Haptic Techniques for Media Control

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Scott Snibbe, Karon MacLean,
Rob Shaw, Jayne Roderick,
William L. Verplank, Mark Scheeff

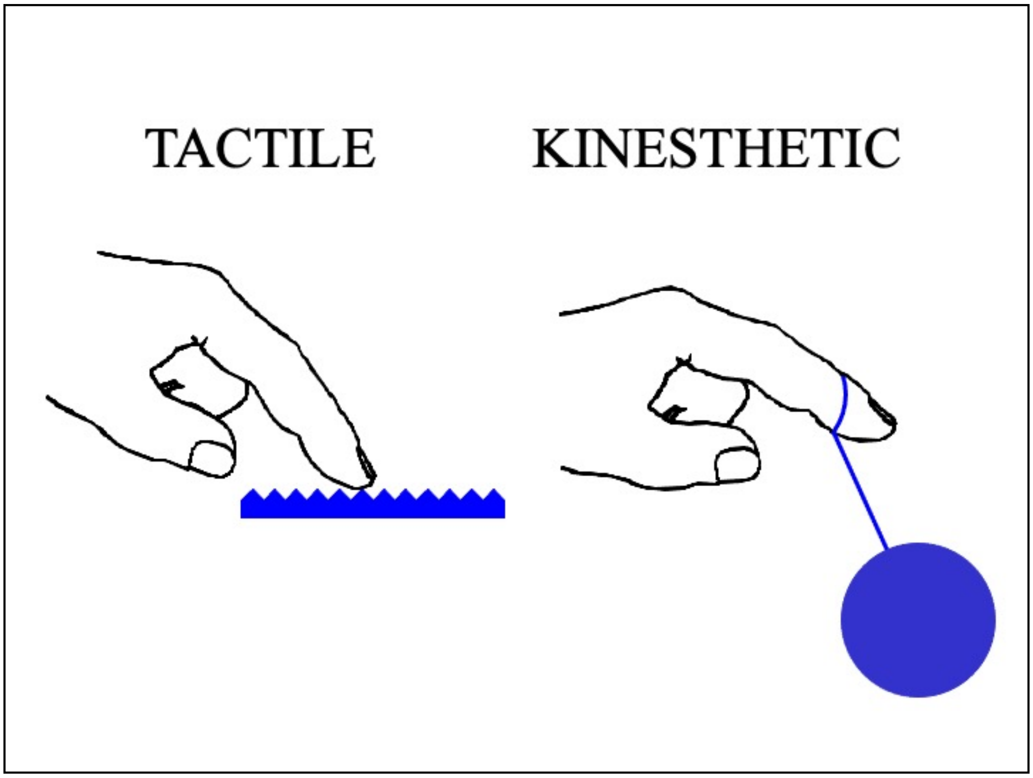
“[Our body] applies itself to space like a hand to an instrument, and when we wish to move about we do not move the body as we move an object. We transport it without instruments as if by magic, since it is ours and because through it we have direct access to space.”

-Maurice Merleau-Ponty

Your body is a direct interface, completely transparent

Try to engage direct perception rather than conscious thought

by bringing interfaces to the intuitive level of the body, we can theoretically both increase control functionality and decrease learning time and ease-of-use



Haptics – was the perceptual study of touch

Now in last 20 years, an engineering discipline, engaging our bodies' muscles and touch receptors

2 aspects to haptics :

tactile is small scale surface features including roughness, wetness, heat

Kinesthetic is "visceral" – gross properties of objects acted on by forces – mass, velocity, force

Media originate in physical form

That physicality had side-effects – we can use our body to manipulate the media

e.g. DJs cut, scratch, fade, speed up and slow down – a physical performance akin to the mastery of the piano

Expert DJs can even feel the sound through the base of the turntable, or cartridge – getting sound through their fingers to match beats

The physicality can be described as a *dynamic system* – the complete system of playback device and physical media and its physical characteristics – how the system behaves when manipulated through forces exerted in the environment

Digitalization of sound means the disappearance of corporeality – DJs stubbornly cling to noisy, dirty records because of their manipulability

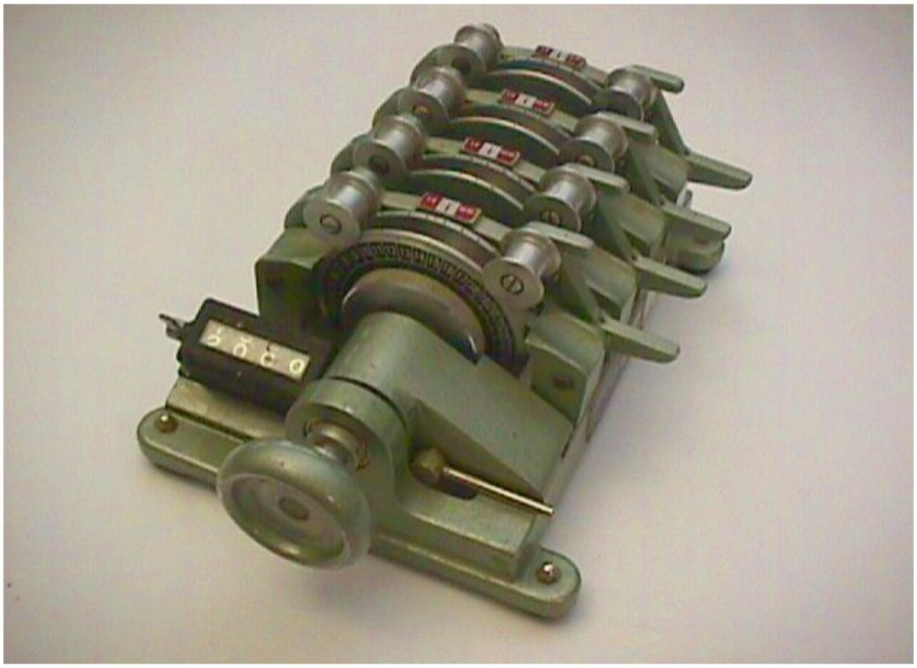
Steenbeck editing table

Film is a physical medium – editors can see frames, pull out strips of film, measure against their body to determine the duration, hang hundreds of scenes beside them while working

Furthermore, “drawbacks” of having to physically review footage create familiarity w/ material and create more chances for happy accidents, also allowing time to reflect on decisions

With digital media, instant access means no time to reflect and “deleted” footage is forever gone

Walter Murch, editor of Apocalypse Now, The Conversation, etc. laments this loss of physicality and claims it greatly works against the medium “In The Blink of an Eye”



Gang synchronizer

Physically manipulate sound and image simultaneously with 2 film reels – great inspiration for this work – very pleasing sensation working with this heavy iron device

Videotape is halfway – we have no physical touch, but we still have the physical duration of the tape

Finally, with non-linear video and audio, we completely lose both the touch of the media and the heft of it

we perceive and interact with a 3D world, this is a device for simulating the world (like probing with a pencil)

Important sub-set of haptic applications are 3D – CAD, medical simulation, simulating musical instruments

These applications focus on rendering the model

Our work is a step removed – interacting with a dynamic system that abstractly CONTROLS the model (media)

3D can be seen as too much too soon for haptics

Cost increases exponentially with each additional degree of freedom

We chose to look at low-DOF devices

Design Principles

- Continuous over discrete control
- Information delivery through touch
- Dynamic systems for control
- Modeless operation
- Tight application and interface communication

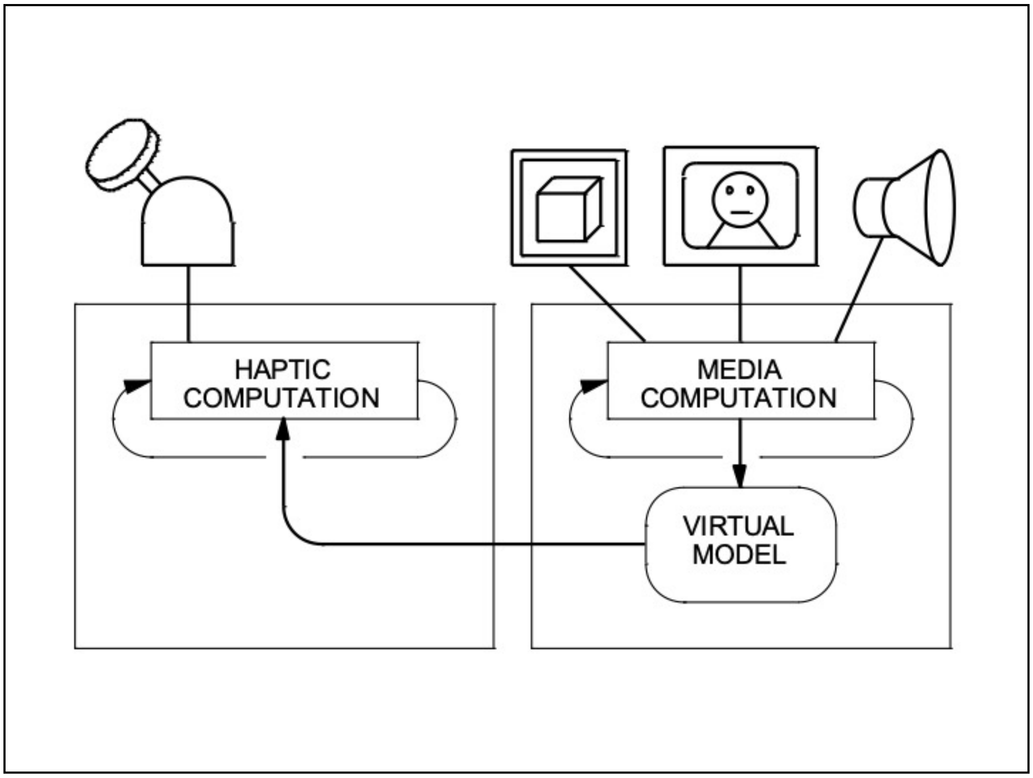
Continuous/Discrete : real-world button or handles. Buttons are cheap and simple. Dials are infinitely variable

