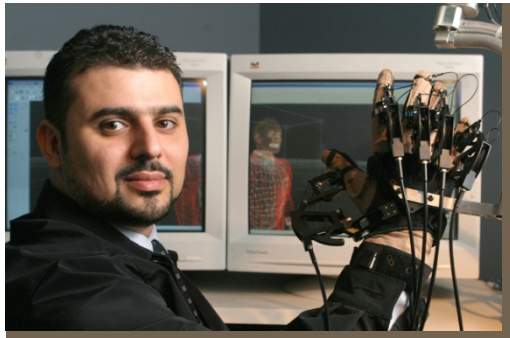

Abdulmotaleb El Saddik

Professor and University Research Chair
Ambient Interactive Media & Communications

Director
Multimedia Communications research Laboratory (MCRLab)

Haptic Audio Visual Media in Ambient Environments

I Feel, I touch, Am I Real?

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L'Université canadienne
Canada's university

Multimedia Communications Research Laboratory

http://www.mcrlab.uottawa.ca

Université d'Ottawa | University of Ottawa

uOttawa.ca

Haptics

"Science of applying force feedback and tactile sensation to human interface with computers."

BMW's iDrive

CyberForce® Tactile Feedback System

CyberGlove

CyberGrasp™ Exoskeleton

VirtualHand® for MotionBuilder

uOttawa

Fact is that ...

- We rely on our sense of touch to do every day tasks such as:
  - Dialing a touch-tone phone
  - Finding first gear in a manual transmission car
  - Playing a musical instrument like a guitar or a piano
- We heavily rely on the tactile and kinesthetic cues we receive.
  - Tactile cues include:
    - textures, vibrations, and bumps;
  - Kinesthetic cues include
    - those such as the weigh of a stone and the impact of hitting a tennis ball.

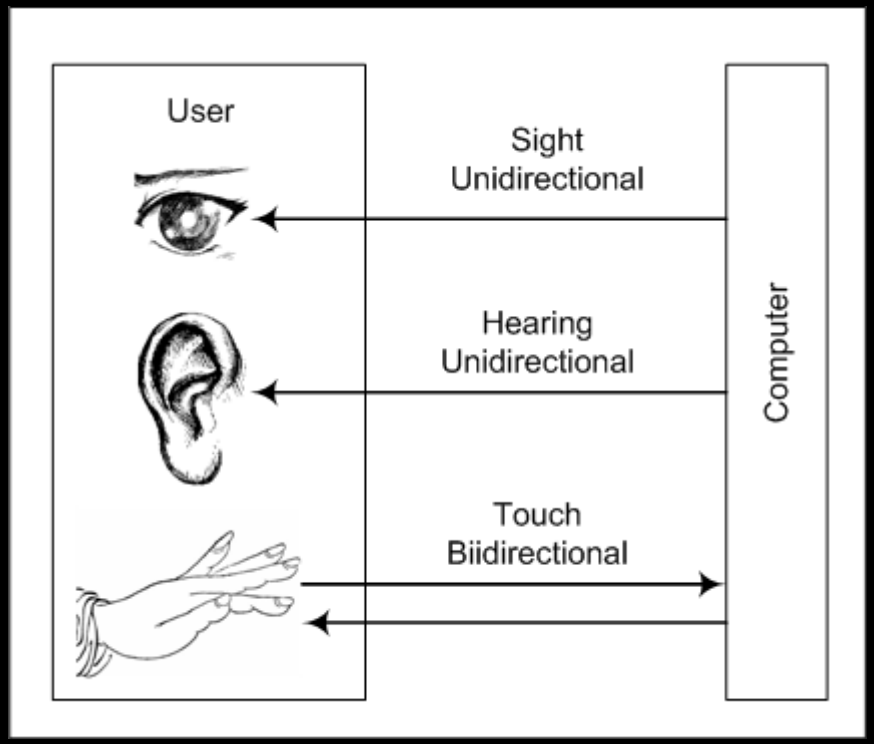
Haptics Information

- Tactile (Cutaneous) Information
  - Spatial Tactile Information
  - Temporal Tactile Information

- Kinesthetic (Proprioceptive) Information

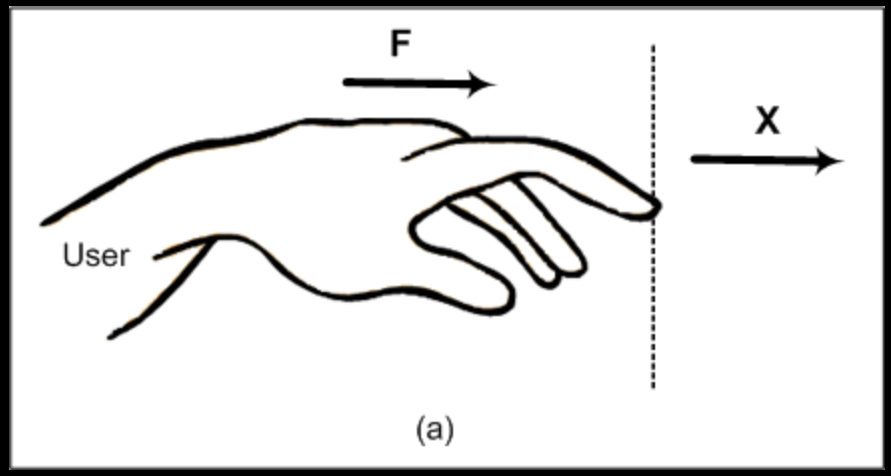
Haptic Information =
Tactile + Kinesthetic (Information)

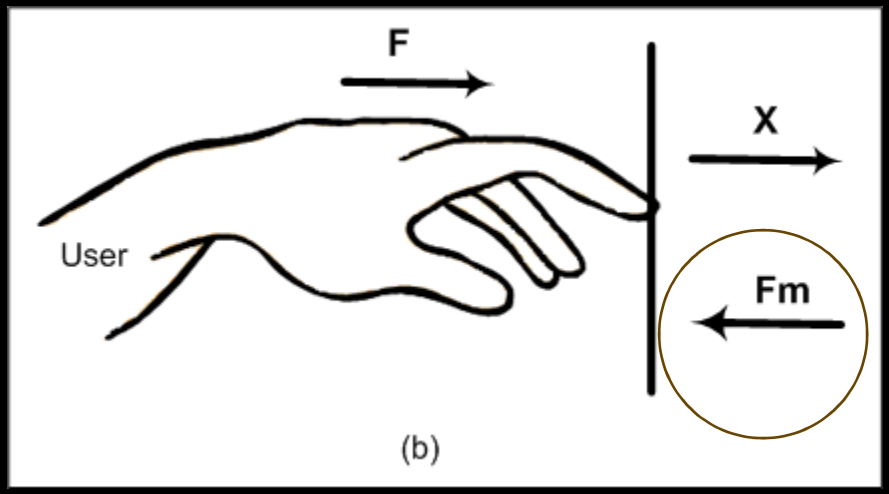
Flow of Information



A distinguished feature of haptics is the bidirectional flow of information

Haptics flow



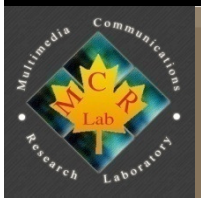


Free space motion

Force feedback when collision is detected

Multimedia Information Systems

Multimedia Information Systems refers to a branch of study wherein systems are designed to extract, create, manage, process and present information from multimedia data.



Haptic Information Systems

- Haptic Information Systems are systems that can extract, create, manage, process and present haptic data.
  - What is haptic data?
  - How do we extract it, create it, manage it process it and present it?

Haptic Data

- What does a touch based interaction encompass
  - *Multiple parameters*: force, pressure, moisture, temperature, texture
  - *Affective*: Pain, Emotional
  - *Communicative*: Gestures
  - *Proprioception*: Awareness of your own actions
  - *Spatial Elements*: leads to spatial perception

Haptic Applications

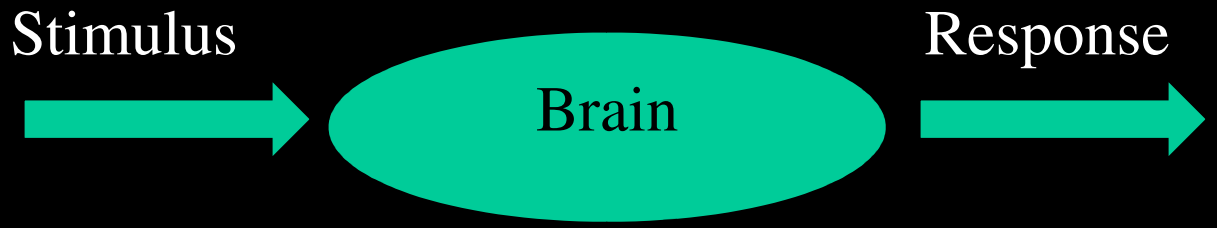
- Medicine
  - Visually impaired
  - Rehabilitation
  - Tele-Surgery
- Education and Training
- Entertainment & Games
- Scientific Data Visualization
- E-commerce
- Arts and design

Topics to cover

Psycophisics

Psychophysics

- Methodology for investigating relationships between:
  - sensations in the **psycho**logical domain and
  - stimuli in the **physic**al domain
- Central to experimental psychology

