Technological issues with multimodal touch input devices

Detjon Brahimaj, Pr. Frederic Giraud, Pr. Betty Semail

L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

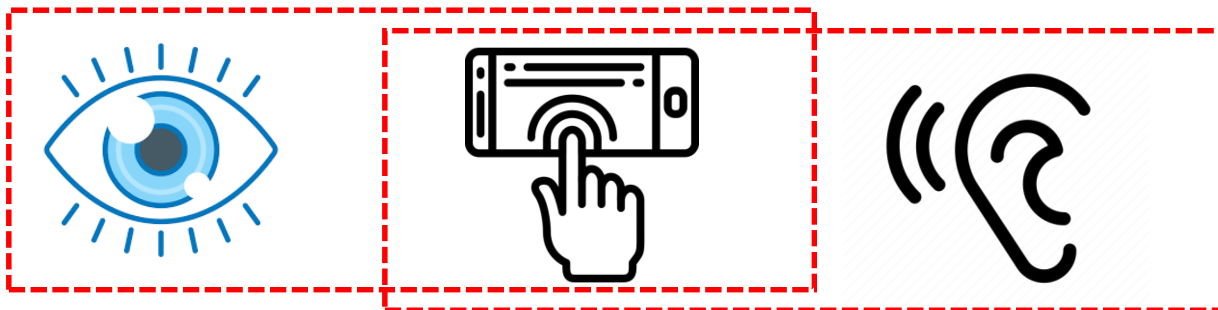
Université de Lille

This project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement No 860114

Introduction

- What is a Multimodal Touch Input Device?

It’s the combination of haptic feedback with one or more modalities



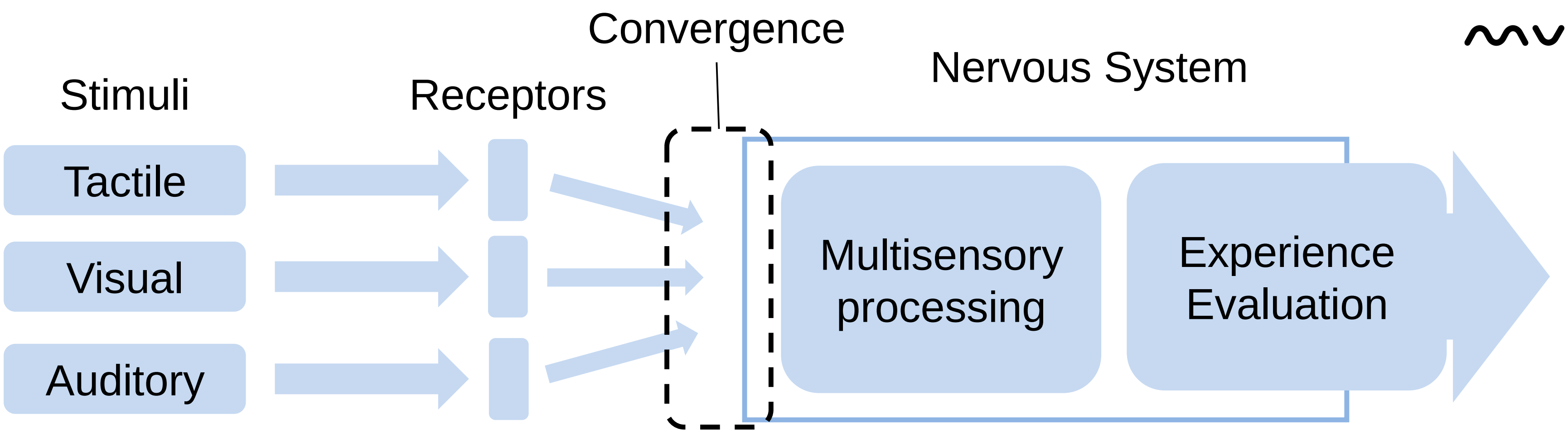
Visual | Haptic | Auditory

Screens
AR glasses
VRHMD
Peripheral light

Speakers
Headphones

Multimodality

- How Multimodality works



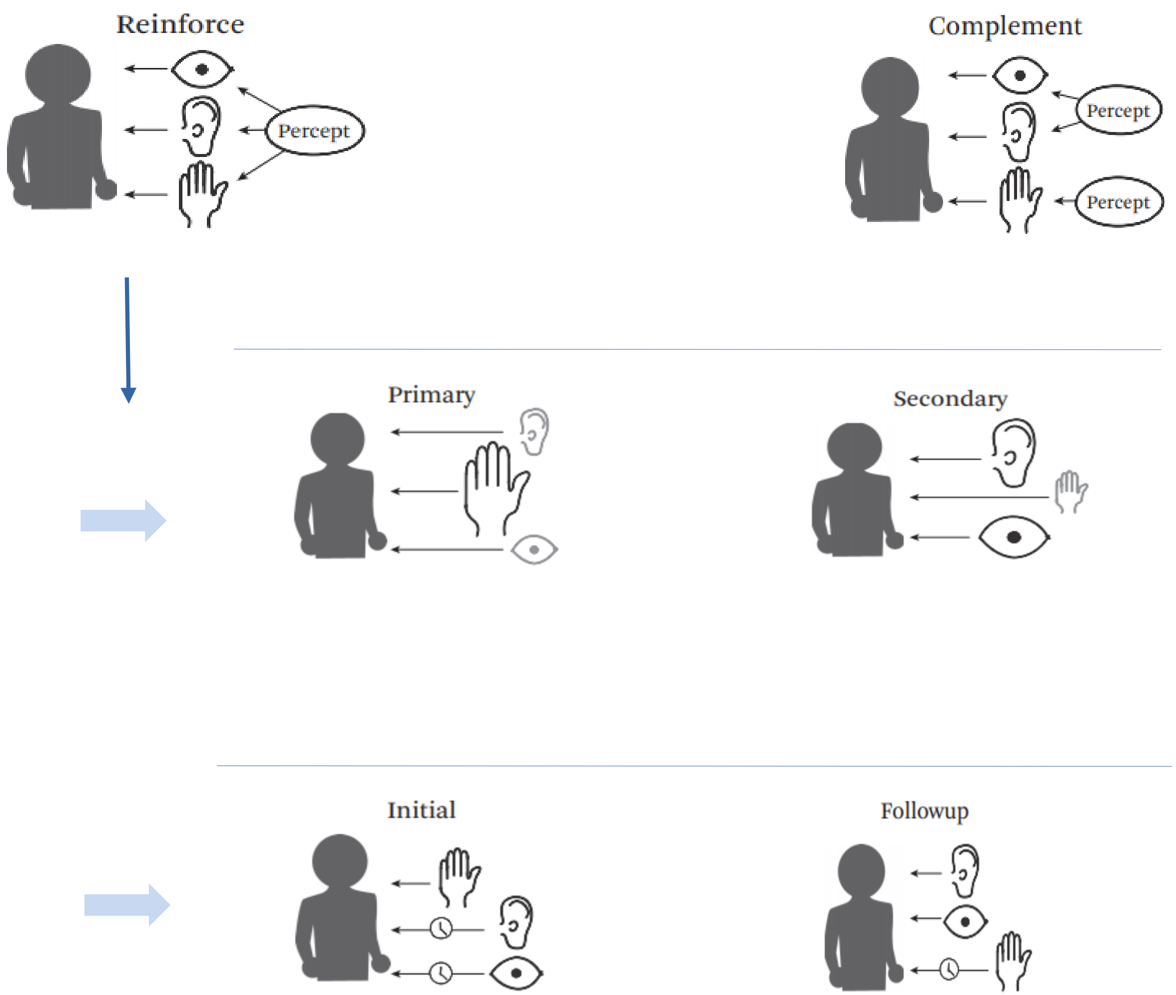
Convergence → Moments when information from different modalities meets

