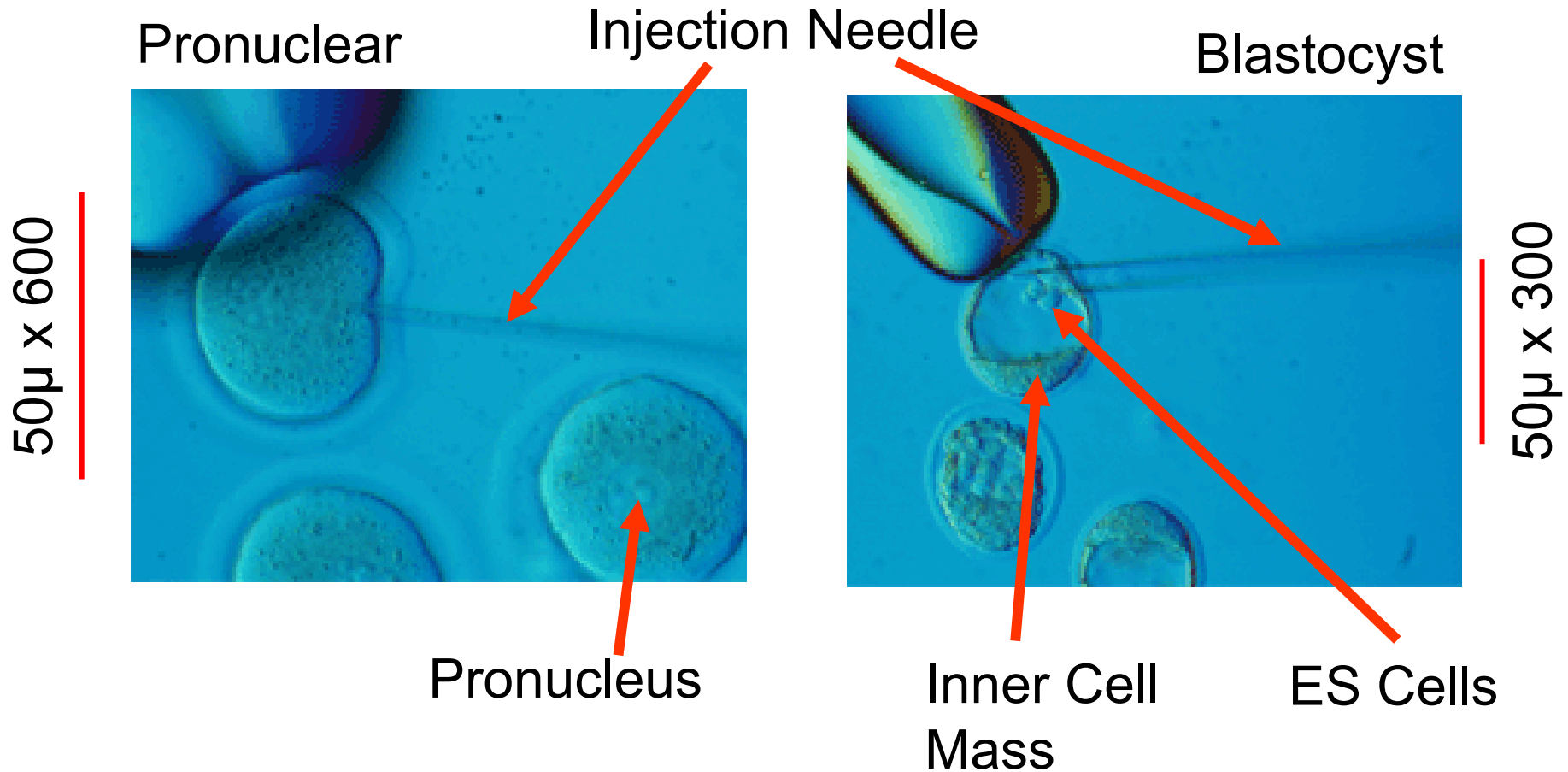
Other Sensors



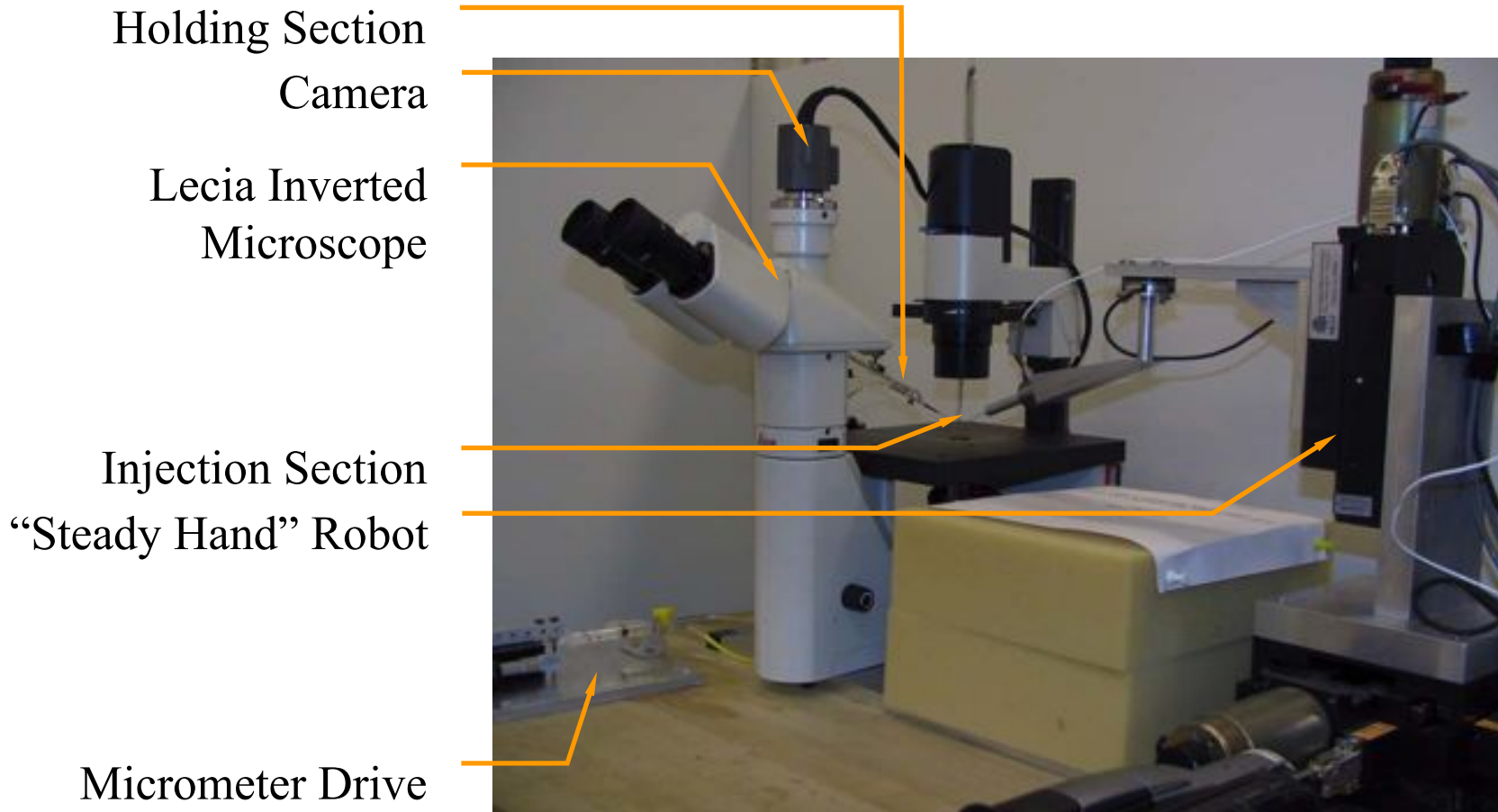
Previous work: steady-hand eye surgery



Driving Application: Transgenic Mice

