Design of NJIT-Robot-Assisted Virtual Rehabilitation System to Train the Hemiplegic Upper Extremity of Children with Cerebral Palsy

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Objective

- Describe the NJIT-RAVR system, which combines adaptive robotics with complex virtual reality (VR) simulations for the rehabilitation of upper extremity impairments and function in children with cerebral palsy (CP).
- Examine the feasibility of this system in the context of two pilot studies.

Outline

- Background
- Methods
  - Hardware
  - Simulations
  - Participants
  - Training procedure and measurements
- Results
  - Kinematics
  - Clinical
- Conclusion

Background

- **Cerebral palsy (CP), a neurodevelopmental disorder of motor control, does impact play and self-care activities such as eating and dressing [Morris C. (2007)] [Reid D. (2004)].**

Massed Practice

- **Important variables in learning and relearning motor skills and in changing neural architecture are the quantity, duration and intensity of training sessions. This suggests the need to shift to more intense, active training protocols. [Merians et, al 2006, Damiano PL, 2009].**

- **Achieve massed intense practice through :**
  - **Constraint induced movement therapy (CIMT)**
  - **Virtual reality (VR) therapy**
  - **Robotic interactive therapy**

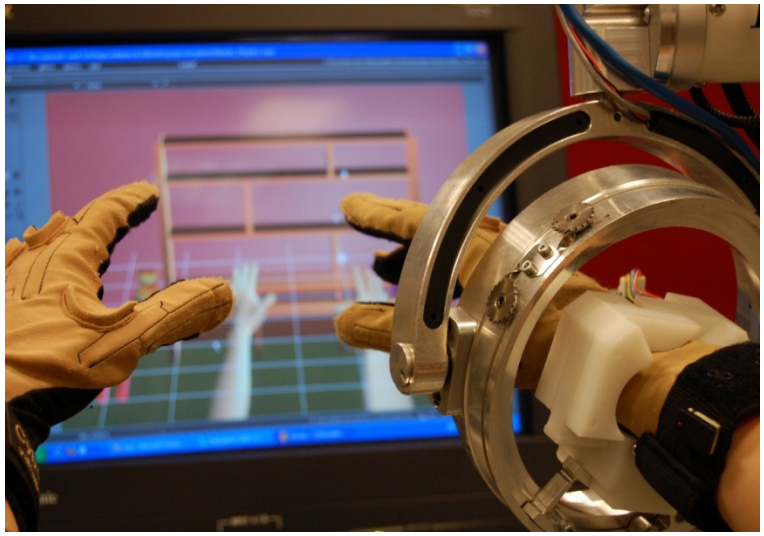
CIMT

- **CIMT is currently being used in children to accomplish the goals of intensive massed practice and shaping.**

- **It has demonstrated the ability to produce major and sustained improvement in motor function in children with spastic hemiplegia secondary to CP. [Charles J. R., Wolf S. L., Schneider J. A., Gordon A. M. (2006)].**

Virtual Reality Therapy

- VR therapy has the capability to create
  - an intensive and interactive massed practice [Sveistrup H. (2004)]
  - motivating environment
  - enable age appropriate play/participation
  - increase sense of self-efficacy [Reid D. T. (2002)]
- The therapist can manipulate the practice intensity and feedback to create individualized treatments [Rizzo A., Kim G. (2005)].



Robotic Interactive Therapy

- Robotic therapy is another rehabilitative approach which hold promise, however limited studies have been done on kids.

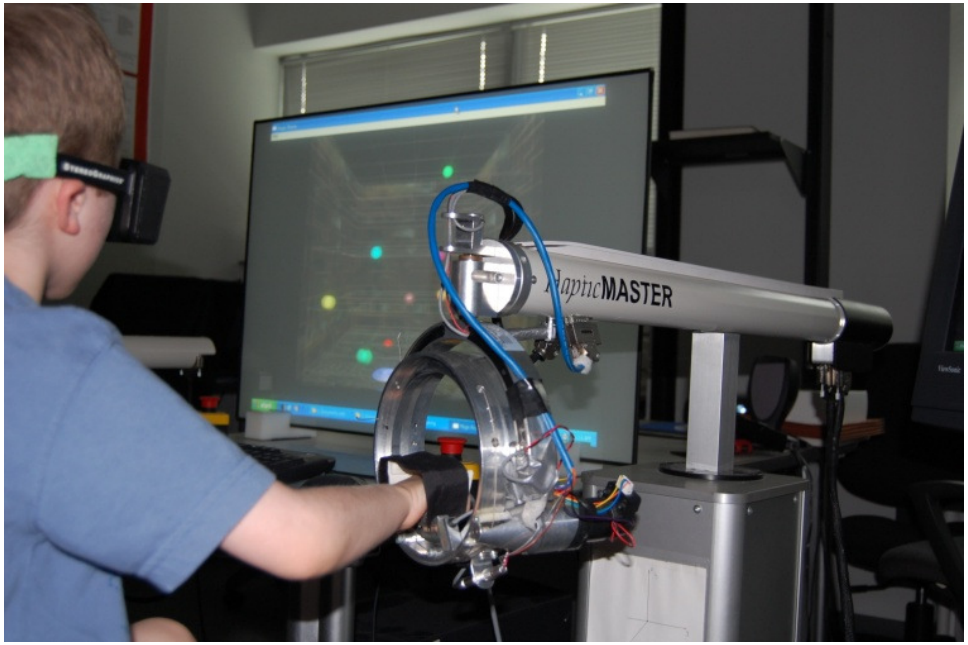
- Recently Fasoli et al (2008) have done massed practice training in a group of children with UE hemiplegia secondary to CP, they used simple virtual environment with assist as needed robotic facilitation, they reported improvements in QUEST and Fugl-Myer assessment scores.