Information through touch: Visual interfaces compete for attention – move control to body to focus on media

Dynamic System: An abstract layer between user and task. This is the leverage a paintbrush or editing table offers over your fingers

Modeless Operation: Modes require a mental accounting of your current state. Modeless tools are trustworthy – e.g. your steering wheel – you don't flip a switch to allow it to change the radio station!

Application/Interface communication: To achieve the goal of control and directness, we need to locate dynamic model with the haptic controller. This presents some architectural challenges – toolkits that treat the haptic device as an I/o peripheral

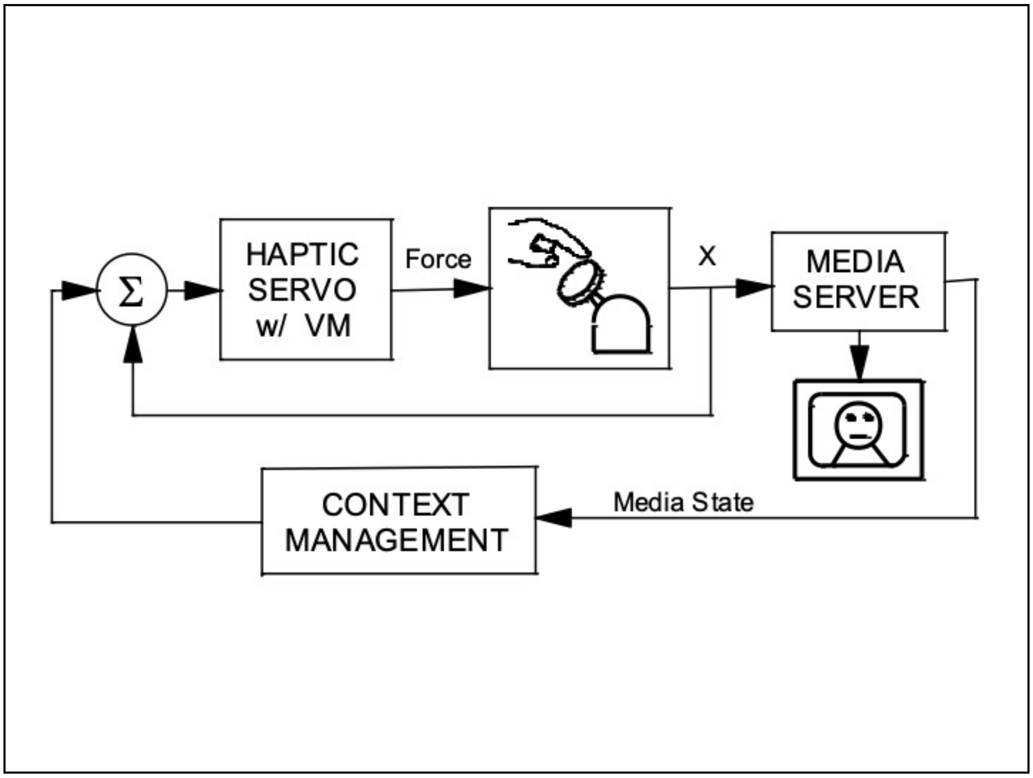


Peripheral model for haptic device

Like mouse or keyboard

Application dominant interface

Haptic device is seen as “display”



Relocating the model to haptic device since that is the tightest connection with user

Device is now not just a display, but a non-linear element driving the application

Requires relocating the virtual model to the haptic processor (can be in same computer or dissociated)

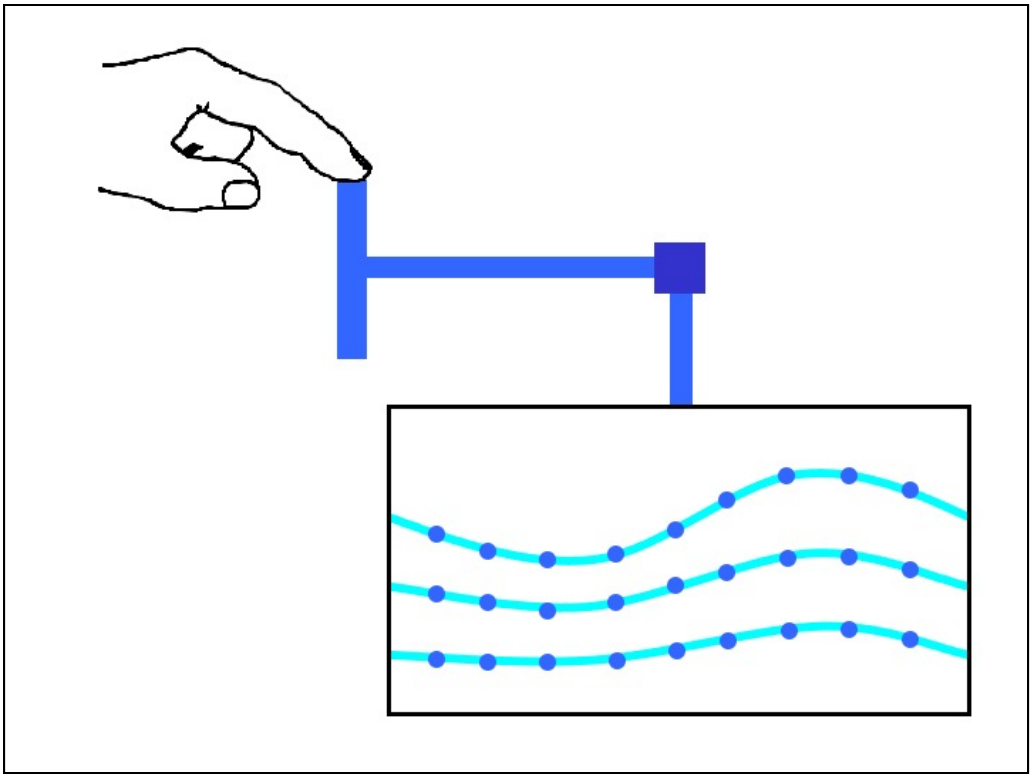
Requires architectural changes – see ASME paper 1999

Low-DOF manipulation – justification

By sensing one dimension you can infer other dimensions

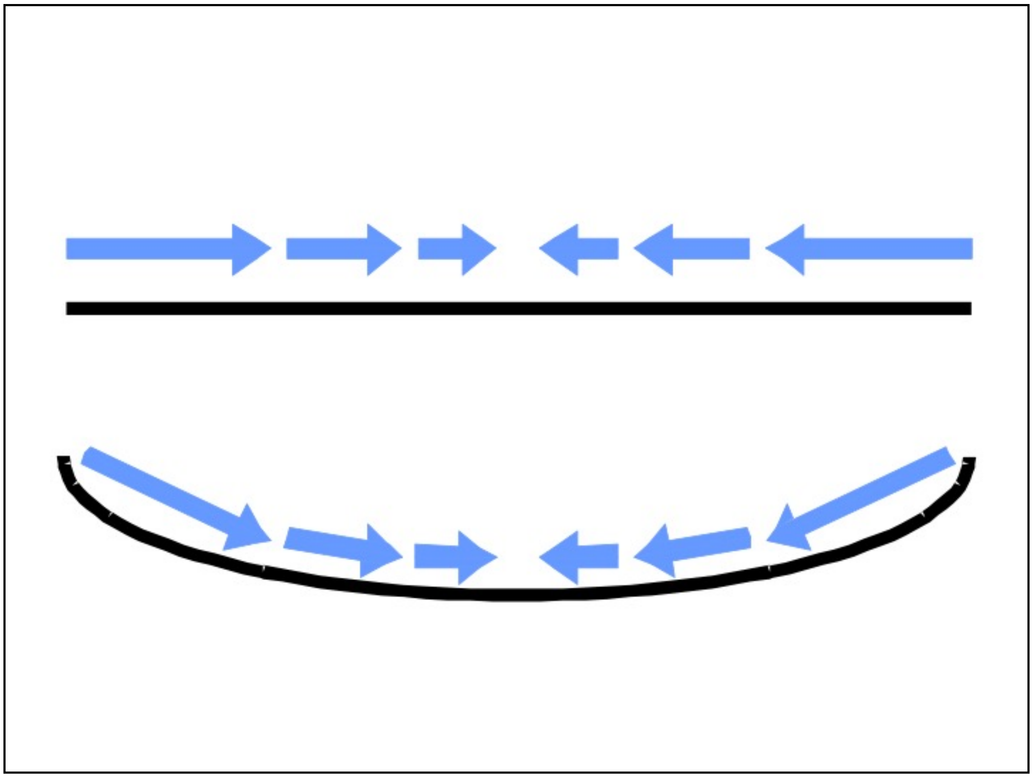
e.g. driving a car – you can infer driving over grass, dirt, holes, hitting objects, much information

Similar insight to other fields – physics: state space – projecting a multi-dimensional system down to a single dimension still preserves valuable information about the system.



