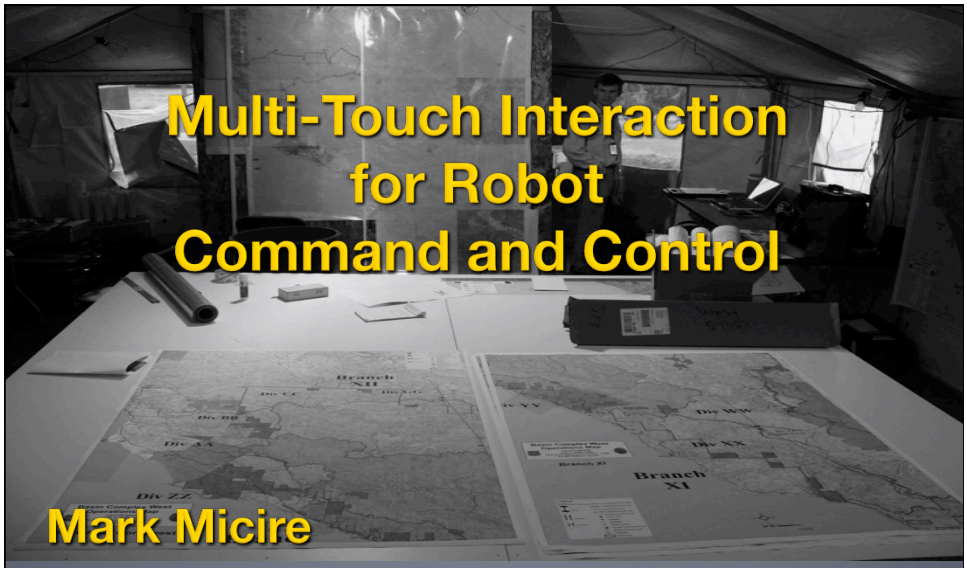
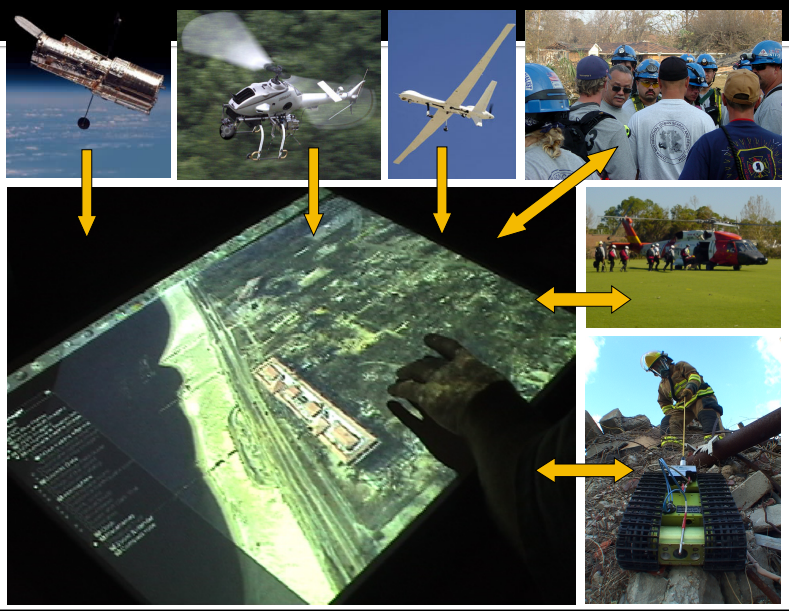


Mark Micire

University of Massachusetts Lowell
Department of Computer Science
mmicire@cs.uml.edu

State of the Practice

Command and Control: Our Vision



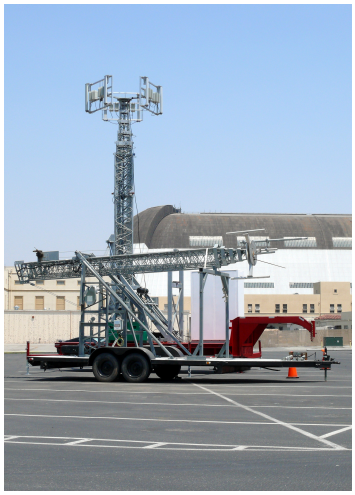
Changing Tech: Robots

Changing Tech: Robots

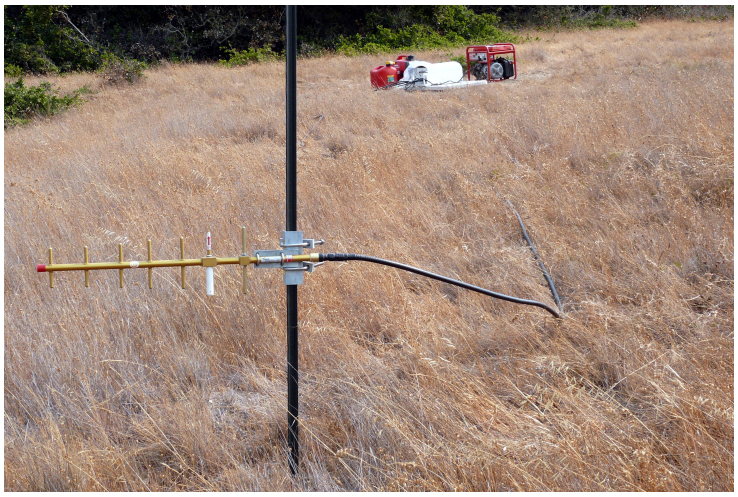
Changing Tech: Robots

Changing Tech: NCO

- Network Centric Operation Theory
  - Improves information sharing
  - Information sharing enhances shared situation awareness
  - Shared situation awareness enables collaboration and self-synchronization
  - Therefore, a dramatic increase in mission effectiveness.



