ETH zürich

Smart Environments without Cameras:
Electrical Field Sensing for Human-Computer Interaction

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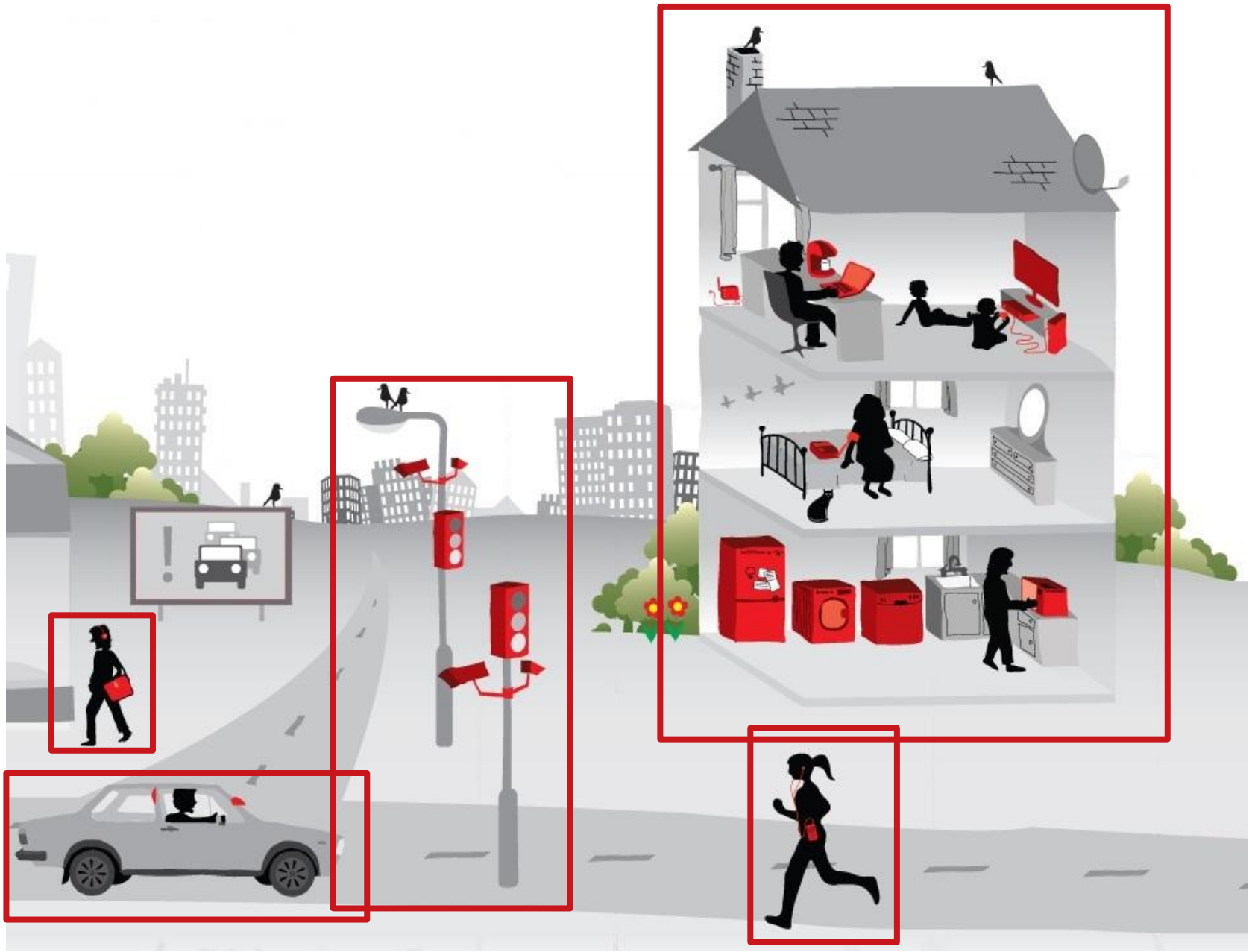
18.3.2014

