AirWave Bundle

Hole-Home Gesture Recognition

and

Non-Contact Haptic Feedback

Talk held by Damian Scherrer on April 30th 2014

New Means of Communicating with Electronic Devices

Input

Whole-home gestures (WiSee)

Response

Non-contact haptic feedback

Known Examples for Gesture Recognition

Known Examples for Haptic Feedback

- In general: Establish a two-way physical communication between an electronic device and it‘s user

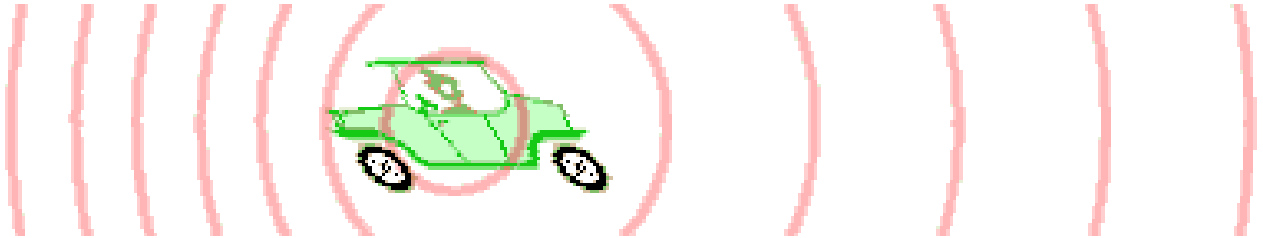
An Approach using EM Signals & Air Vortex Rings

→ Gesture recognition and haptic feedback without instrument-alisation of the body

→ A new way to communicate with electronic devices?

WiSee, a New Approach for through-the-wall Gesture Recognition

- Signal source can be a standard IEEE 802.11 a/g/n transmitter
- Transmitted signals are reflected by humans that are in range
- If the person is moving the signal is Doppler-shifted
- Reflected signals are received by receivers of the same standard



Q: Which frequency-band (2.4Ghz or 5GHz) should be used?

Doppler-Shifts Contain Information of Motion

- Doppler-Shifts are proportional to the speed of human motion:

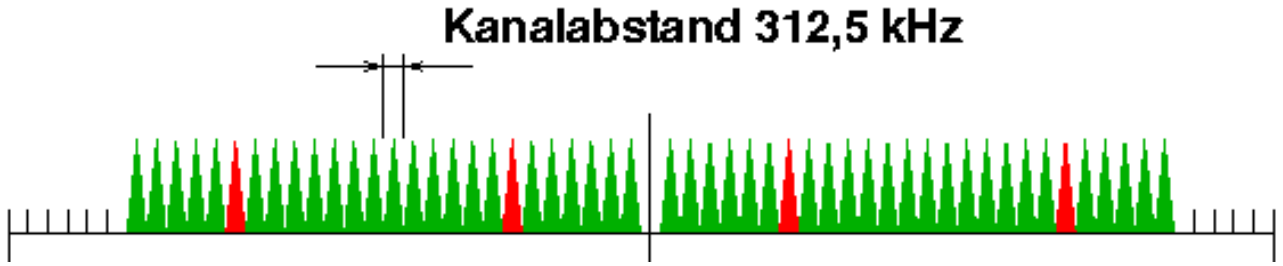
$$\Delta f = \frac{2v \cos\theta}{c} f$$

- Assuming human motion directly towards the receiver at 0.5m/s
  - This leaves us with a Doppler-shift of nearly 17Hz
- (5GHz WiFi-band: Channels of 20MHz, divided into 64 sub-channels of 312.5kHz bandwidth each and 250k symbols/s)

→ It seems we have a problem here!