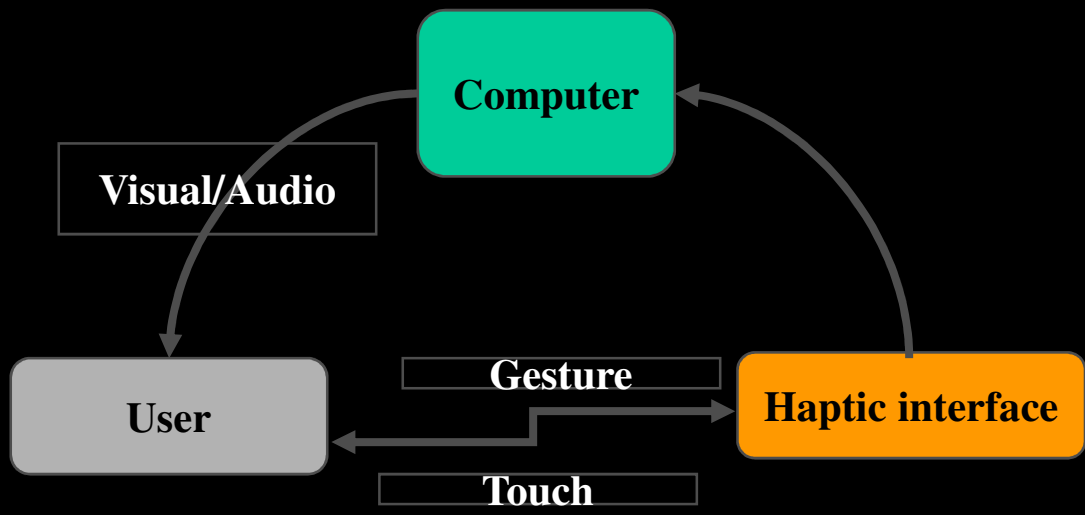


Topics to cover

Haptics Interfaces

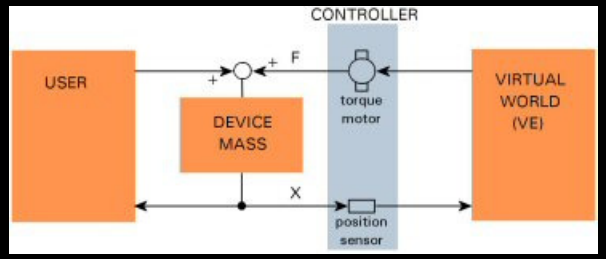
Bidirectional exchange of energy

- Passive Devices
  - Programmable dissipation;
    f (time or position)
- Active Devices
  - The energy exchange is entirely a function of the feedback control

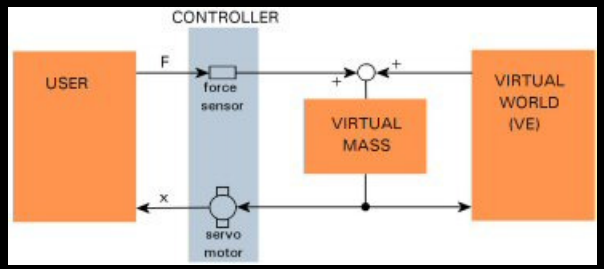


Principle of Operation

- Impedance Control
  - The actuators act as force source, and position is measured

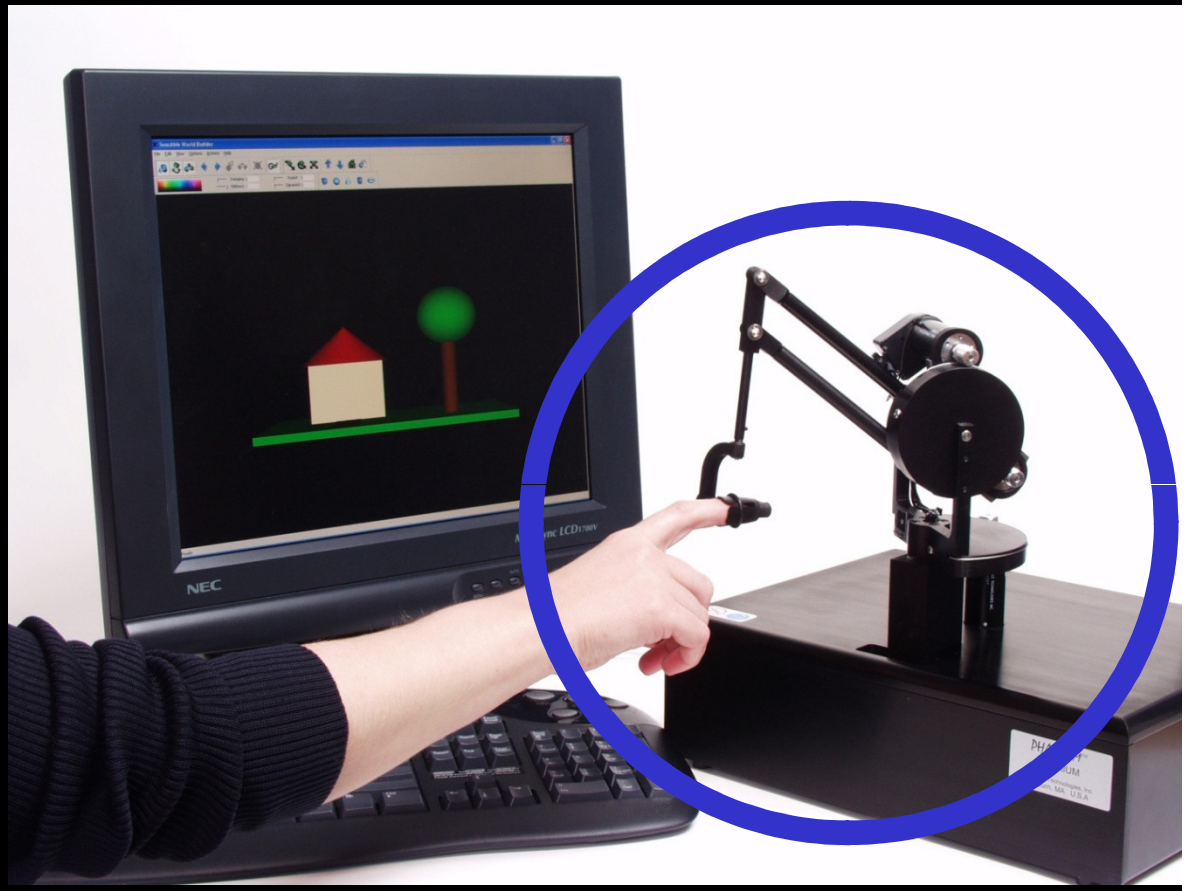


- Admittance Control
  - The actuators act as position source, and then the force is measured



Haptic Interfaces

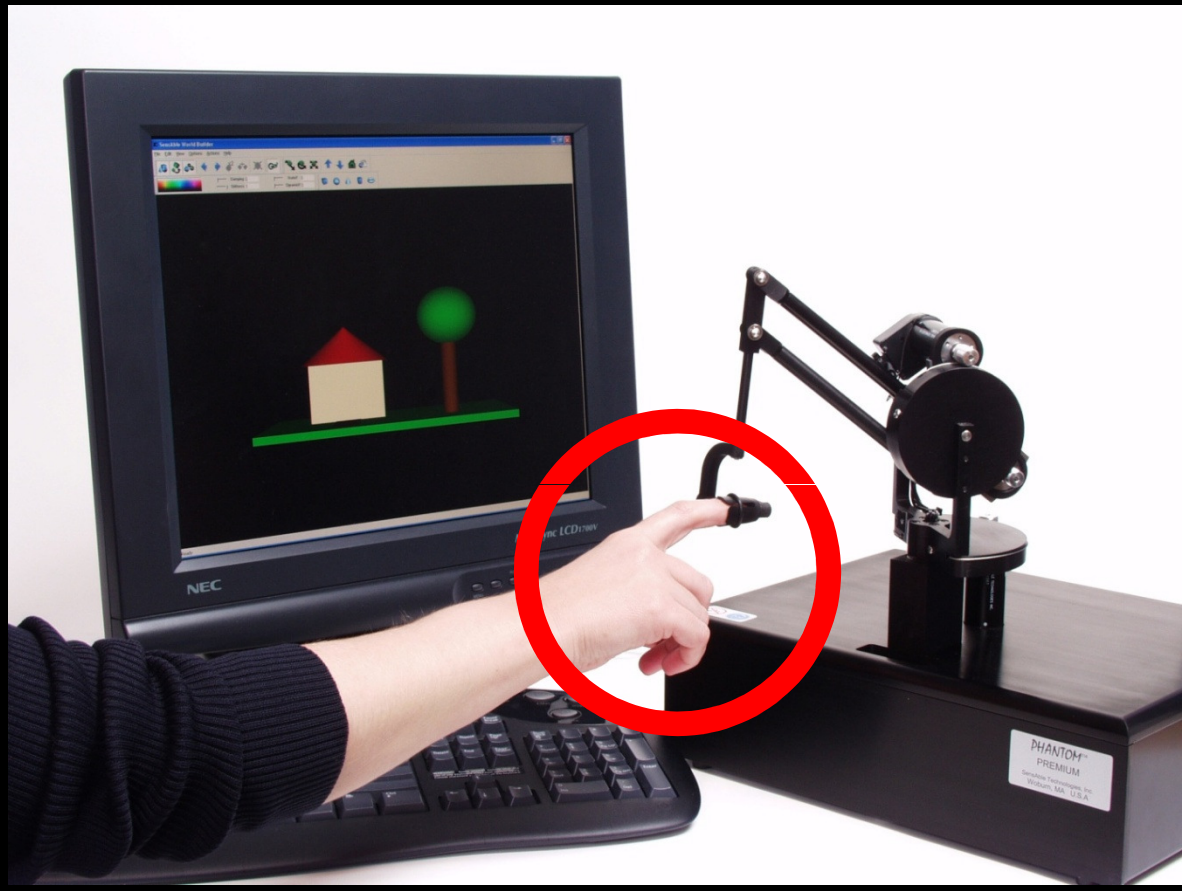
- A haptic interface is a device which allows a user to interact with a computer by receiving tactile/force feedback.
- A haptic device achieves the tactile feedback by applying a degree of opposing force to the user along the x, y, and z axes.
- A haptic interface serves to orient users to the location and nature of objects in a virtual space.



Source: SensAble Tech., USA

Haptic Rendering

- Haptic rendering is the process of computing and generating forces in response to user interactions with virtual objects.
- Haptic rendering enables a user to touch, feel, and manipulate virtual objects through a haptic interface.



Graphical/Haptic Rendering

Source: SensAble Tech., USA

Principles of Haptic Rendering

- **A haptic rendering algorithm is made of two parts:**
  - **Collision Detection:**
    - As the user manipulates the probe of the haptic device, the new position and orientation of the haptic probe are acquired, collisions with the virtual objects are detected
  - **Collision Response**
    - If a collision is detected, the interaction forces are computed using preprogrammed rules for collision response, and conveyed to the user through the haptic device to provide him/her with the tactual representation of 3D objects and their surface details.