Multisensory processing → Integration of the received information

Experience Evaluation → Different layers

Multimodality

- Multisensory Haptic Interactions: Information relationship



Information Relevance

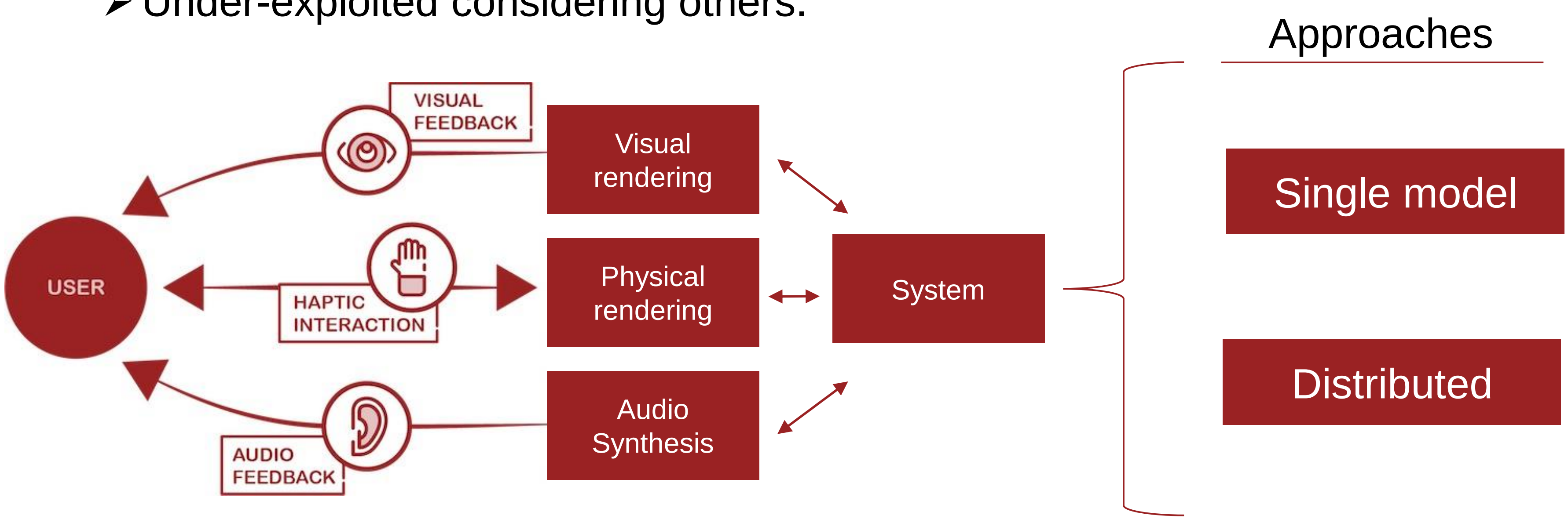
Temporal-Detail

K. E. MacLean, O. S. Schneider, H.Seifi. 2017. Multisensory haptic interactions: understanding the sense and designing for it. The Handbook of Multimodal-Multisensor Interfaces: Foundations, User Modeling, and Common Modality Combinations - Volume 1. Association for Computing Machinery and Morgan & Claypool, 97–142.

Multimodal interfaces

- ❑ Fusion-based
  - ➢ Co-process input modes
  - ➢ Optimized to support a specific range of tasks

- ❑ Temporally cascaded
  - ➢ Modes integrated depend on temporal aspects
  - ➢ Under-exploited considering others.



1-Oviatt, S., Schuller, B., Cohen, P., Sonntag, D., Potamianos, G., & Kruger, A. (Eds.) (2017). The Handbook of Multimodal-Multisensor Interfaces, Volume 1: Foundations, User Modeling, and Common Modality Combinations. (ACM Books Series; Vol. 14). Association for Computing Machinery (ACM).