Ubiquitous Computing Seminar FS2014

institute for pervasive computing

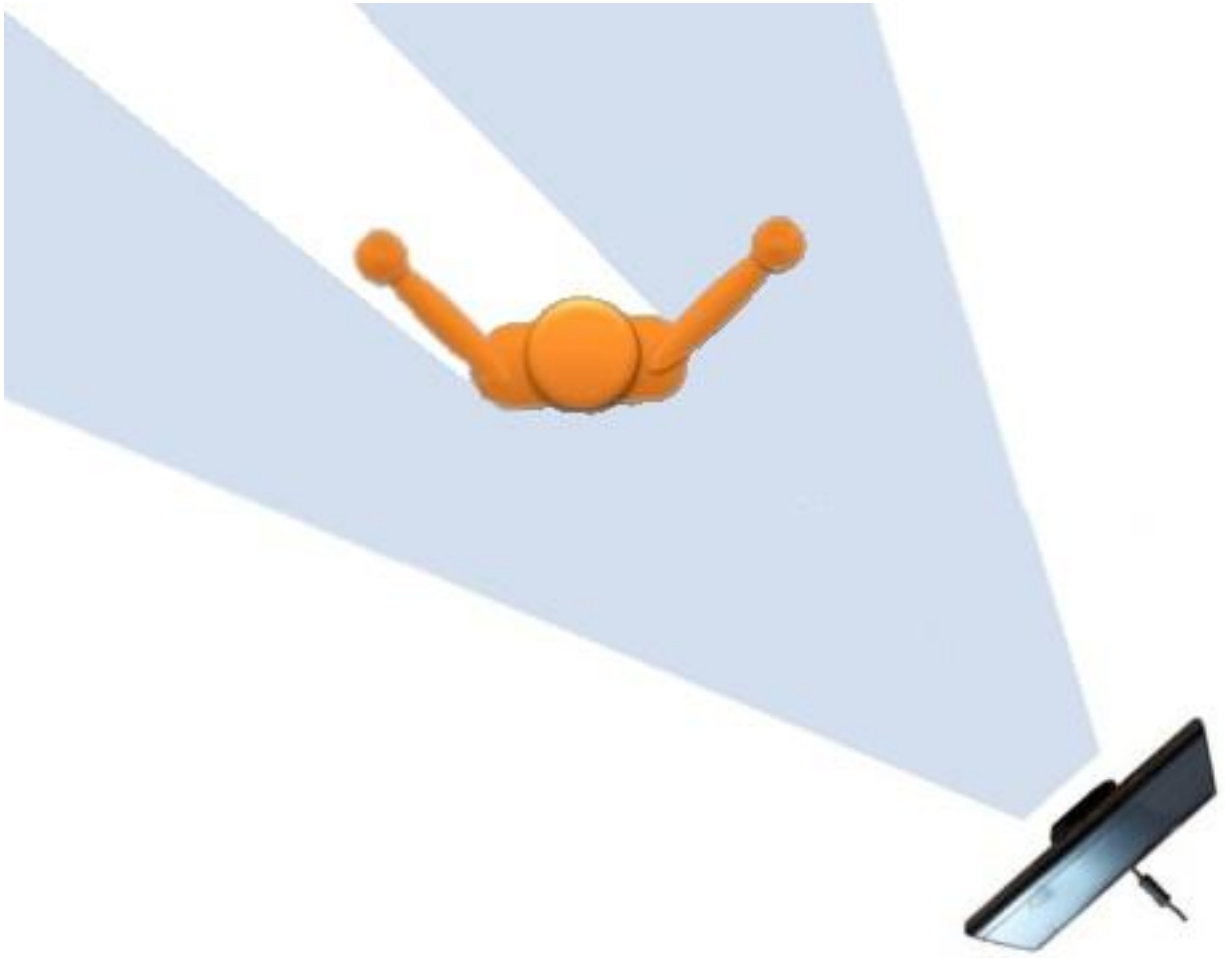


At Home: Kinect

There are some problems with cameras…

Illumination

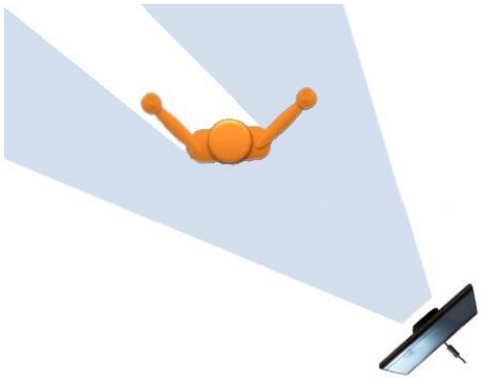
Occlusion



Bandwidth

Power Consumtion

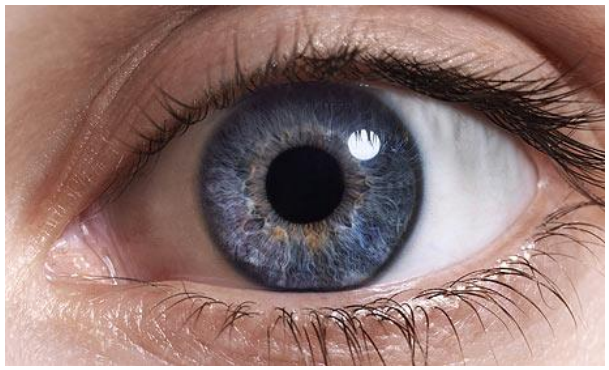
Cost



Privacy?

Other Sensing Methods?

- Vision is one of our main senses



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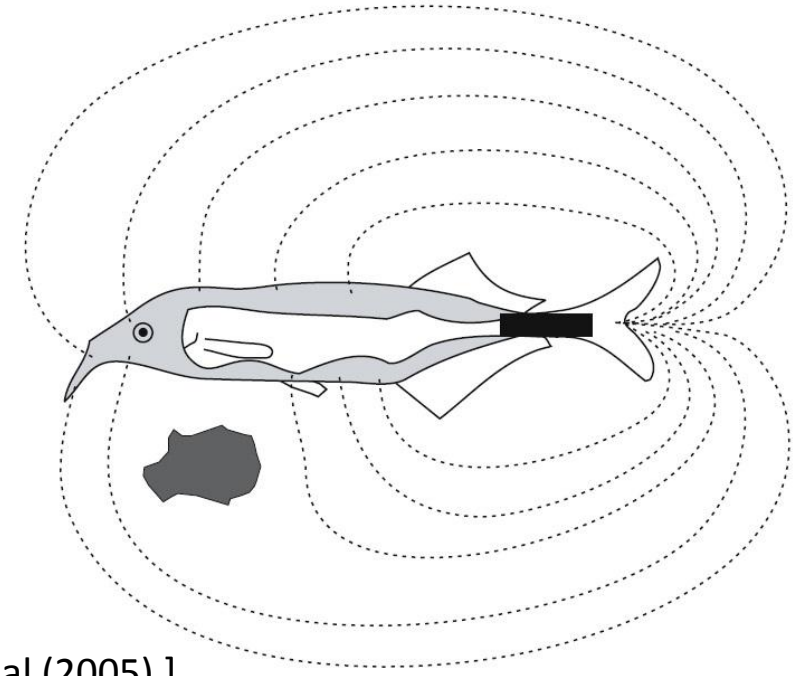
- What else could we try?