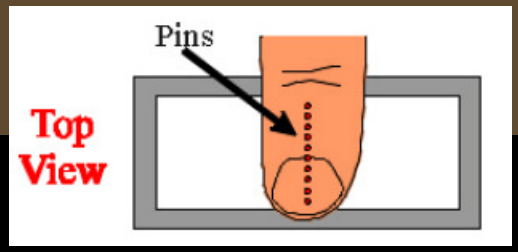
Tactile Displays

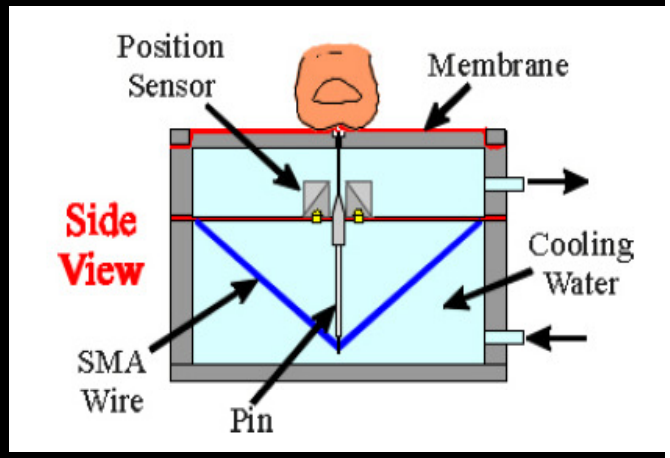
- Render feedback data that presents an object's surface geometry or texture and enable the user to feel the surface of the virtual objects
- Tactile sensation can be applied in three ways:
  - Vibration: Enable the user to feel the texture of the surface by using electrical vibrators

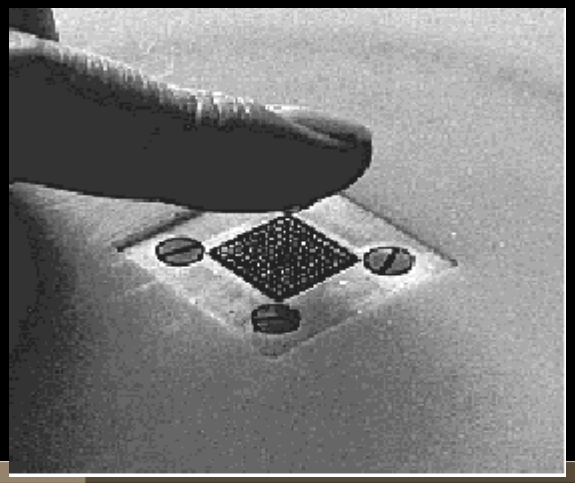
CyberTouch [Immersion Corporation].

Tactile Displays

- Small-scale shape (Shape display):
  - Convey information about the shape and surface texture of an object
  - Consist of an array of closely-spaced pins that can be individually raised and lowered against the finger tip to approximate the desired shape
- Thermal display







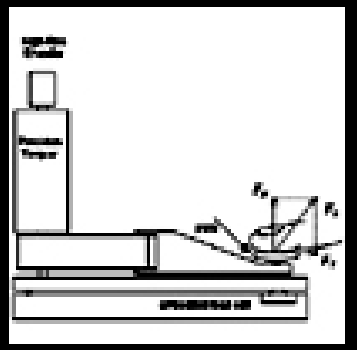
Courtesy of University of Exeter

Kinesthetic Interfaces

- DOF: (Degree of freedom) is the number of parameters which may be independently varied
  - Low DOF Devices: (1 to 3 DOF)
    - Types of 1 DOF interactions include opening a door with a knob
    - Examples of 2-DOF exist in everyday life-using a mouse to interact with a PC
    - 3-DOF interaction, the force direction isn't trivial
  - High DOF Devices: (4 to 6 DOF)
  - Very High DOF; (More than 6)

Low degree of Freedom

Other examples come from devices that have been developed for the gaming industry such as haptic steering wheels and joysticks and games pads



The *Pantograph* is typical example of two actuated degrees of freedom in the horizontal plane

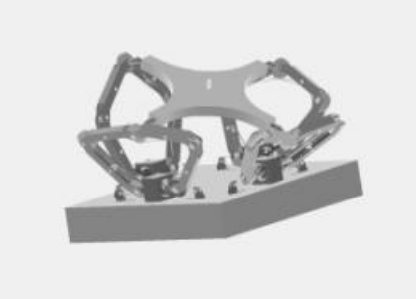
Low degree of Freedom

The haptic master is a commercial example of a 3 DOF force controlled haptic interface

The Phantom device can exert forces at one point in three dimensions

High Degree of Freedom

6-DOF Tactile Simulator

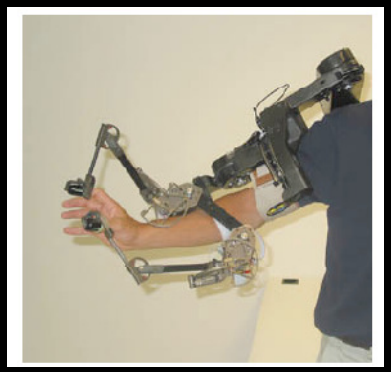


A six-degree-of-freedom hand controller with force feedback capabilities designed over a mobile platform [4]

6-DOF DELTA

It offers 6 active degrees-of-freedom in translation and rotation and was designed to display high-fidelity, high-quality kinesthetic and tactile information [5]

Very High Degree of Freedom



The Mechanical Design of a Haptic Interface for the Hand, from the Scuola Superiore S. Anna The PERCRO Laboratory is only capable of actuating the index finger and thumb

with CyberGrasp™, its force-reflecting exoskeleton fits over a CyberGlove® and adds resistive force feedback to each finger

The Rutgers Master II - New Design Force-Feedback Glove from the Rutgers University is able to provide force feedback of 16 N to each of the fingers

Commercial Haptic Products

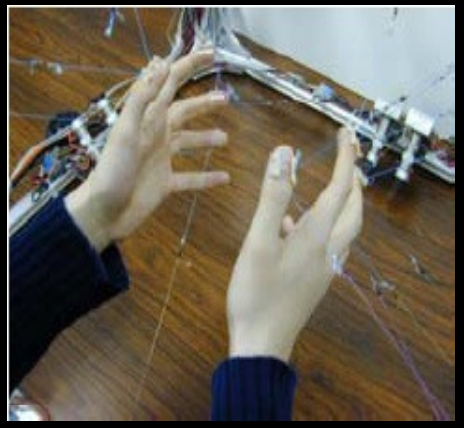
Haptic Knob – BMW iDrive
[Immersion Corporation]

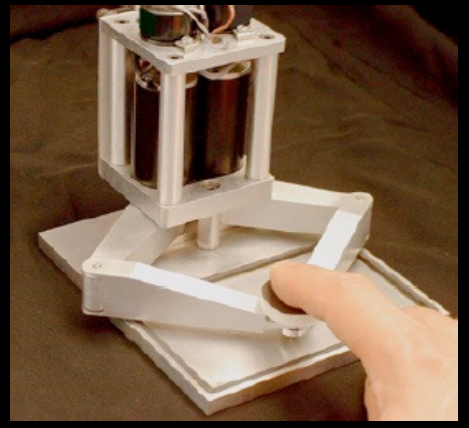
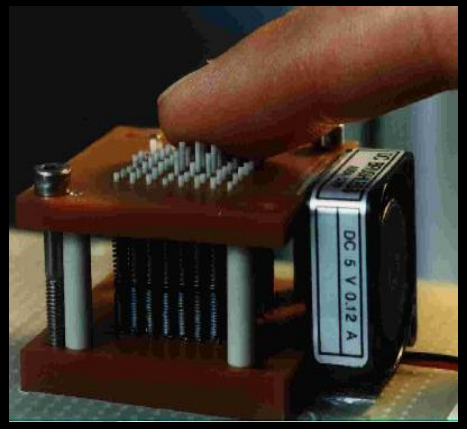
Vibetonz Mobile Player
[Immersion Corporation]

Logitech Wingman Force Feedback Mouse
[Logitech]

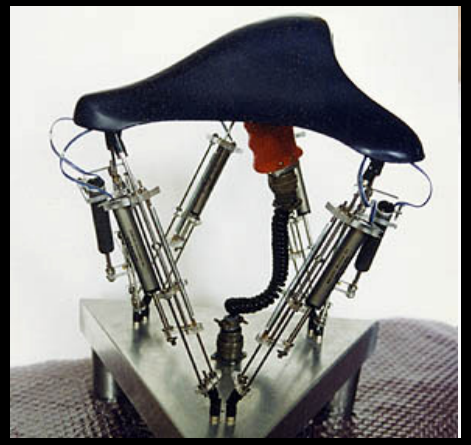
Laparoscopic Surgical Workstation
[Immersion Corporation]