Thus, we can simulate the connection of a low-DOF device to a high-DOF simulation and valuable information will get to the user

Particularly if enhance by visual and auditory stimuli, which are much stronger than the haptic sensation

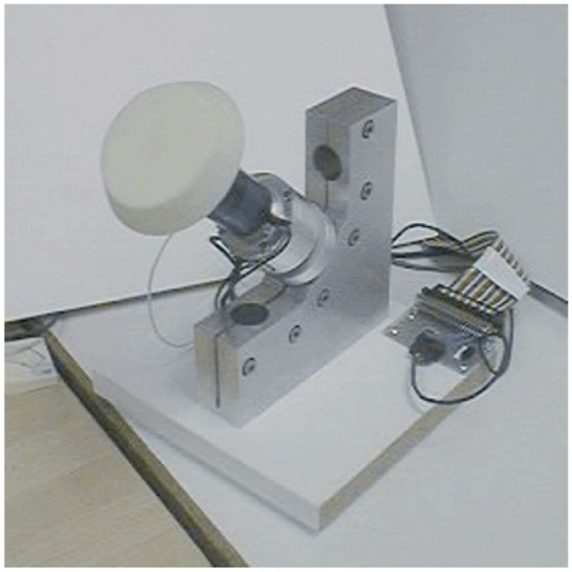


Orthogonal force actuation “Force shading”

Project components of higher-dimensional force onto lower – users perceive the higher-dimensional shape

e.g. you feel like you fall into a basin, when you are just drawn to a point

Shrinivasan @ MIT



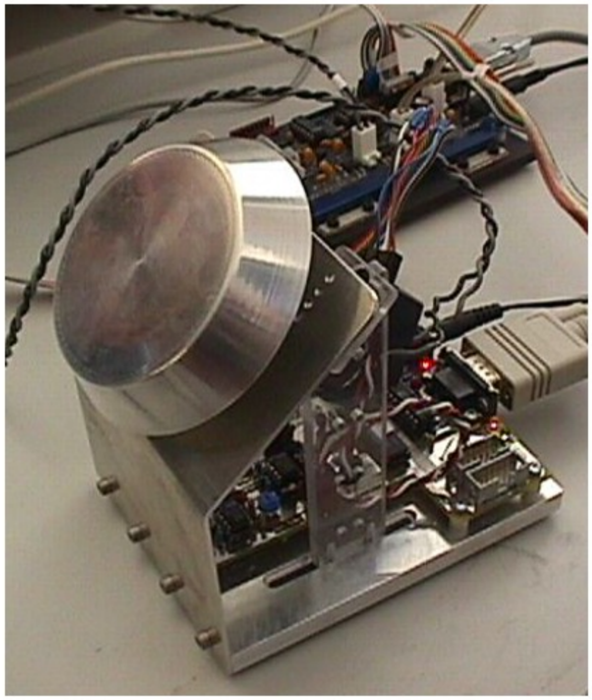
Orthogonal force SENSING – actuate in 1 DOF, but sense in > 1 – can be used, for example, to give users illusion of selectively engaging with the system

BIG WHEEL – The Rolls Royce haptic device

6-axis force sensing, 90Watt motor, 4000-line optical encoder – ultra-high quality

Can be mounted in 3 orientations

Prototype behaviors to decide which axes to leave out in specific applications

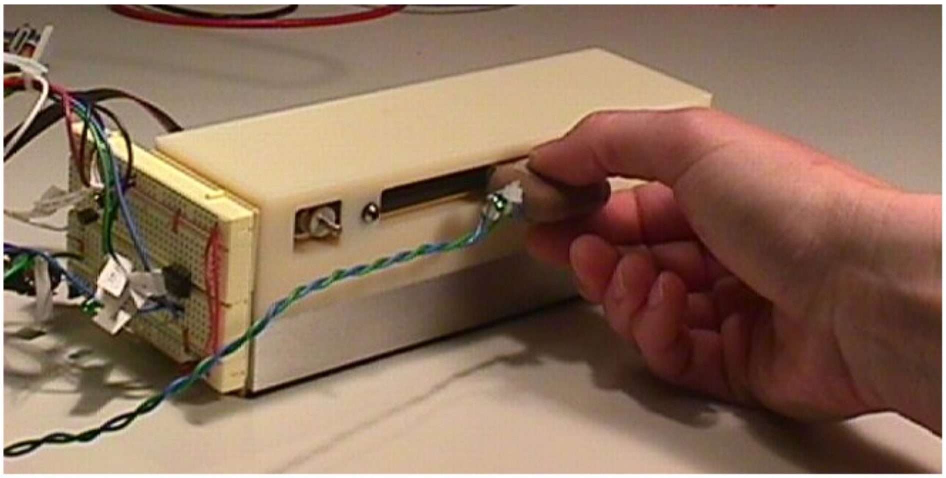


Cheap force sensing wheel

How low can we go

Inexpensive motor, force sensing using displacement of arm using hall-effect & optical sensors

More exemplary of consumer-level technology



Slider: Absolute positioning

Use physical memory – (e.g. controls of a car). Haptic landmarks

Small maxon Motor/encoder driving a belt – some compliance, but still worked well

Force sensor (FSR) on handle

Brake – Passive haptic display

Only remove energy from a system, all the energy comes from the user

No surprises, scares from users

Low cost, power,

No closed-loop control – have to use visual or auditory illusions to compensate which I will mention

Tagged Handles

Tagged Handles

Haptic devices can change behavior without changing appearance!

This scares some users, but more importantly, makes a system unpredictable based on its appearance

Also, different handles are better for different tasks

Tagged handles – behavior determined by shape or texture of handle – creates modeless system – state is physically implicit

Rock-n-Scroll

Game-like interaction – one hand

Actuated wheel, with passive sprung 2^{nd} axis

Hand size, ergonomics

Controlling Media with Haptic Interfaces

- Haptic Navigation & Control
- Haptic Annotation
- Functional Integration

3 main application areas

Navigating digital media streams

Physical marking of content

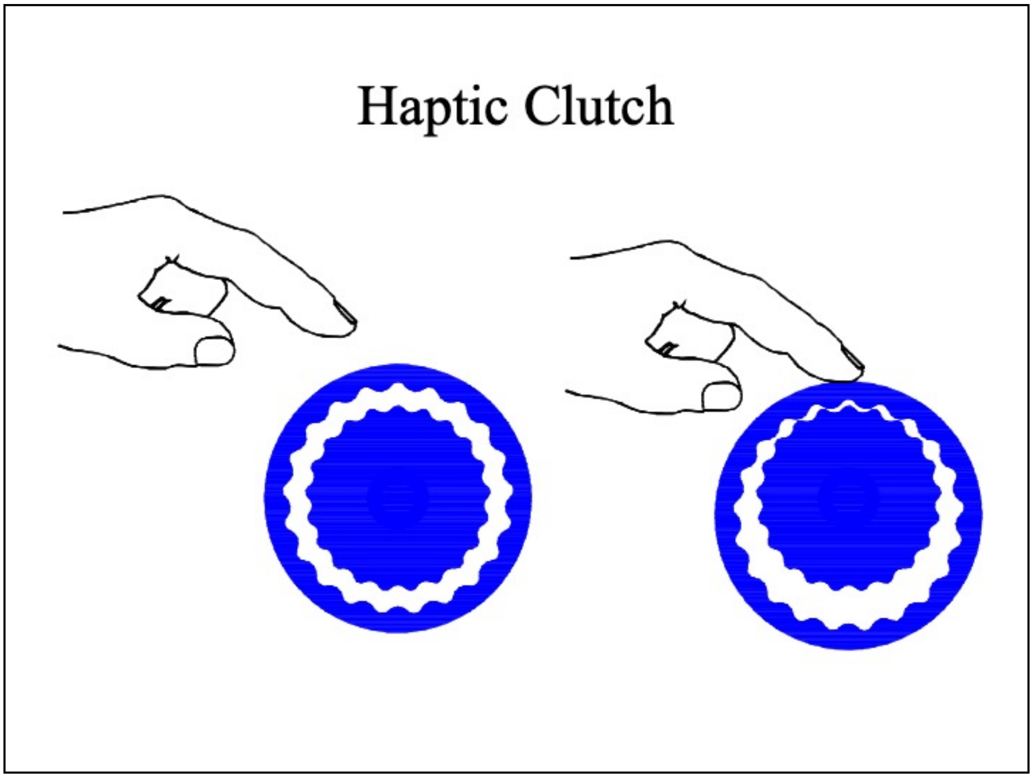
Incorporating multiple metaphors & techniques for real-world applications