Hypothesis

- We hypothesize that combining robotic facilitation with rich VE's will facilitate massed practice and corresponding improvements in motor function in children with UE hemiplegia secondary to CP.

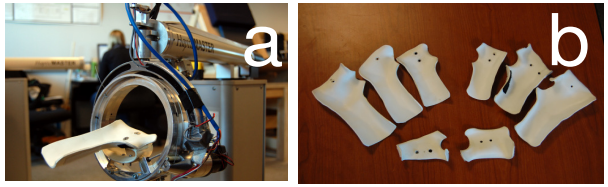
Hardware

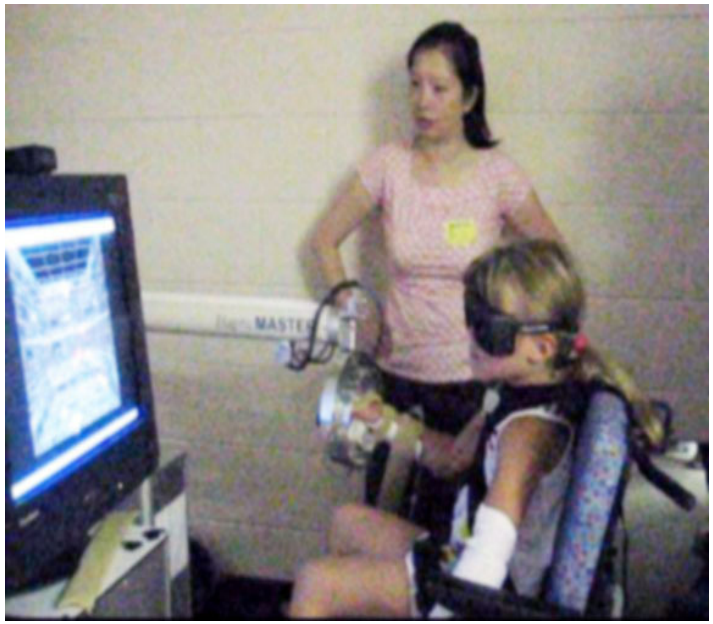
- HapticMaster Robotic Arm
  - Force-controlled haptic interface
  - Haptic effects can be generated
  - Has 6 degrees of freedom (X, Y, and Z, Pitch, Yaw and Roll) when Ring Gimbal is added
  - Force, velocity and position are measured in real time
  - Acquisition rate is up to 1000Hz



Hardware

- Forearm and hand based volar splints
- Seating system: Leckey chair





Simulations

- Games' Design
  - Bubble Explosion
  - Cup Reach
  - HammerHM
  - CarRaceHM
  - Falling Objects
  - PilingUpHM

Participants

- Four Children with spastic hemiplegia secondary to Cerebral Palsy (CP).
- Inclusion Criteria: The subjects has to
  - be cognitively able to follow instructions
  - tolerate 90 degrees of passive shoulder flexion
  - actively supinate 5 degrees.
- The first two subjects took the therapy few weeks before the other group. The seating system and simulations were updated based on the findings from the first group.

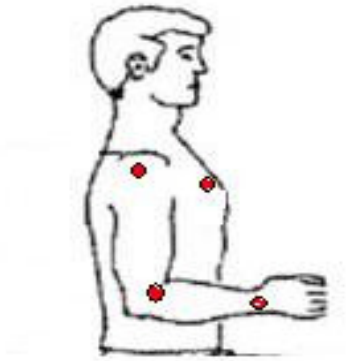
Subject #	Age	sex	cognition	diagnosis	dominant Hand
S1	8y	M	5yrs old (mild mental retardation)	left hemi	RIGHT
S2	16y	M	Within normal range	right hemi	LEFT
S3	10y1m	M	Within normal range	left hemi	RIGHT
S4	7y7m	F	Within normal range	right hemi	LEFT

Training procedure

- Participants used the NJIT-RAVR System for one hour, three days a week for three weeks.
- Subjects performed four sets of ten reaches utilizing the Bubble Explosion simulation to initiate each session for performance testing purposes.
- The subjects played a combination of three or four of the other simulations depending on therapeutic goals, and subject's tolerances and preferences for the remainder of the sixty minute session.