Changing Tech: NCO



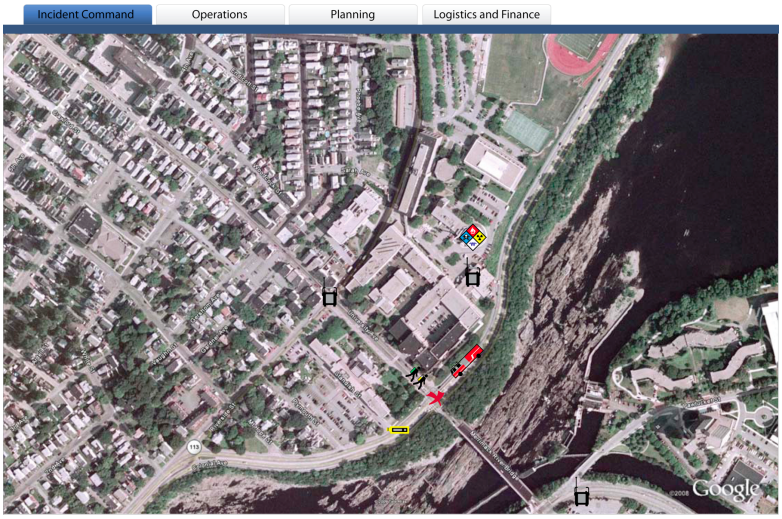
Changing Tech: NCO

Changing Tech: Multi-Touch

Microsoft Surface

MERL (now Circle Twelve) DiamondTouch

Scenario



Problem Statement

- For the emergency responder demographic, there may not be the opportunity for in depth training on new technologies
- If multi-touch tools are to be used effectively in SAR, ease of learning is important key to widespread acceptance and use
- This research explores this basic requirement of ease of learning and usability in the gesture set for multi-touch command and control interfaces for robots

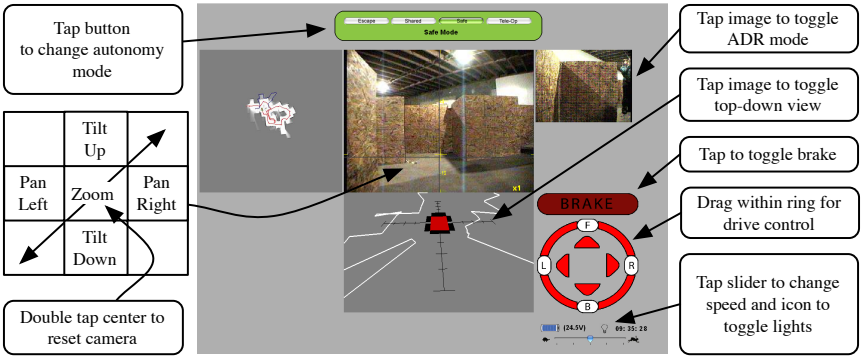
Research Goal

- Multi-touch can provide enhanced ease of learning in time-critical and safety-critical domains when implemented correctly
- By studying the biomechanics of the human hand and leveraging the natural responses of users human-robot interaction can be enhanced for single and multiple robot control
- The goal is to maximize ease of learning and therefore lessen the training time required for proficient control of the robot or robot teams

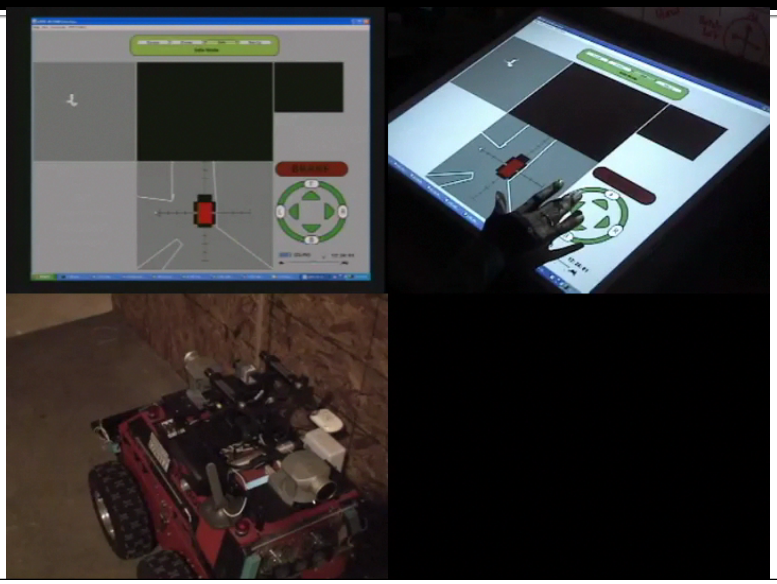
Outline

- **Single Robot Control Prototype**
- Hand Detection and Registration
- DREAM Controller
- Single Robot Control Redesign
- User Generated Gestures
- Multi-Robot Command and Control