Haptic Navigation & Control

- Browse and navigate channels or within a show/movie (like TiVO)
- Problems: Rapidly find a channel, show, scene, frame

Means for finding footage with videotape – jog/shuttle wheel

One task is to replace the jog/shuttle for digital media, enhancing functionality and effectiveness



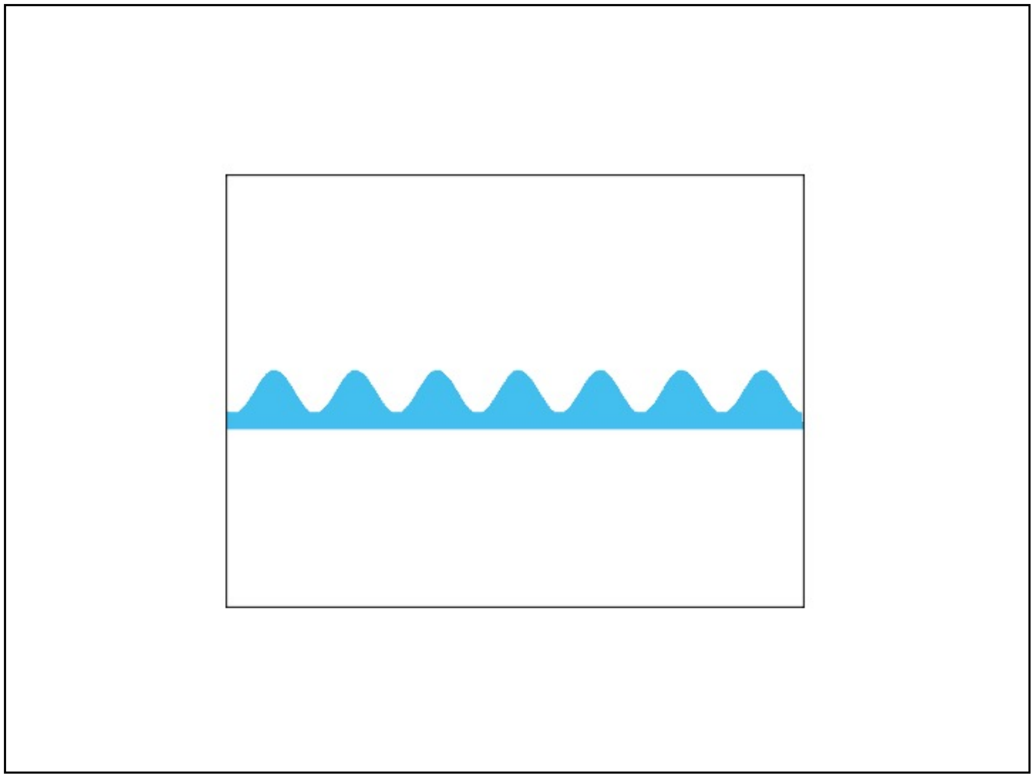
Haptic Clutch

Clutched engagement of a concentric pair of wheels

Pressing down on outer wheel, creates engagement with intertial inner wheel – 2nd axis is force-sensed, 1DOF device

Bumps correspond to features in media, e.g. frames – feel each individual frame

Can couple, or run free – after imparting velocity to inner wheel, a physical force, sometimes large, is required to stop footage – re-imparting physicality to the medium



Clutch interactive program

Helps to understand the simulation

Inaccuracies:

in our implementation it is FORCE not displacement that engages

Your body provides compliant damping for the probe that makes the system more stable

Key observation : body can stabilize unstable or oscillating dynamic systems – we naturally move to absorb energy, like riding a horse

Haptic Clutch Dynamic Model

The equal and opposite force transmitted between the virtual inner and real outer wheel, dependent on orthogonal force:

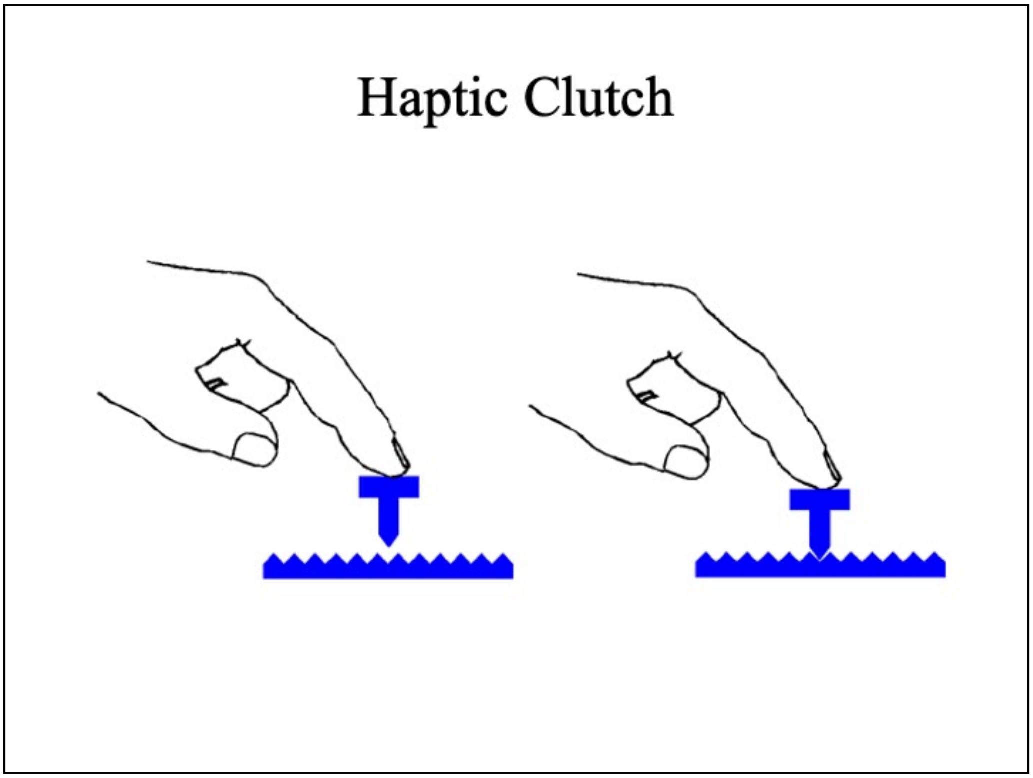
$$F_{clutch} = f_{\perp} h \sin(x_o - x_i)$$

Simulate the virtual Newtonian inner wheel:

$$0 = M_i \ddot{x}_i - F_{clutch}$$

The force applied to the actuator (DC servomotor):

$$F_{act} = B_o \dot{x}_o - F_{clutch}$$



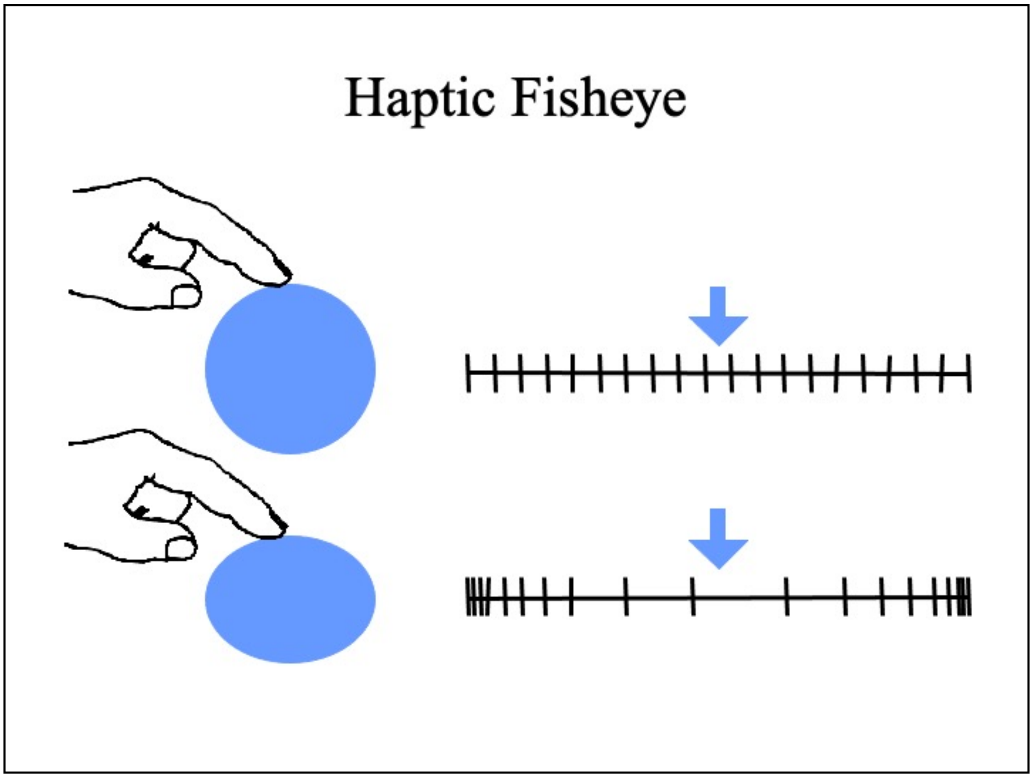
VIDEO

Unique challenges in applying clutch

Audio must be pitch-corrected for comprehensibility at differing speeds (e.g. voicemail)

