Haptic Movies

Using haptics to improve the cinematographic experience

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Outline

1. My background
2. Haptics
3. Tactile
4. Kinesthesia
5. Hapseat
6. HFX Studio
7. Conclusion

My background

Background in HCI

2010 Master Student/Research associate at Inria, Bordeaux, France

→ Human-Robot Interaction

2011 Ph.D. Student at Technicolor / Inria, Rennes, France

→ Haptics

2014 Researcher at Technicolor, Rennes, France

→ Virtual Reality / Haptics

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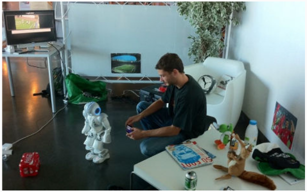

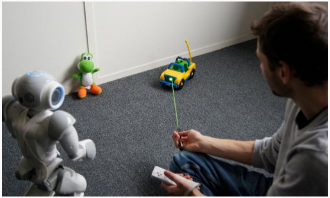

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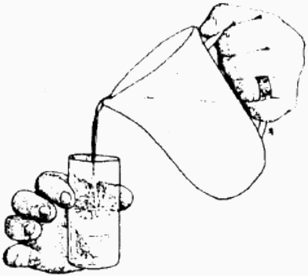
Haptics

Definition

- → Science of Touch
- → From the Greek *haptesthai*: to catch, to touch
- → Encompasses tactile and kinesthetic phenomena

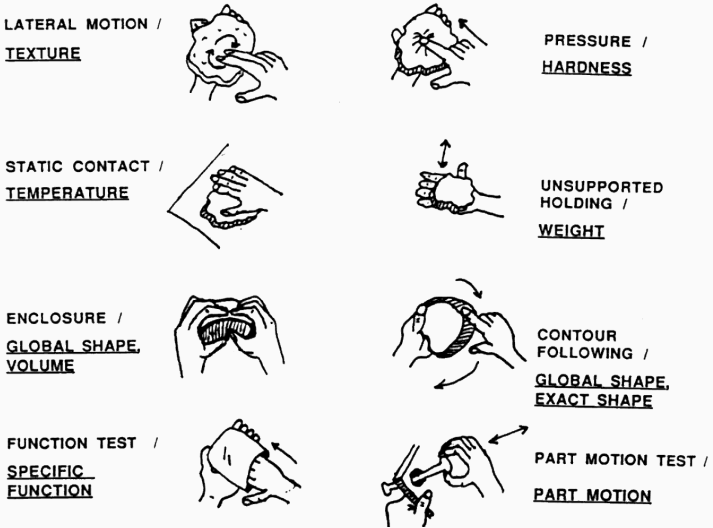
Position
Movement
Force
Resistance

Texture
Vibration
Friction
Temperature



[Johansson and Westling, 1987]

Haptic exploration

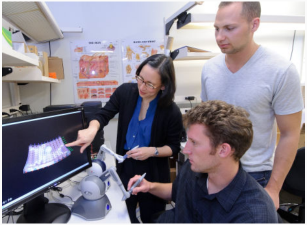


[Klatzky et al., 1990]

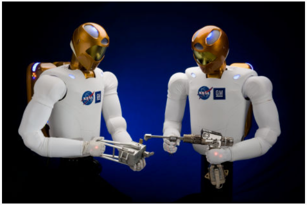
Applications

Entertainment

Health



Education

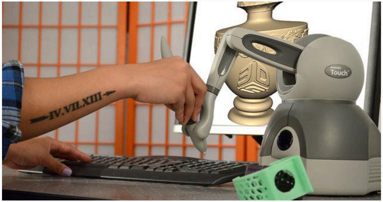


Teleoperation

Companies

- 3D Systems
- Force Dimension
- Immersion
- CJ 4DPLEX
- D-BOX
- Ultrahaptics
- Technicolor

3D SYSTEMS



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Companies

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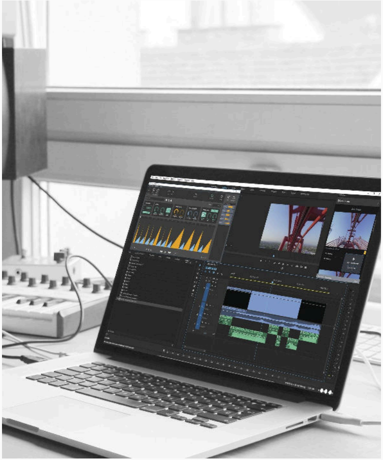
immersion®



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Companies

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D-BOX

Companies

- 3D Systems
- Force Dimension
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- Technicolor

ultrahaptics

Companies

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- Ultrahaptics
- Technicolor

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Workflow

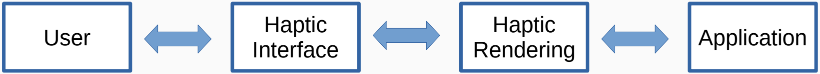


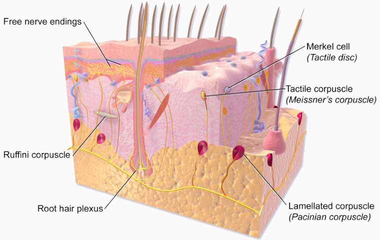
Figure: workflow for haptic applications

- User: controls haptic interface and feels haptic feedback
- Haptic interface: interface between real world and application
- Haptic rendering: algorithm that computes forces to be rendered
- Application: virtual environment or distant robot

Tactile perception

Tactile Perception

- → Perception provided by the skin
- → Mechanoreceptors
  - → Merkel cells
  - → Ruffini corpuscles
  - → Pacinian corpuscles
  - → Meissner's corpuscles
  - → Root hair plexus
  - → Free nerves endings