2- J.Leonard, J. Villeneuve. Fast audio-haptic prototyping with mass-interaction physics. *HAID 2019 - International Workshop on Haptic and Audio Interaction Design*, Mar 2019, Lille, France

Available Technologies

- Haptic classification

3 S of haptics

Shape	Global, Local
Substance	Mass, Stiffness, etc.
Surface	Texture, Friction, Temperature

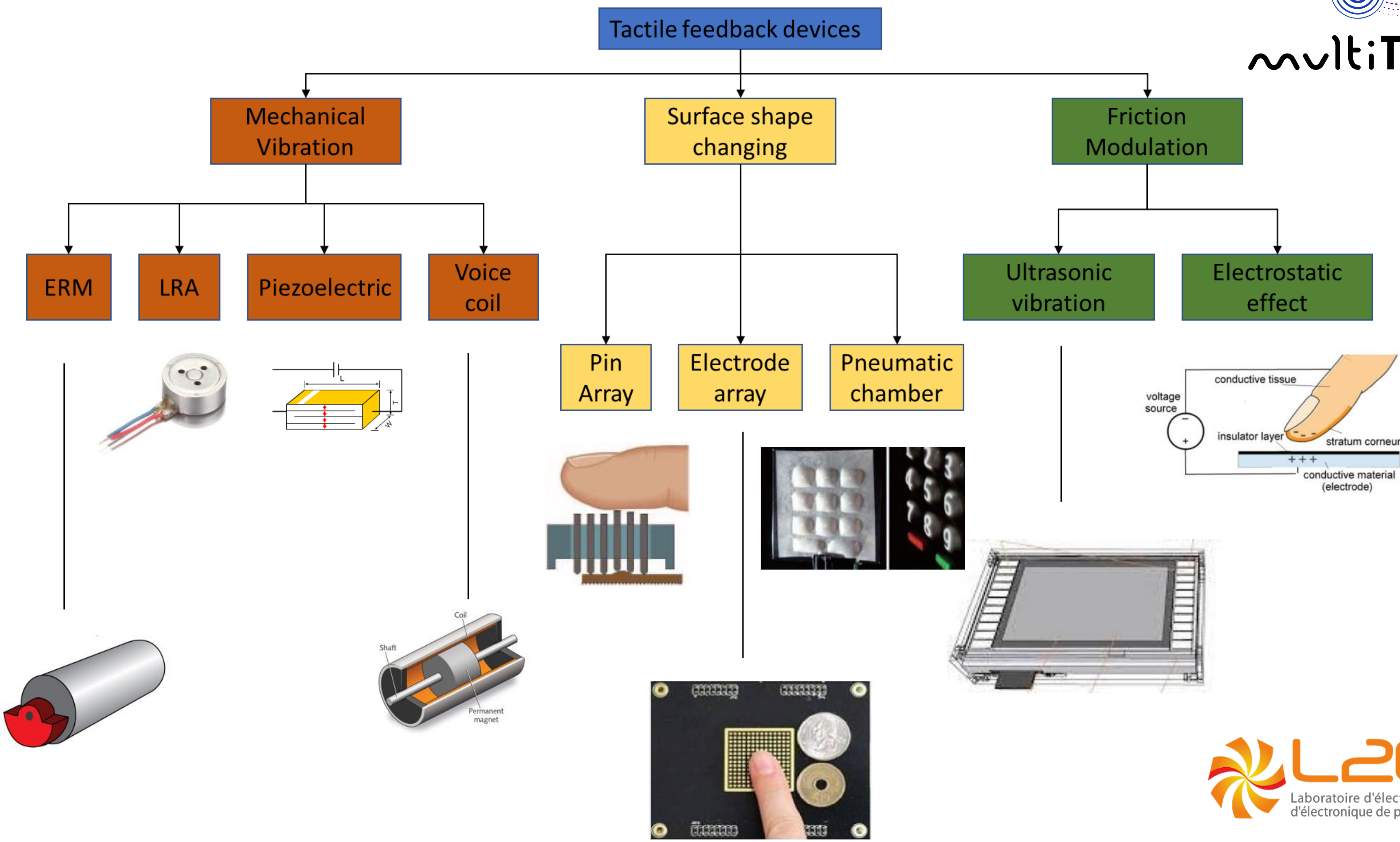
Touch input device Classification

Tactile feedback devices

1-Wang, D., Y. Guo, S. Liu, Yuru Zhang, Weiliang Xu and Jing Xiao. “Haptic display for virtual reality: progress and challenges.” Virtual Real. Intell. Hardw. 1 (2019): 136-162.
2- Basdogan, C., F. Giraud, Vincent Lévesque and S. Choi. “A Review of Surface Haptics: Enabling Tactile Effects on Touch Surfaces.” IEEE Transactions on Haptics 13 (2020): 450-470.

Available Technologies

multiTOUCH



L2EP
Laboratoire d'électrotechnique et d'électronique de puissance de Lille

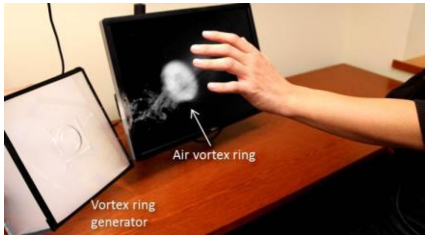
1-Wang, D., Y. Guo, S. Liu, Yuru Zhang, Weiliang Xu and Jing Xiao. “Haptic display for virtual reality: progress and challenges.” Virtual Real. Intell. Hardw. 1 (2019): 136-162.
2- Basdogan, C., F. Giraud, Vincent Lévesque and S. Choi. “A Review of Surface Haptics: Enabling Tactile Effects on Touch Surfaces.” IEEE Transactions on Haptics 13 (2020): 450-470.

Available Technologies

- Another category, Contactless Haptic Technologies

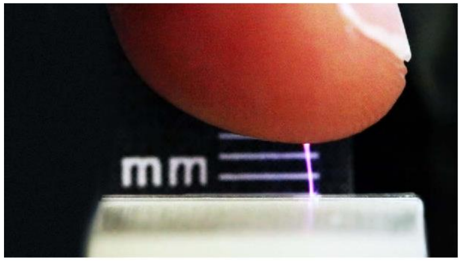
Contactless Haptic

- Air-based
  - Controlled air stream
  - Subwoofers
  - Ultrasound Array
- Others
  - Laser and electric arcs
  - Electromagnetic fields

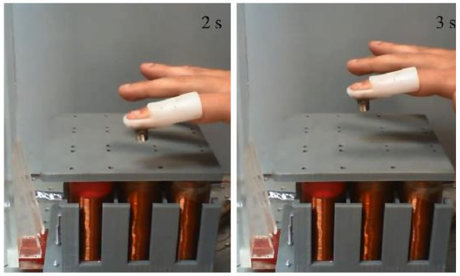


[1]