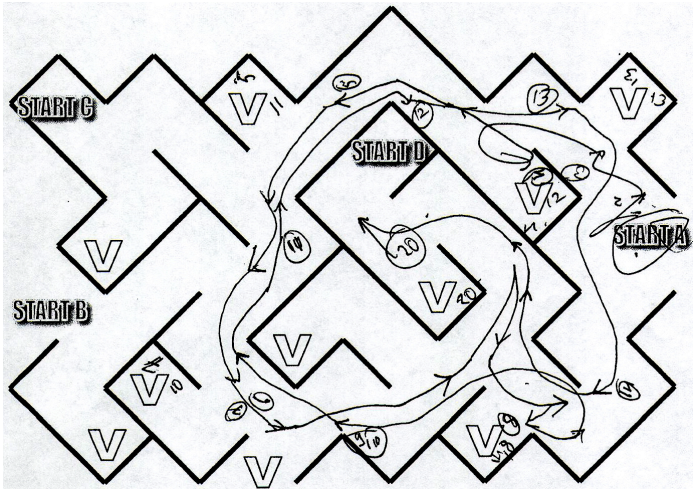
Single Robot Control



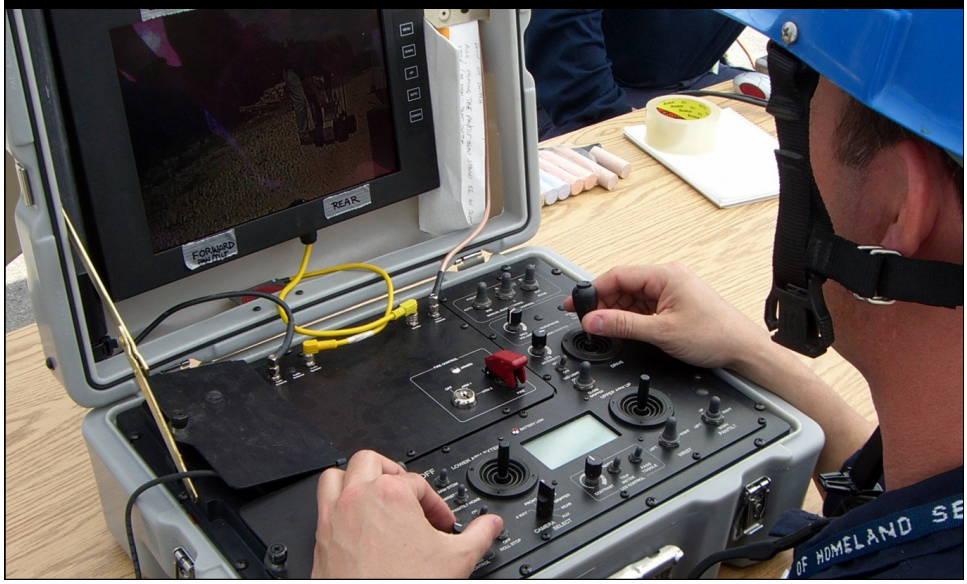
Performance Validation



Evaluation



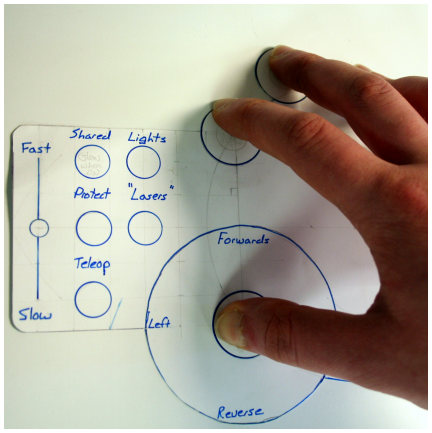
State of Practice: Chording



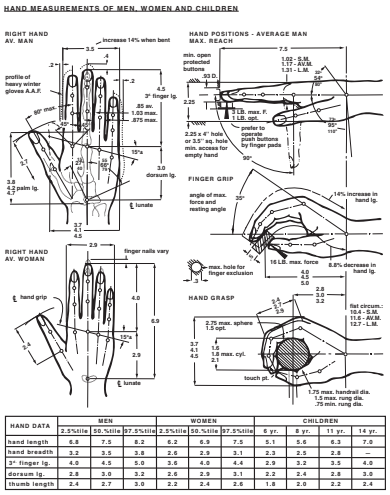
Muscle Memory: Video Games

Photo credit: www.joystiq.com (left) and iRobot (right)

Concept to Paper Prototype



Hand Detection Problem



HAND DATA	MEN			WOMEN			CHILDREN			
	2.5%tile	50.%tile	97.5%tile	2.5%tile	50.%tile	97.5%tile	6 yr.	8 yr.	11 yr.	14 yr.
hand length	6.8	7.5	8.2	6.2	6.9	7.5	5.1	5.6	6.3	7.0
hand breadth	3.2	3.5	3.8	2.6	2.9	3.1	2.3	2.5	2.8	–
3d finger lg.	4.0	4.5	5.0	3.6	4.0	4.4	2.9	3.2	3.5	4.0
dorsum lg.	2.8	3.0	3.2	2.6	2.9	3.1	2.2	2.4	2.8	3.0
thumb length	2.4	2.7	3.0	2.2	2.4	2.6	1.8	2.0	2.2	2.4

Need an algorithm to:

- Detect hand
- Register fingers
- Determine handedness

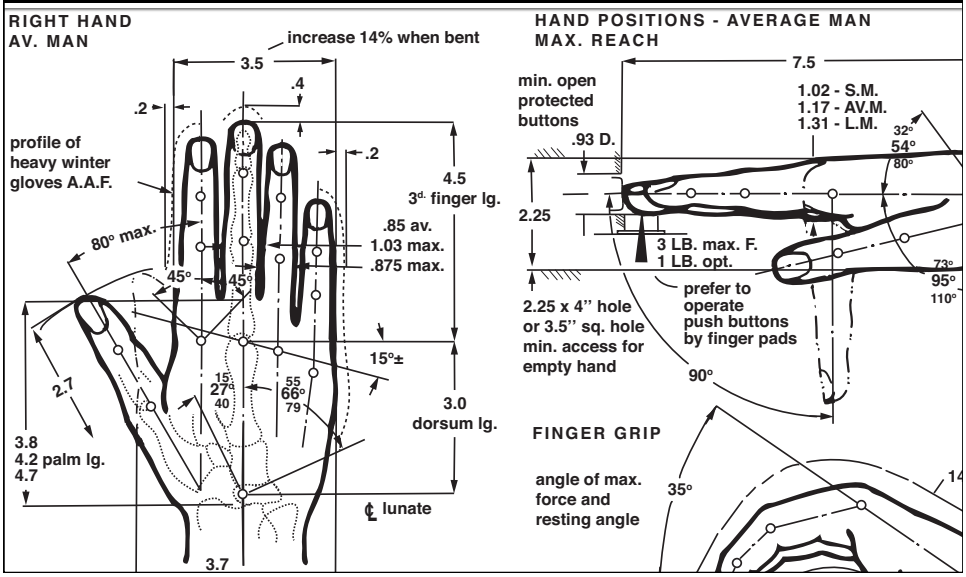
Must be:

- Fast
- Accurate

Ideally should be:

- Orientation in sensitive
- Work for all hand configurations

Human Anatomy is Bounded

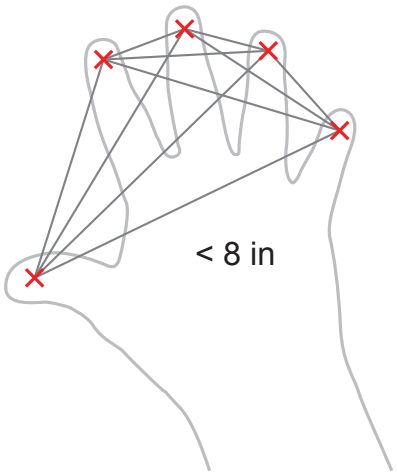


Outline

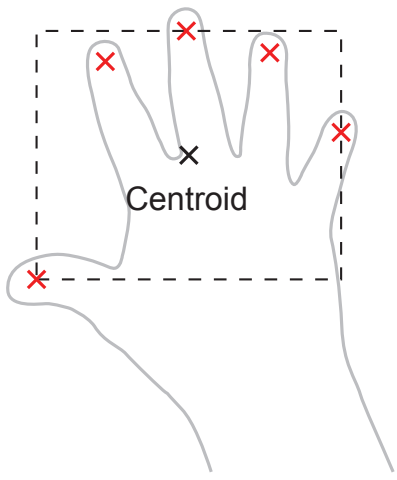
- Single Robot Control Prototype
- **Hand Detection and Registration**
- DREAM Controller
- Single Robot Control Redesign
- User Generated Gestures
- Multi-Robot Command and Control