?

Other Senses: Elephantnose Fish

- Weakly electric
- Uses electric fields to detect nearby objects



[modified after Bullock et al (2005)]

Modeling Electric Fields with Capacitors

- Electric Fields can be modeled with capacitors
- Plate capacitor is the simplest model

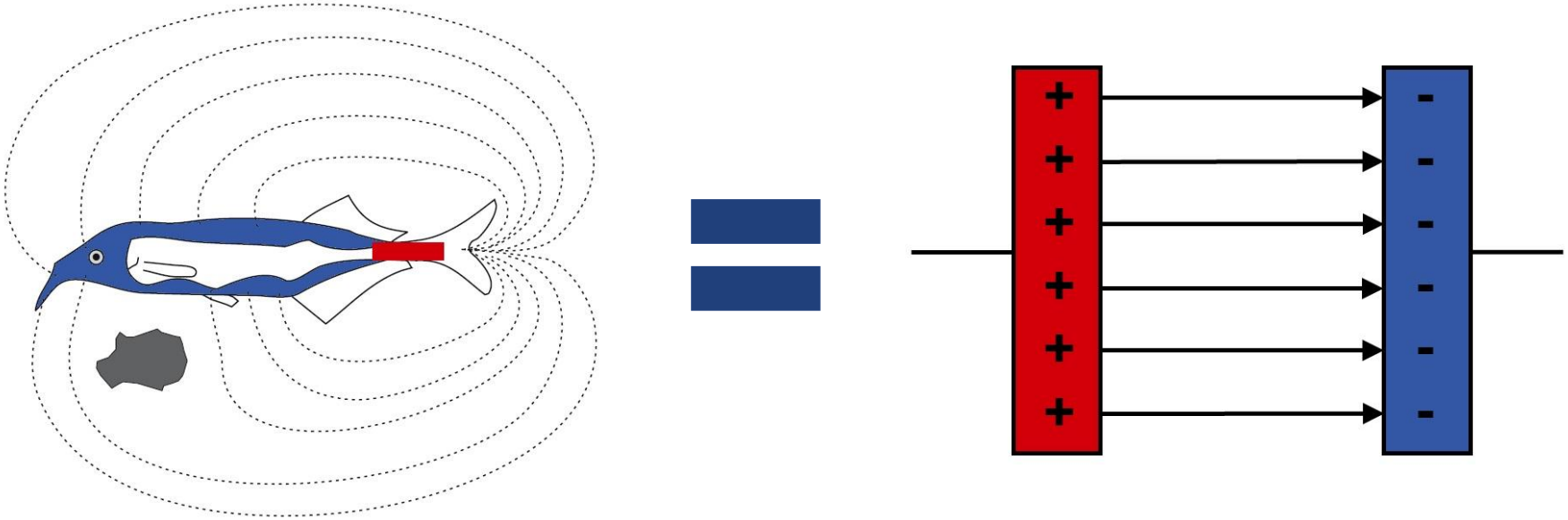
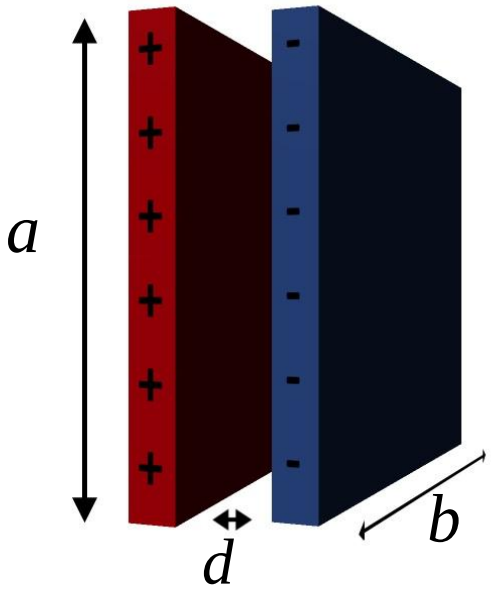