[2]



[3]



[4]

1-S. Gupta, D. Morris, S. Patel, and D. Tan, "AirWave: Non-Contact Haptic Feedback Using Air Vortex Rings," in Proceedings of UbiComp '13, 2013, pp. 419–428.
2-S. Hashizume, A. Koike, T. Hoshi, and Y. Ochiai, "Sonovortex: Rendering multi-resolution aerial haptics by aerodynamic vortex and focused ultrasound," Proc. SIGGRAPH '17 Posters, 2017.
3-D. Spelmezan, D. R. Sahoo, and S. Subramanian, "Sparkle: Hover Feedback with Touchable Electric Arcs," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '17, 2017, pp.
4-A. Adel, M. Micheal, M. Self, S. Abdennadher, and I. Khalil, "Rendering of Virtual Volumetric Shapes Using an Electromagnetic-Based Haptic Interface," Proc. IEEE/RSJ Int. Conf. Intell. Robot. Syst. - IROS '18, 2018.

Examples #1

❑ HapTable: A multimodal visual-haptic system

3 main modules:

- Gesture detection
- Visual display
- Haptic feedback
  - Electromechanical piezo - static gesture
  - Electrostatic actuation - dynamic gesture

<u>Experiment</u> 1: Vibrotactile Flow

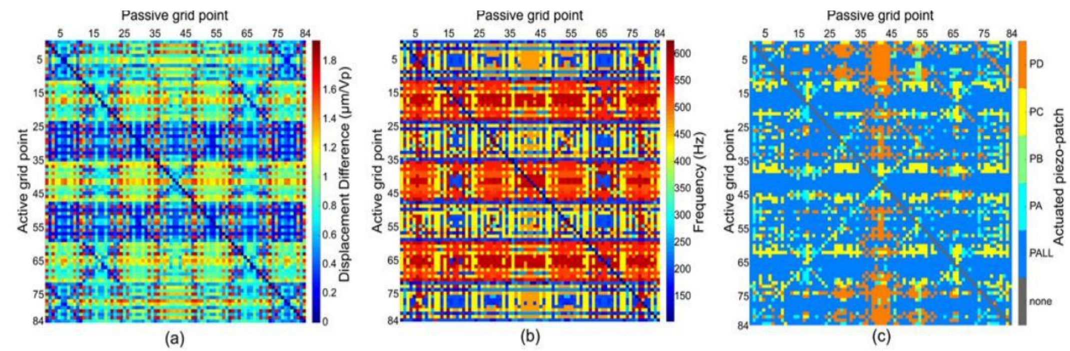
<u>Experiment</u> 2: Haptic knob

S. E. Emgin, A. Aghakhani, T. M. Sezgin and C. Basdogan, "HapTable: An Interactive Tabletop Providing Online Haptic Feedback for Touch Gestures," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 25, no. 9, pp. 2749-2762, 1 Sept. 2019

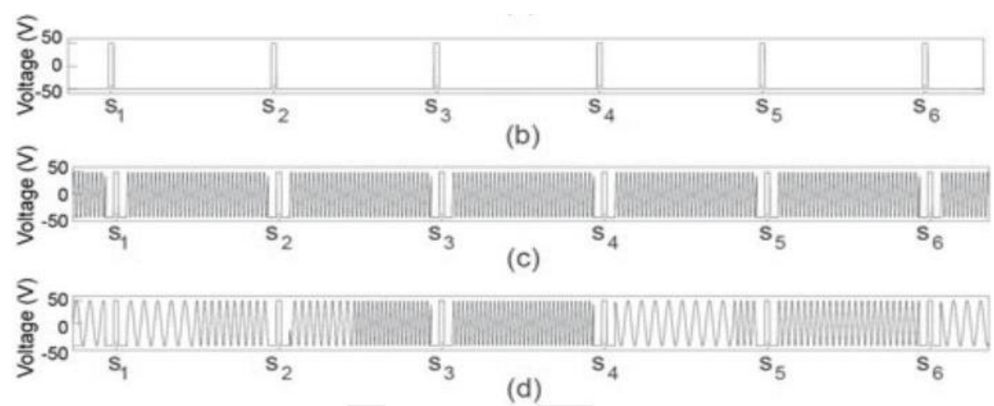
Laboratoire d'électrotechnique et d'électronique de puissance de Lille

Example #1

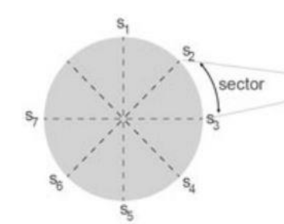
- HapTable: A multimodal visual-haptic system
  - Piezoelectric actuators
    - Vibration maps
      - Displacement difference
      - Frequency
      - Actuated Piezo patch



  - Electrostatic Force
    - Different sectors is mapped to an item on the menu
      - (b) haptic detent at sector crossings
      - (c) haptic detent and constant friction
      - (d) haptic detent and velocity–based friction



  - Results



Adding haptic feedback to a virtual knob improves interaction quality, user experience, and also the confidence of the user

S. E. Emgin, A. Aghakhani, T. M. Sezgin and C. Basdogan, "HapTable: An Interactive Tabletop Providing Online Haptic Feedback for Touch Gestures," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 25, no. 9, pp. 2749-2762, 1 Sept. 2019

Laboratoire d'électrotechnique et d'électronique de puissance de Lille

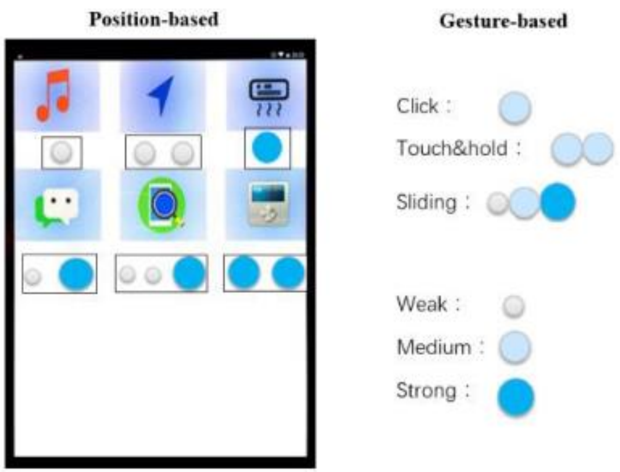
Examples #2

- Multimodal In-Vehicle Interactive System

  - ***Haptic***
    ERM used to provide additional information. Different vibration stimuli were generated based on user position or gestures.
  - ***Auditory***
    Used to confirm completion of a gesture or to give additional information such as the chosen button.
  - ***Visual***
    Classical Tablet