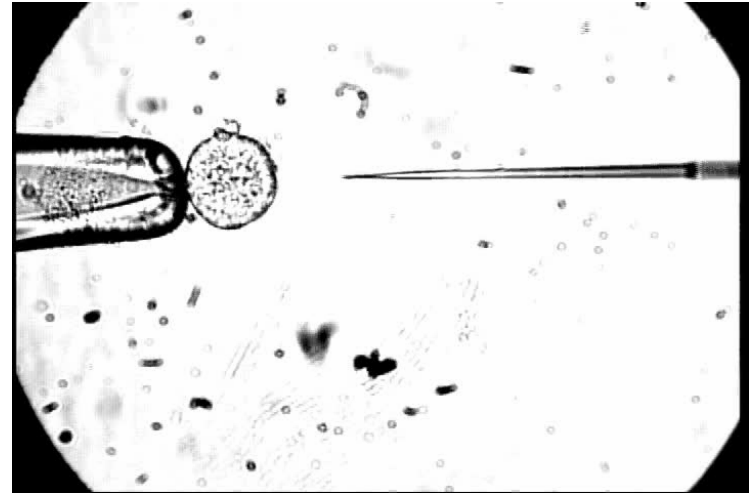


Our Experimental Setup



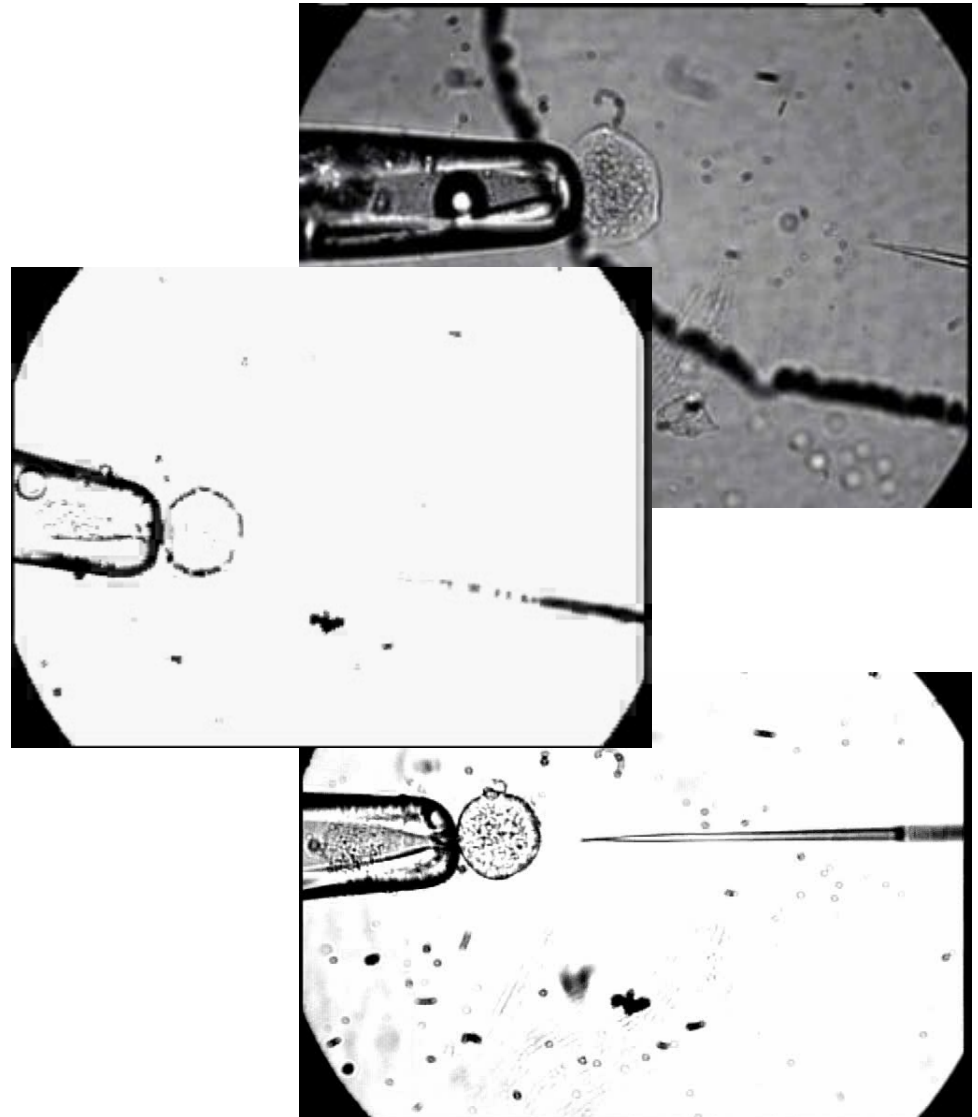
Steady-hand protocol

1. Select embryo & place in pipette (as before)
2. Guide the injection needle to the cell using compliant motion
3. Perform injection
 - a. Insert pipette into cell
 - b. Inject and hold needle for some time.
 - c. Withdraw pipette
4. Check for cell survival