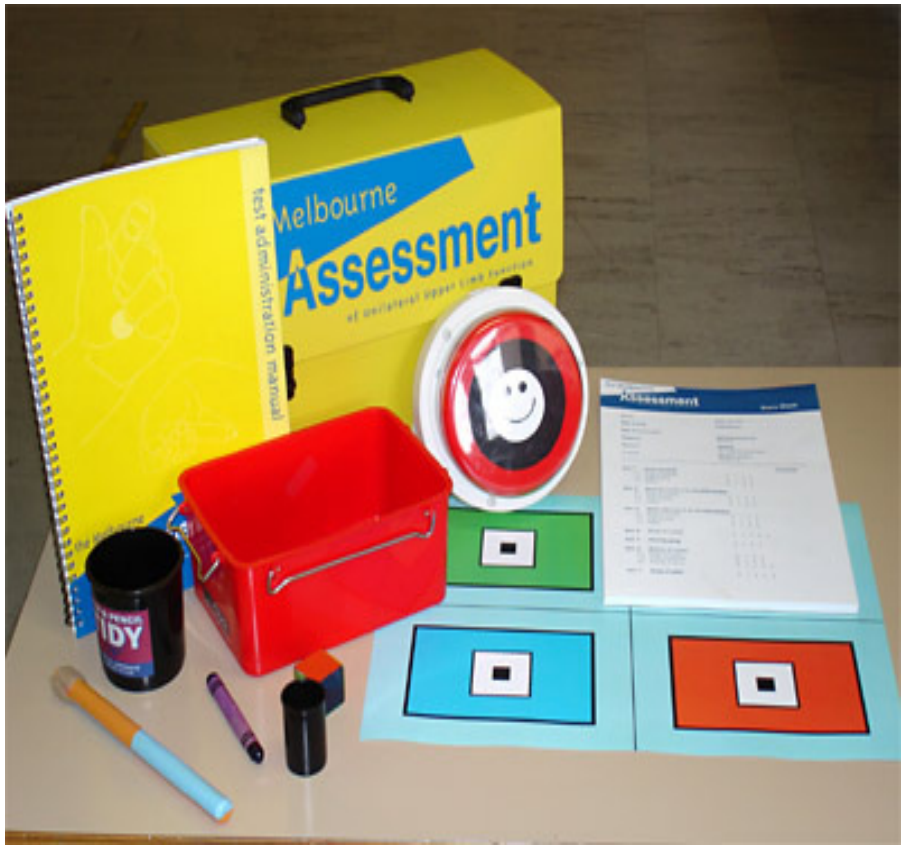
Methods

- Kinematic Measurements
  - Bubble explosion activity was used for kinematic pretesting and post testing
  - End point of the robot
  - Electromagnetic sensor



Clinical Measurements

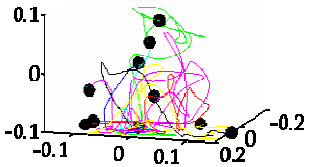
- Melbourne Assessment of Unilateral Upper Limb Function