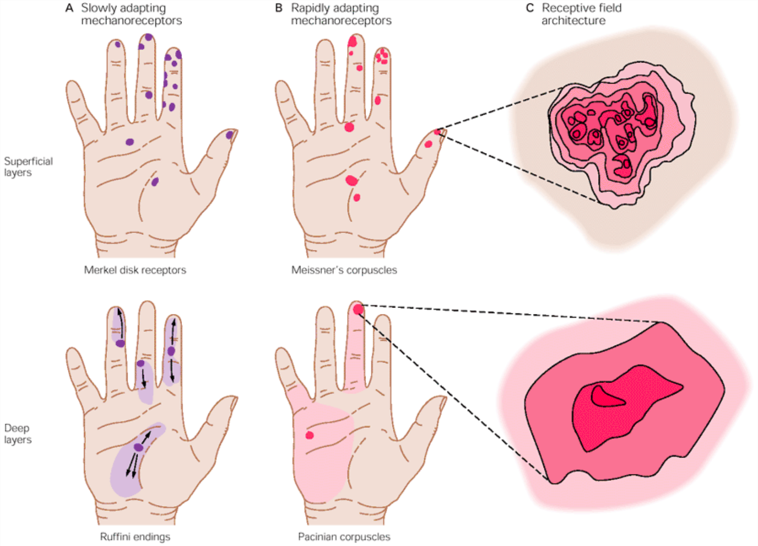


Tactile perception

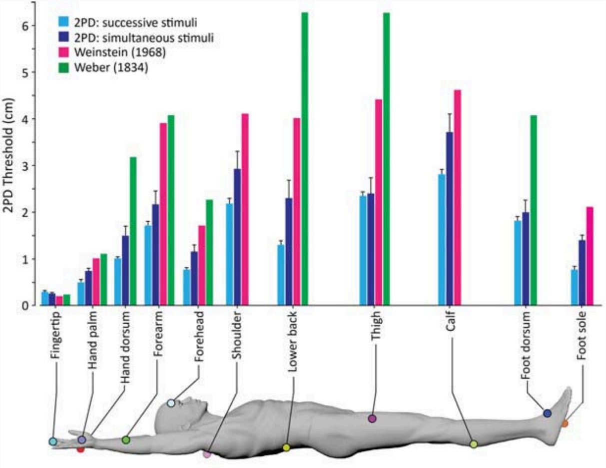
Nom	Type	Stimulus frequency	Receptive field	Role
Merkel cells	SA-I	0-10Hz	Small	Edge, pressure
Ruffini corp.	SA-II	0-10Hz	Large	Skin stretch
Meissner corp.	FA-I	20-50Hz	Small	Pressure
Pacinian corp.	FA-II	100-300Hz	Large	Deep pressure, vibration

Table: Mechanoreceptors characteristics

Tactile perception



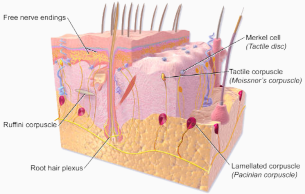
Tactile perception



[Mancini et al., 2014]

Thermal perception

- → Thermal reception is due to free end nerves
- → Not yet well understand
- → Thermoreceptors detect variations
  - → heat receptors ([30,46 $^\circ C$])
  - → cold receptors ([10 and 35 $^\circ C$])



Tactile illusions

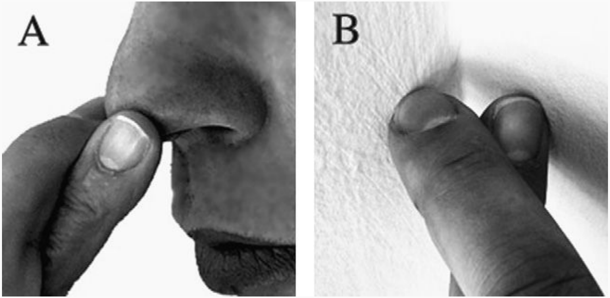


Figure: Aristotle's illusion. When fingers are crossed and eyes closed, two surfaces are perceived instead of one (A). The opposite illusion is to feel a single texture instead of two (B).

[Hayward, 2008]

Tactile illusions

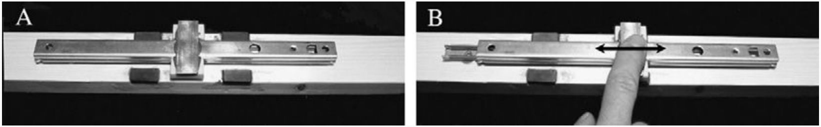


Figure: Illusion of bumps and holes. Made with a slider and magnets. The magnets reduce the speed of the slider, inducing illusion of bumps and holes.

[Hayward, 2008]

Illusions tactiles

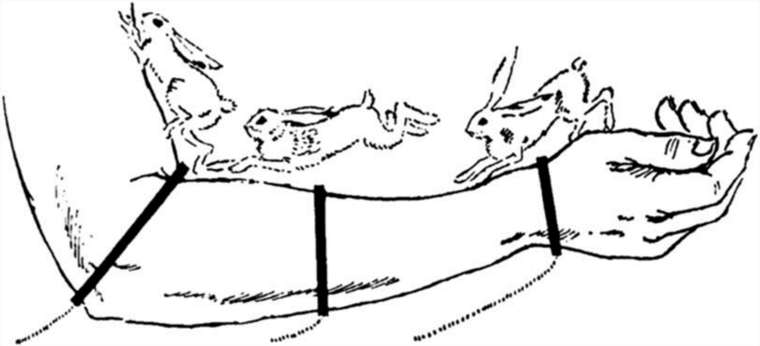


Figure: ”Cutaneous rabbit illusion”. When 3 vibrations are successively applied on the skin surface, only one stimulus is felt.

[Tan et al., 1997]

Tactile illusions

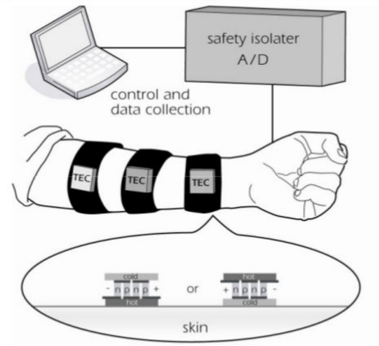
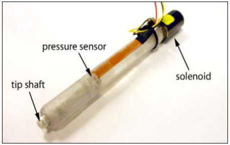


Figure: Thermal grill illusion. Hot (40°C) and cold (20°C) stimuli successively applied on the skin. A burning sensation is felt.

[Salzer et al., 2007]

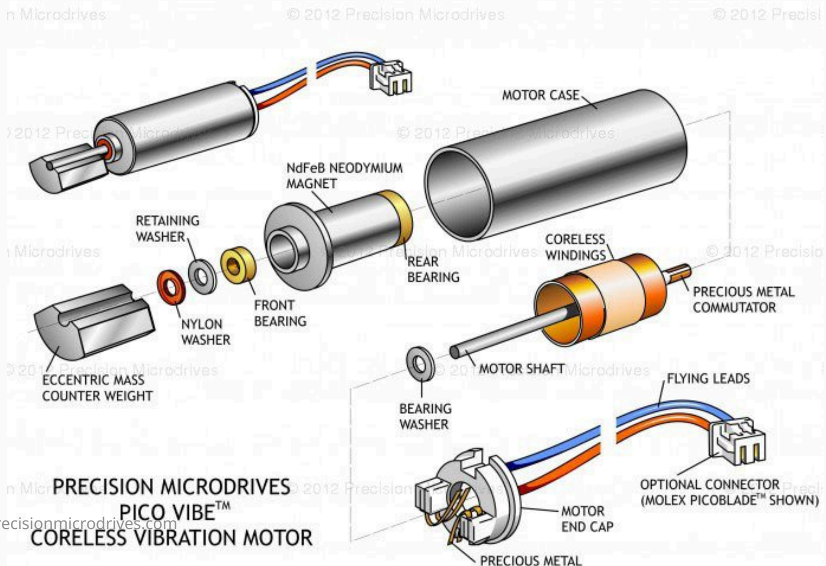
Tactile interfaces - Contact

→ Vibrating motors
→ Solenoid



©Cybertouch.com [Lee et al., 2004] [Abdur Rahman et al., 2010]