Narrowing Down Sub-Channel Bandwidth

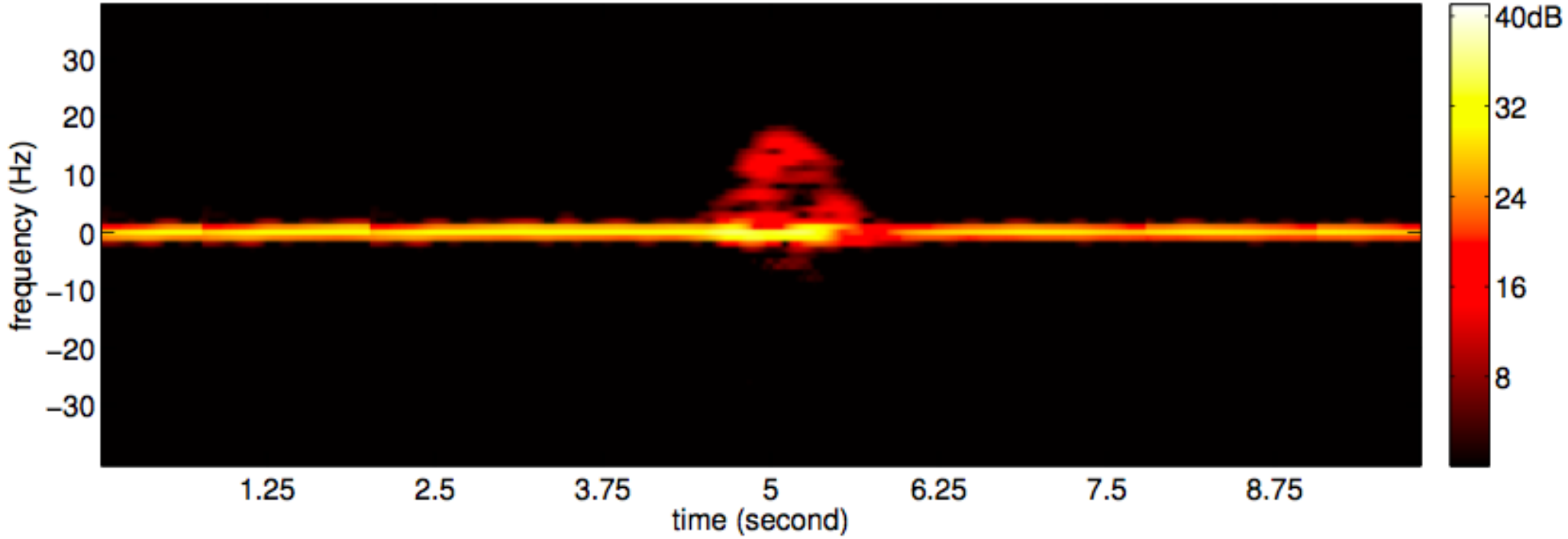
- Assumptions:
  - OFDM (Orthogonal Frequency Division Multiplexing) Channel
  - Same symbol is sent over considered timespan
  - Transmitter is sending constantly



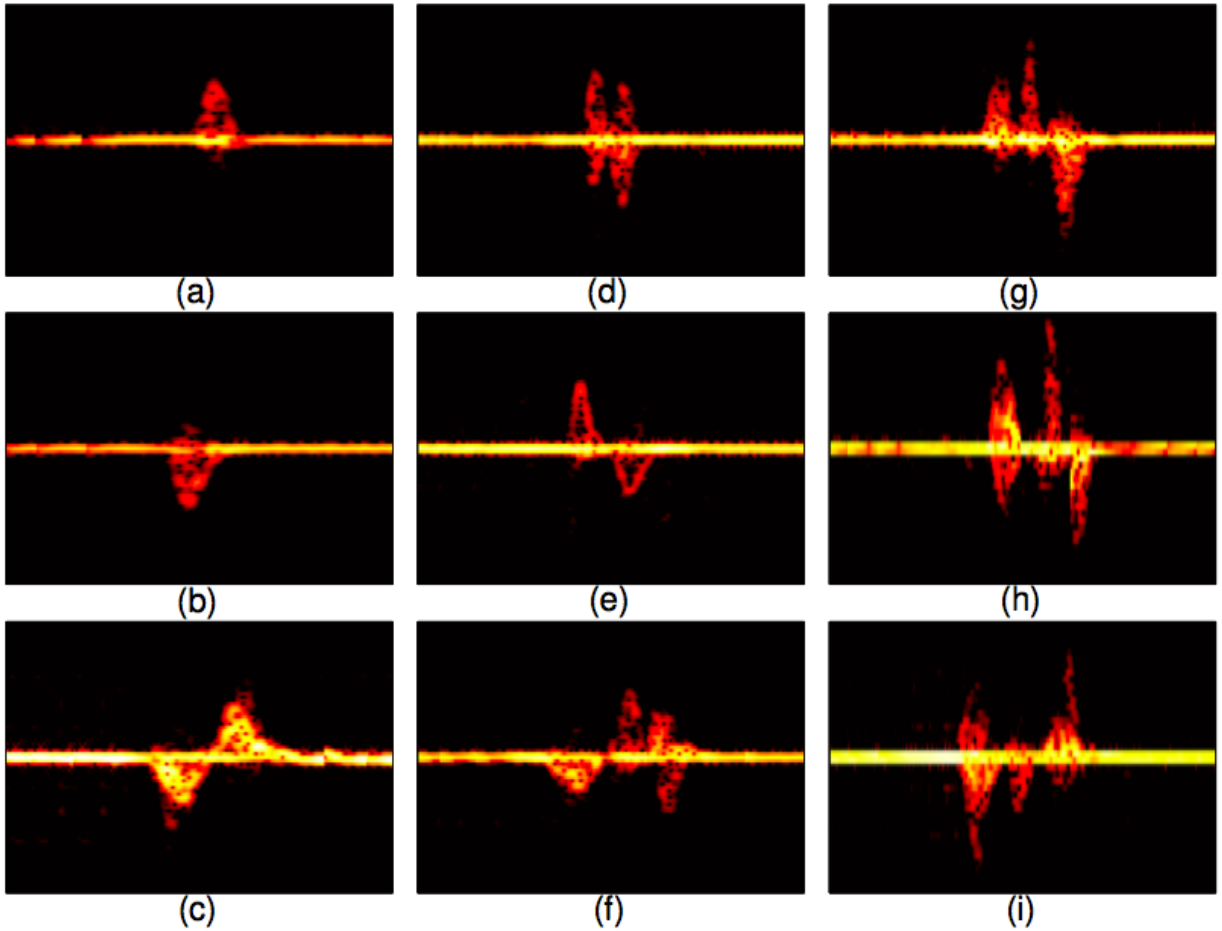
- Taking a large FFT over M consecutive symbols reduces the bandwidth of each sub-channel by a factor of M