Plate Capacitor

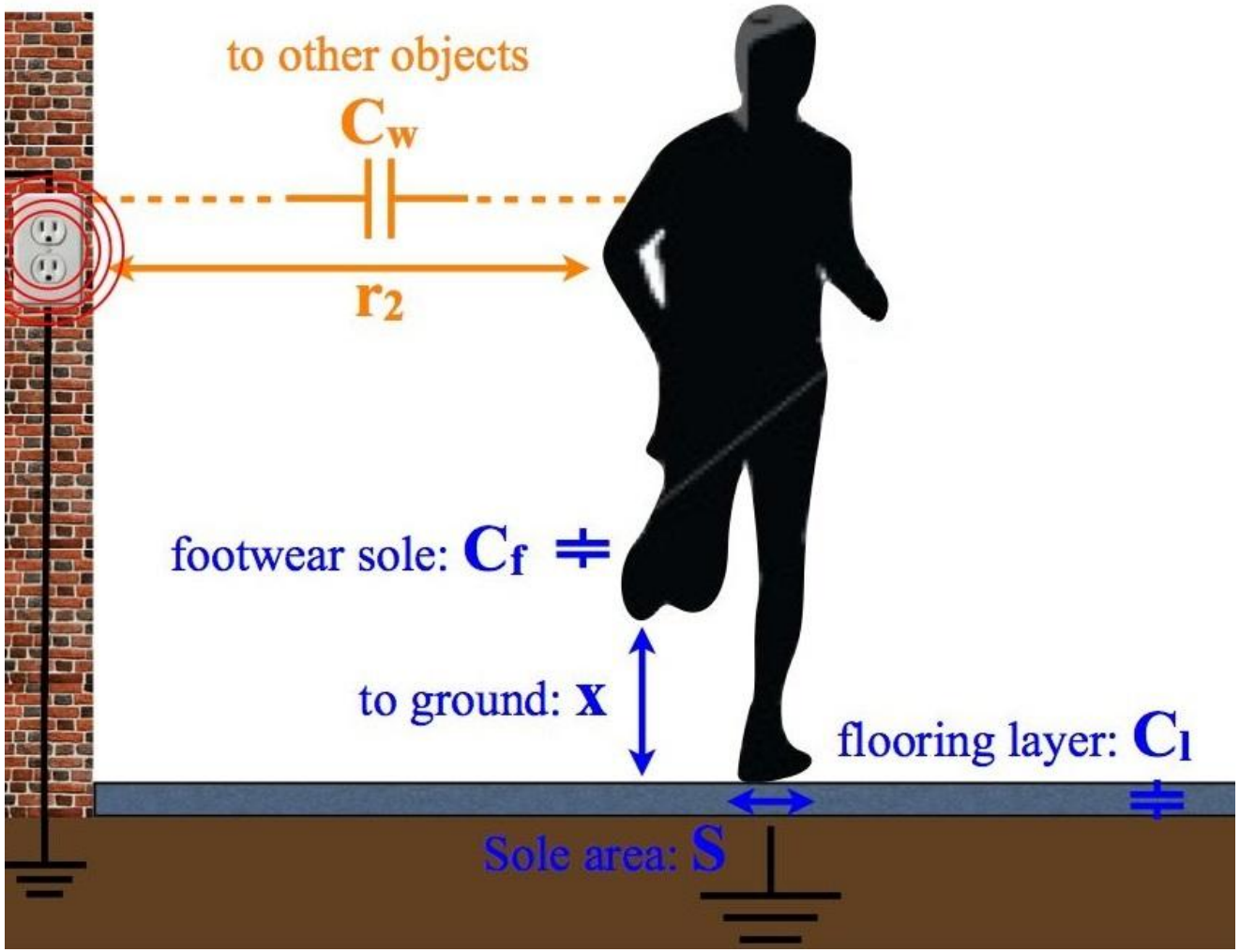


$$A = a \cdot b$$

$$E = \frac{Q}{\varepsilon A} = \frac{U}{d}$$

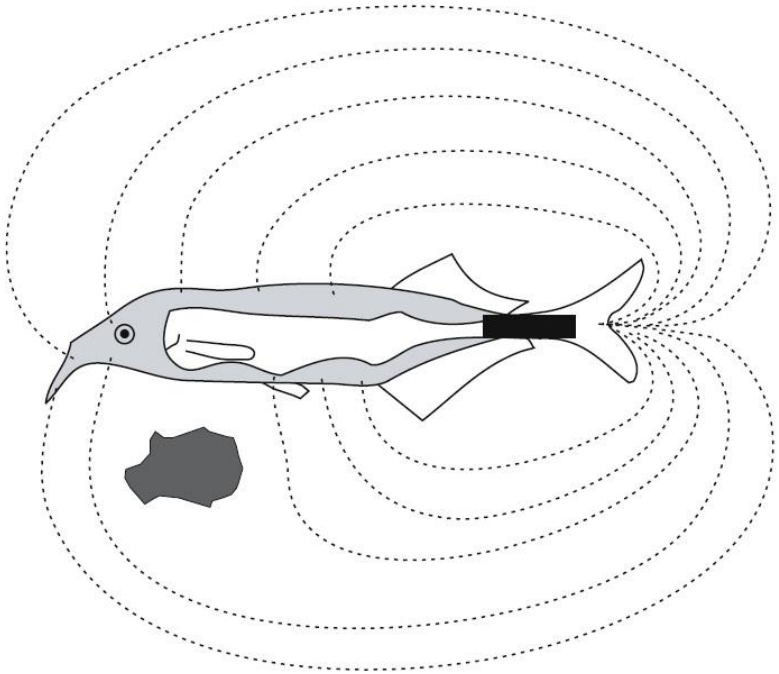
$$U = \frac{Qd}{\varepsilon A}$$

Capacitors in the Environment

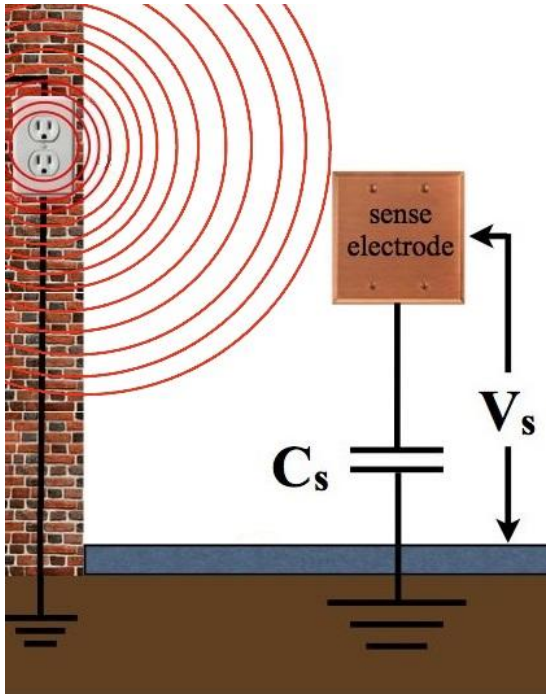


[Mujibiya, Rekimoto (2013)]