Eccentric rotating mass vibration motor (ERM)



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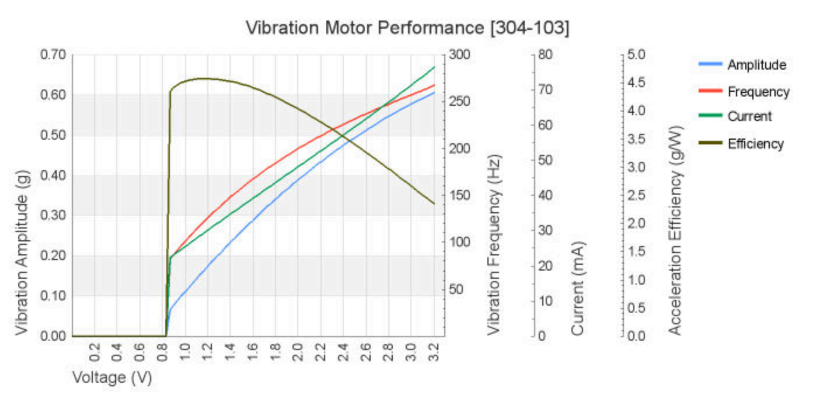
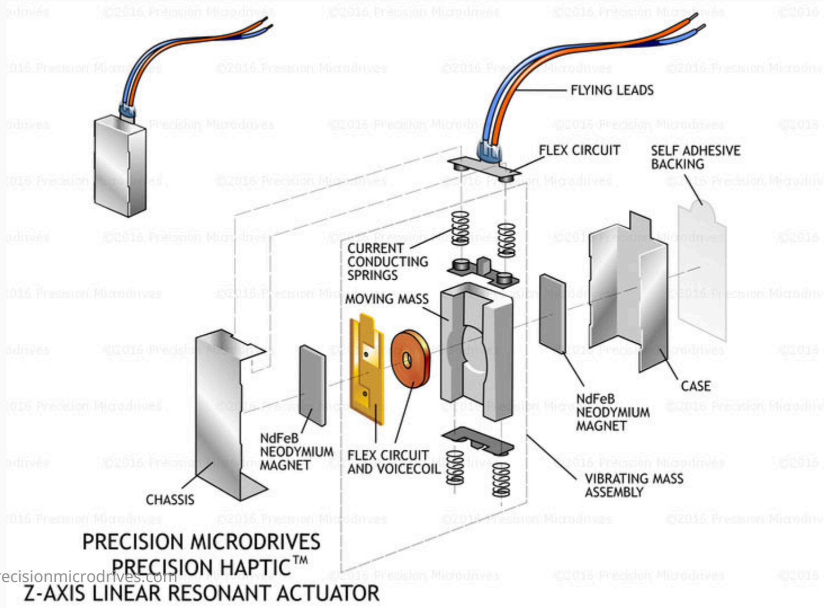


Linear resonant actuator (LRA)



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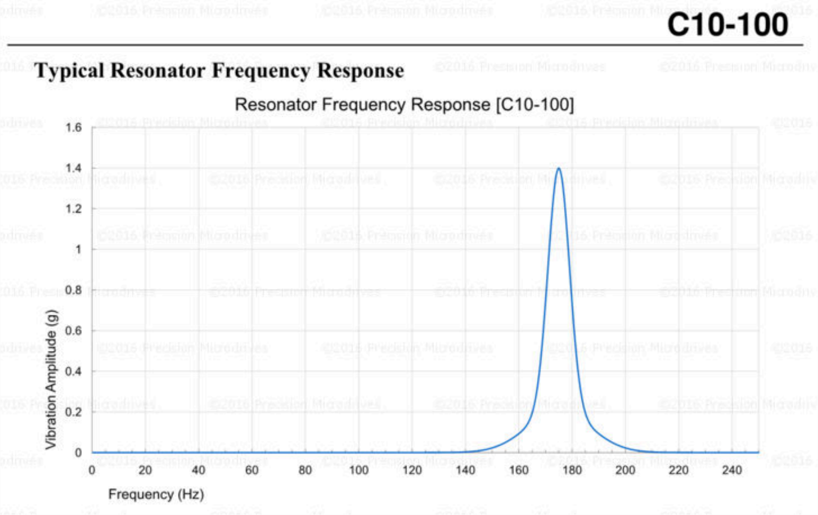
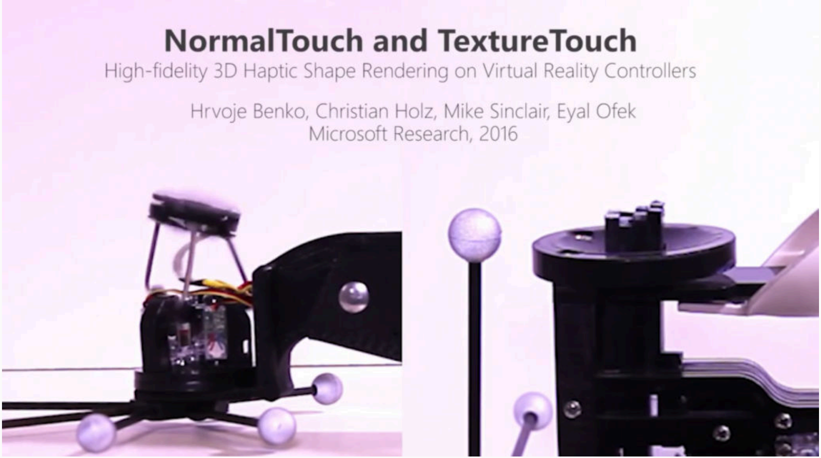


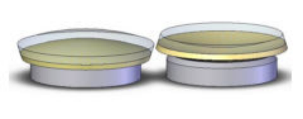
Tactile interfaces - Contact

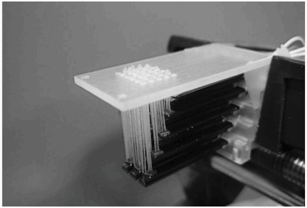


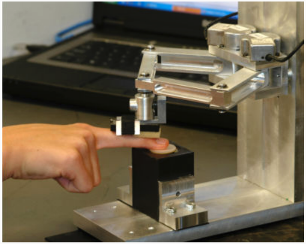
[Benko et al., 2016]

Tactile interfaces - Texture

- → Pin array
- → Piezo-electric actuator
- → Electrostatic vibration







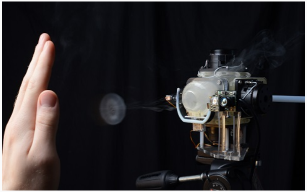
[Yang and Kwon, 2008][Winfield et al., 2007]