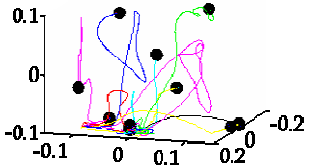
Results

Kinematics results based on robot recording during Bubble Explosion simulation

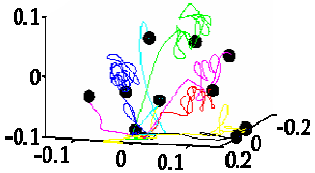
S1 day 1



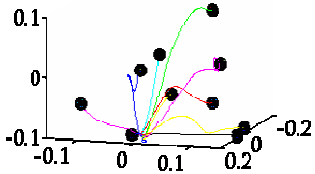
S1 day 9



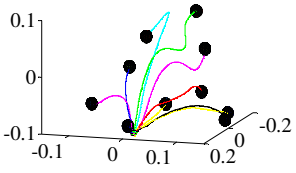
S3 day 1



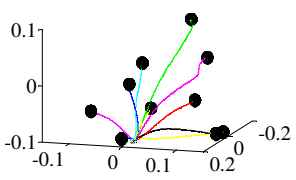
S3 day 9



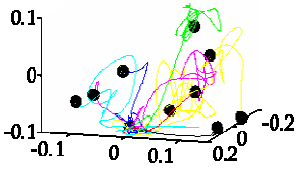
S2 day 1



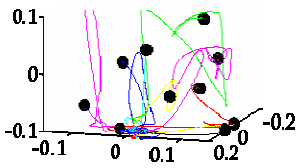
S2 day 9



S4 day 1

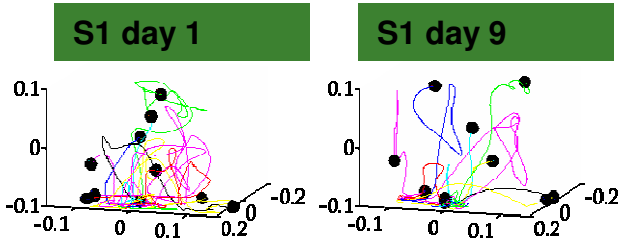


S4 day 9



Results

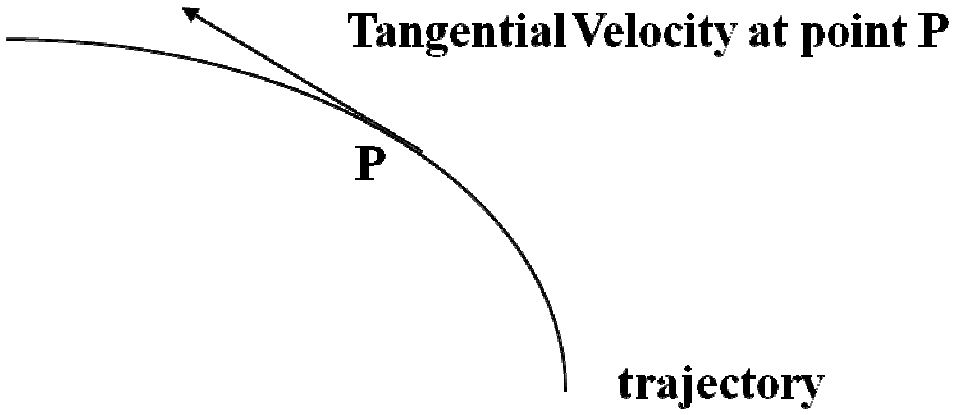
Kinematics results based on robot recording during Bubble Explosion simulation

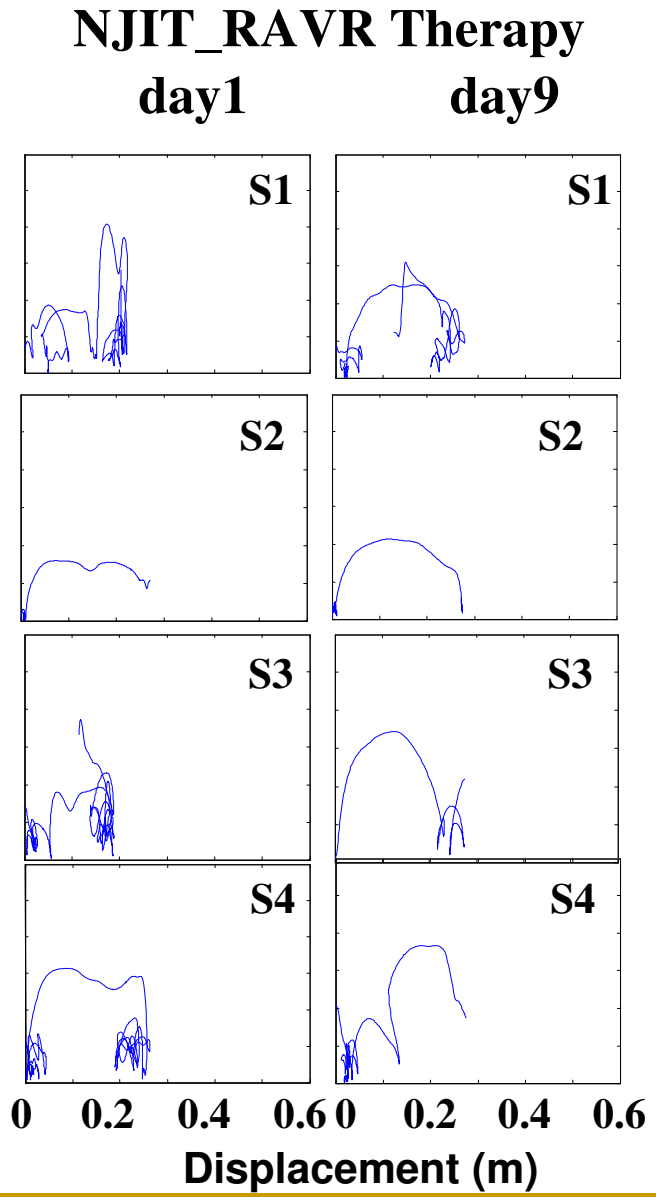


Percent Improvement	Duration (s)	Path Length (m)	Smoothness
S1	6.53%	13.46%	21.09%
S2	32.30%	4.39%	49.26%
S3	67.01%	64.25%	93.87%
S4	0.94%	18.02%	-0.99%