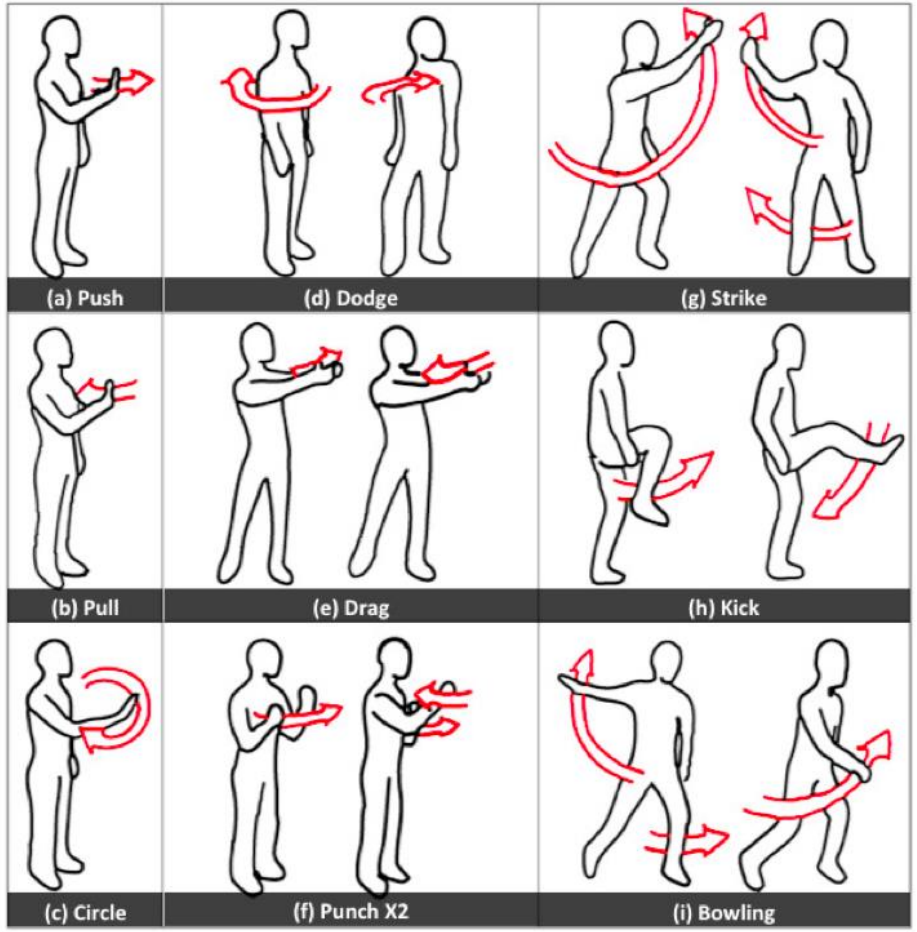
Extracting Doppler-Shifts

- Sliding window of 0.5 s results in a resolution of about 2Hz
- Perform FFT every 5 ms