We also tried 2d applications – direct manipulation tasks like painting or sculpting were less compatible, because the clutch forces interfere with interaction forces of medium

Clutch does seem like it could be well suited to CAD



Haptic Fisheye

Continuously varying haptic resolution – here based on orthogonal pressure

Analagous to graphical or photographic fisheye views – immediate access to detail while seeing greater context

With video – rapidly browse an entire movie while still having access to individual frames continuously without switching mode

Haptic Fisheye Dynamic Model

The force applied to the actuator is a sinusoidal linear relation to the position within the media stream:

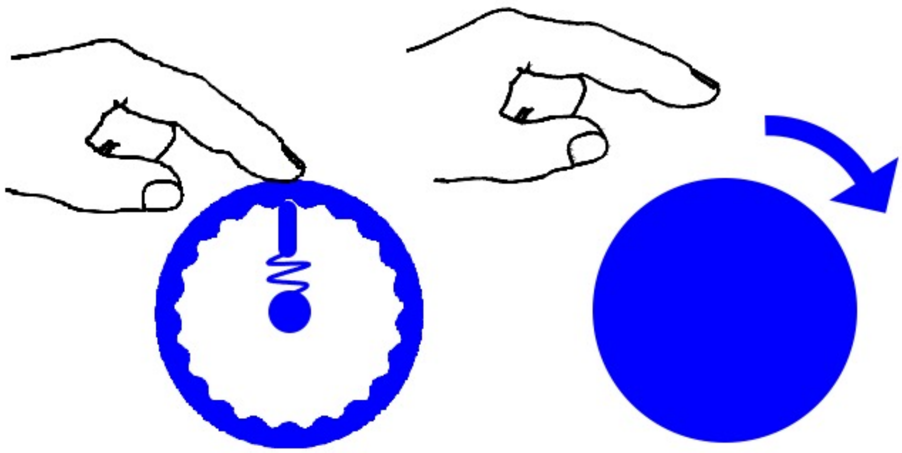
$$F_{act} = h\sin(\pi(x_m - \lfloor x_m \rfloor))$$

Position within the media stream is determined by a non-Newtonian system. Velocity of the simulated media position is directly tied to the velocity of the physical wheel, scaled by the orthogonal force:

$$\dot{x}_m = f_{\perp}\dot{x}_w$$

VIDEO of fisheye

Frictionless Shuttle



Frictionless Shuttle

One of the few where wheel moves when not touched by user

While being touched, gives evenly spaced detents (e.g. per frame of video w/ 30 per revolution)

When let go, the wheel stays spinning at the speed let go – without friction

Maintaining strict correspondence between wheel and constant speed video

Like the "shuttle" control of video, except still provides ABSOLUTE rather than relative control and is thus more precise

Some of the magic you can do w/ haptics

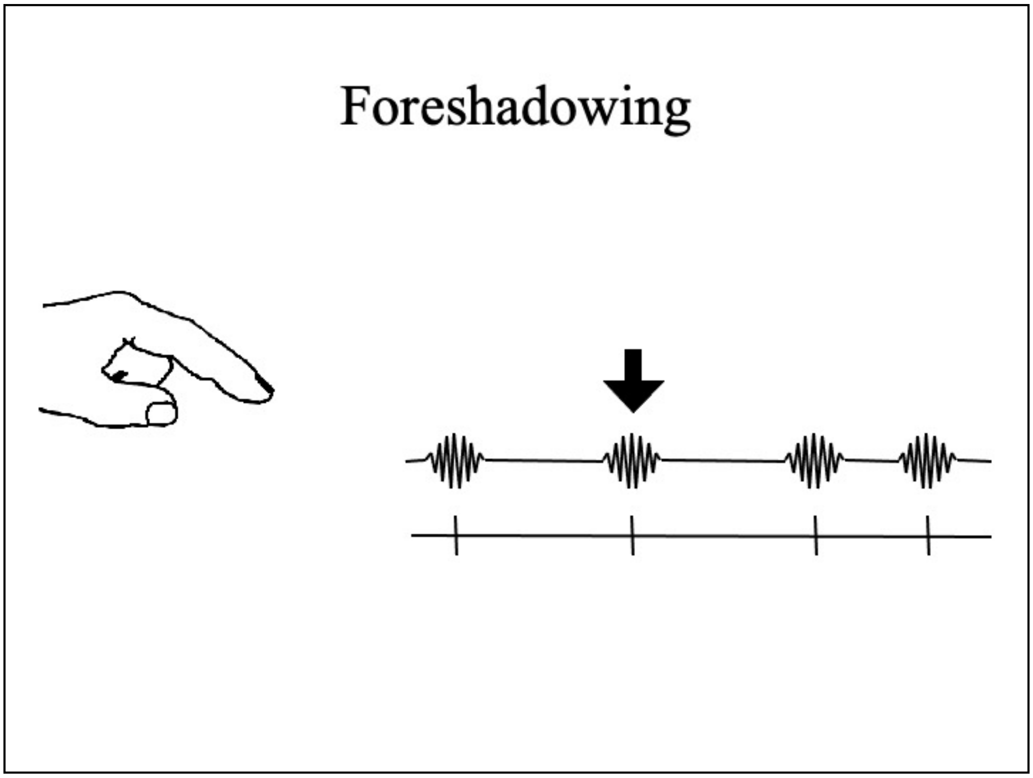
Touch can be determined w/ force sensor or by measuring error in PID controller, capacitance is another way of sensing

Implementation – detents like before and velocity w/ PID controller – standard control theory

Haptic Annotation

- Mechanical (songs, albums, frames, scenes)
- Automatic (action, color, emotion)
- Human (actor, genre, cross-references, time, space, location)

- Methods: force, texture, frequency, rhythm
- “hapticons” – abstract mappings from feeling to content



Foreshadowing

Visual marks are always overshot for the simple reason that you have to see it before you begin to stop

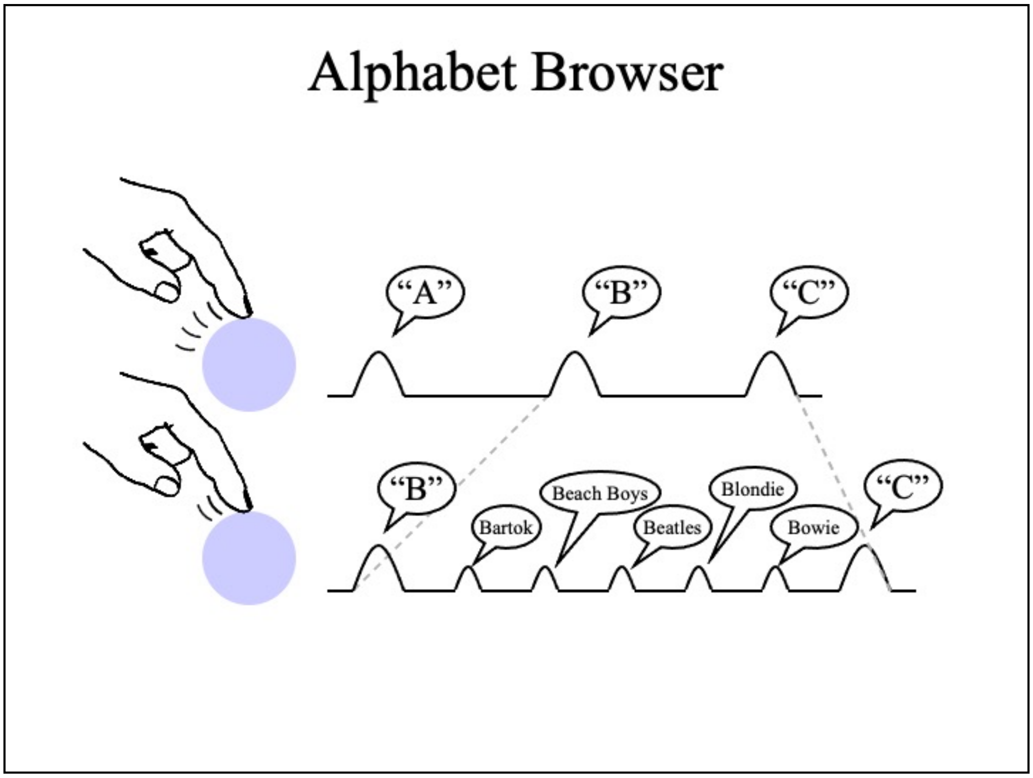
Foreshadowing allows one to get a haptic cue BEFORE a mark appears