Active and Passive Electric Field Sensing



Actively emit field and sense distortion

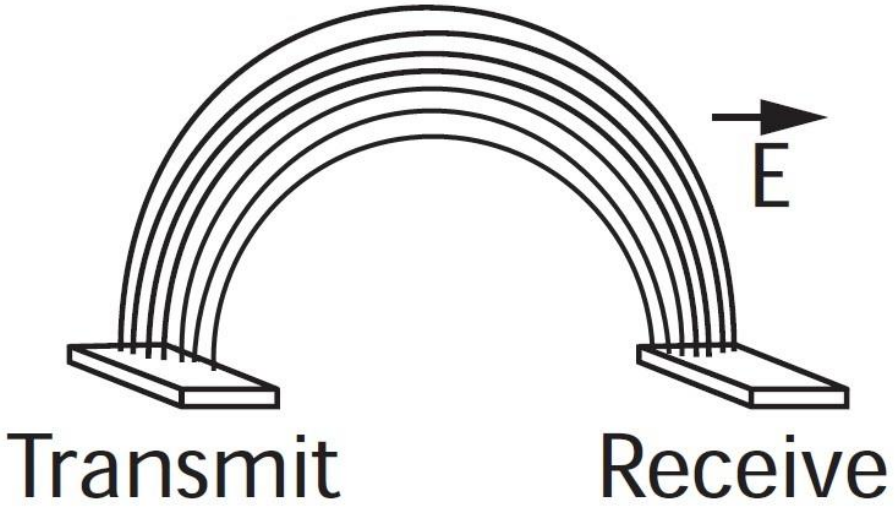


Passively sense fields from the environment

[modified after Mujibiya, Rekimoto (2013);]

Shunt Mode

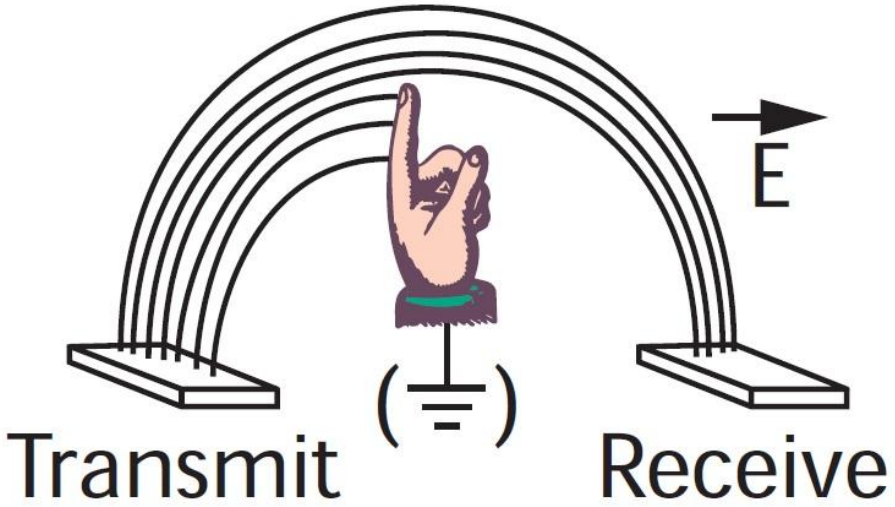
- Transmit electrode transmits electric field
- Receive electrode measures electric field



[Smith et al (1998)]