Examples Haptic devices

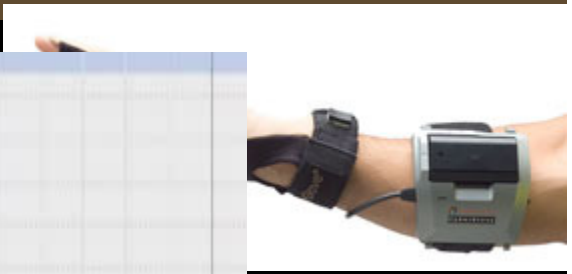







Haptic Gloves

CyberForce
[Immersion Corpor

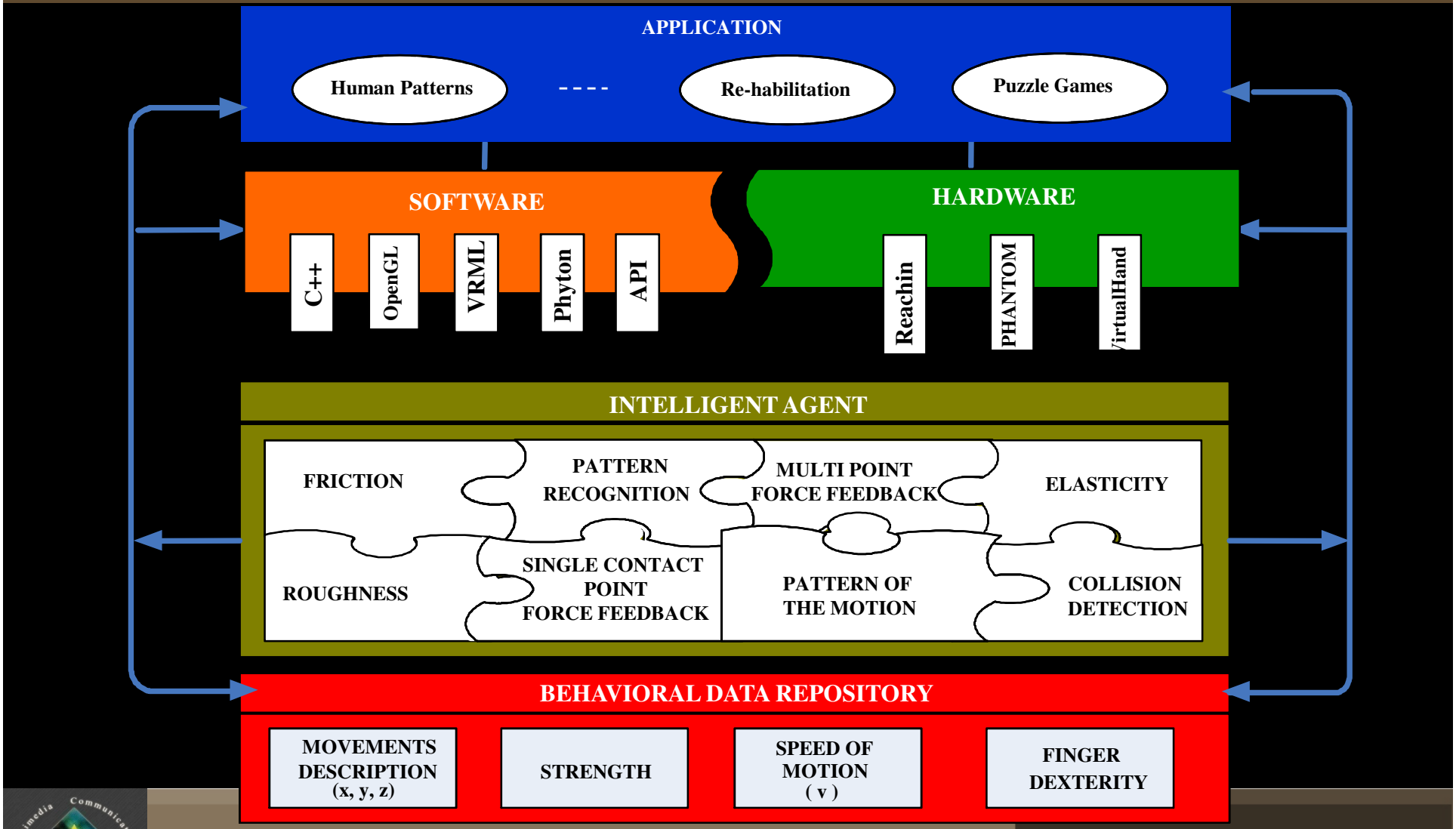


yberTouch
sion Corporation]

The Problems ...

- **Device heterogeneity**
  - Use heterogeneous devices in the same application
- **API heterogeneity**
  - Usually the APIs are associated with devices
- **No standard assembly line development**
  - Device-specific application development environments

AmI-based Haptic Framework



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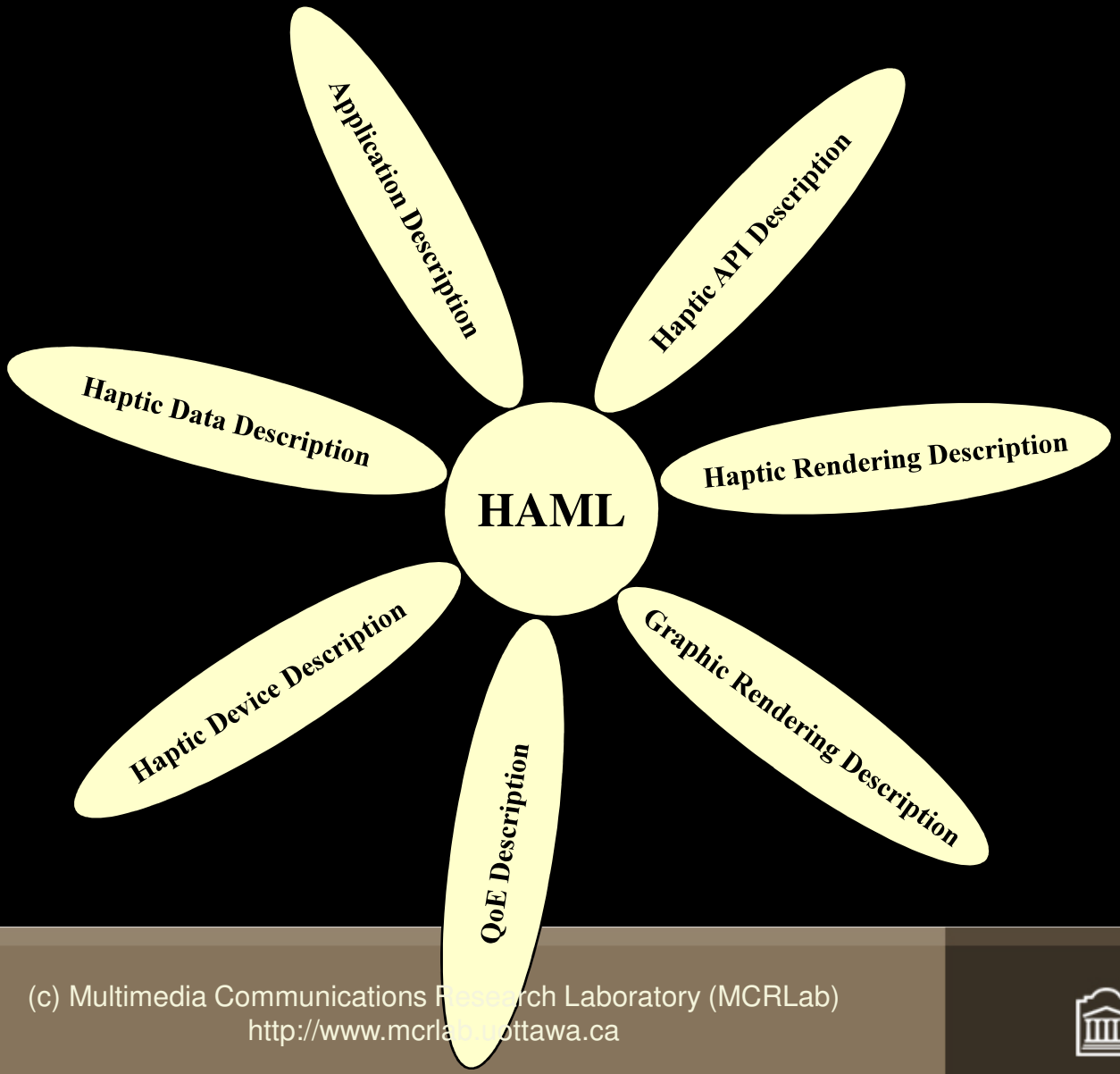
HAML Structure

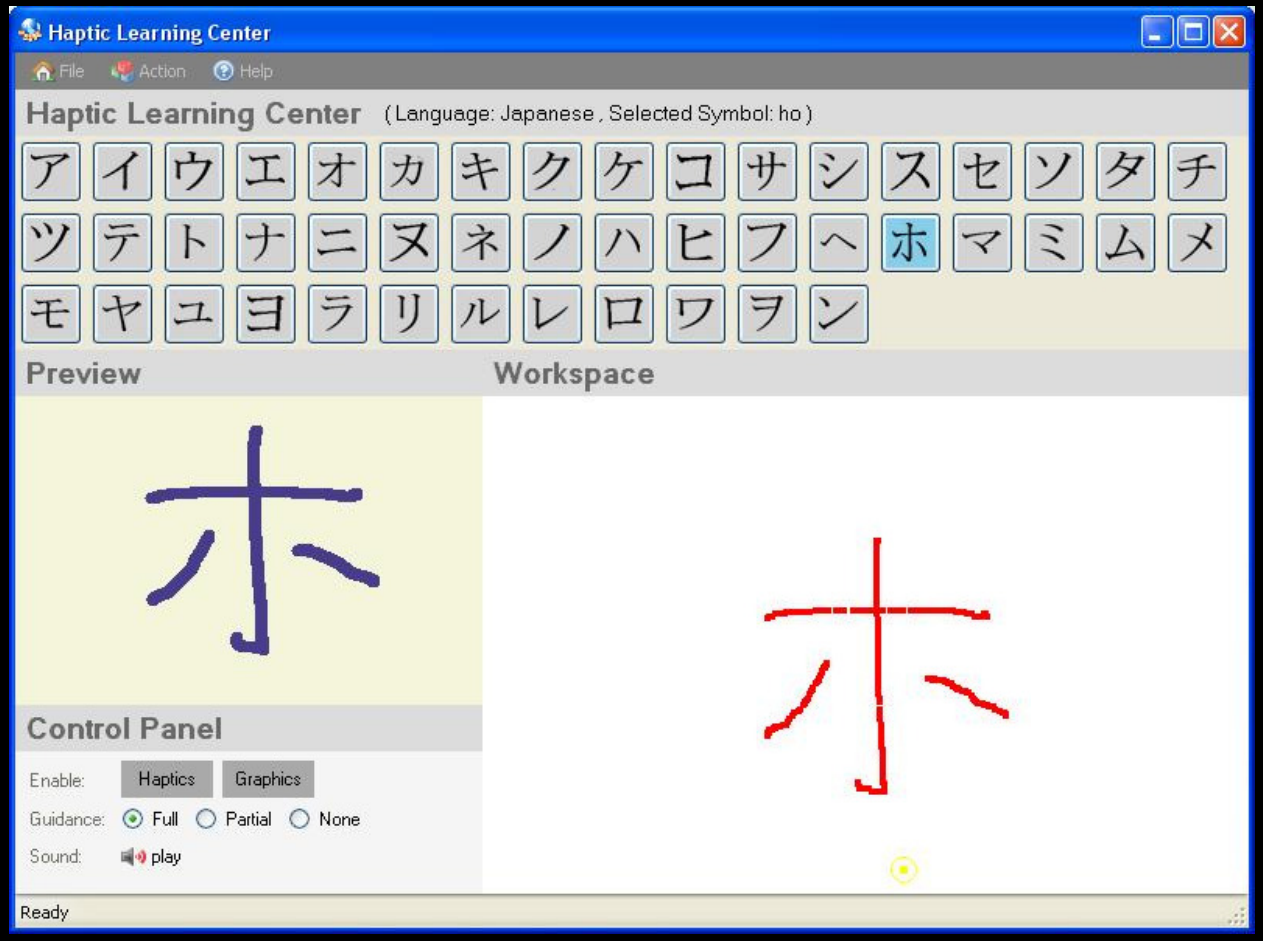


The Haptic Player

- Haptic Player:
  - Makes the transformation to the player device frame based on HAML descriptions
  - Provides extrapolation and interpolation of haptic data
  - Provides workspace scaling