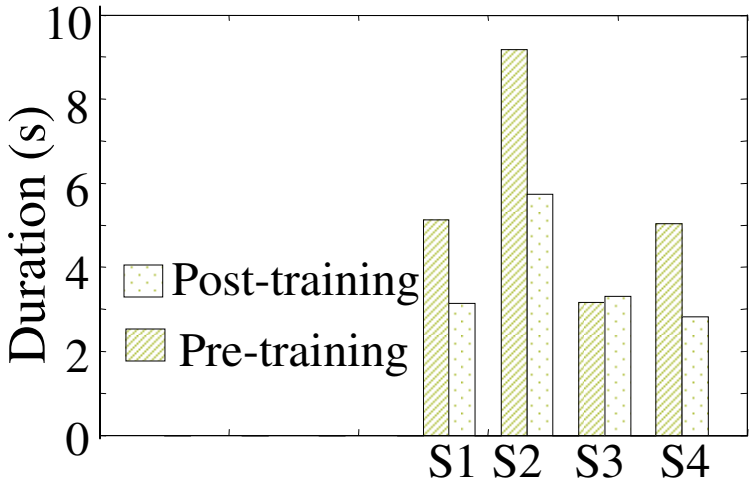
Tangential Velocity

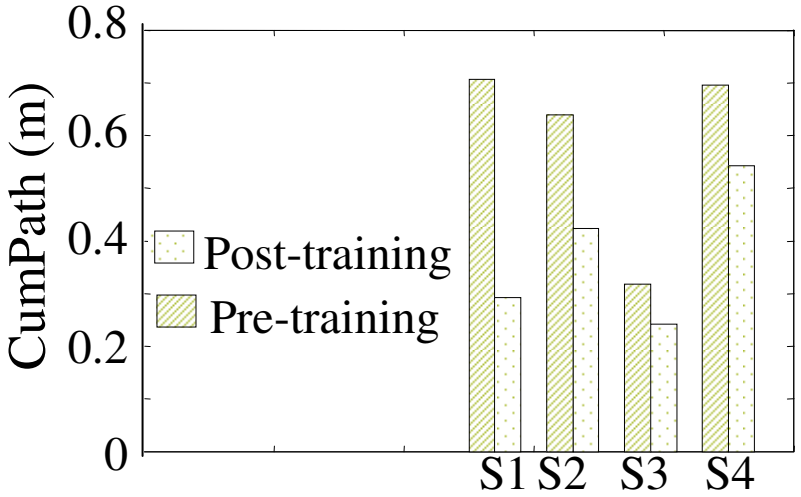
Tangential Velocity is the instantaneous linear velocity of a body moving in a circular path; its direction is tangential to the circular path at the point in question

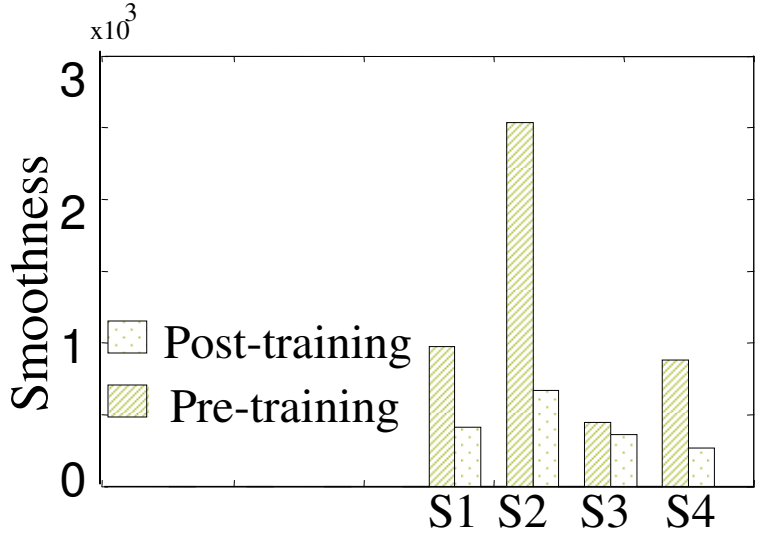




Cup



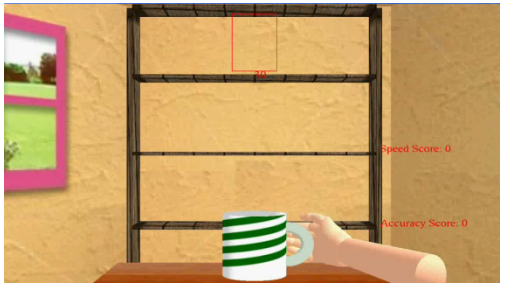




➢**Duration:** average time to reach each cup in seconds. The smaller value, the better performance.

➢**CumPath:** average path length to reach each cup in meters. The smaller value, the better performance.

➢**Smoothness:** the score that indicate how smooth (less jerk) the subject moves during the trial. The smaller value, the better performance.



Results

- Clinical Assessment

	Melbourne assessment		Reach Forward time (s)		Reach sideways Time (s)		Hand to Mouth Time (s)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
S1	40.2%	42.6%	1.9	1.2	n/a	1.4	n/a	n/a
S2	74.6%	75.4%	3.6	2.9	3.7	2.3	15.1	10.7
S3	76.2%	77.1%	4.5	1.5	2.4	1.8	2.2	1.6
S4	59.8%	67.2%	2.9	1.5	2.2	0.8	5.4	4.6

Conclusion

- The two feasibility studies showed that the 4 subjects who completed 9 hours of training without ill effects, do demonstrated improvement, at the impairment level and the functional level.

- The approach of NJIT-RAVR system offers many advantages :
  - Therapeutic tasks can be modified to match subject's need and interest.
  - The robot can be used to assist the subject to perform and learn new challenging tasks.
    - assistance levels provided by the robot can increase, allowing subjects to complete the number of repetitions necessary to facilitate beneficial cortical adaptations.