Input to the Algorithm

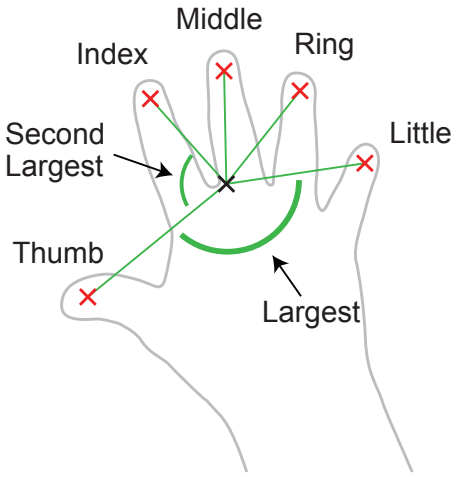
Hand Detection



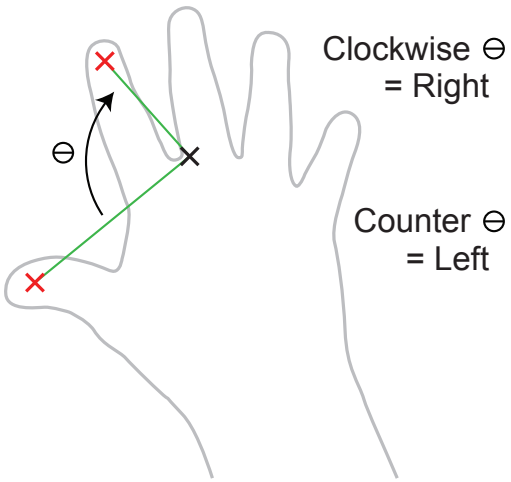
Finger Registration



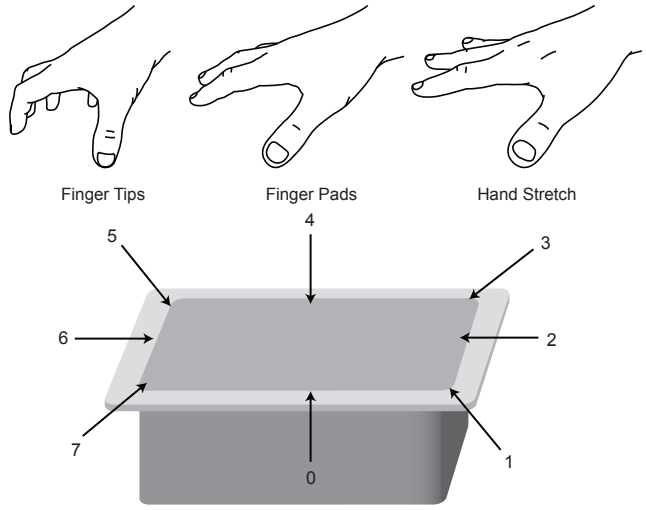
Finger Registration



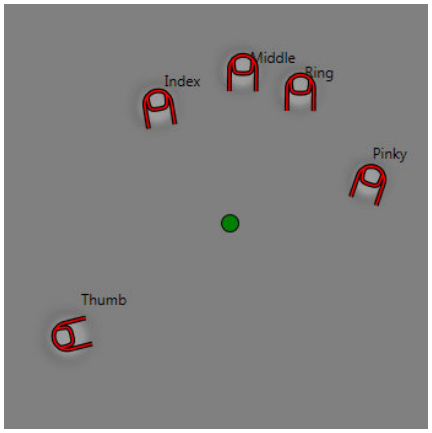
Hand Registraton



Performance Validation



Performance Validation



Performance Validation

Hand and finger recognition rates by hand

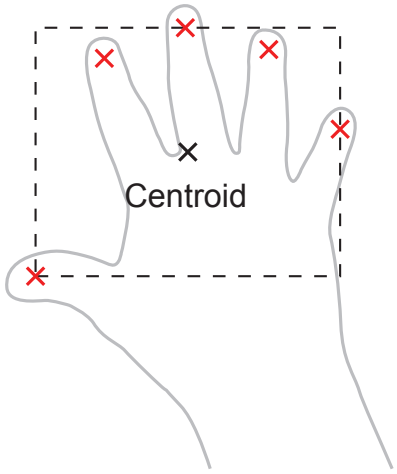
	Tips	Pads	Stretch
Right Hand	56 of 65 (86.15%)	61 of 65 (93.85%)	62 of 65 (95.38%)
Left Hand	59 of 65 (90.77%)	60 of 65 (92.31%)	62 of 65 (95.38%)
Both	115 of 130 (88.46%)	121 of 130 (93.08%)	124 of 130 (95.38%)

Performance Validation

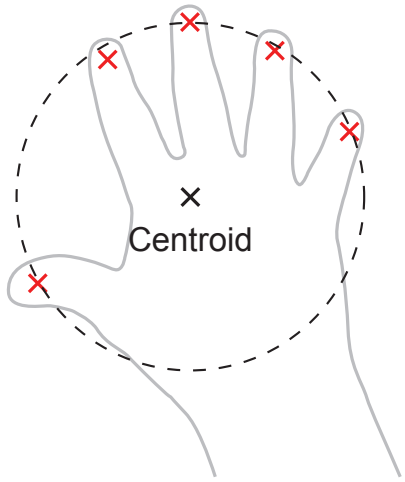
Hand and finger recognition rates by board position