Mapping Shift-Patterns to Gestures





Support Multiple Humans using MIMO 1

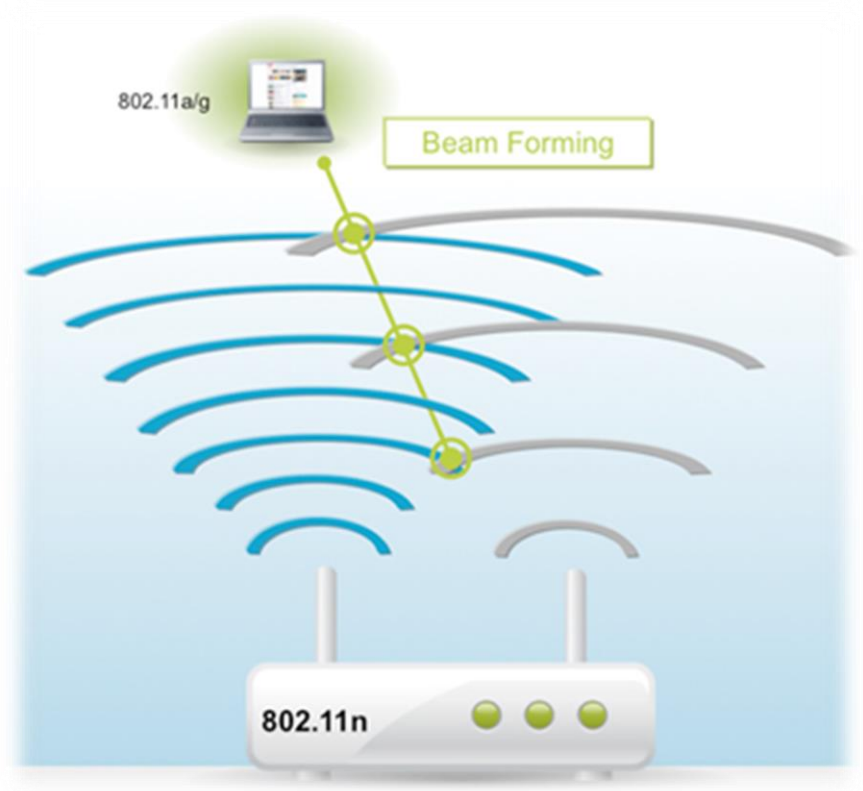
- Objectives:
  - Lock onto one user among other humans
  - Differentiate between users
- Method:
  - Use personal preamble gestures
  - Maximise Doppler energy for an individual

$$D_m = \sum_{n=1}^{N} W_n D_{nm}$$

D: Doppler energy m: Preamble segment N: #Antennas W: Complex Weight

Support Multiple Humans using MIMO 2

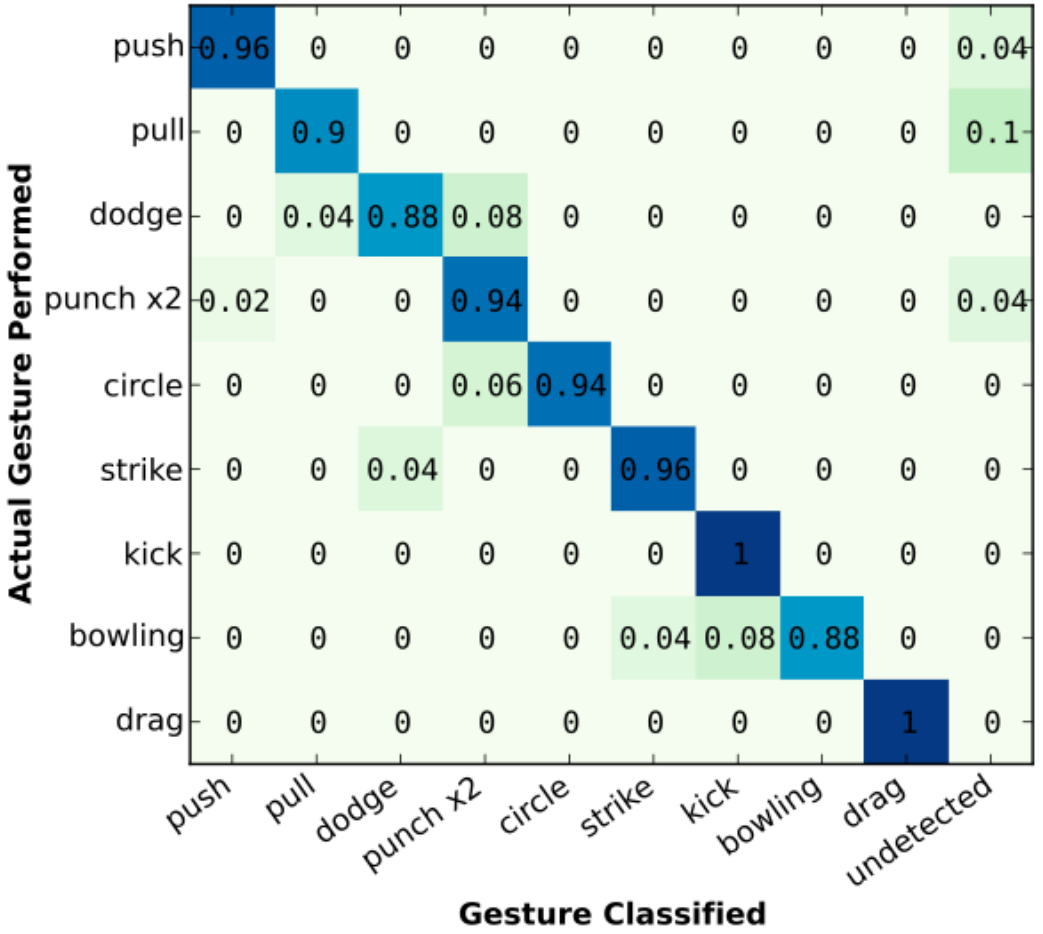
- Looking at it from a physical perspective: Beam-forming