References

- Morris C. (2007).Definition and classification of cerebral palsy: a historical perspective. Dev Med Child Neurol Suppl, 109, 3-7.
- Reid D. (2004). The influence of virtual reality on playfulness in children with cerebral palsy: a pilot study. Occup Ther Int., 11, 131-144.
- Merians AS, Poizner H, Boian R, Burdea G, and Adamovich S, (2006). Sensorimotor training in a virtual reality environment: does it improve functional recovery poststroke?, Neurorehabilitation and Neural Repair, 20 (2), 252-67 .
- Damiano PL (2009). Rehabilitative Therapies in Cerebral Palsy: The Good, the Not As Good, and the Possible, Journal of Child Neurology.
- Charles J. R., Wolf S. L., Schneider J. A., Gordon A. M. (2006). Efficacy of a child-friendly form of constraint-induced movement therapy in hemiplegic cerebral palsy: a randomized control trial. Dev Med Child Neurol, 48, 635-642.
- Sveistrup H. (2004). Motor rehabilitation using virtual reality. J Neuroeng Rehabil, 1, 10.
- Reid D. T. (2002). Benefits of a virtual play rehabilitation environment for children with cerebral palsy on perceptions of self-efficacy: a pilot study. Pediatr Rehabil, 5, 141-148.
- Rizzo A., Kim G. (2005). A SWOT analysis of the field of virtual reality rehabilitation and therapy. Presence, 14, 2005.
- Fasoli SE, Fragala-Pinkham M, Hughes R, Hogan N, Krebs HI, Stein J (2008). Upper limb robotic therapy for children with hemiplegia, American Journal of Physical Medicine and Medicine Rehabilitation, 87, 926-936.

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Thank you!

Questions?

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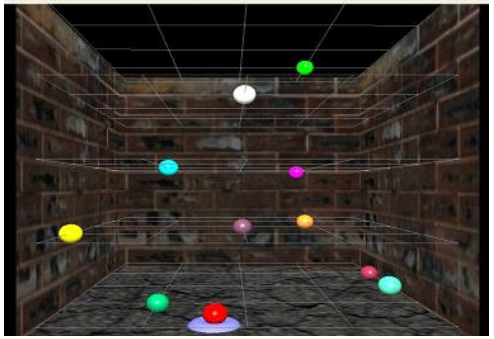
Department of Biomedical Engineering

Bubble Explosion



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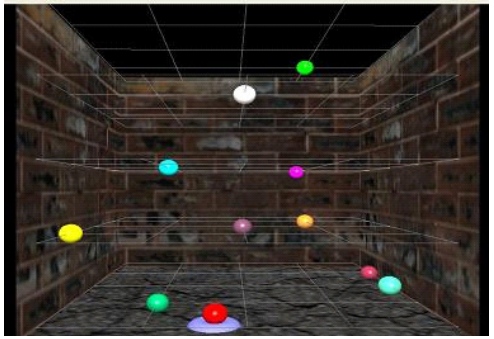
Bubble Explosion



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Cup Reach

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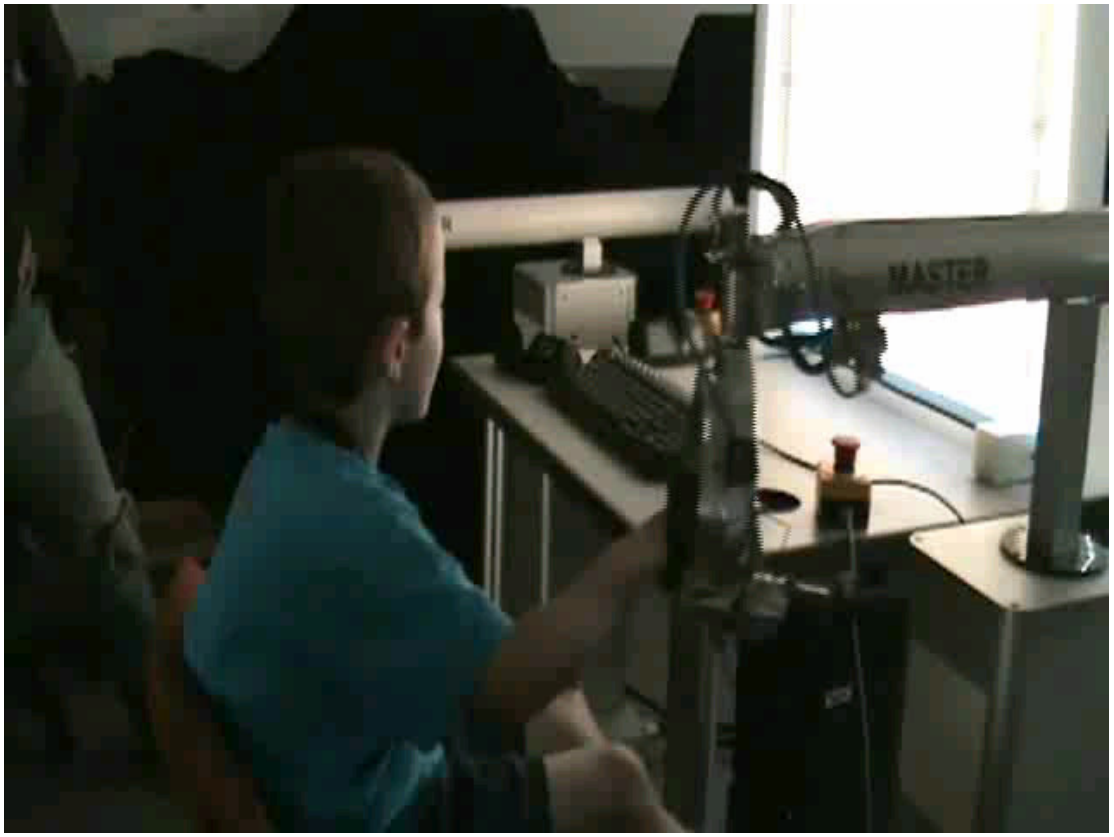
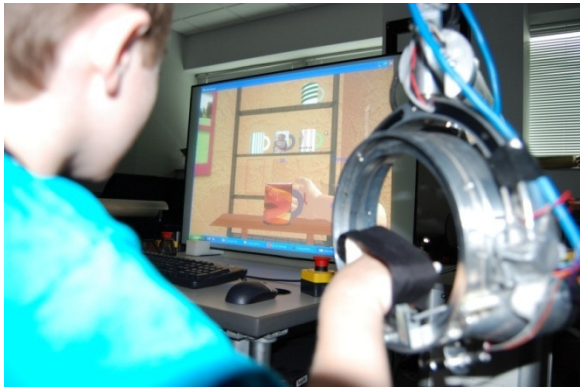
Cup Reach