	Position 0	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6	Position 7
Overall	54 of 54 (100%)	44 of 54 (81.48%)	48 of 48 (100%)	52 of 54 (96.30%)	40 of 41 (97.62%)	38 of 42 (90.48%)	42 of 42 (100%)	38 of 53 (70.37%)
Right overall	27 of 27 (100%)	24 of 27 (88.89%)	24 of 24 (100%)	24 of 27 (88.89%)	20 of 21 (95.24%)	17 of 21 (80.95%)	21 of 21 (100%)	21 of 27 (77.78%)
Right tips	9 of 9 (100%)	8 of 9 (88.89%)	8 of 8 (100%)	8 of 9 (88.89%)	6 of 7 (85.71%)	5 of 7 (71.43%)	7 of 7 (100%)	5 of 9 (55.56%)
Right pads	9 of 9 (100%)	8 of 9 (88.89%)	8 of 8 (100%)	8 of 9 (88.89%)	7 of 7 (100%)	6 of 7 (85.71%)	7 of 7 (100%)	8 of 9 (88.89%)
Right stretch	9 of 9 (100%)	8 of 9 (88.89%)	8 of 8 (100%)	8 of 9 (88.89%)	7 of 7 (100%)	6 of 7 (85.71%)	7 of 7 (100%)	8 of 9 (88.89%)
Left overall	27 of 27 (100%)	20 of 27 (74.07%)	24 of 24 (100%)	27 of 27 (100%)	21 of 21 (100%)	21 of 21 (100%)	21 of 21 (100%)	20 of 27 (74.07%)
Left tips	9 of 9 (100%)	7 of 9 (77.78%)	8 of 8 (100%)	9 of 9 (100%)	7 of 7 (100%)	7 of 7 (100%)	7 of 7 (100%)	5 of 9 (55.56%)
Left pads	9 of 9 (100%)	6 of 9 (66.67%)	8 of 8 (100%)	9 of 9 (100%)	7 of 7 (100%)	7 of 7 (100%)	7 of 7 (100%)	7 of 9 (77.78%)
Left stretch	9 of 9 (100%)	7 of 9 (77.78%)	8 of 8 (100%)	9 of 9 (100%)	7 of 7 (100%)	7 of 7 (100%)	7 of 7 (100%)	8 of 9 (88.89%)

Problem: Finger Registration



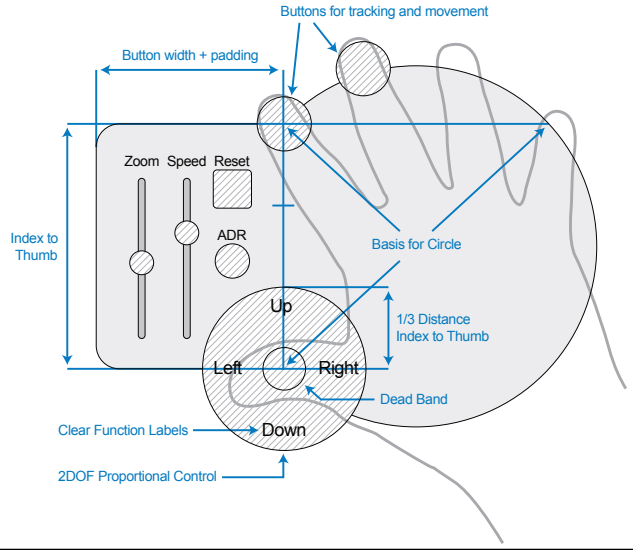
Possible Solution



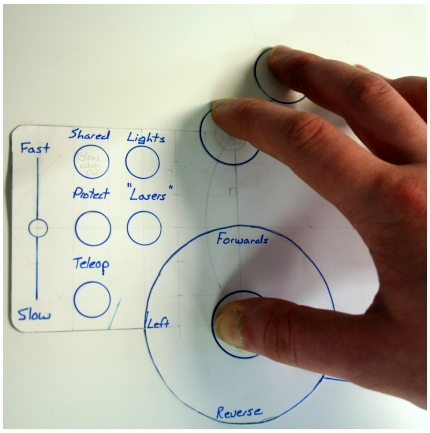
Outline

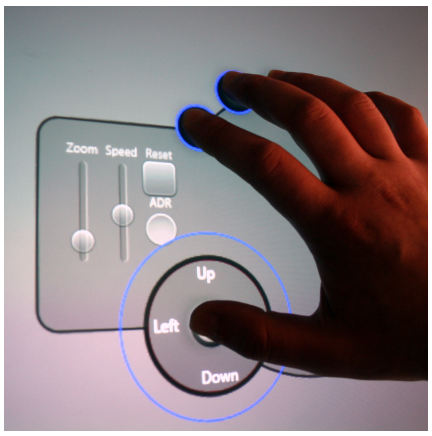
- Single Robot Control Prototype
- Hand Detection and Registration
- **DREAM Controller**
- Single Robot Control Redesign
- User Generated Gestures
- Multi-Robot Command and Control

Form and Function



DREAM Controller

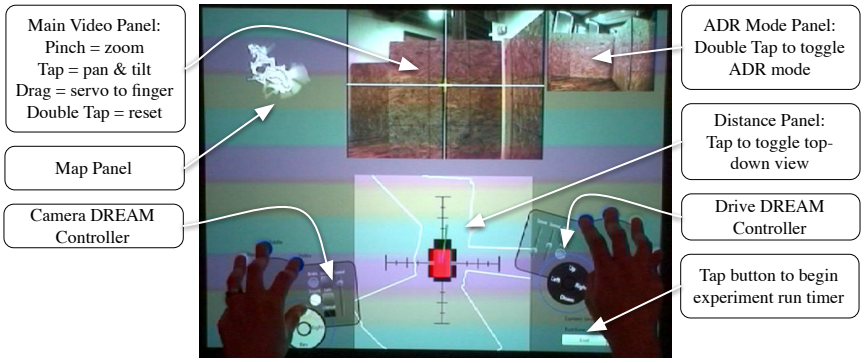




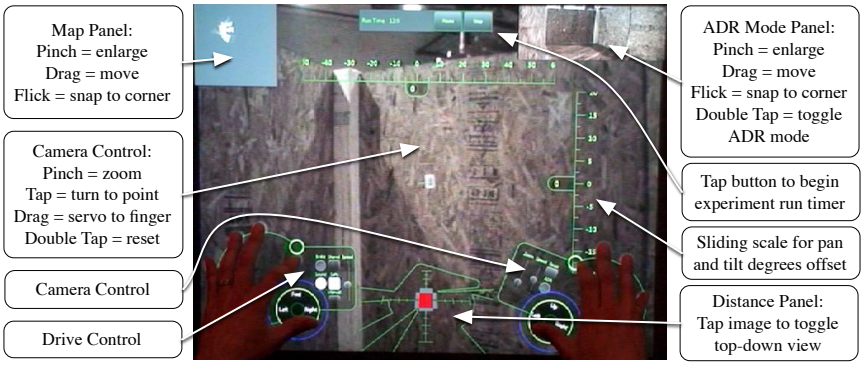
Outline

- Single Robot Control Prototype
- Hand Detection and Registration
- DREAM Controller
- **Single Robot Control Redesign**
- User Generated Gestures
- Multi-Robot Command and Control