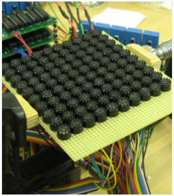
Tactile interfaces - Texture

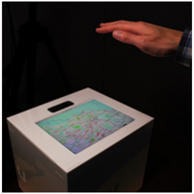
[Bau et al., 2010]

Tactile interfaces - contact-less

- → Air vortex generator
- → Ultrasonic transmitters array

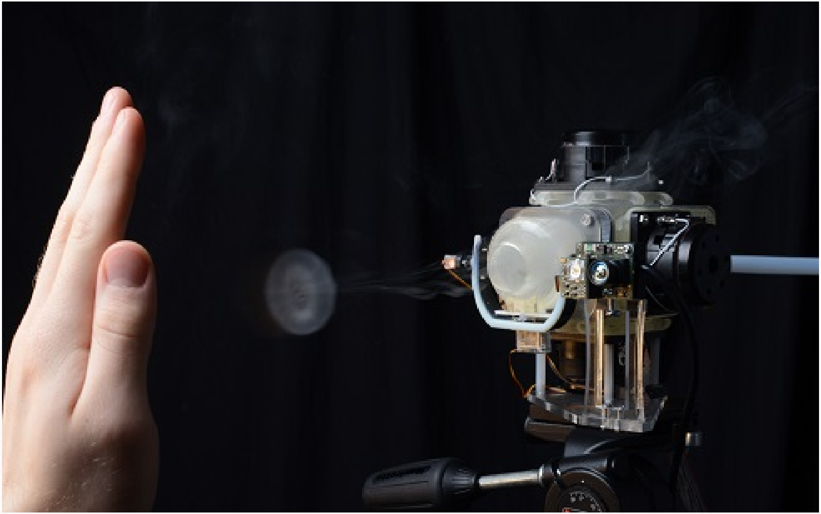






[Alexander et al., 2011] [Sodhi et al., 2013]

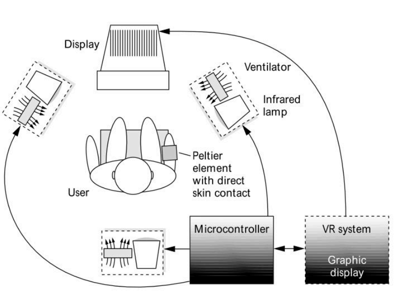
Tactile interfaces - contact-less

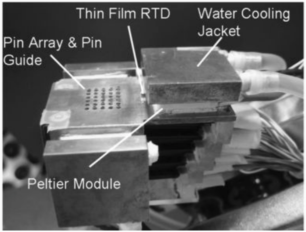


[Sodhi et al., 2013]

Tactile interfaces - thermal

- → Fan + heat source
- → Peltier module

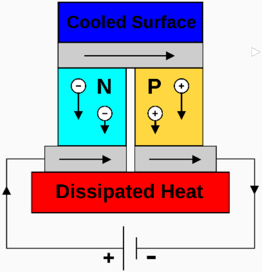


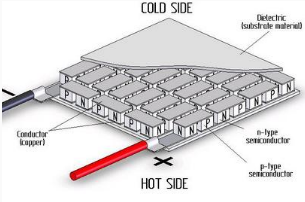


[Dionisio, 1997] [Yang and Kwon, 2008]

Peltier effect

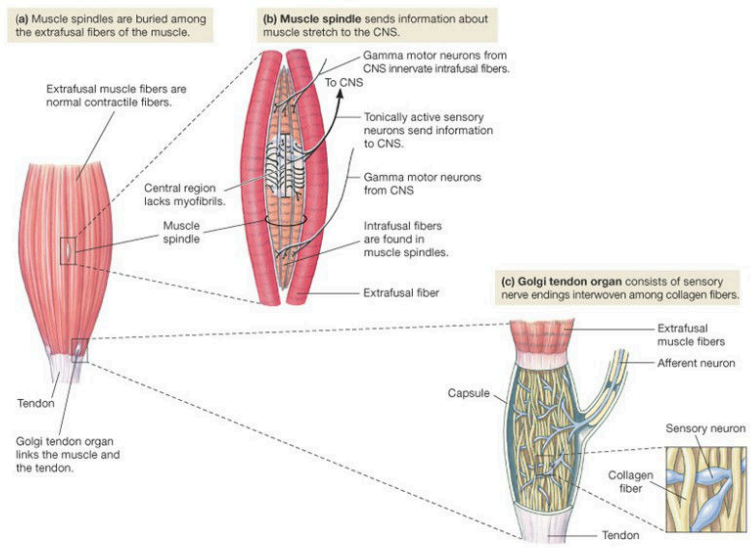
- → Convert electricity into heat
- → Heat generated when a current is made to flow through a junction between two conductors, N and P
- → Discovered in 1834 by Jean-Charles Peltier



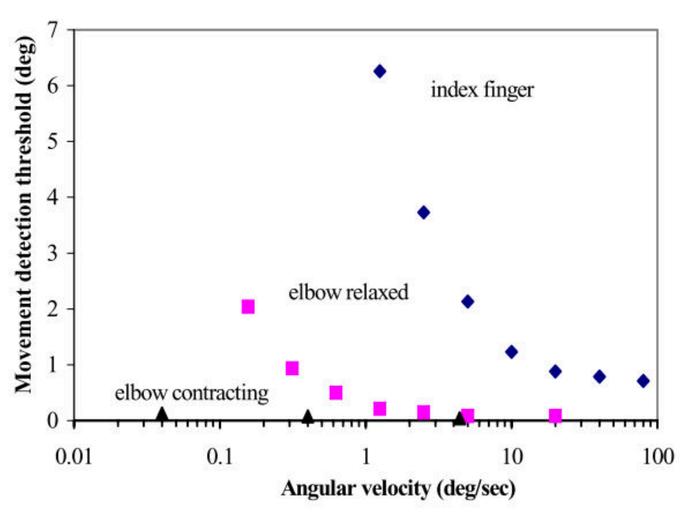


Kinesthesia

Kinesthetic perception



Kinesthetic perception



[Jones, 2000]

Kinesthetic perception

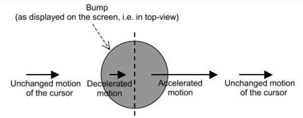
Variable	Resolution	Differential Thresholds
Limb movement	0.5-1°	8% ([4,9%])
Limb position	0.8-7°	7% ([5,9%])
Force	0.06N	7% ([5,12%])
Rigidity	-	17% ([8,22%])
Viscosity	-	19% ([14,34%])
Intertia	-	28% ([21,113%])

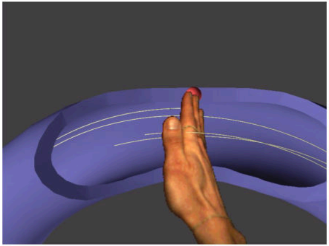
Table: Kinesthetic sensibility

[Jones, 2000]