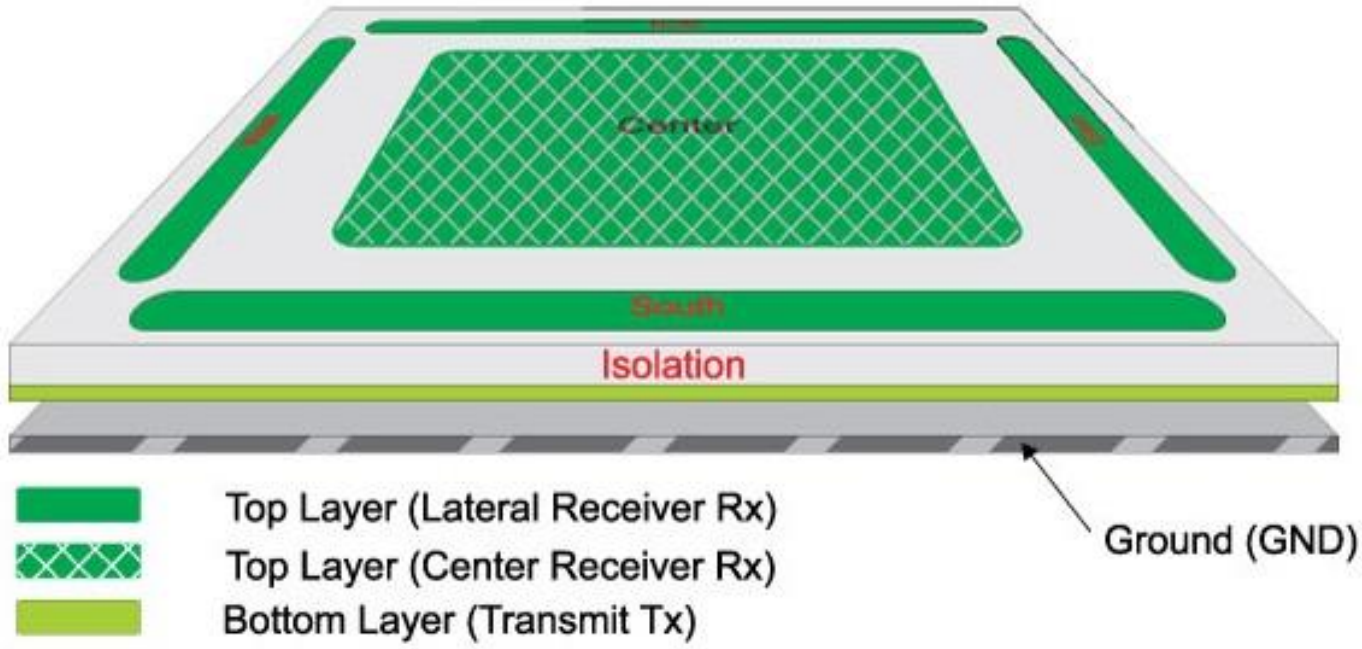
Shunt Mode

- Body acts as (virtual) ground
- Body „shunts“ signal to ground
- Received signal decreases

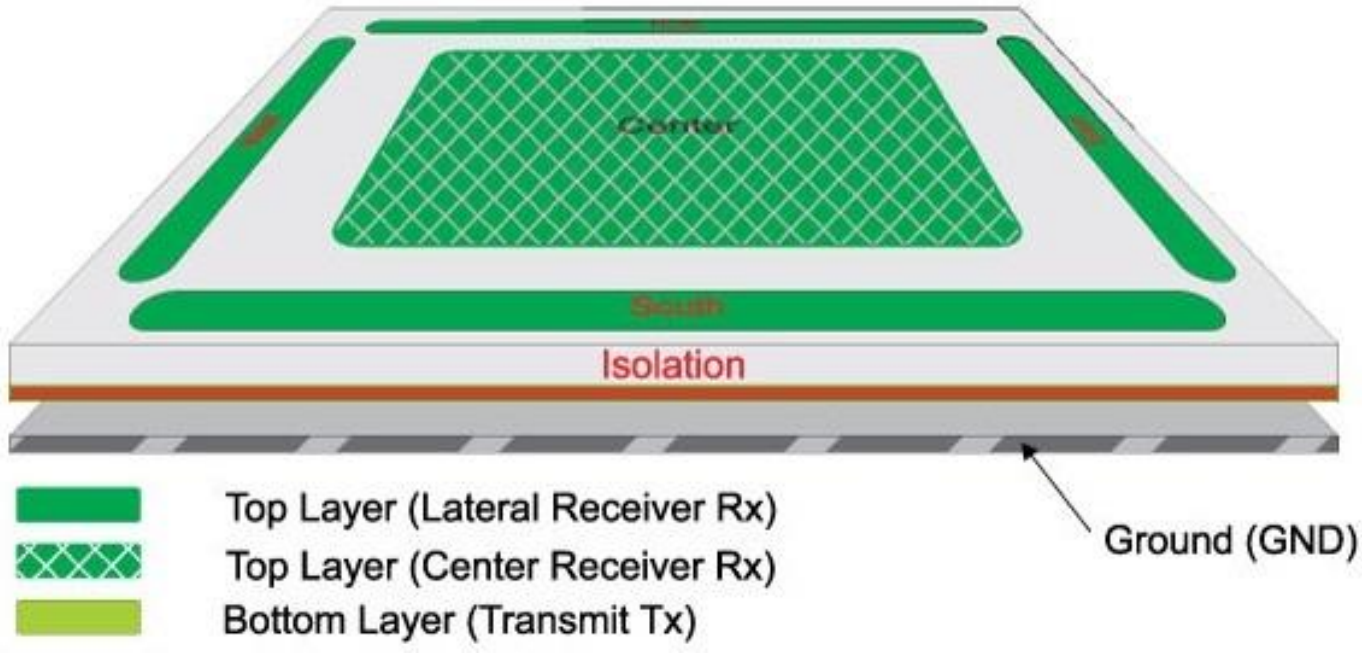


[Smith et al (1998)]