This application uses the knob like a traditional spring-centered shuttle wheel

Texture gradually increases as you approach a mark

New marks can be added by a firm press

Active haptic nudges did not work, since they interfered with the shuttling



Alphabet Browser

For browsing through large media collections – like a big MP3 library

Particularly with portable devices, screens are small, hard to read, and show limited information

Haptic knob + auditory display = eyes-free browsing of thousands of titles

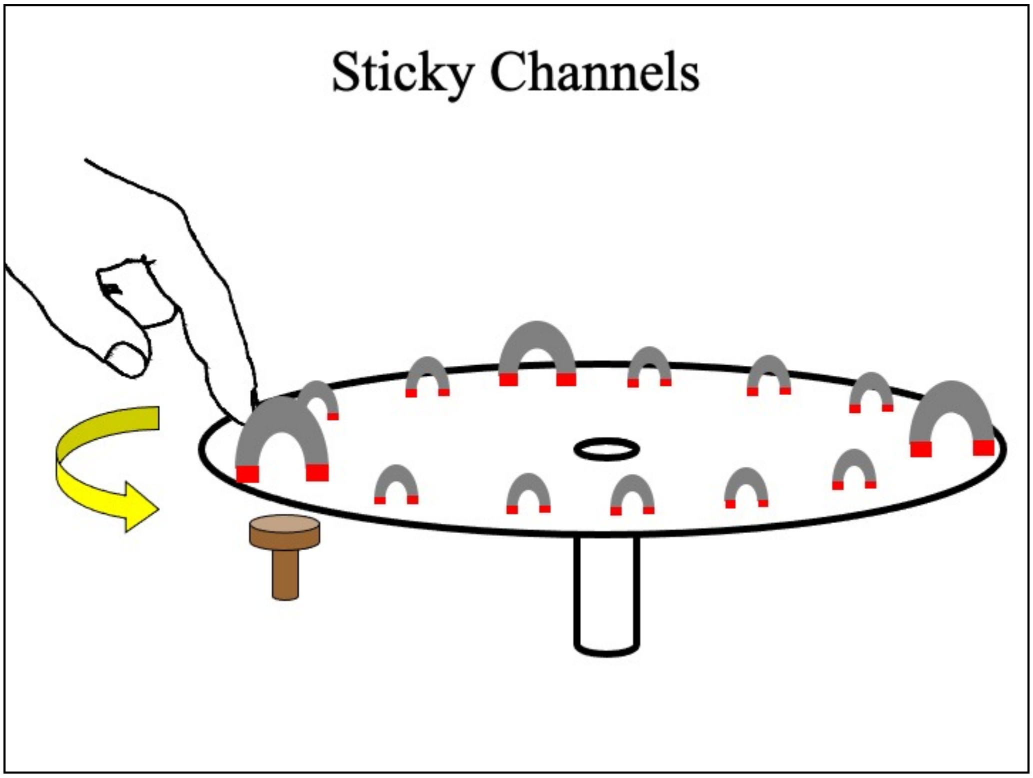
Rapid – letters, Slower – artists, Slower – titles, etc. Haptic cues

Also implemented for voicemail

Haptic feedback increased accuracy over audio alone

Other applications : phones, car radio, email on wireless devices

VIDEO



STICKY CHANNELS

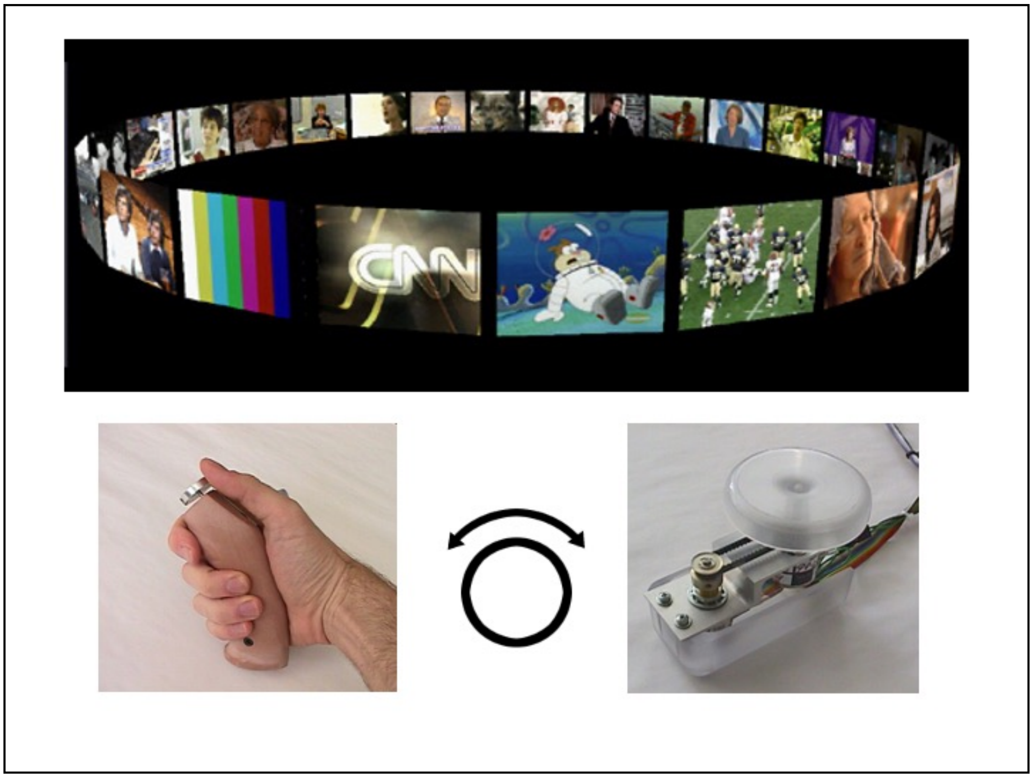
Sticky channels behavior – more force on favorite channels, to find them intuitively

Like wagon trails – ruts that get worn in – can be determined based on frequency of visit, or manually annotated

Applications: TV, video, voicemail, MP3

Informal studies of heavy TV viewers showed positive responses

Slider w/ absolute positioning helped w/ redundant spacial cue, but was not necessary



VIDEO CAROUSEL

Obvious correspondence between the mental “ring” of channels and the dial of these devices

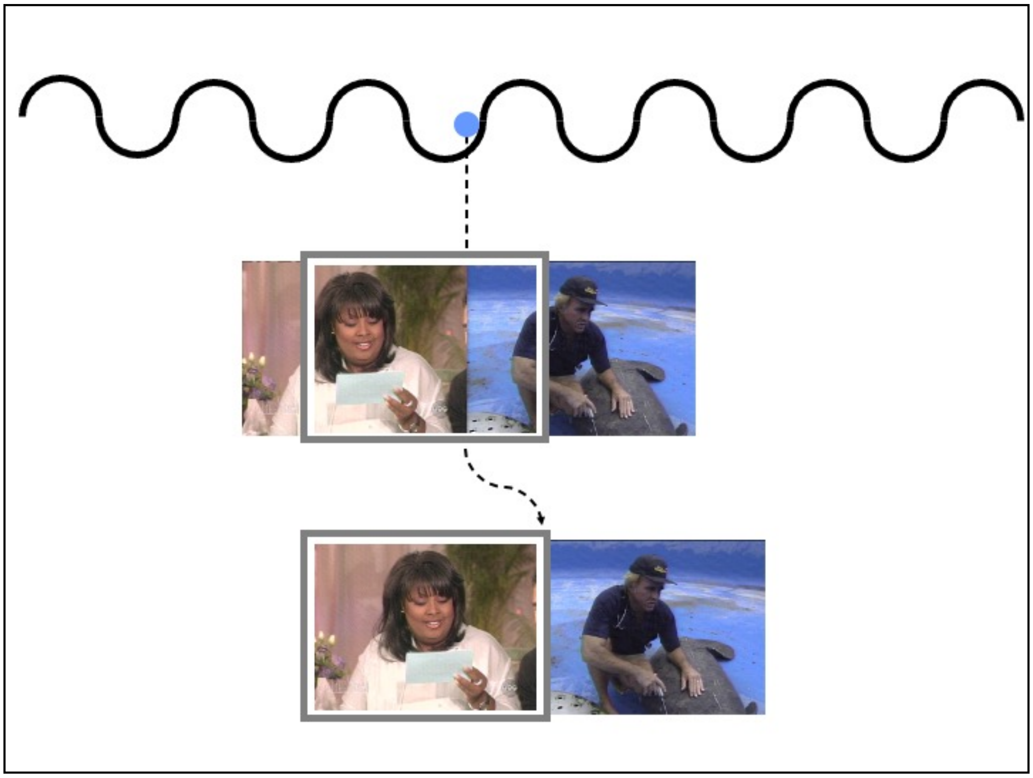
Make mental representation visual

Combine with sticky channels

After stopping, channel zooms into fill the screen

(Rock-n-scroll & brake)