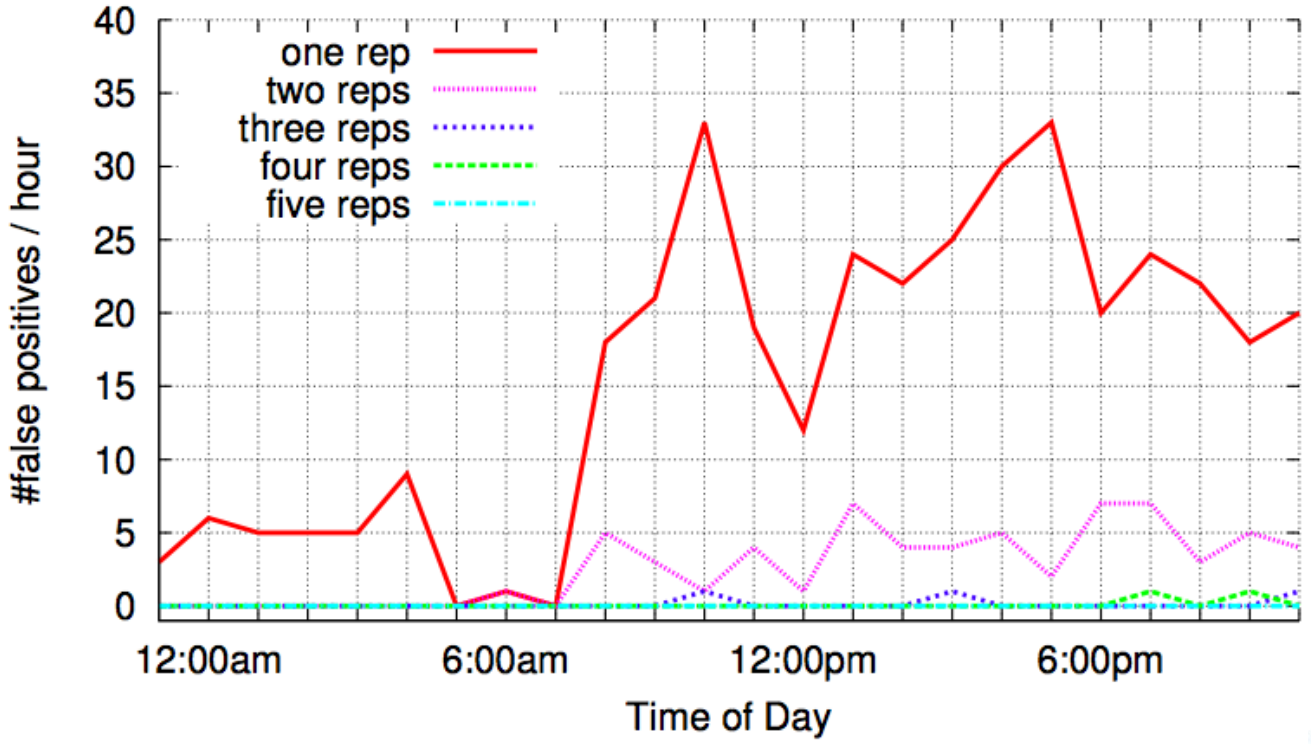


Addressing Multipath

Q: How should the problem of multipath be addressed?

