Haptic Audio Visual Media in Ambient Environments

I Feel, I touch, Am I Real?

Université d’Ottawa | University of Ottawa
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® MotionBuilder

(c) Multimedia Communications Research Laboratory (MCRLab)
http://www.mcrlab.uottawa.ca
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)
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 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

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Topics to cover

Psycophysics
Psychophysics

- Methodology for investigating relationships between:
  - sensations in the psychological domain and
  - stimuli in the physical domain
- Central to experimental psychology

Stimulus → Brain → Response
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

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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

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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.

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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.
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 a typical example of two actuated degrees of freedom in the horizontal plane.
Low degree of Freedom

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

The haptic master is a commercial example of a 3 DOF force controlled haptic interface.
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
A Distributed Virtual Environment for Industrial Training

Discover Laboratory
University of Ottawa

http://www.discover.uottawa.ca

Haptic Gloves

CyberTouch
(Immersion Corporation)

CyberForce
(Immersion 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

APPLICATION

Human Patterns
Re-habilitation
Puzzle Games

SOFTWARE

C++
OpenGL
VRML
Phyton
API

HARDWARE

Reachin
PHANTOM
VirtualHand

INTELLIGENT AGENT

FRICTION
PATTERN RECOGNITION
MULTI POINT FORCE FEEDBACK
ELASTICITY

ROUGHNESS
SINGLE CONTACT POINT FORCE FEEDBACK
PATTERN OF THE MOTION
COLLISION DETECTION

BEHAVIORAL DATA REPOSITORY

MOVEMENTS DESCRIPTION
(x, y, z)
STRENGTH
SPEED OF MOTION (v)
FINGER DEXTERITY

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HAML Structure

HAML

- Application Description
- Haptic API Description
- Haptic Rendering Description
- Graphic Rendering Description
- Haptic Data Description
- Haptic Device Description
- QoE Description

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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

Haptic Learning Center
(Language: Japanese, Selected Symbol: ho)

Preview
Workspace

Control Panel
Enable: Haptics Graphics
Guidance: Full Partial None
Sound: Play

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http://www.mcrlab.uottawa.ca
Mohamad Eid, Mohamed Mansour, and Abdulmotaleb El Saddik

A Multimedia Handwriting Learning Tool

Université d'Ottawa | University of Ottawa
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)

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A Biometrics-embedded System Based on Haptics for User Authentication in Virtual Environments
### Why Use Haptics?

<table>
<thead>
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<th></th>
<th>Time</th>
<th>2D Position</th>
<th>3D Position</th>
<th>Force</th>
<th>Pressure</th>
<th>Angular orientation</th>
<th>Torque</th>
<th>Velocity</th>
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Introduction

Haptic Systems

Biometrics Systems
Related Work: Behavioral Biometrics

Dynamic Signature Verification
[Fernandez et al., 2005], [Plamondon, 1990], … plentiful

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

Please Draw Your Paragraph On The Grid

Bank of Ottawa

$1000.00

Please sign your name at the green rectangle. Five attempts are allowed in rectangle.
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

- Single Point Interaction
- Multiple Point Interaction
- HAPTIC DEVICE

Functional Approach:
- DTW (Dynamic Time Warping)
- Spectral Analysis (FFT)

Parametric Approach:
- K-Means
- Majority Class.

Information Content:
- Euclidean Distance
- Neural Networks
Authentication with Analysis of Information Content

**Verification**

- Kmeans
- PCA
- Spectral
- DTW
- Euclidean
- NN

Equal Error Rate
- EER=4.5%

**Identification**

- Spectral
- DTW
- Euclidean
- NN

Performance
- EER=27%
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.

<table>
<thead>
<tr>
<th>Subject</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average ‘Z’ Distance for both trials</td>
<td>271</td>
<td>591</td>
<td>436</td>
<td>467</td>
<td>333</td>
</tr>
</tbody>
</table>
Thank you

Merci

Vielen Dank

Teşekkürler

Hvala

Gracias

Dankie

Obrigado!

شكرًا

Grazie

Bedankt

Köszönettel

Díky