Kinesthetic illusions

- → Pseudo-haptics
- → Illusion of force-feedback
- → Delay control / visual feedback

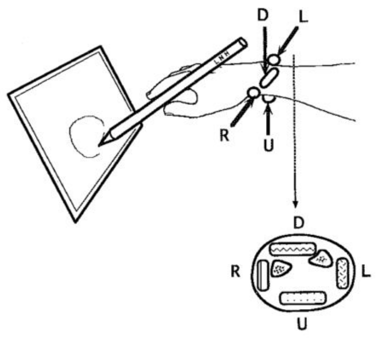


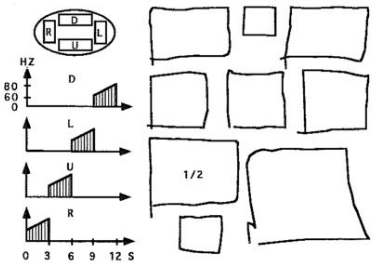


[Pusch et al., 2008] [Lécuyer, 2009]

Kinesthetic illusions

- → Illusion of movement
- → Vibration applied on tendon





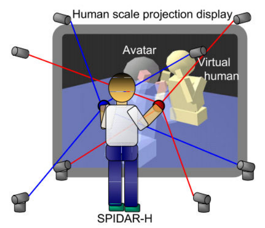
[Roll and Gilhodes, 1995]

Force-feedback devices

→ Impedance (in: position, out: force)
→ Admittance (in: force, out: position)

Force-feedback devices

- → Wearable (ex: CyberGrasp, exoskeleton)
- → Electrical muscle simulation (ex: Impacto)
- → Extended workspace (ex: SPIDAR)



 [Lopes et al., 2015] [Hasegawa et al., 2006]

Force-feedback devices

Hapseat

Use case #1

→ How to use of haptics to enrich a movie experience?

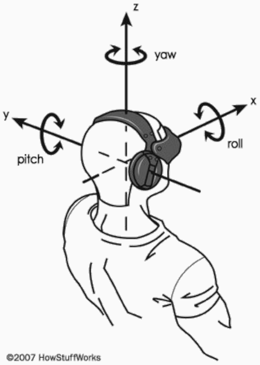
→ a.k.a. 4D cinema

→ Perception of motion ≠ haptics

https://www.cj4dx.com

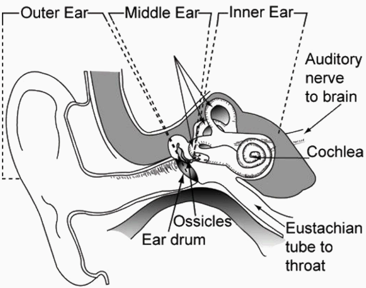
Perception of motion

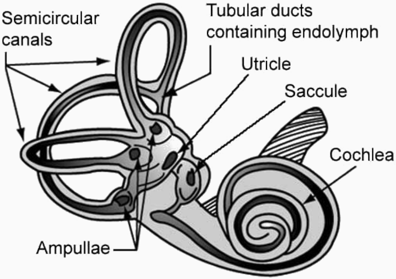
- → Perception of the movement of the body in space
- → Proprioception
  - → Vestibular system
  - → Haptic perception



Vestibular System

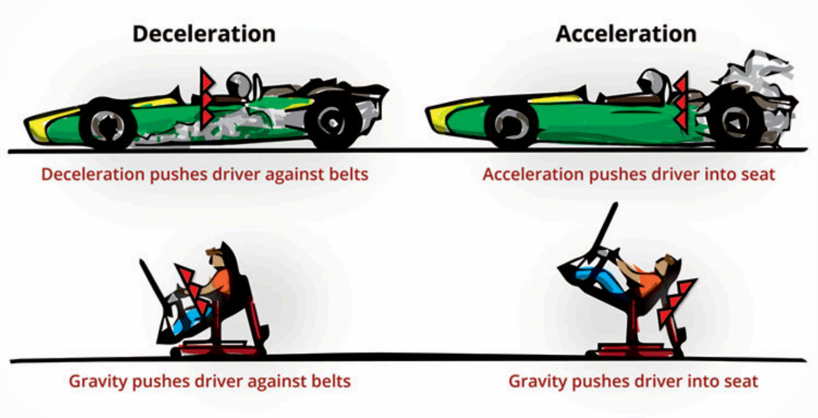
- → 3 semi-circular canals → angular speed
- → 2 otolithic organs → linear acceleration
  - → Saccule
  - → Utricle





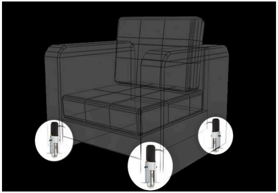
Illusion of motion

- otolithic organs perceive gravity as a force



Related work on motion simulation

Sensation of motion



Motion platform

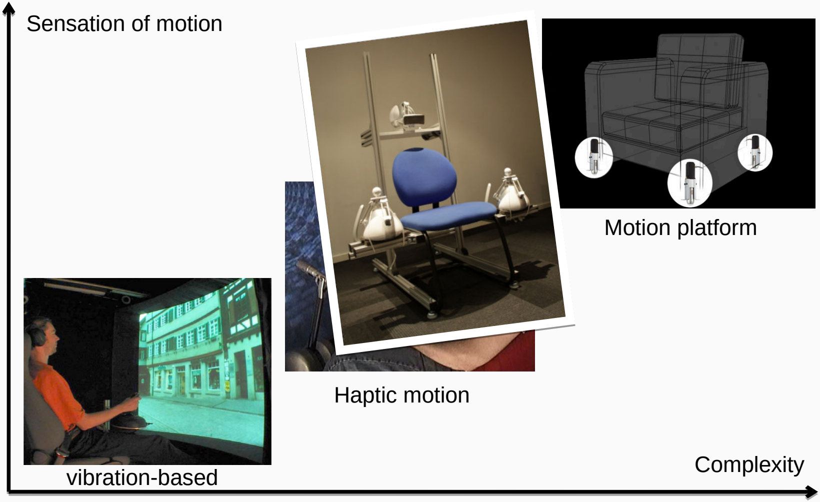
Haptic motion

vibration-based

Complexity

[Riecke et al., 2005] [Ouarti et al., 2014]

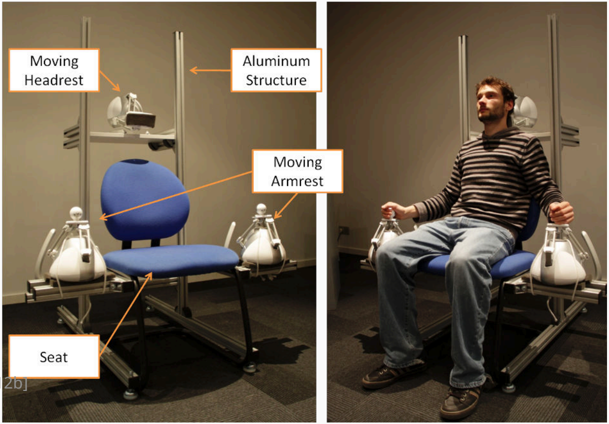
Related work on motion simulation



[Riecke et al., 2005] [Ouarti et al., 2014]