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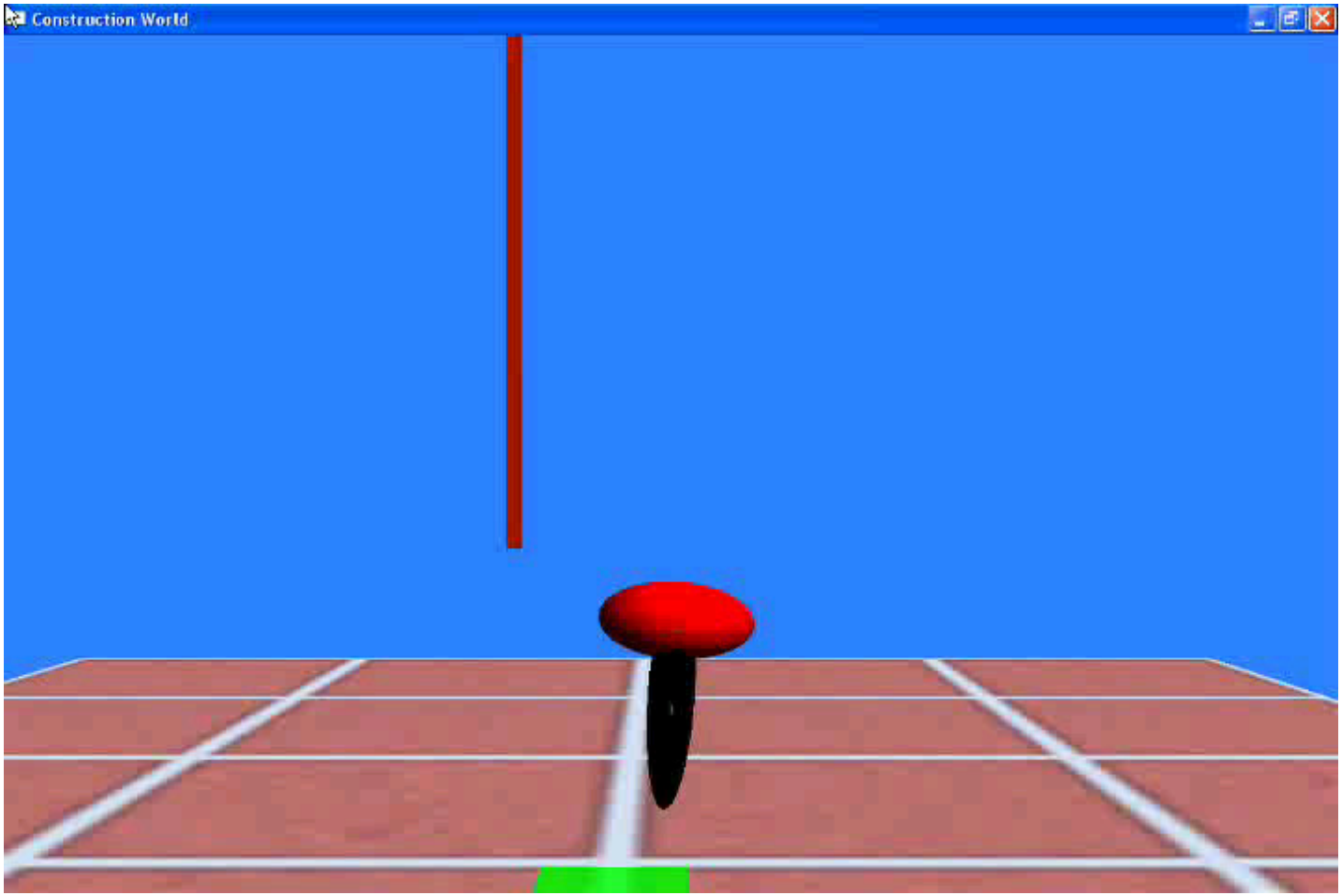
HammerHM



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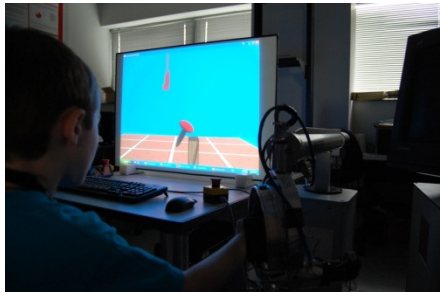
HammerHM



