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):

\[ \frac{L_{\text{slug}}}{D_a} = \frac{4V_{\text{displaced}}}{\pi D_a^3} \]

• 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