- 5 trials:
  1. Only Vision – no driving
  2. Visual and Auditory
  3. Visual and haptic
  4. Visual and Auditory and Haptic
  5. Multimodal – no driving

Sliding gesture interaction



Vibration schematic diagram

Zheng J., Zhang W. (2020) Multimodal In-vehicle Touch Screens Interactive System's Design and Evaluation. In: Nunes I. (eds) Advances in Human Factors and Systems Interaction. AHFE 2020.

Examples #2

- Multimodal In-Vehicle Interactive System's
  - Driving simulation while completing a secondary task on the tablet.
    Instructions given as text and speech
    Eye tracker and gaze calibration

No significant difference between trials in terms of →
- The Accuracy and Completion Time
- Lane Deviation

Significant difference →
- Glance Time Off Road → T 4 (M=0.397s, SD=0.021)
  T 1 (M=0.934s, SD=0.102)
- Perception Questionnaire → Multimodal rated more than other conditions

Completing a secondary task with the multimodal touchscreen could not have an influence on driving Efficiency or safety but improves the user experience

Zheng J., Zhang W. (2020) Multimodal In-vehicle Touch Screens Interactive System's Design and Evaluation. In: Nunes I. (eds) Advances in Human Factors and Systems Interaction. AHFE 2020.

Examples #3

- ❑ Augmenting In-vehicle Voice and Tactile interface

Usability Issues

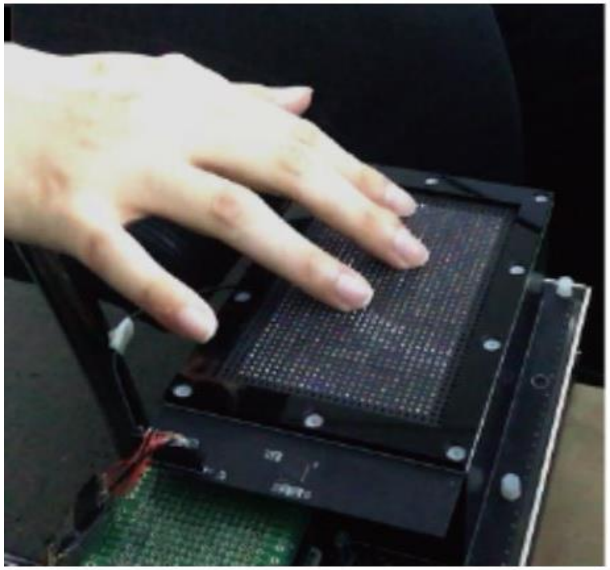
- Speak or wait
- Short term memory dependency
- Error recognition and error correction difficulties are other usability issues of the VUI

Speech recognition module

Google Cloud Speech API

Pin-array haptic feedback

40 × 25 pin grid with 2.5 mm spacing



Primary task: Change lane when a sign is displayed

Secondary task: train reservation or Message sending

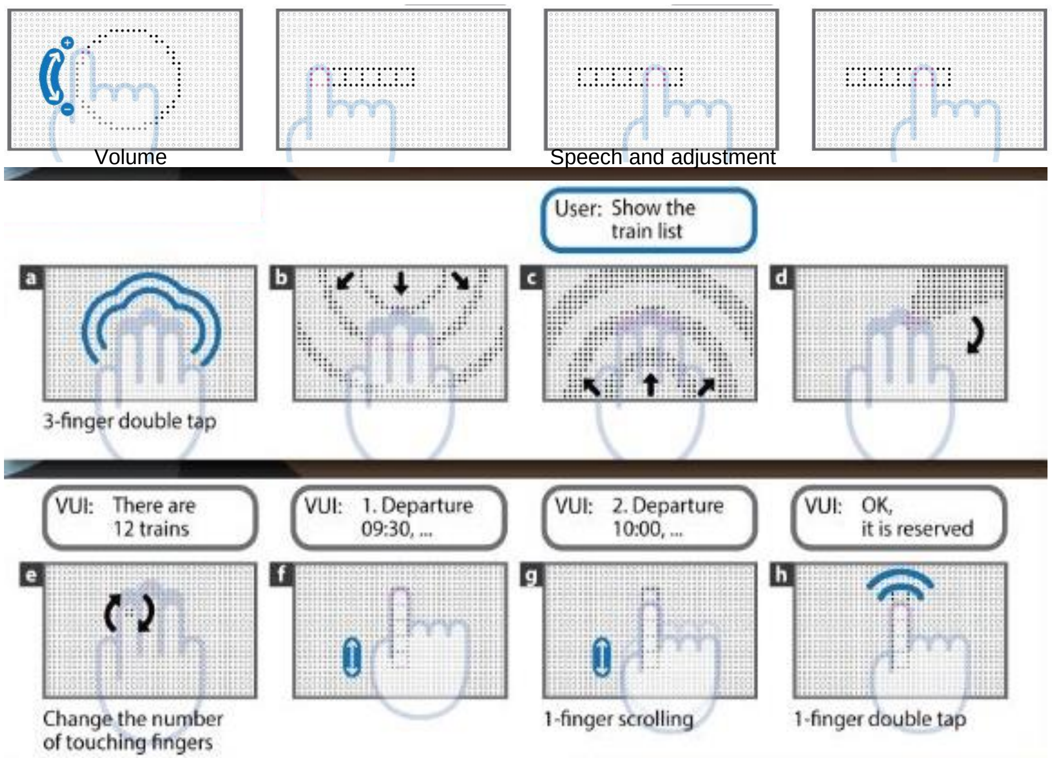
Jingun Jung, Sangyoon Lee, Jiwoo Hong, Eunhye Youn, and Geehyuk Lee. 2020. Voice+Tactile: Augmenting In-vehicle Voice User Interface with Tactile Touchpad Interaction. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20).