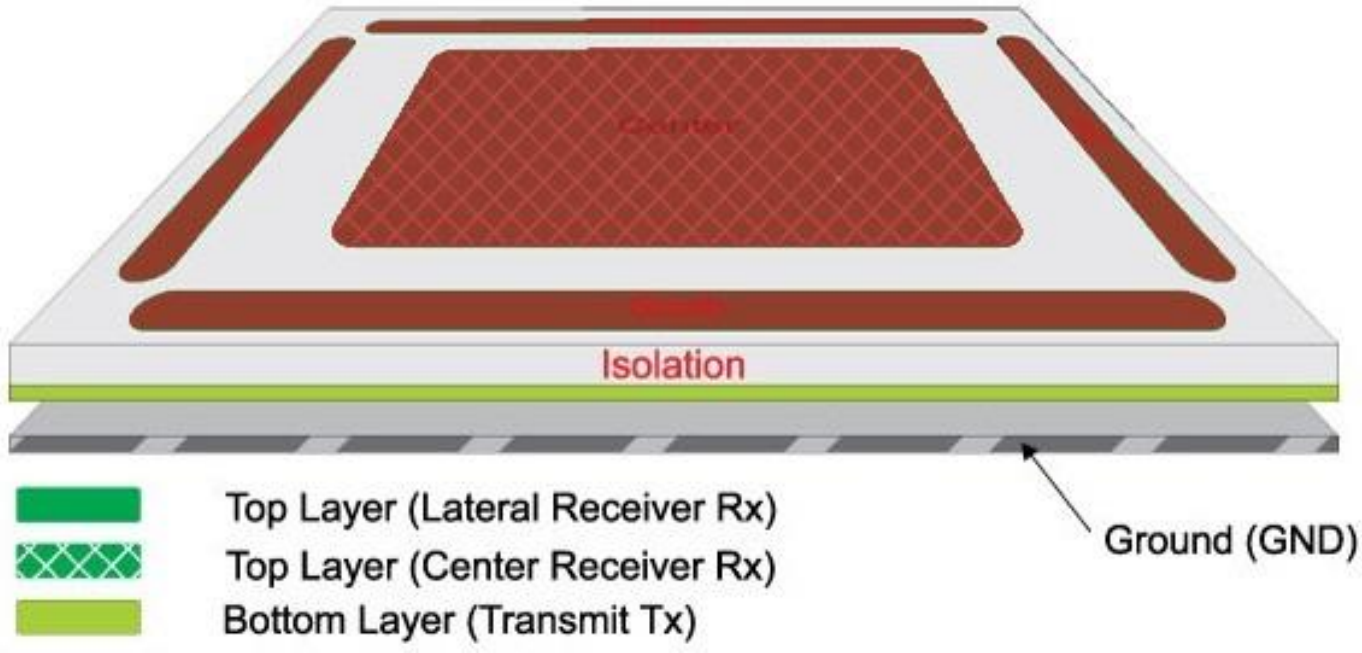
GestIC Electrode



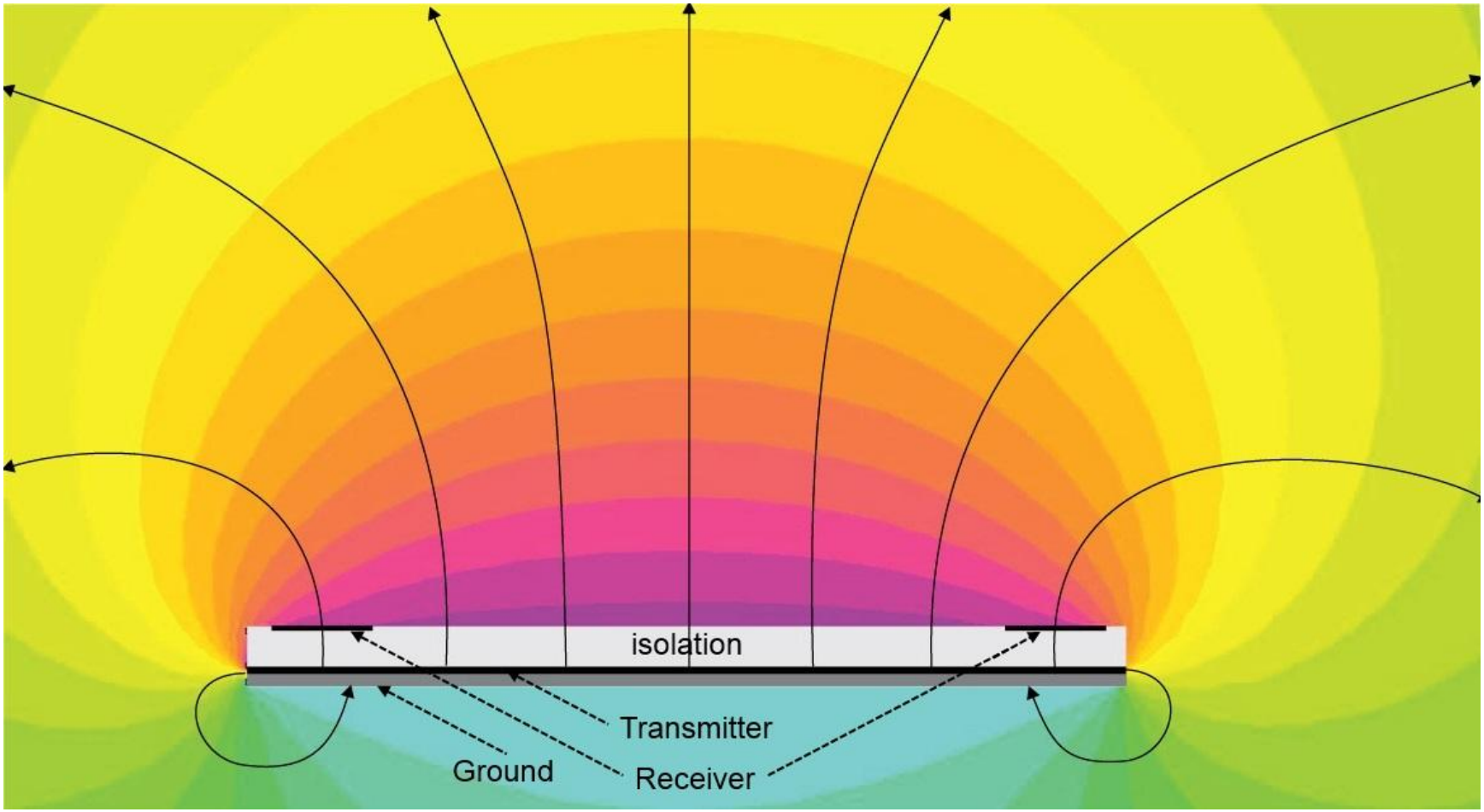
GestIC Electrode