Practical Results





Quick Summary on WiSee

- Using a standard WiFi setup
- Human movements create Doppler-shifts
- Detect Doppler-shifts after narrowing down sub-channel bandwidth
- Map discrete frequency-shift-pattern to predefined gestures
- Identify multiple users using complex MIMO weights

Formation of Vortex Rings

- Fixed volume of gas (slug) is pushed out of an aperture
- Low pressure region is formed around periphery region of aperture
- Vorticity increases until reaching the critical mass

Air Vortex Rings Optimised for Haptic Feedback 1

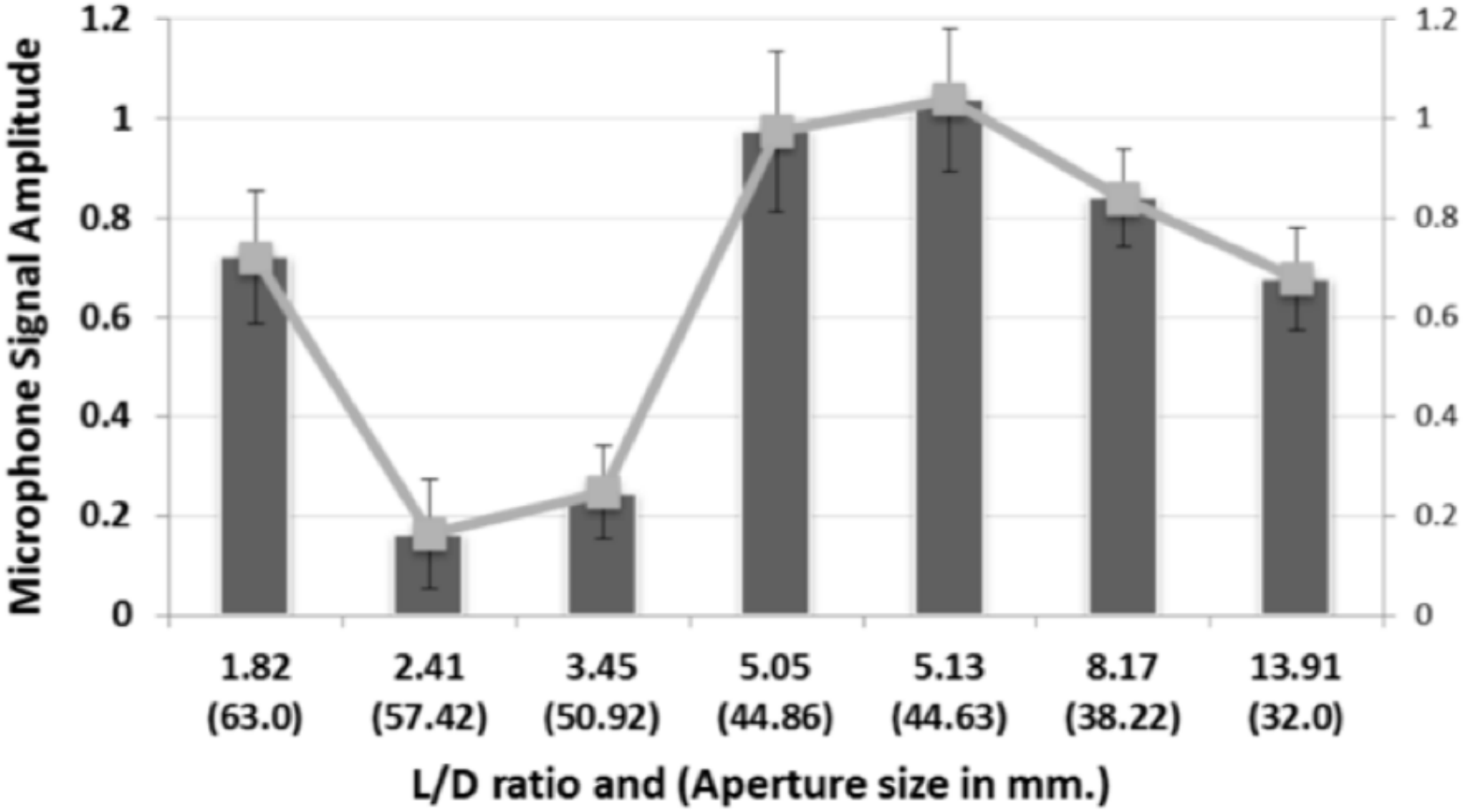
- Stability of vortex defined as follows (formation number):

$$L_{slug}/D_a = \frac{4V_{displaced}}{\pi D_a^3}$$

  - Previous research has shown that an L/D ratio between 1 and 4 forms a stable vortex
  - Vortex propagation speed equals half the slug speed