Examples #3

❑ Augmenting In-vehicle Voice and Tactile interface

Secondary task train reservation(TR) or Message sending(MS)

- *Task Completion Time*
  Voice+Tactile was significantly shorter than Voice-only for both TR and MS



- *Driving performance*
  Neither interfaces had a significant effect on driving performance for both TR and MS
- *Gaze Behavior*
  They only looked at the device to locate it and place their right hand on it (t< 1s)
- *Task Workload*
  Higher for TR vs MS but no significant difference between Voice+Tactile and Voice-only

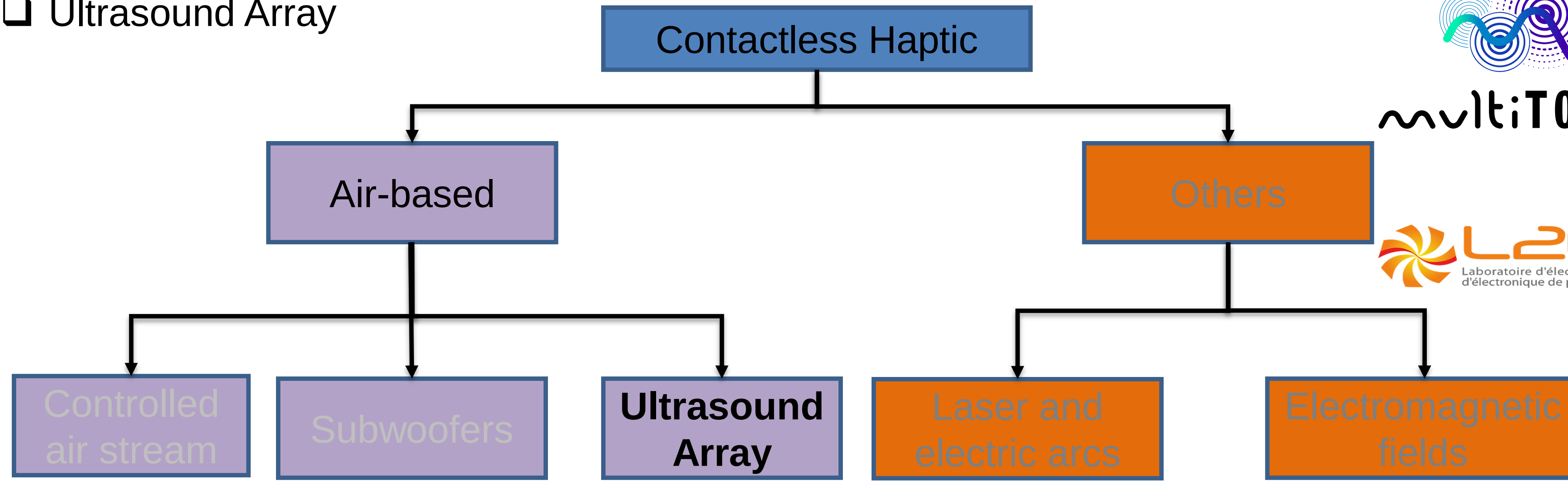
Jingun Jung, Sangyoon Lee, Jiwoo Hong, Eunhye Youn, and Geehyuk Lee. 2020. Voice+Tactile: Augmenting In-vehicle Voice User Interface with Tactile Touchpad Interaction. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20).

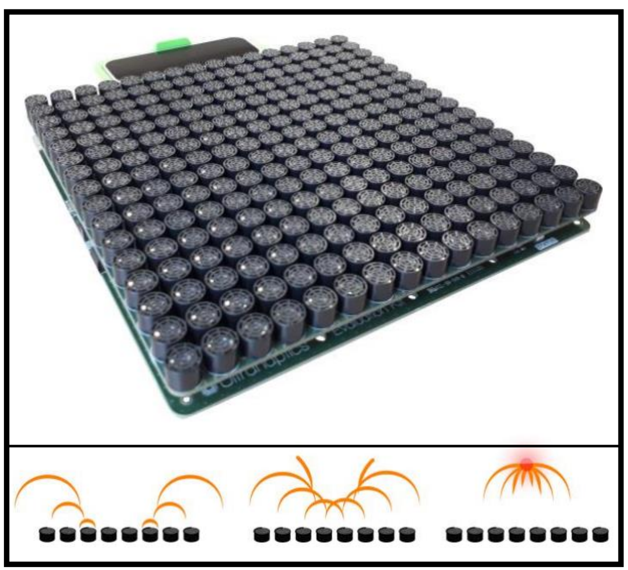
multiTOUCH

L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

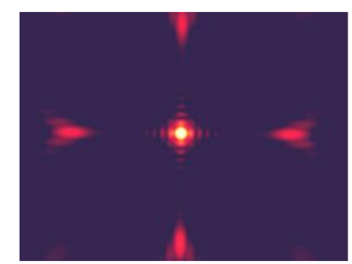
Available Technologies

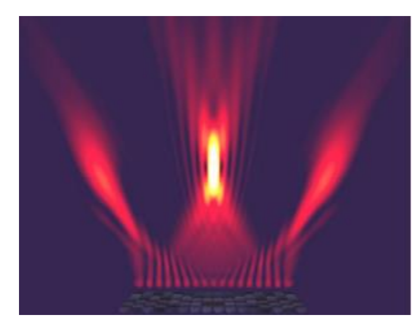
- Ultrasound Array





- Precision
- Strength and Perception
- Range
- Size, Weight, Cost, Power consumption, Heat dissipation
- Noise