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HammerHM (measurand)

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CarRaceHM

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CarRaceHM

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FallingObjects

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FallingObjects

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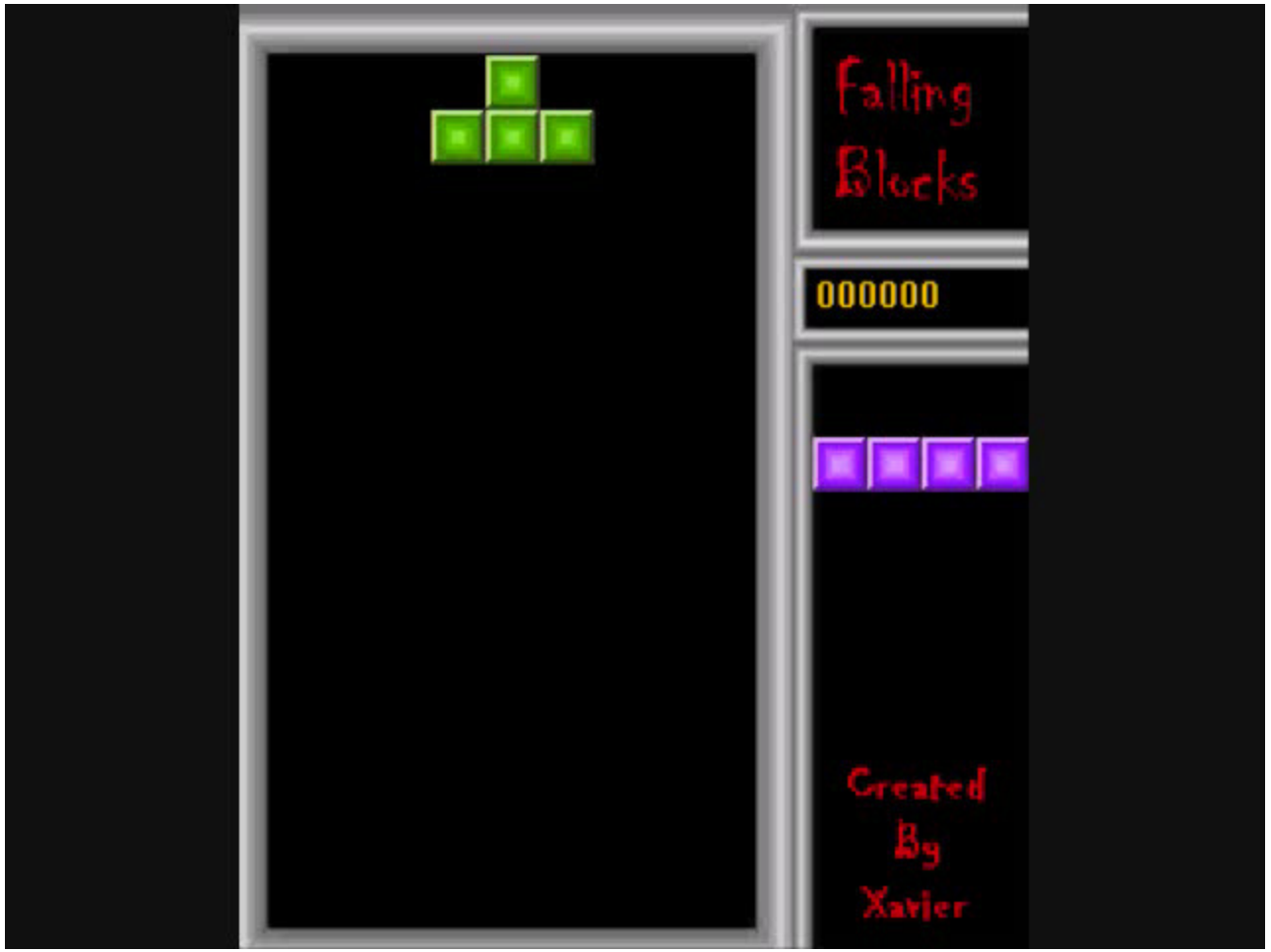
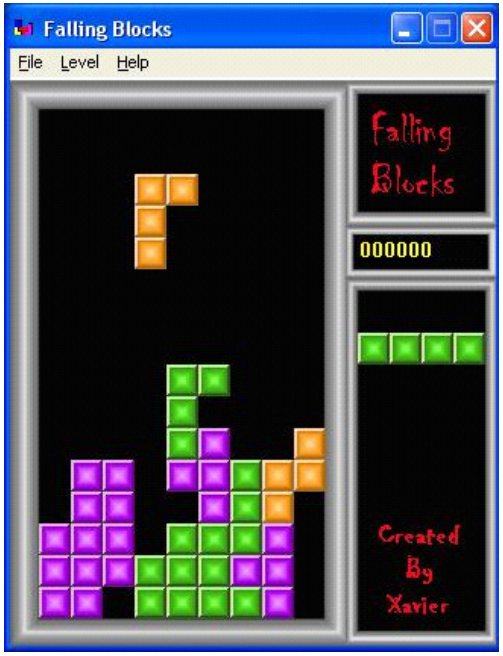
PilingUpHM



PilingUpHM



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