- Comprises three components:
  - The HAML loader
  - The transformation component
  - The haptic rendering component

Handwriting Learning System



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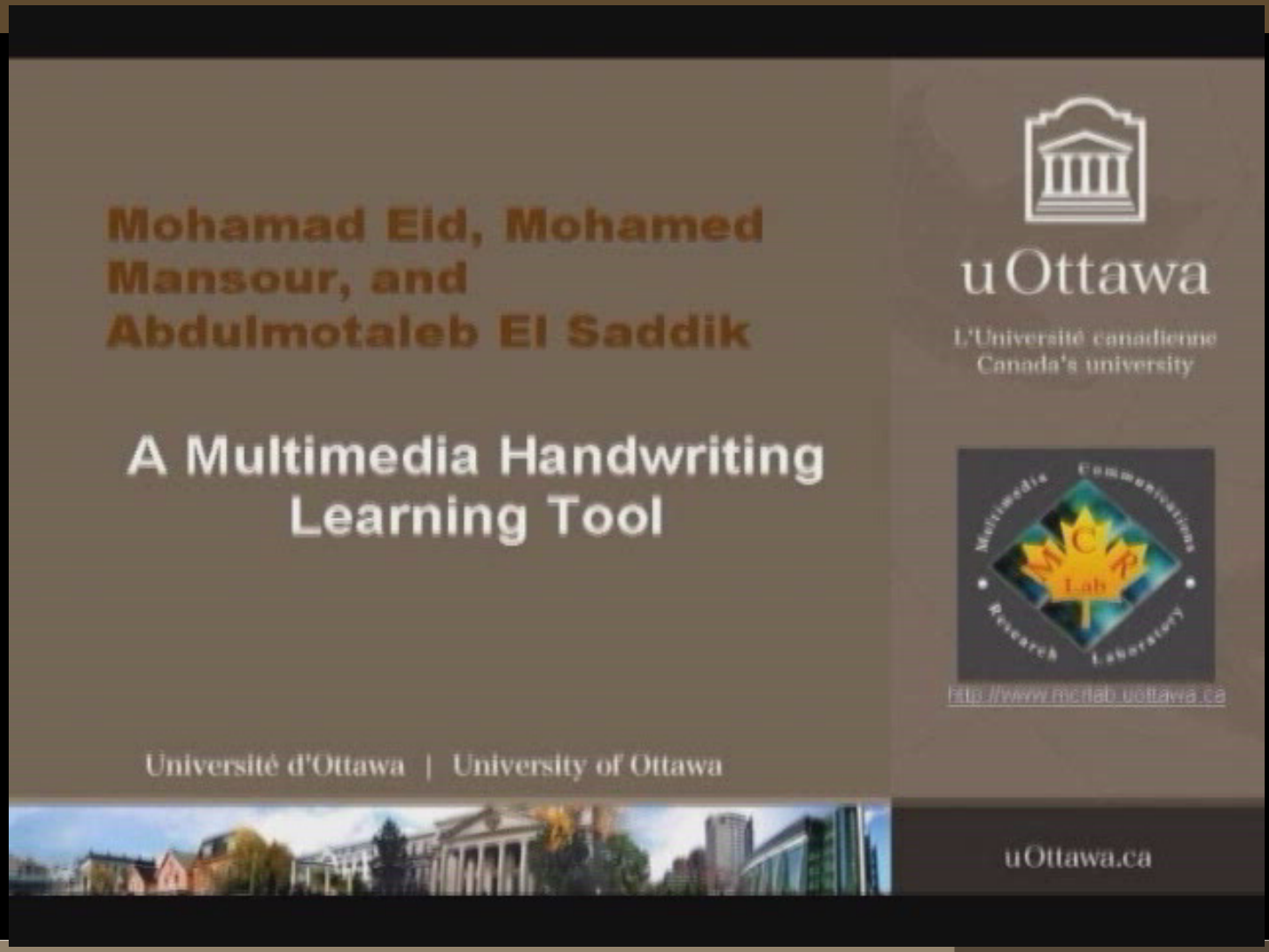
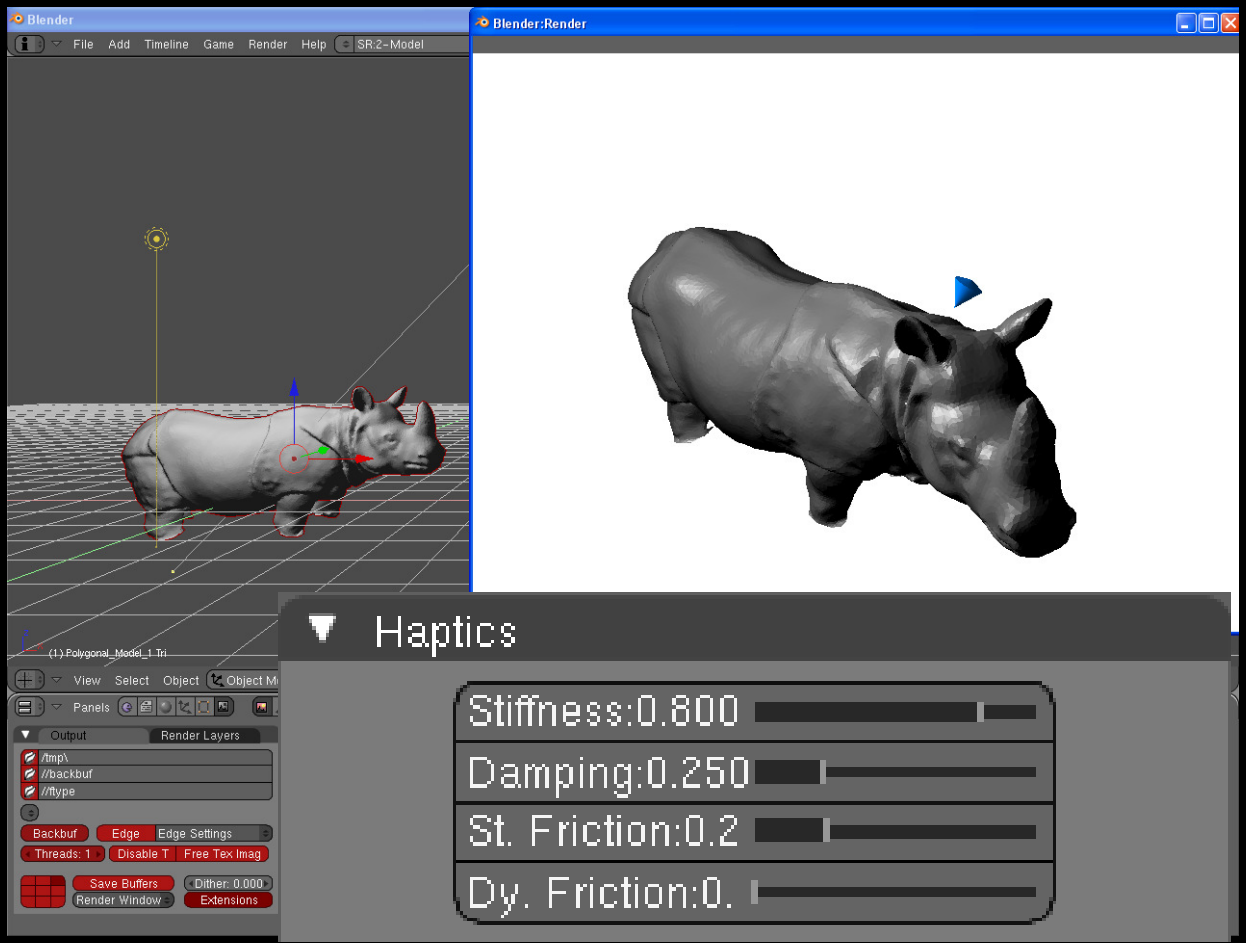


Haptics and Authoring

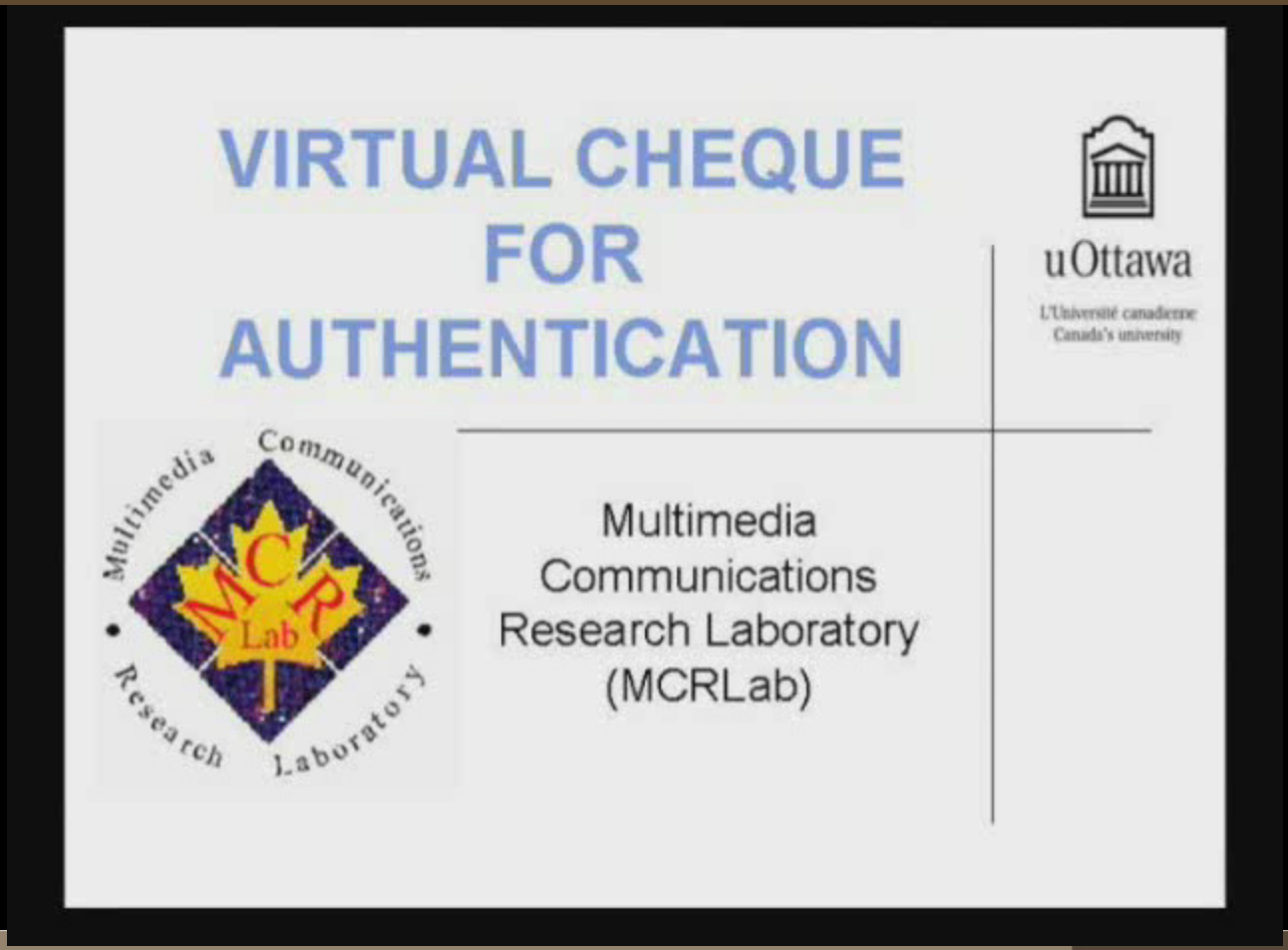
- Multimedia contents
  - Graphic images
  - 3D models
  - Audio and video files
  - And recently haptic stimuli
- Multimedia authoring tools
  - Integrate the disparate media elements into a cohesive multimedia application