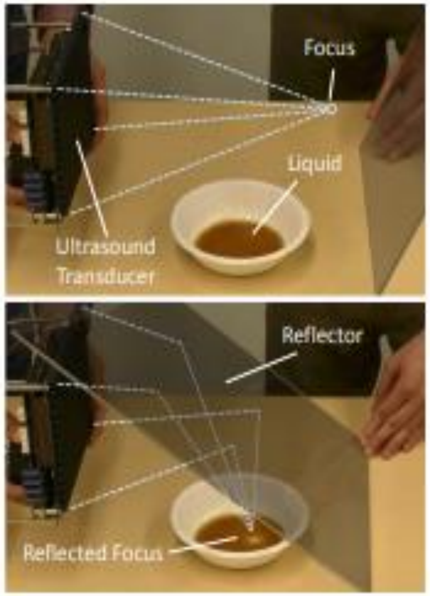


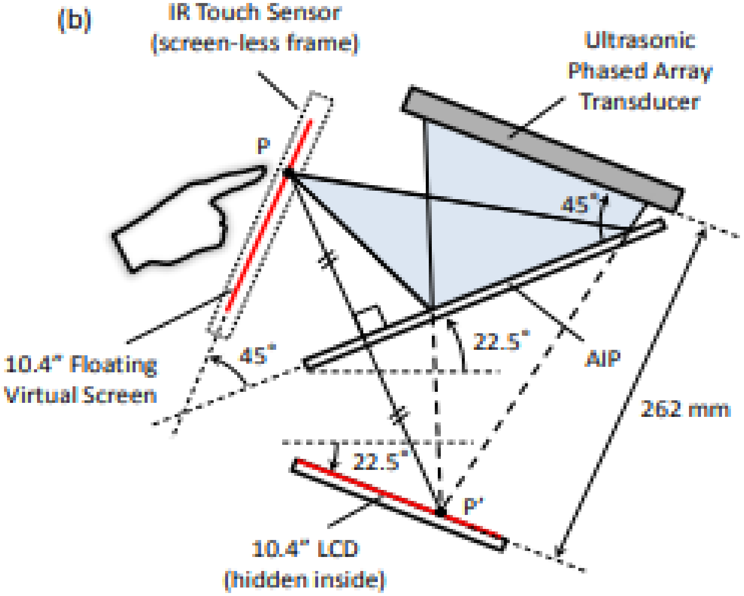


Rakkolainen I, Freeman E, Sand A, Raisamo R, Brewster S. A Survey of Mid-Air Ultrasound Haptics and Its Applications. IEEE Trans Haptics. 2021 Jan-Mar;14(1):2-19.

Example #1

- Haptomime
  - Main components
    - A liquid crystal display (LCD)
    - An Aerial Imaging Plate (AIP)
    - Embedded speakers
    - An ultrasonic phased array transducer



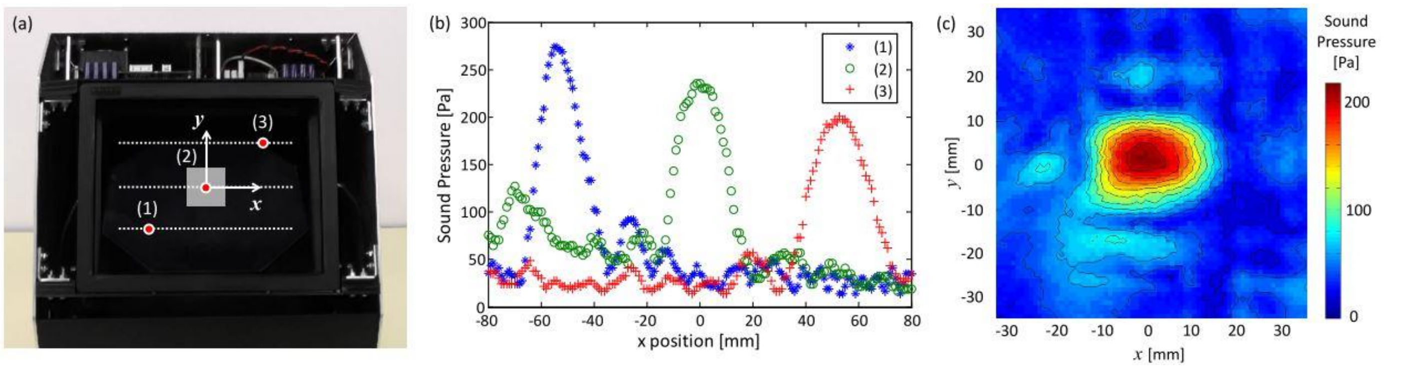


Yasuaki Monnai, Keisuke Hasegawa, Masahiro Fujiwara, Kazuma Yoshino, Seki Inoue, and Hiroyuki Shinoda. 2014. HaptoMime: mid-air haptic interaction with a floating virtual screen. In Proceedings of the 27th annual ACM symposium on User interface software and technology (UIST '14).