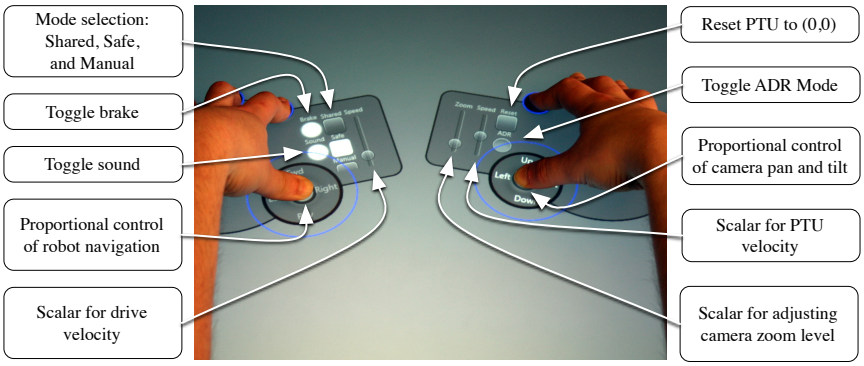
Surface:Window



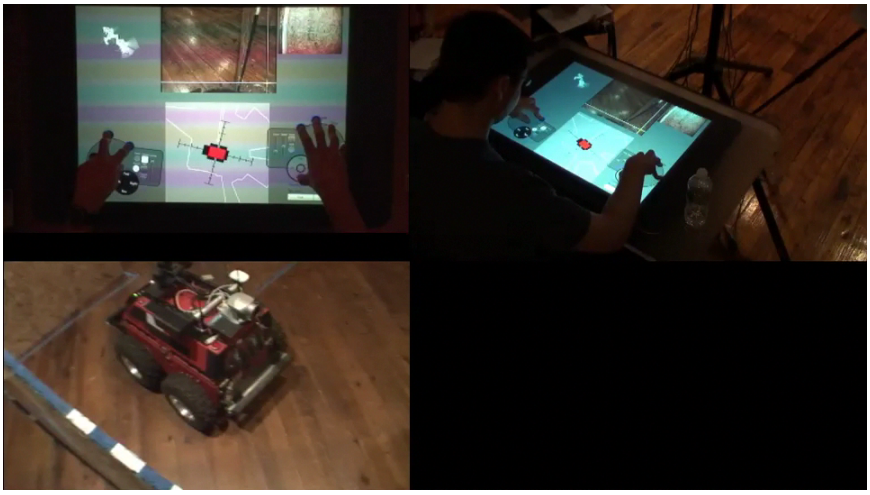
Surface:FullScreen



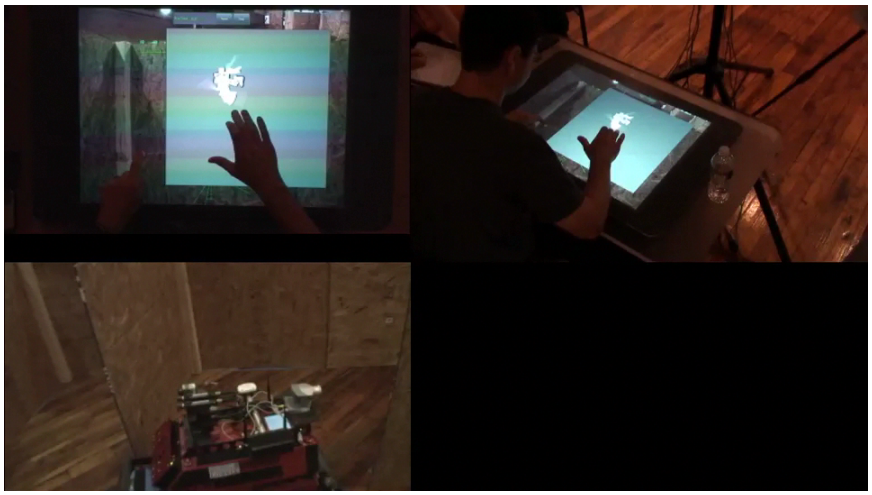
DREAM Controller



Surface:Window



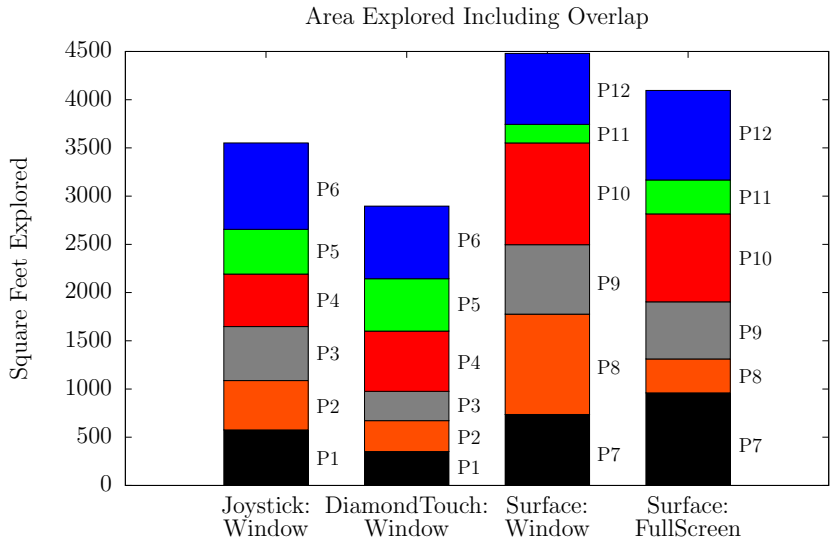
Surface:FullScreen



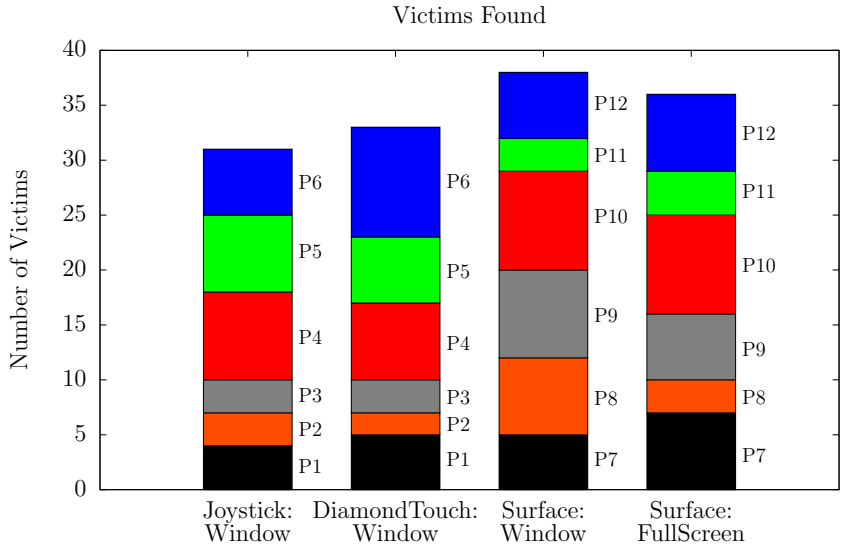
Benefits of Design

- Automatic sizing and orientation on every hand placement
- Tracking of hand
- Look-away during use and creation
- Full chording capabilities
- Orientation insensitivity