VIDEO

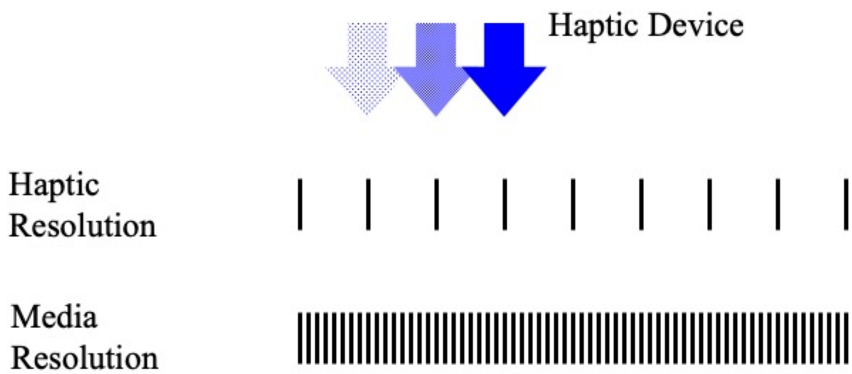


Visual correction for open loop control

With break, we could not force the device to frame boundaries, so we visually correct when user does not stop on frame boundaries

Convincing illusion worked for all users tested (about 50 ppl from outside our group but within Interval)

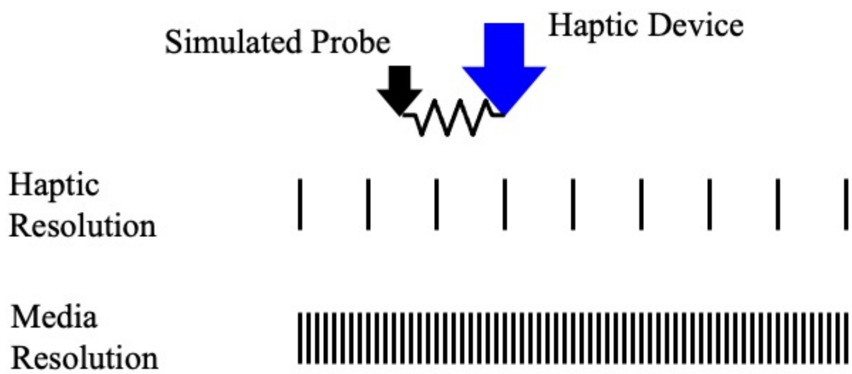
Aliasing Problems



Some media (like audio) is extremely fine grained

Problem – haptic device resolution is too course

Aliasing Solution – Virtual Probe



Virtual Probe – solution to aliasing

Probe is simulated at high refresh rate – attached by spring to real probe

Thus it can reach the inbetween spots – only dependent on numerical accuracy and temporal frequencies

Tagged Handle Wheel

Tagged handles – applications

Universal remote replacement – 5 functions: channel, video browsing, audio level, etc

Pushbuttons change media target – MP3 library, channels, movie

VIDEO

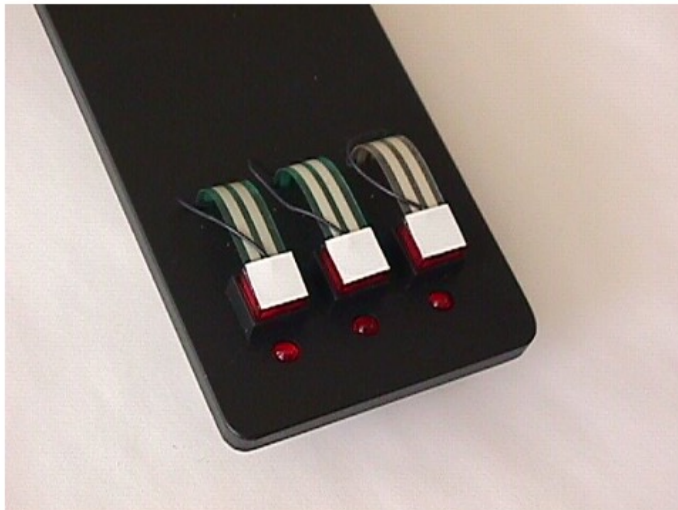
Problem – top-mounted buttons can't leverage physical memory, since the wheel moves

Solution – mount wheel inside device

The side you engage on determines the behavior and we still only have one motor

Did not have a chance to implement, but studies found this the most desirable form factor

Preview Button



Preview Button

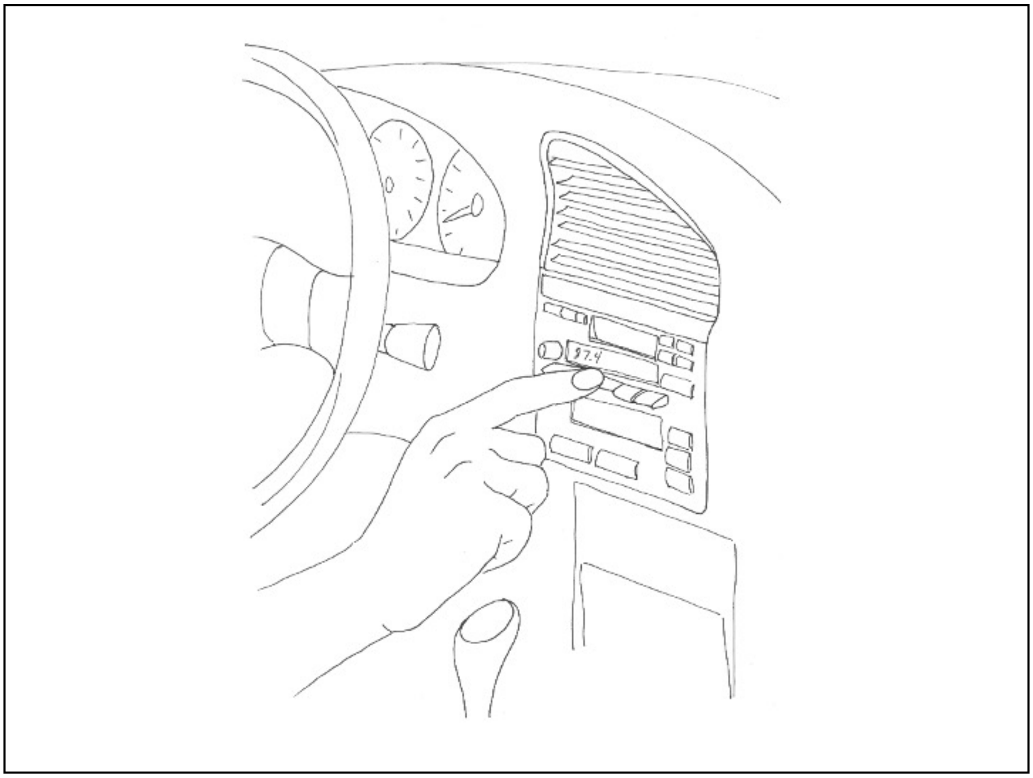
Pressure sensors on buttons allow the preview of what the button will do

e.g. radio – light touch fades in the sound slightly, firm push engages

Also can be used for TV – picture-in-picture

Haptic feedback can annotate type of media (e.g. rock, classical). This version had no haptic feedback