HAMLAT Implementation



Haptic Authoring Tool (video)

A Biometrics-embedded System Based on Haptics for User Authentication in Virtual Environments



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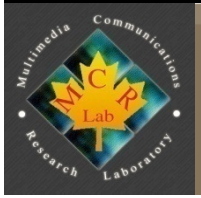
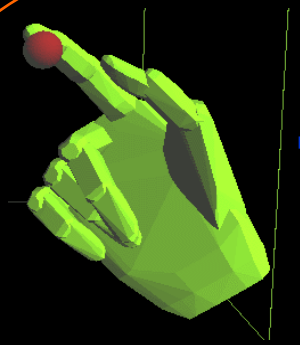
Why Use Haptics?

	Time	2D Position	3D Position	Force	Pressure	Angular orientation	Torque	Velocity	
Keyboard	✓								
Mouse	✓	✓							
CyberGlove	✓	✓	✓			✓			
Digital Tablet	✓	✓			✓	✓			
Haptics	✓	✓	✓	✓	✓	✓	✓	✓	



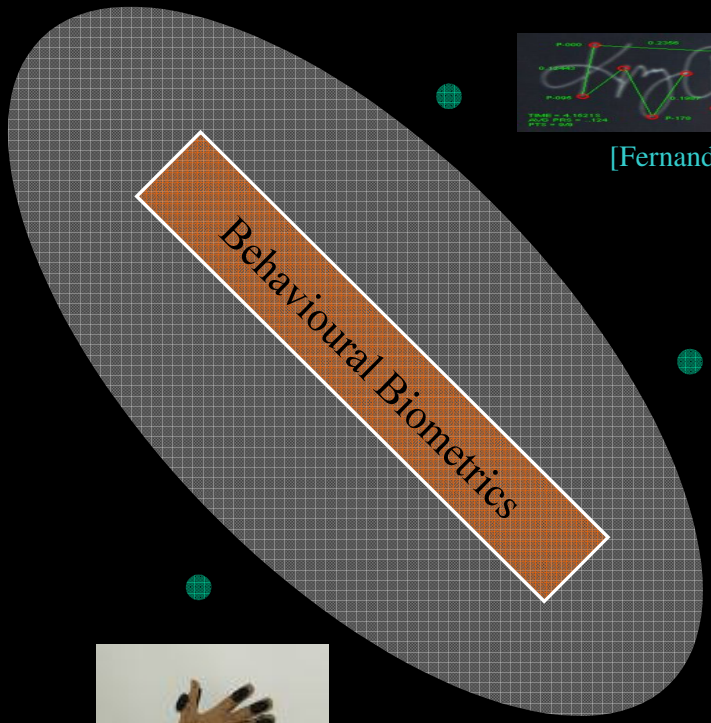
Introduction

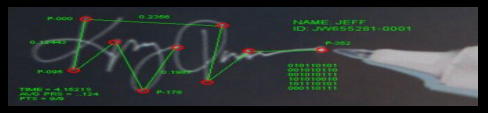
Haptic Systems



Biometrics Systems

Related Work: Behavioral Biometrics





Dynamic Signature Verification

[Fernandez et al, 2005],[Plamondon, 1990], …plenty

Keystroke Dynamics

[Joyce and Gupta , 1990]
[Umpresh and Williams, 1985]
[Obaidat and Sadoun,1997] and more

CyberGlove:DataGlove

[Everitt and McOwan, 2003]

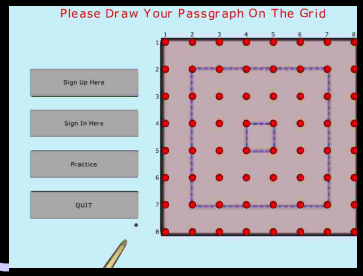
Mouse :DSV

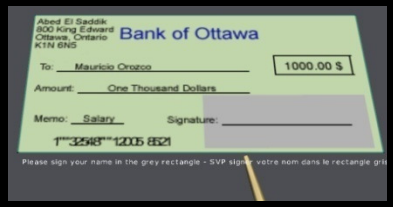
[Everitt and McOwan, 2003]

Single Point Interaction

PHANToM Haptic Desktop

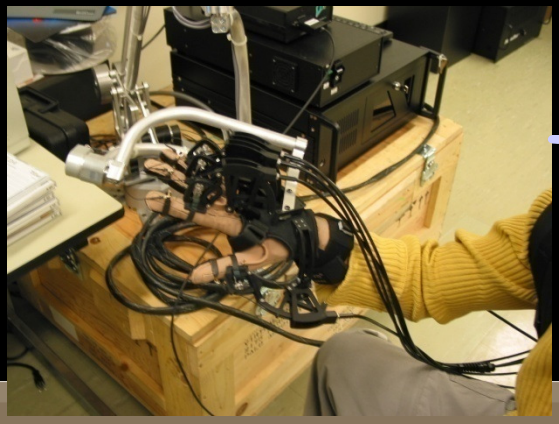
Applications

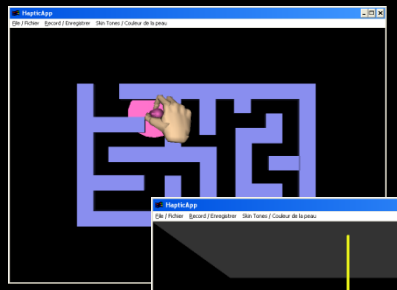


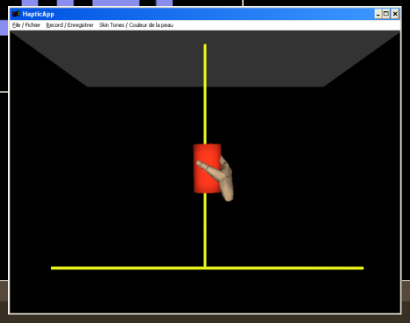


Multiple Point Interaction

CyberGrasp Unit







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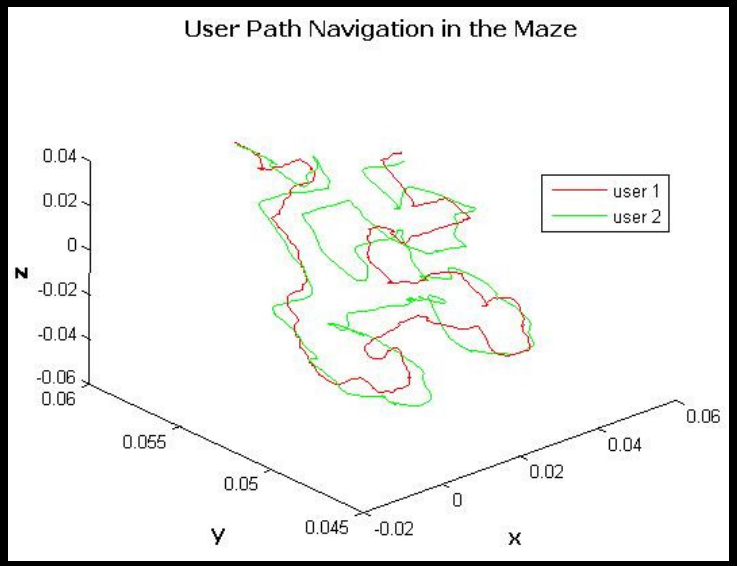
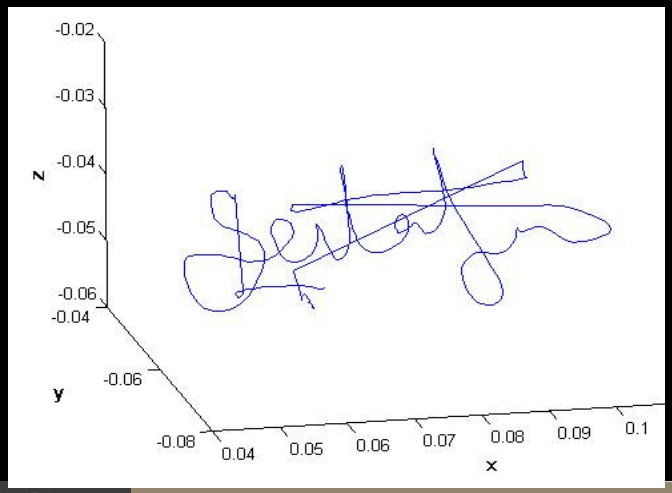
Data Acquisition

Database consists ~ 109 volunteers
(> 2 year)

Each providing 10 genuine samples:
+ Handwritten signature
+ Maze solved
+ Dialled telephone codes