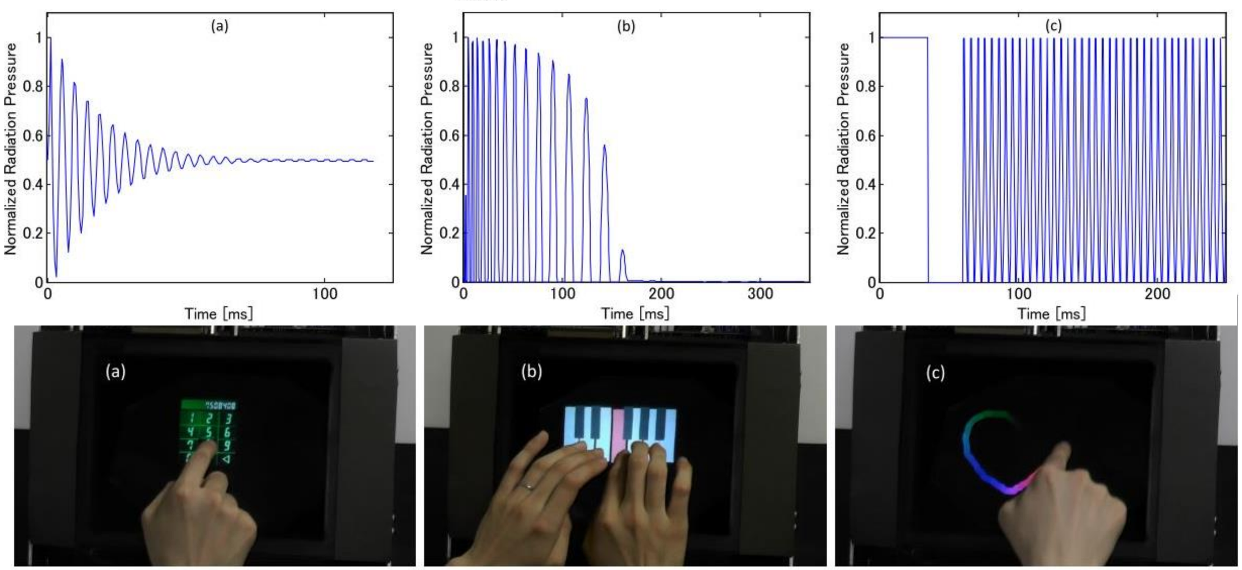
Example #1

- Haptomime

  The entire system is controlled by a Windows 7 computer that drives the LCD and the ultrasonic transducer based on the data acquired from the IR touch sensor.



- Haptic represent a crucial feedback for the system
- AIP has a narrow angle view
- Signal modulation reduce the perceived stimuli



keypad | Piano | Drawing

Yasuaki Monnai, Keisuke Hasegawa, Masahiro Fujiwara, Kazuma Yoshino, Seki Inoue, and Hiroyuki Shinoda. 2014. HaptoMime: mid-air haptic interaction with a floating virtual screen. In Proceedings of the 27th annual ACM symposium on User interface software and technology (UIST '14).

Example #2

- Mid-Air Gesture Interaction in Cars
  - ***Haptic***
    Mid-air Ultrasound haptic
    - 500 ms functional feedback on the palm
    - Circular gesture - circular motion
    - 500 ms at index - Victory gesture
    - Swipe – wall moving accordingly
  - ***Auditory***
    Headphones
    - Note associated with gesture with a duration of 300ms
  - ***Visual***
    Monitor
    LED strip
    - Swipe – Yellow light mimicking the gesture direction
    - Circular – Blue light incrementing (CW/CAW)
    - V – Blue light from ends to centre strip or RED

Figure 2. Experiment set-up.

5 conditions: V | U | AU | AU | UP

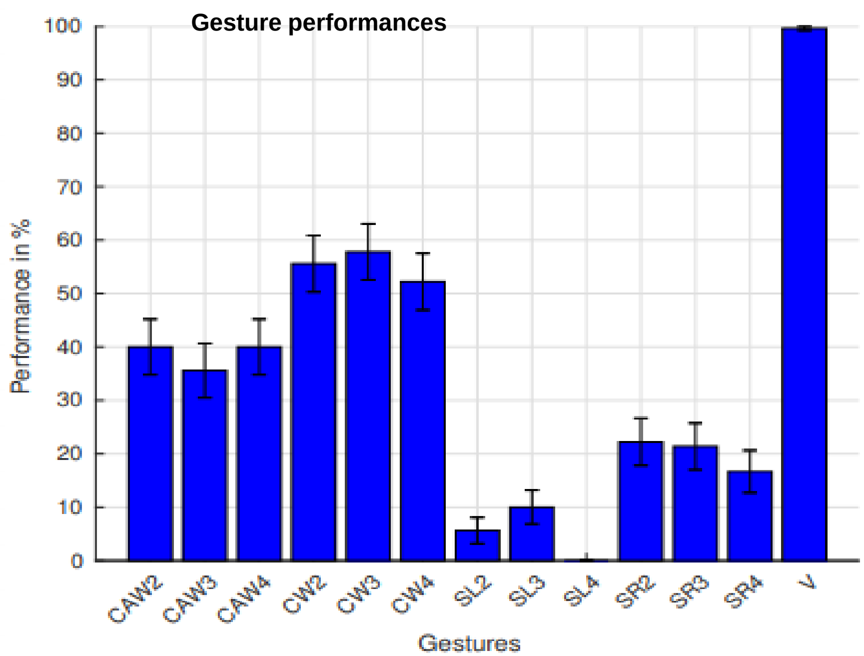
Shakeri, Gözel, John Williamson and S. Brewster. "May the Force Be with You: Ultrasound Haptic Feedback for Mid-Air Gesture Interaction in Cars." Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (2018).

Example #2

- Mid-Air Gesture Interaction in Cars

Change lane while performing a second task (gesture):
a) pop up message box - bottom of the screen
b) speech instructions - headphones

V U VU AU UP



V	U	UV	UA	UP
51.68%	21.11%	46.29%	52.22%	47.40%
10.06 s	8.22 s	10.16 s	10.58 s	9.98 s

Table 2. Secondary task performance (%) and duration (seconds) depending on condition. (V: visual; U: ultrasound; UV: ultrasound-visual; UA: ultrasound-audio; UP: ultrasound-peripheral.)

Shakeri, Gözel, John Williamson and S. Brewster. "May the Force Be with You: Ultrasound Haptic Feedback for Mid-Air Gesture Interaction in Cars." Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (2018).

L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

Summary

- Technological limitations
  - Simple actuators = simple control but less enhancing
  - Complex actuation methods = more tactile feedback
    How to control the system for more realistic feedback
  - Contactless technologies gives new possibilities but we still need to overcome limitations related with rendered and control of stimuli
  - To find out the best multimodal input for an interface is still an open research question.

- Biological limitations
  - Cognitive load while interacting with a MMIS
  - Cognitive load with multiple modalities
  - Integration of different modalities

1-H. Gunasekaran, "Multimodal enactive interface: Design principles grounded on cognitive neuroscientific basis," 2019 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), 2019.

2-Kuriakose B, Shrestha R, Sandnes FE. Multimodal Navigation Systems for Users with Visual Impairments—A Review and Analysis. Multimodal Technologies and Interaction. 2020;

Open questions

- Multimodality may increase task performance as the task gets gradually more difficult?
- Effectiveness of multimodality is scenario specific?
- Is our perception knowledge enough?
- Adding more cues could result in a masking effect of one over others?

Laboratoire d'électrotechnique et d'électronique de puissance de Lille

multiTOUCH

THANKS FOR YOUR ATTENTION

multiTOUCH

Questions?