Results: Area Explored



Results: Victims Found



Lessons Learned

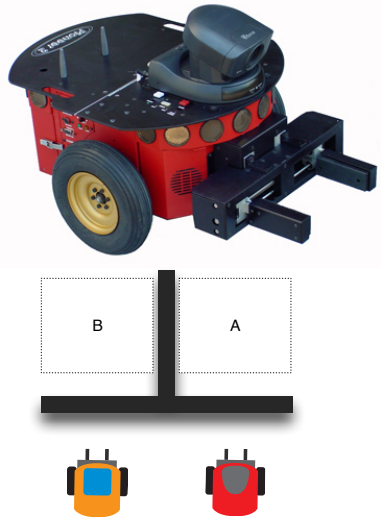
- Be very careful with visual affordances (Hint: try not to use them at all)
- Control metaphors must be consistent regardless of implementation details
- Use biomechanics as much as possible to allow chording and look-away
- Exploit muscle memory from video games and other computer experiences

Outline

- Single Robot Control Prototype
- Hand Detection and Registration
- DREAM Controller
- Single Robot Control Redesign
- **User Generated Gestures**
- Multi-Robot Command and Control

Experiment Tasks

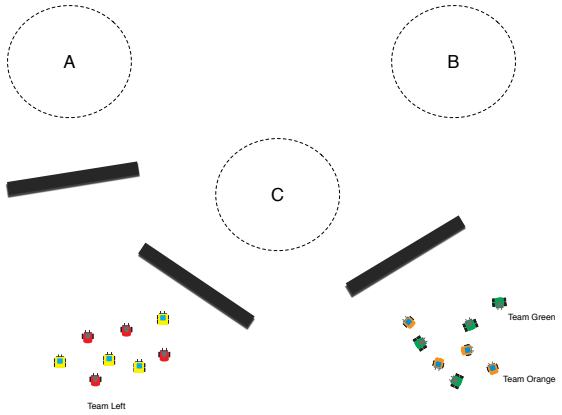
- Presented with the tasks and asked to think aloud while completing them
- Asked to "use their finger, fingers, hand, or hands on the tabletop to express how they would command the robot(s) to complete the tasks"
- Analogous to the paper prototype method [Snyder 03]



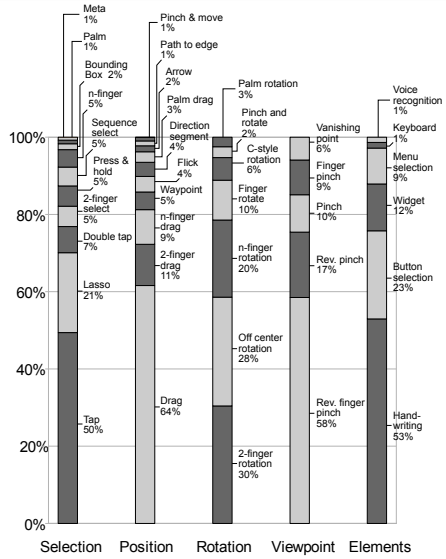
Experiment Details

- 32" Mitsubishi DiamondTouch
- 26 tasks
- 31 people participated
- Avg. age was 27.5 years (SD=10.1)
- All had experience with computers
- 17 played video games
- 9 played real-time strategy games
- 29 reported experience with touch screen or stylus-based devices
- 18 had used touch screen phone

Example Task



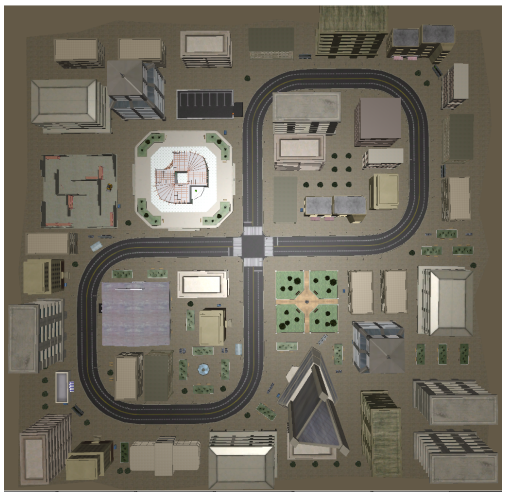
Gesture Distribution



Outline

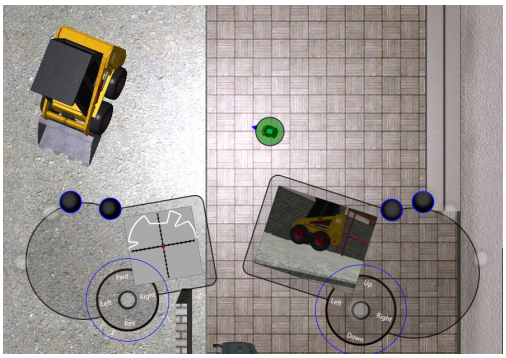
- Single Robot Control Prototype
- Hand Detection and Registration
- DREAM Controller
- Single Robot Control Redesign
- User Generated Gestures
- **Multi-Robot Command and Control**