Injection step strategies

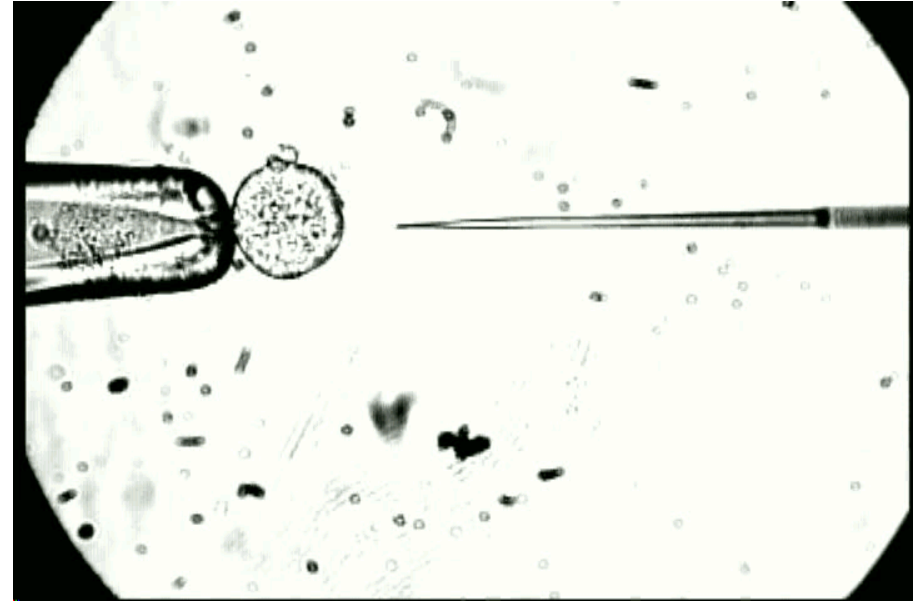
- Compliant
 - The robot complies with scaled user forces
- “Augmented” compliant
 - Asymmetric and non-linear compliance gains
 - Slow approach
 - Faster withdrawal to facilitate sealing
 - Selective locking of DOF
- Supervisory
 - User selects injection point and robot injects



Slow motion of actual insertion



Compliant



Supervisory

Results

Completion times for different strategies

	# Trials	Time Required (seconds)		Survival Rate
		Average	Std. Dev	
Approach	20	109.8	78.5	
Injection/ Withdraw				
Compliant	2	1.6	-	100%
Augmented	8	0.747	0.067	100%
Supervisory	12	0.678	0.024	100%

- These results are from single user trials, not trained in conventional setup
- These times are indicative of speed of microinjection and are preliminary

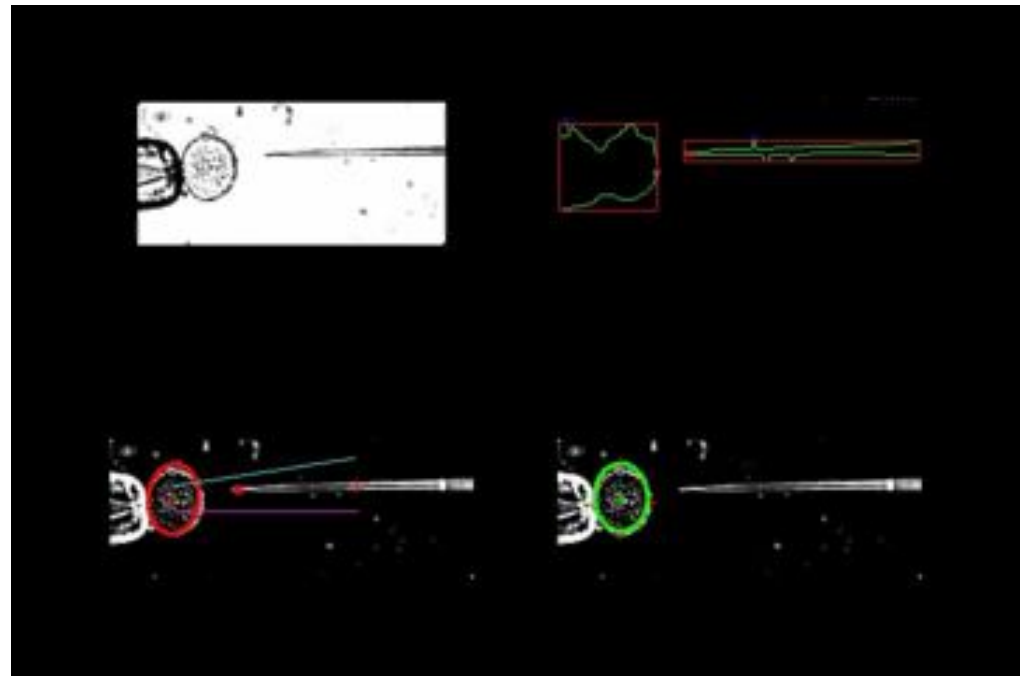
Preliminary Conclusions

- Significant improvement in cell survival over conventional manual approach
- Performance of different injection strategies appears to be about the same
 - 100% injection survival vs. 40-70% manual method
 - All very fast with respect to rest of procedure
 - Larger sample may show some differences in survival and time
- Potentially big gain from further improvements to approach phase



Future work

- Explore combined vision and force based strategies to speed up approach
- Subjective evaluation by trained users
- Develop a custom robot for cell manipulation
- A viable tool for bio-manipulation



Acknowledgements

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 - Director, Transgenic Core Laboratory, Johns Hopkins U.
- Prof. Greg Hager
 - CISST ERC, Johns Hopkins University
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 - IIS-98-01684 (Steady Hand Robot)