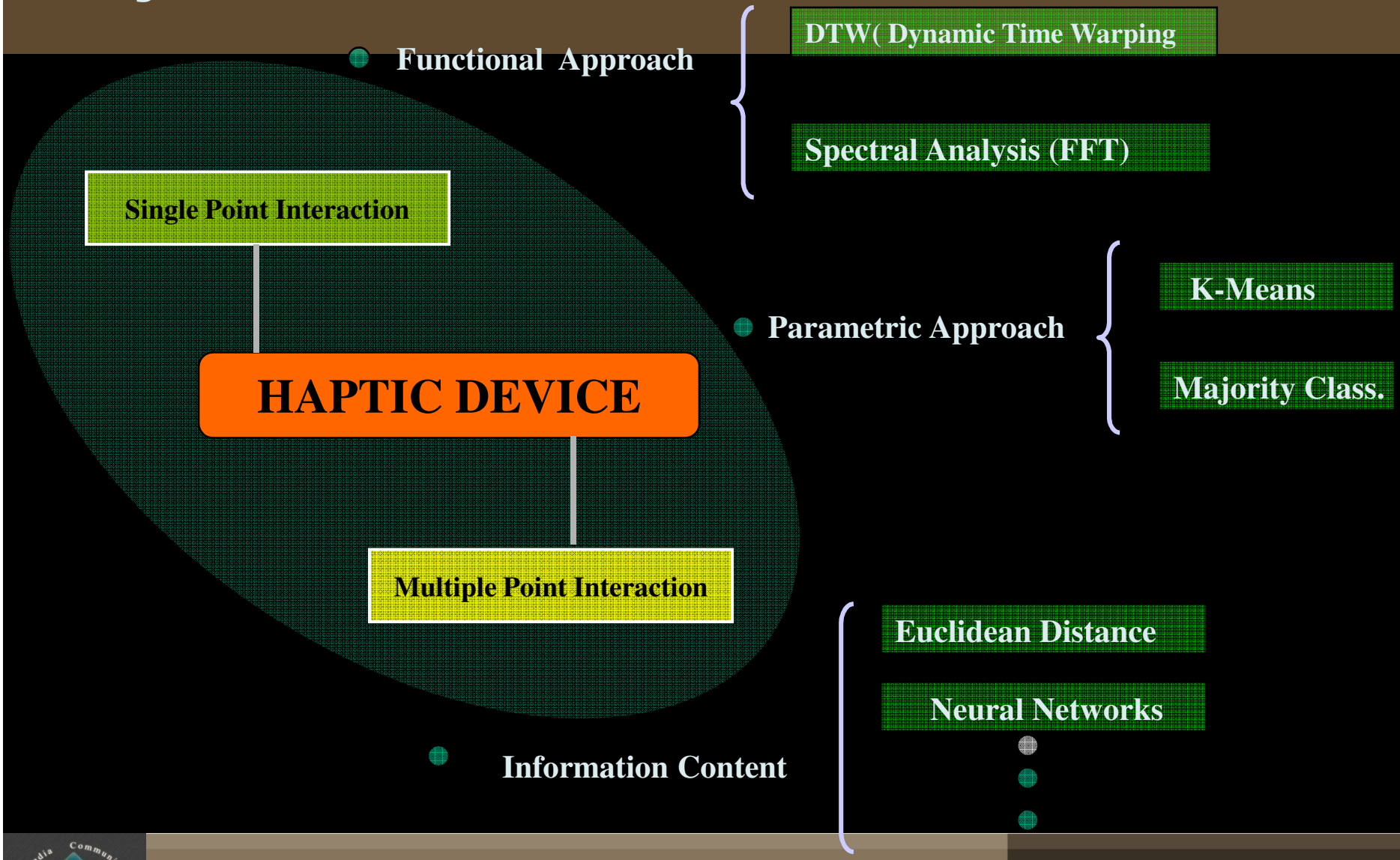




Participants were given the opportunity to practice each application before

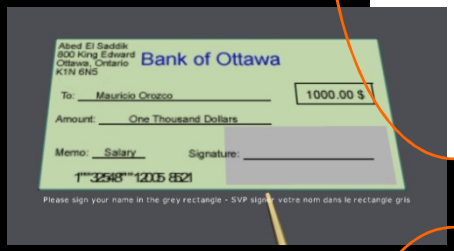
Each process recorded among others parameters the pen's position(x,y,z), force applied (N) and device angle (φ)

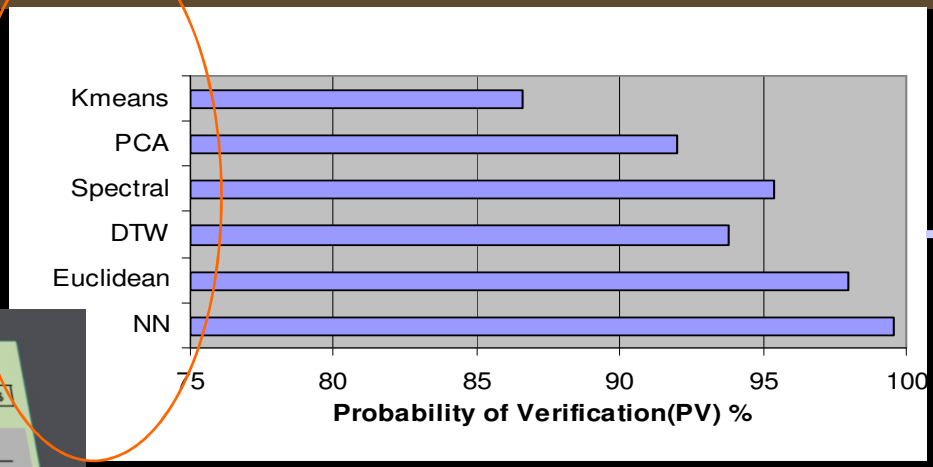
Analysis


Functional Approach
DTW(Dynamic Time Warping
Spectral Analysis (FFT)
Single Point Interaction
HAPTIC DEVICE
Multiple Point Interaction
Parametric Approach
K-Means
Majority Class.
Information Content
Euclidean Distance
Neural Networks