HapSeat

→ Sensation of motion induced by force-feedback
→ 3 contact points = 6 DoF
→ Suitable for consumer settings



[Danieau et al., 2012b]

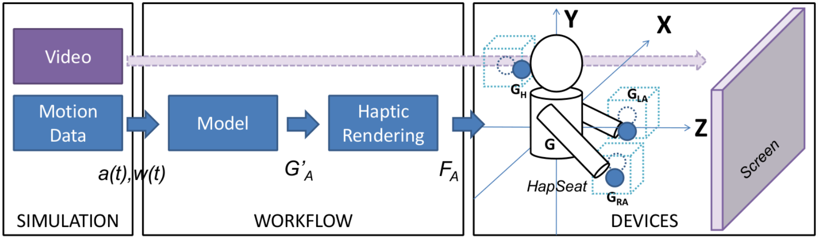
HapSeat

[Danieau et al., 2012b]

Motion rendering

→ Motion defined linear acceleration ($a^t = [x_c, y_c, z_c]^t$) and angular speed ($w^t = [\phi_c, \theta_c, \psi_c]^t$)

→ captured by IMU



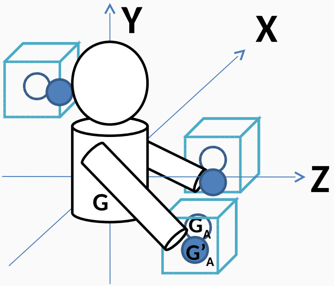
[Danieau et al., 2012b]

Motion rendering

$$\overrightarrow{G_A G'_A} = f(\vec{T}, \vec{R}) \qquad (1)$$

$$f(\vec{T}, \vec{R}) = \frac{\|\vec{T}\|\vec{T} + \|\vec{R}\|\vec{R}}{\|\vec{T}\| + \|\vec{R}\|} \qquad (2)$$

$$\vec{T} = \begin{bmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & k_z \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \end{bmatrix} \qquad (3)$$



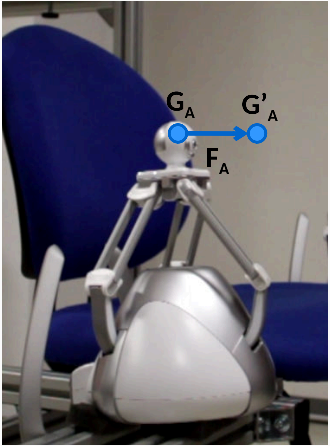
$$\vec{R} = (R_x(m_x\phi_c(t))R_y(m_y\theta_c(t))R_z(m_z\psi_c(t)) - I_3)\overrightarrow{GG_A} \qquad (4)$$

$k, m =$ scaling factor; $I_3 =$ identity matrix

Motion rendering

- → Novint Falcon = impedance control (force)
- → Model computes a position
- → Computation of force (spring-damping model)
- → $F_A = k(G'_A - G_A) - dV_A$

k spring constant, *d* damping constant



User Study

- Questions
  - Quality of the simulated motion?
  - Impact on the quality of the user experience?
- Materials
  - 2 video sequences: Real car and Virtual car driving
  - 4 haptic feedback: Physical Model, Geometrical Model, Random and None.
- 17 Participants

User Study

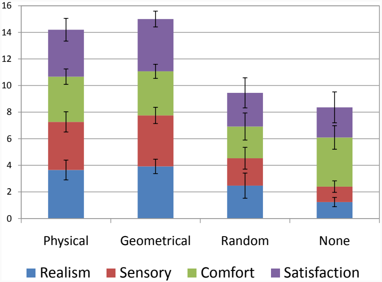
- QoE described by 4 factors
  - Based on Presence [Witmer1998] and Usability [ISO 9241-11]
  - 7 questions evaluated on 5-point scale

Factor	Question
Realism	How much did this experience seem consistent with your real-world experiences?
	How strong was your feeling of self-motion?
Sensory	How much did the haptic feedback contribute to the immersion?
	Were the haptic and visual feedback synchronized together?
Comfort	Was the system comfortable?
	How distracting was the control mechanism?
Satisfaction	How much did you enjoy using the system?

Table: questionnaire

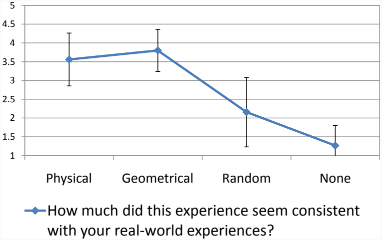
Results

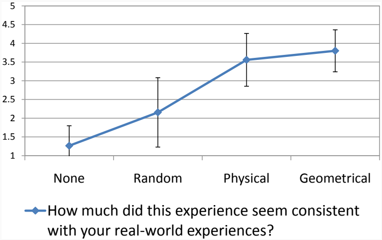
→ HapSeat enhances QoE
  → Models > Random and None
  → Physical Model ≈ Geometrical Model
→ Realism, Sensory and Satisfaction factors improved
→ Comfort is stable



Results - Realism factor

- → Haptic feedback consistent with user's experience
- → HapSeat triggers feeling of self-motion
- → Physical Model ≈ Geometrical Model > Random > None
- → Real Car ≈ Virtual Car



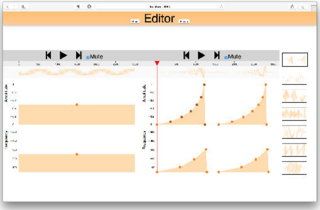


HFX Studio

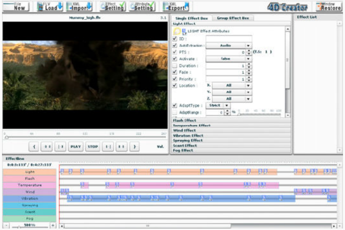
Use case #2

- How to design haptic effects?
- Haptic effects = haptic feedback for movies
- Challenging issue
  - Numerous haptic sensations
  - Heterogenous devices
  - Whole user's body
  - Synchronization with AV content

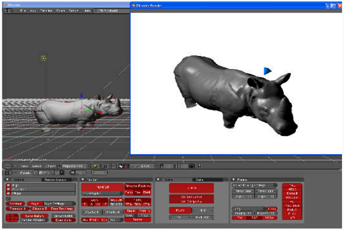
State-of-the-art



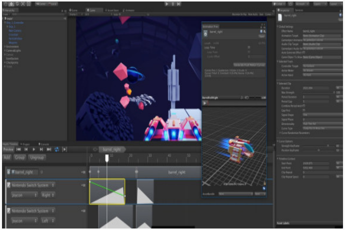
[Schneider and MacLean, 2016]