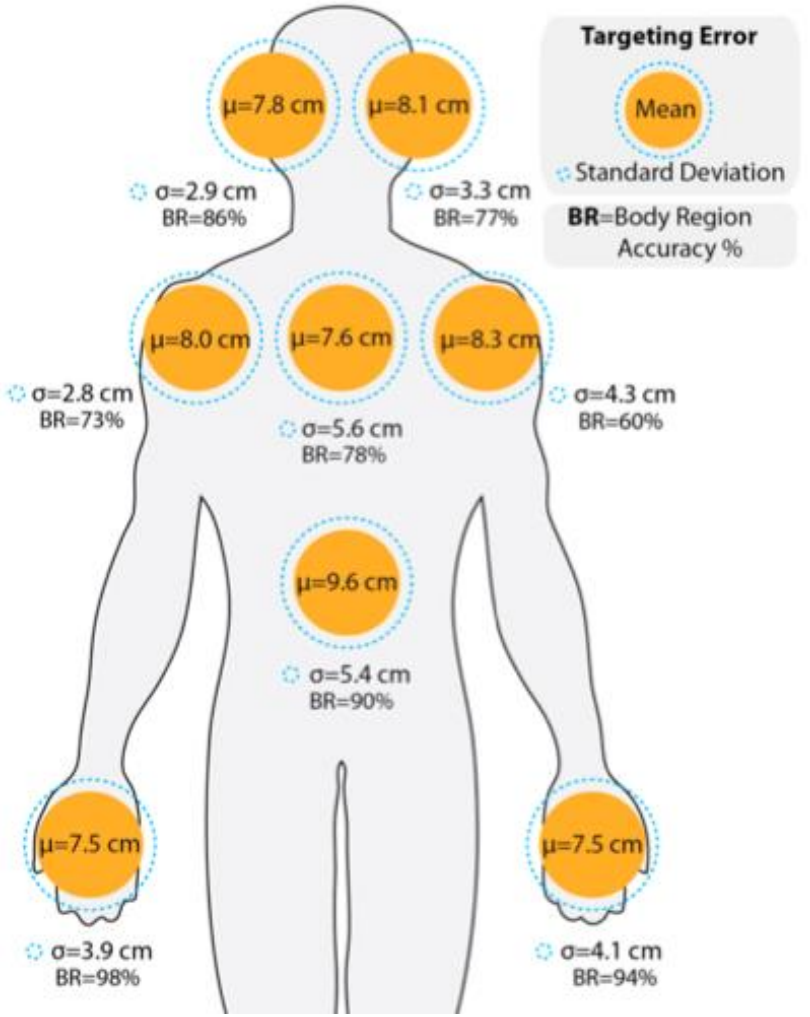
→ Find parameters that maximise pressure applied by a vortex