Authetication with Analysis of Information Content

Verification



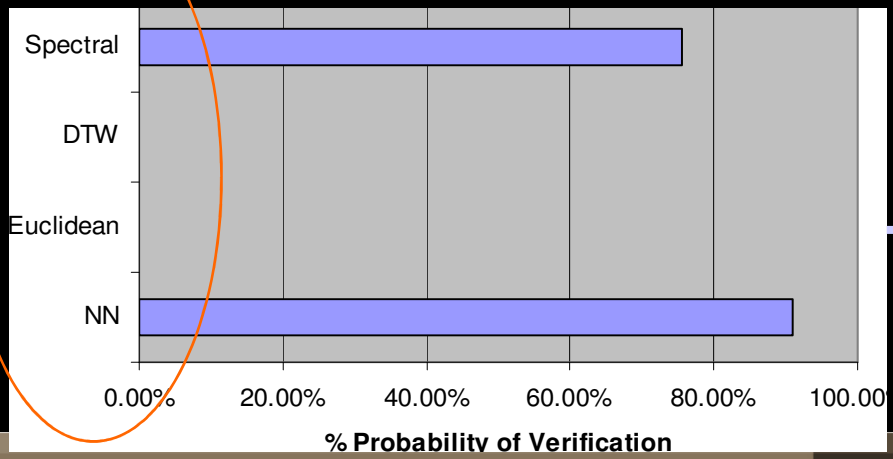


Equal Error Rate

EER=4.5%

Performance

Identification



EER=27%

Multimedia Communications Research Laboratory MCR Lab

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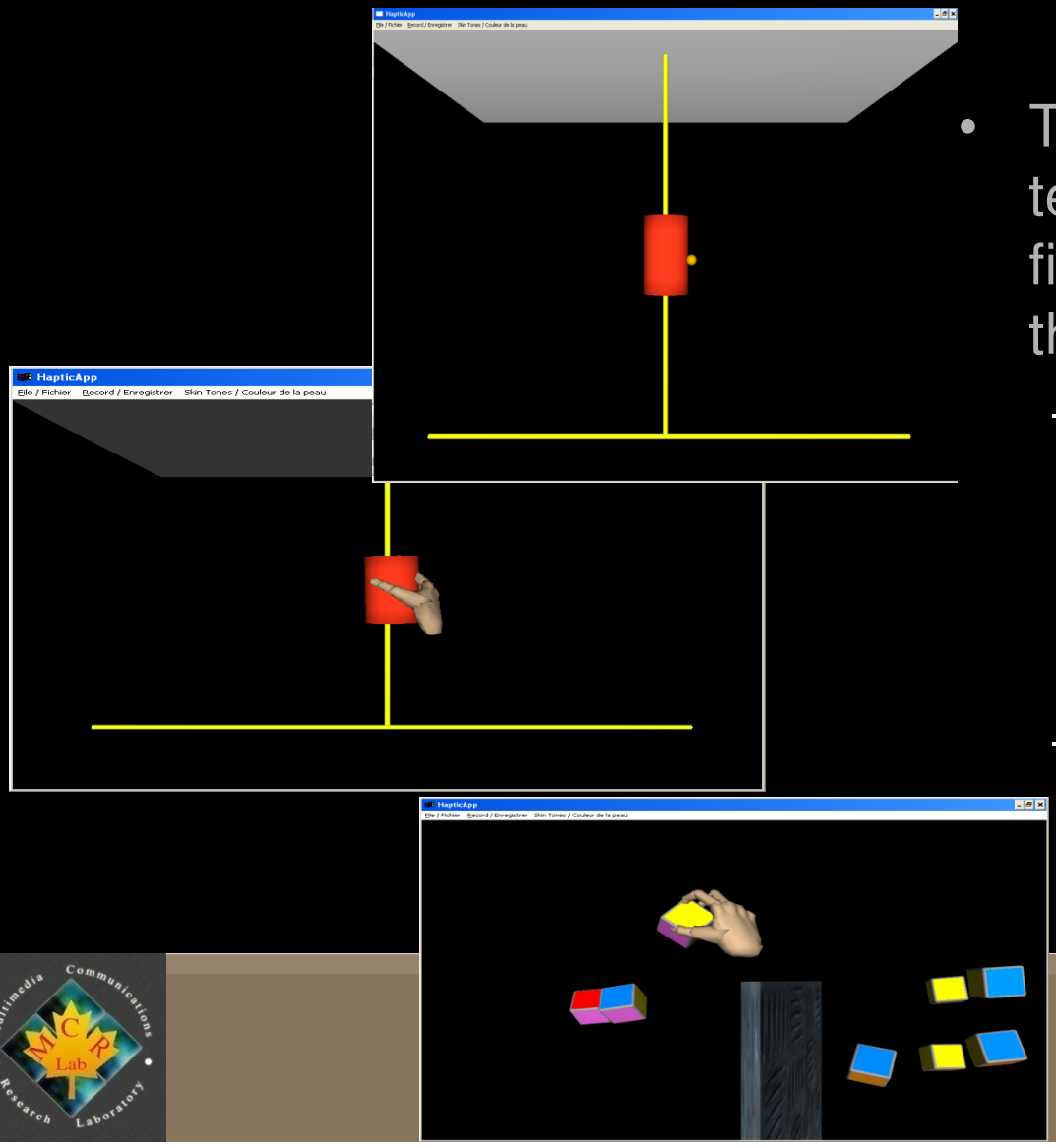
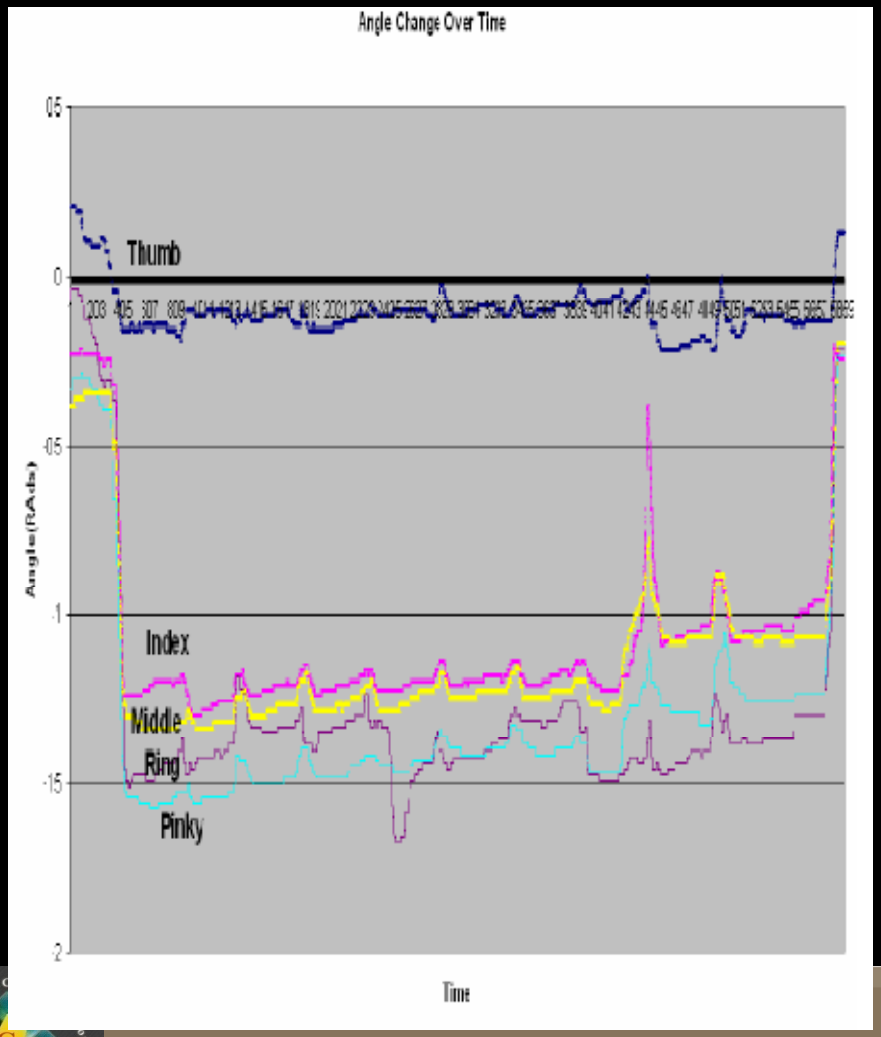
Rehabilitation Applications: Hand Exercises



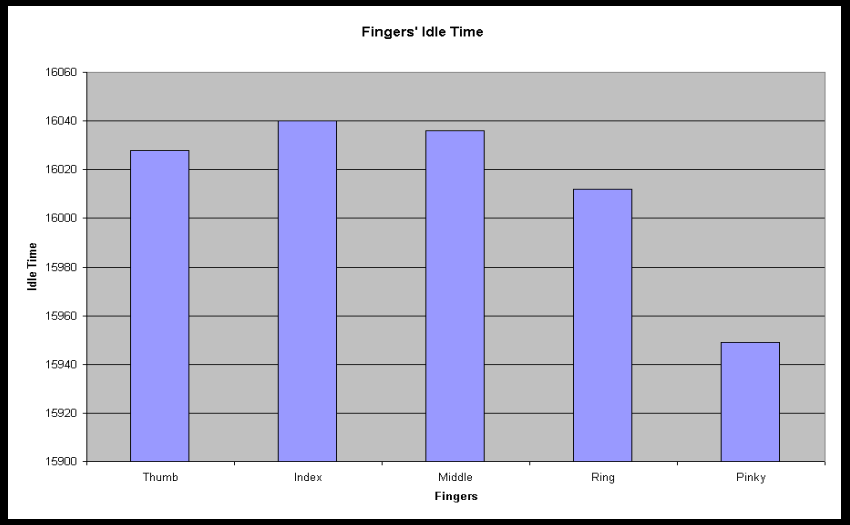
- Two exercises have been tested and analyzed with five healthy volunteers from the University of Ottawa.
  - Virtual Cup: Lifting a cup (two weights, one 2.5 times heavier than the other) and navigating across the space.
  - Cubes: Arranging eight cubes according to a color pattern.

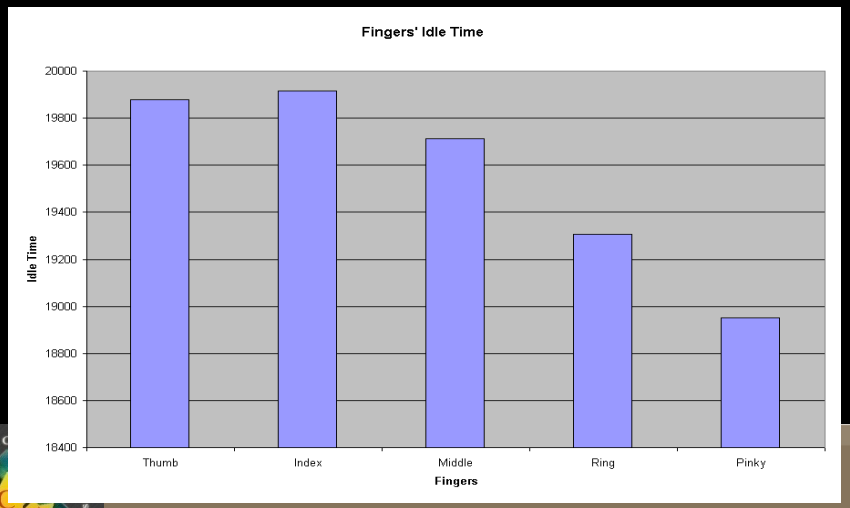
Raw and Extracted Data



- Data collected during the exercise includes:
  - Angle of the middle phalange of each finger.
  - Time elapsed during the exercises.
  - Position of the hand in the virtual space.
- From raw data, the following information has been extracted:
  - Finger idle time for each finger during the exercise.
  - Distance covered along each axis during the exercise.
  - Average velocity of the hand throughout the exercise.
- Analysis was performed on finger idle time.

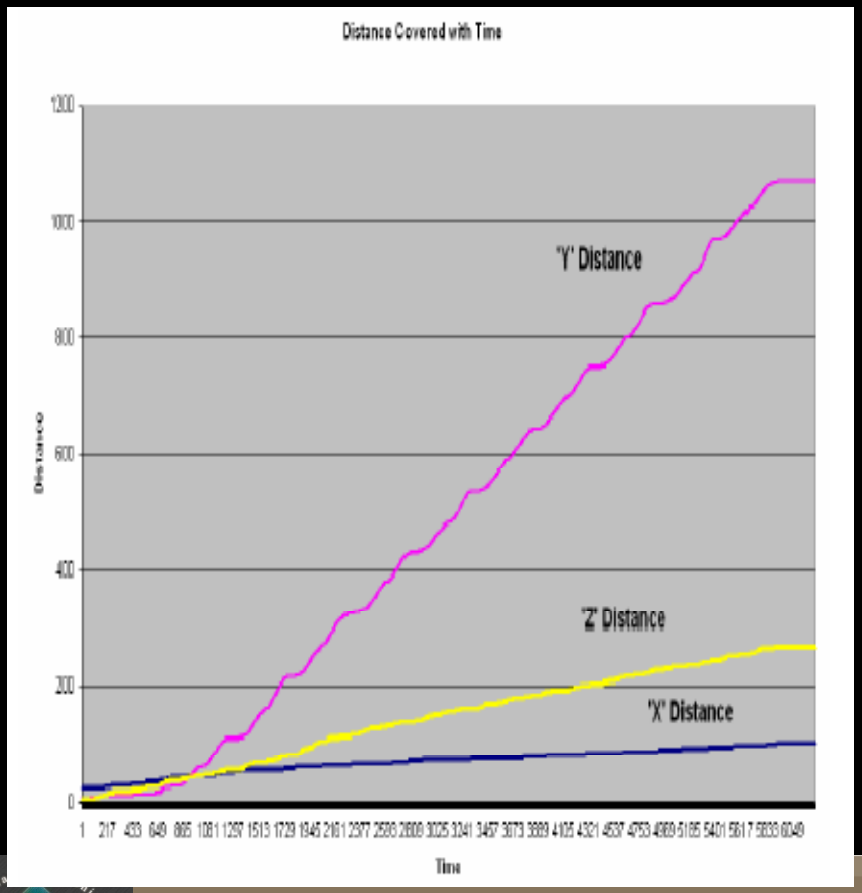
Analyzing Finger Idle Time





- Finger Idle Times for Cup (top) and Cubes exercises for the same subject (bottom).
- Gap in idle time between the index and pinky fingers is considerably large.
- Being that these two fingers are the edge finger that hold an object (excluding the thumb, which has a different positional orientation than the other fingers), this might insinuate a weaker or improper grip of the subject.

Distance Covered (Cup exercise)



- Graph for trial involving heavier cup.
- Comparing the distance covered along the Z axis (cm) for all subjects could be an indication of how stable a subject's hand was.

Subject	1	2	3	4	5
Average 'Z' Distance for both trials	271	591	436	467	333

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