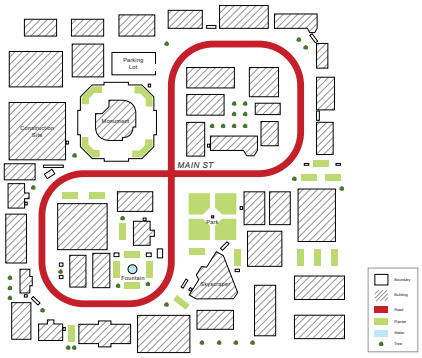
Our Goal



Gestures for Robot Control

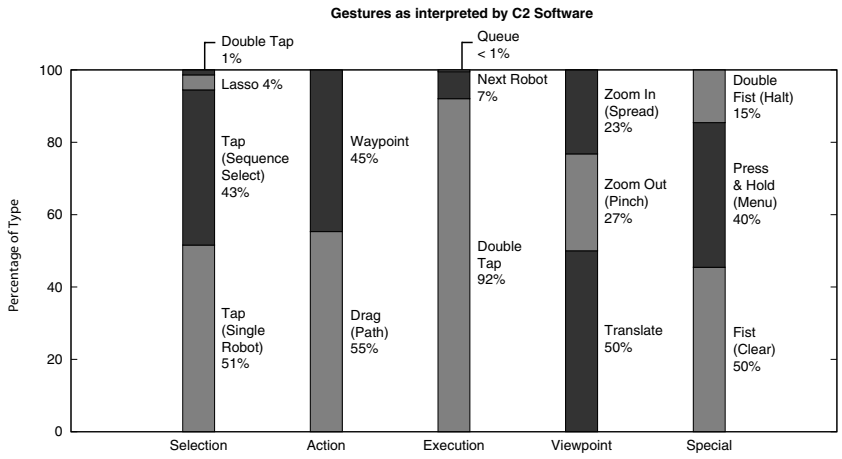
Experiment





Experiment

Results

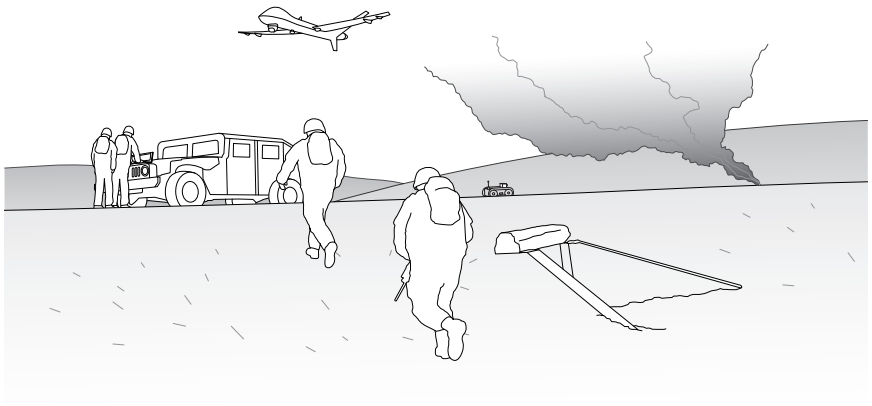


Contributions

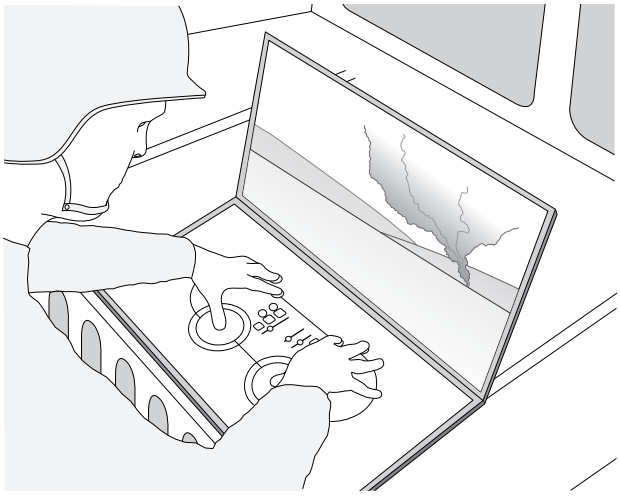
- Performance model of table-top touch interfaces based on Fitts's Law
- Validation of multi-touch human-robot interaction compared to a traditional joystick-based single robot interface
- Algorithm for five-point hand identification and finger registration
- Dynamically resizing, ergonomic, and multi-touch (DREAM) controller for joystick emulation
- Taxonomy and coding rule set for multi-touch multi-robot interaction on tabletop surfaces
- A user generated multi-touch gesture set optimized and tested for ease of learning
- Integrated interface designed specifically for multi-touch interaction that combines high level command and control of robot teams and individual control of single robots

Backup Slides

Future Implementations



Future Implementations



Results: Area Explored

Table 1: Area explored including overlap in the USAR arena (in squared feet).

	2007 Study			2010 Study	
Participant	Joystick: Window	DiamondTouch: Window	Participant	Surface: Window	Surface: FullScreen
1	576	352	7	736	960
2	512	320	8	1040	352
3	560	304	9	720	592
4	544	624	10	1056	912
5	464	544	11	192	352
6	896	752	12	736	928
Total	3552	2896	Total	4480	4096
Average	592.00	482.67	Average	746.67	682.67
SD	154.13	185.33	*SD*	313.15	288.65

Results: Area Explored

- Farther using **Joystick:Window** then **DiamondTouch:Window** with weak significance *(p = 0.07, t(11) = 2.02)**
- Farther using **Surface:Window** then **DiamondTouch:Window** with weak significance *(p = 0.056, t(10) = 2.16)**
- Farther using **Surface:FullScreen** then **DiamondTouch:Window** with weak significance *(p = 0.09, t(10) = 1.85)**

*using a one- tailed unpaired t-test with unequal variance with $\alpha = 0.05$

Results: Victims Found

Table 1: Victims found in the USAR arena.

	2007 Study			2010 Study	
Participant	Joystick: Window	DiamondTouch: Window	Participant	Surface: Window	Surface: FullScreen
1	4	5	7	5	7
2	3	2	8	7	3
3	3	3	9	8	6
4	8	7	10	9	3
5	7	6	11	3	4
6	6	10	12	6	7
Total	31	33	Total	38	36
Average	5.17	5.50	Average	6.33	6.00
SD	2.14	2.88	*SD*	2.16	2.19

Results: Victims Found

- **Surface:Window** showed a 23% and 16% increase compared to **Joystick:Window** and **DiamondTouch:Window** respectively
- **Surface:FullScreen** showed a 16% and 9% increase compared to **Joystick:Window** and **DiamondTouch:Window** respectively

Results: Incidents

Table 1: Number of destructive incidents per square foot in the USAR arena.

	2007 Study			2010 Study	
Participant	Joystick: Window	DiamondTouch: Window	Participant	Surface: Window	Surface: FullScreen
1	0.005	0.000	7	0.031	0.008
2	0.070	0.034	8	0.013	0.051
3	0.002	0.069	9	0.026	0.036
4	0.000	0.002	10	0.008	0.022
5	0.000	0.026	11	0.037	0.009
6	0.002	0.004	12	0.015	0.025
Average	0.013	0.023	Average	0.022	0.025
SD	0.028	0.027	*SD*	0.012	0.016