Air Vortex Rings Optimised for Haptic Feedback 2



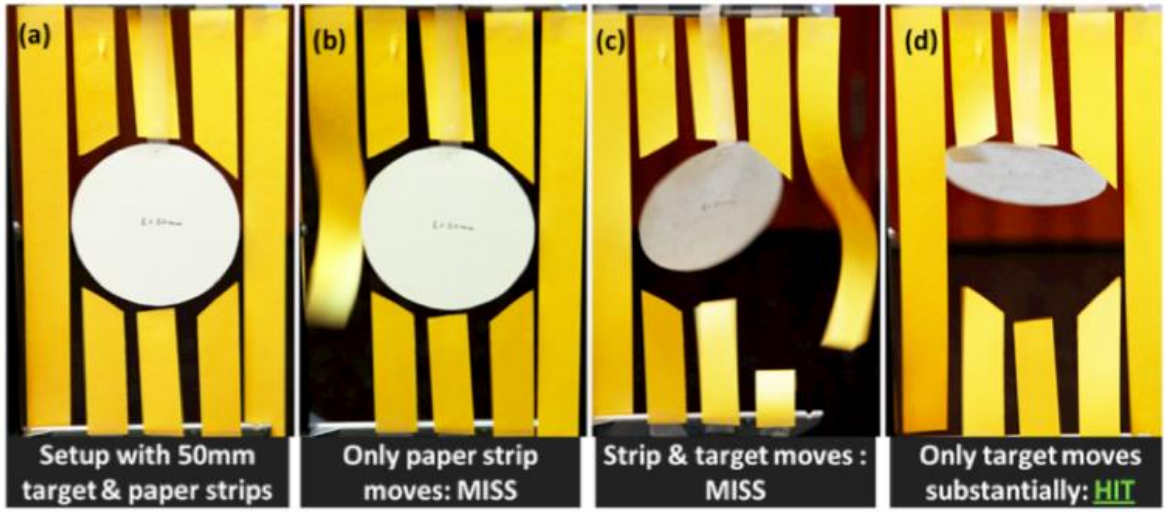
Found Parameters Proved to be Useful 1

- Vortex rings are shot at targeted person at a distance of 2.5m
- 8 body locations, 10 test subjects
- Subjects not instructed concerning clothing

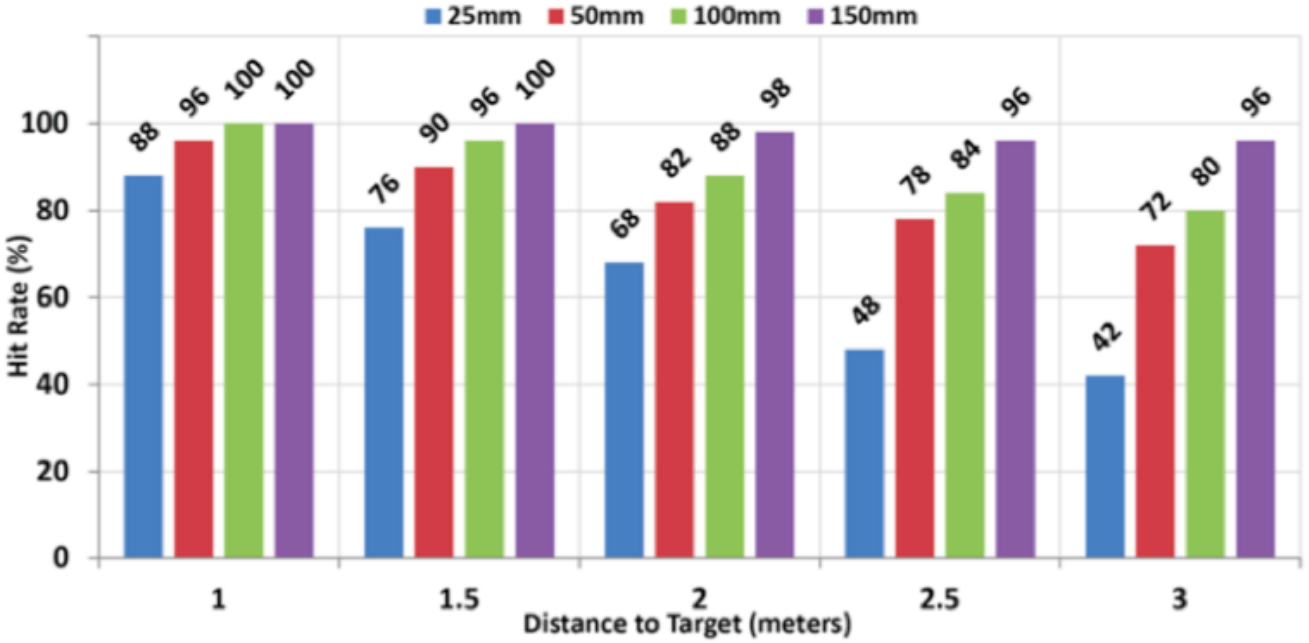


Found Parameters Proved to be Useful 2

- Experiment Setup:



- Experiment Results:



Summary and Possible Applications

- WiSee: Proof of concept (link)

- Possible Applications:
  - Use air vortex rings for applications with non-obvious feedback
  - Have gestures recognised when under the shower
  - …invent your own ☺

References

- Whole-Home Gesture Recognition Using Wireless Signals
  - Qifan Pu, Sidhant Gupta, Shyamnath Gollakota and Shwetak Patel
  - MobiCom 2013.
- AirWave: Non-Contact Haptic Feedback Using Air Vortex Rings
  - Sidhant Gupta, Dan Morris, Shwetak Patel, Desney Tan
  - UbiComp 2013

Q & A