[Kim, 2013]



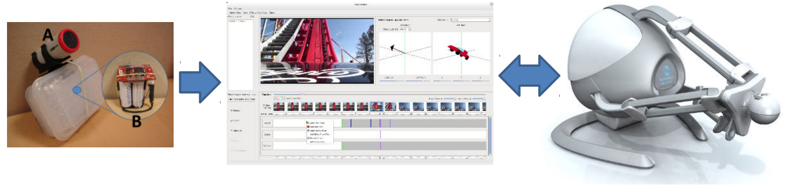
[Eid et al., 2008]



[Rihn and Tullis, 2017]

Authoring tool - H-Studio

→ Capture of motion data
→ Manual edition thanks to force-feedback device
→ Preview of haptic effects



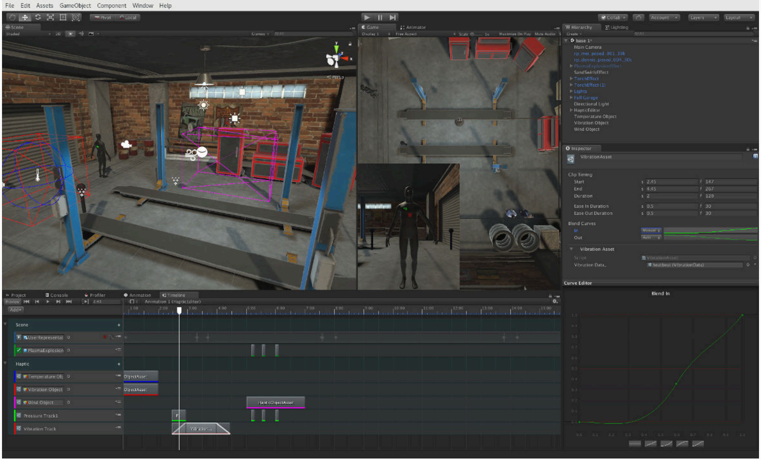
Capture device:
video and motion recording

H-Studio:
processing and authoring

Force-feedback device:
authoring and preview

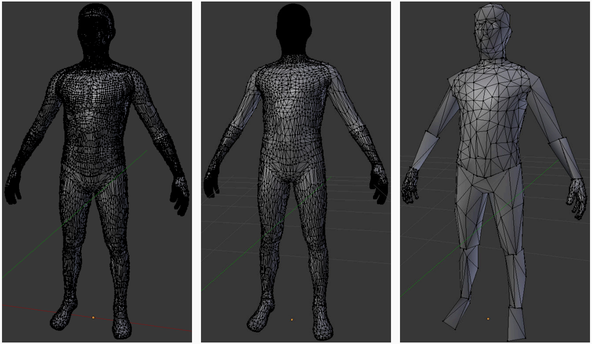
[Danieau et al., 2012a][Danieau et al., 2013]

HFX Studio



Unity®based editor
Timeline system

Haptic perceptual models



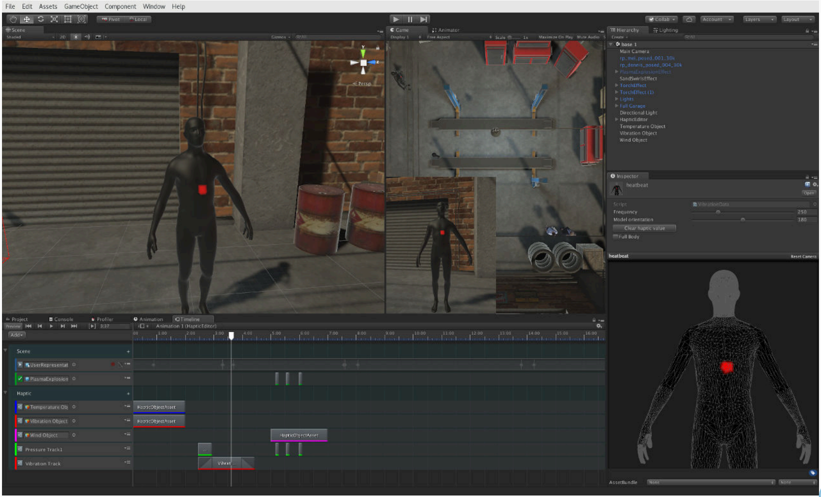
pressure vibration temperature

- → Abstract representation of haptic perception (tactile spatial acuity)
- → Vertex density = two points thresholds

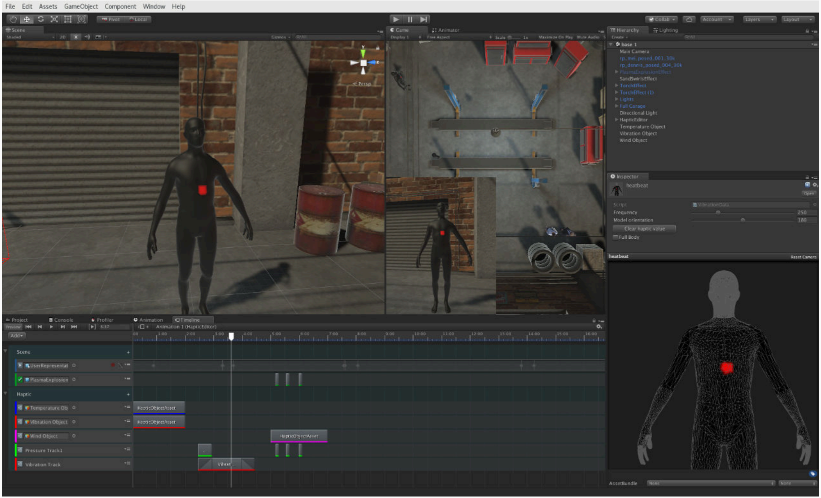
[Mancini et al., 2014] [Erp, 2005] [Jones and Ho, 2008]