VIDEO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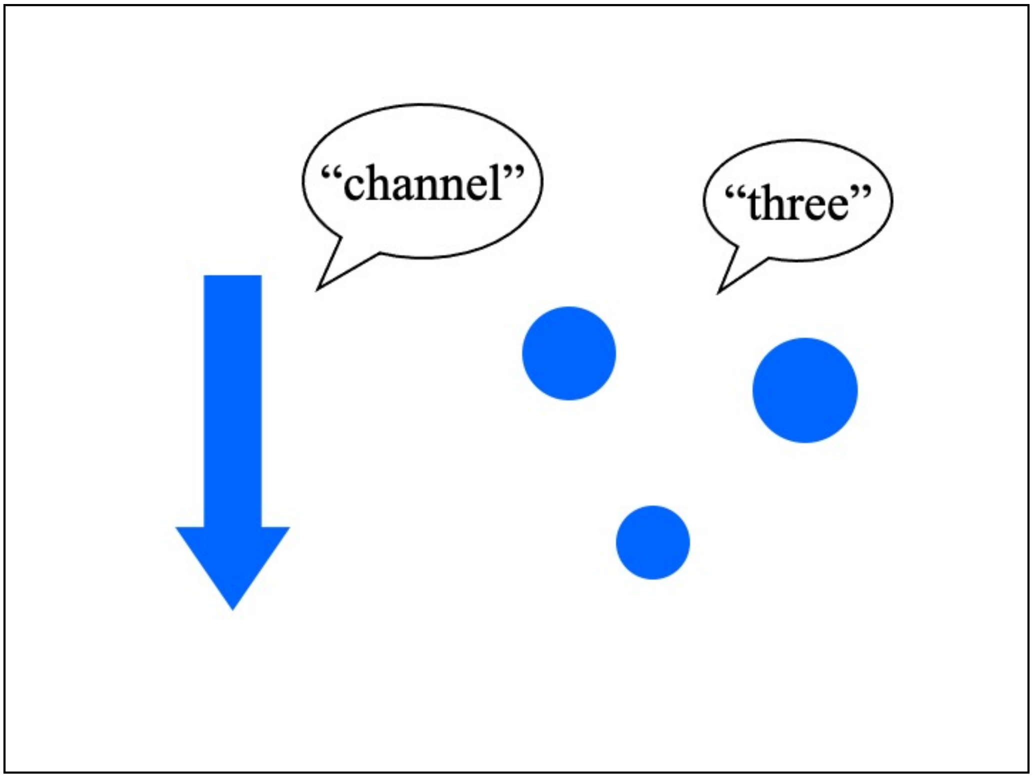
Multi-touch pad

Multi-touch pad

How to create a language with multiple fingers for manipulating media



Gesture language – verb/object

e.g. channel 3

Play, stop, etc.

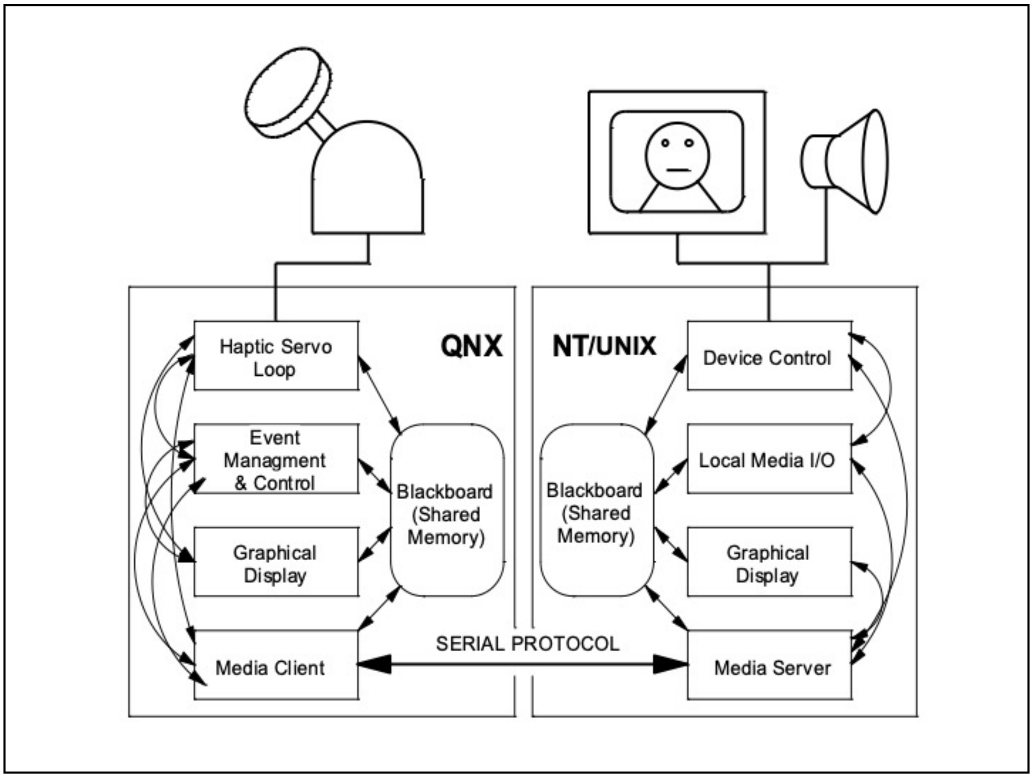
VIDEO

Observations

- Functional integration + simplification
- Quality of experience based on experience and intuition of designers/engineers
- Hand-crafting is essential to quality
- Texture works better than force for annotation
- Careful physical design of devices to invite proper use
- Compliantly mounted devices reduce salience and controllability

Successful in both integrating functionality and simplifying interface – only small, non-rigorous sample for study

Relied on non-rigorous methods for creating experiences – we could use more formal standards & research


QNX
NT/UNIX
Haptic Servo Loop
Event Managment & Control
Graphical Display
Media Client
Blackboard (Shared Memory)
Blackboard (Shared Memory)
Device Control
Local Media I/O
Graphical Display
Media Server
SERIAL PROTOCOL

Future work

- Power consumption is biggest obstacle to widespread use
- Encapsulate new metaphors into standalone devices (e.g. fisheye or clutch)
- Define and develop haptic language
- Take active haptic inventions and create new passive mechanical systems

Haptic Language – what are nouns, verbs, what are mutually exclusive signals http://www.snibbe.com/scott/research.html

UIST 2001 Paper & Clutch Applet
Prior haptics papers

Power Budget for Rock-n-Scroll

Actuation
Scroll motor, jammed to maximum torque in our application
400 mw power
Scroll duty cycle, estimate **25%**
100 mw power during scrolling

Computation
10ma, 5V 50 mw

Miscellaneous
5ma, 5v 25mw

Battery capacity
1700 mwh for two AA nicads
divided by
(**100mw+50mw+25mw**)

gives **10 hr** of continuous scrolling.

- Power cradle
- Early warning (like phone)
- Graceful degradation (still works unpowered)

Cost Analysis
Shipping Products 1999/2000

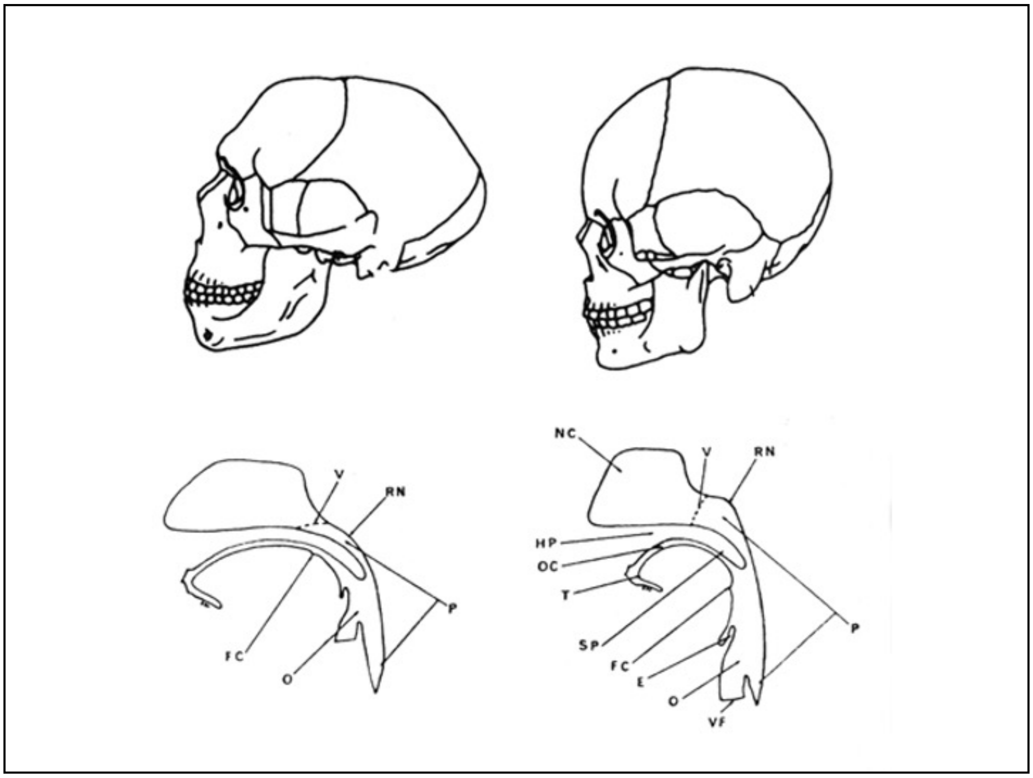
Immersion joysticks and mice

couple motors with pots
microprocessor
circuit board
many plastic parts
Production in 10,000X
≈$100

Furby

motor
1 mip microprocessor
circuit board
many plastic parts
sound, light sensing
several switches
Production 10,000,000X

≈ $30



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