Effects #1: Egocentric

→ Design on the user's body
→ Spatial resolution depends on the model

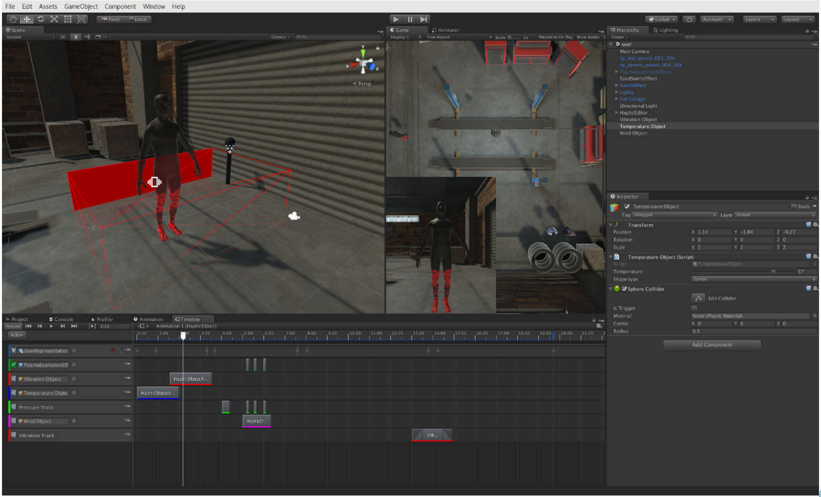


Effects #1: Egocentric

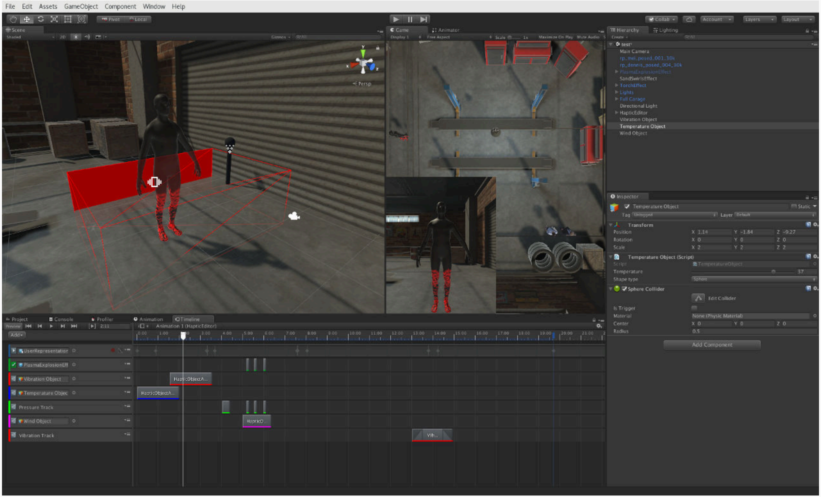


Effects #2: Allocentric

→ Design in the world space
→ Egocentric effect dynamically generated

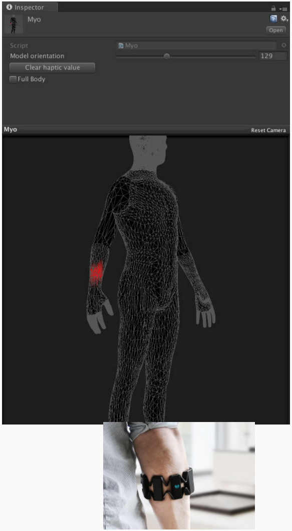


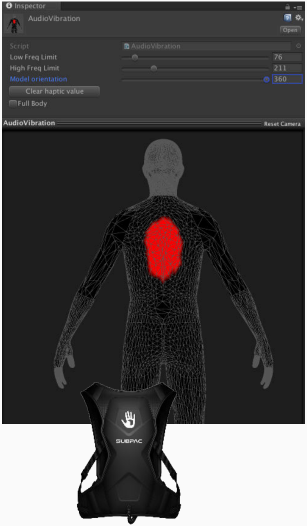
Effects #2: Allocentric



Haptic devices

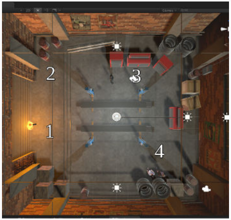
→ Capabilities defined with haptic model



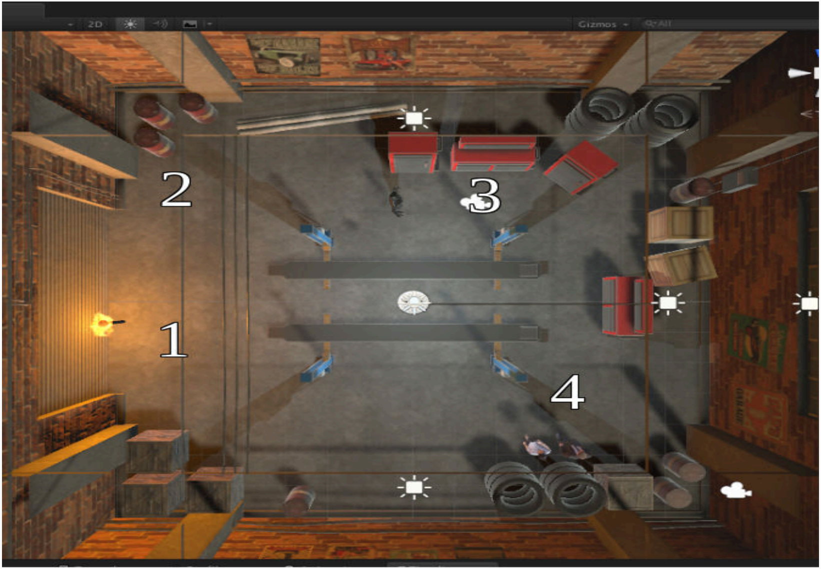


Pilot User Study

→ Evaluation of the usability
→ Qualitative study
→ 4 tasks
  → T1 (ambiance): warm effect + vibrations
  → T2 (spatial): turn right
  → T3 (context): lightning strokes
  → T4 (temporal): heart beat

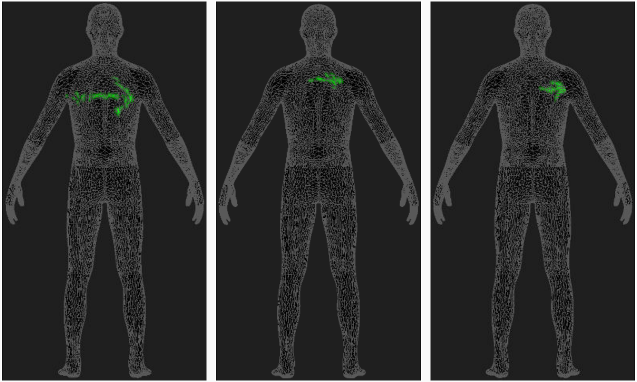


Pilot User Study



Results

- → 8 participants (age 38.25). Unity experts
- → Tasks successful
- → Positive feedback: *very intuitive, nice tool*



Results: qualitative study

- Egocentric effects
  - Less intuitive than allocentric
  - Timeline system efficient
- Allocentric effects
  - Similar to regular gameobject
  - Use of timeline not clear
- Interface control
  - Seamless integration to Unity
  - Vertex selection to be improved
- Design choices
  - Choice between ego or allocentric effect

Conclusion

Conclusion

- → Haptics = science of touch
  - → Tactile perception
  - → Kinesthetic perception
- → Sense of motion $\approx$ proprioception
  - → Haptic perception
  - → Vestibular perception
- → Applications in movie industry
  - → New device for simulating motion
  - → Interface for designing haptic effects
  - → Evaluation of the user experience

Thank you for you attention!

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