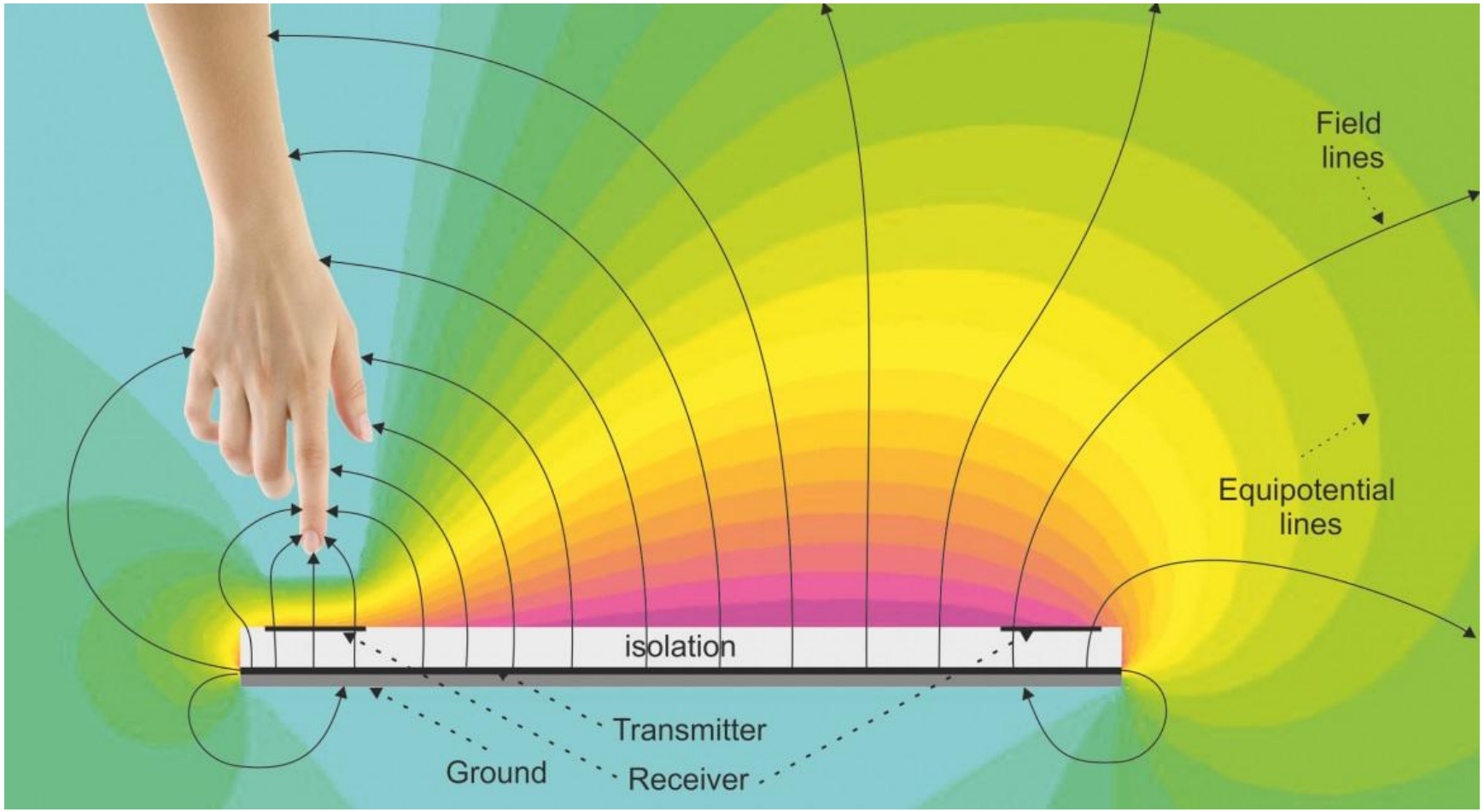
GestIC Electrode



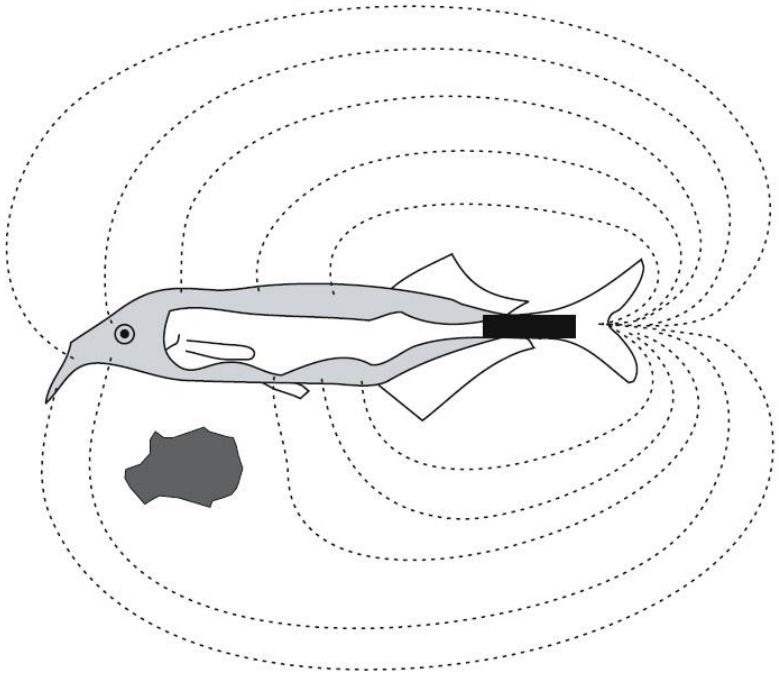
GestIC Electric Field



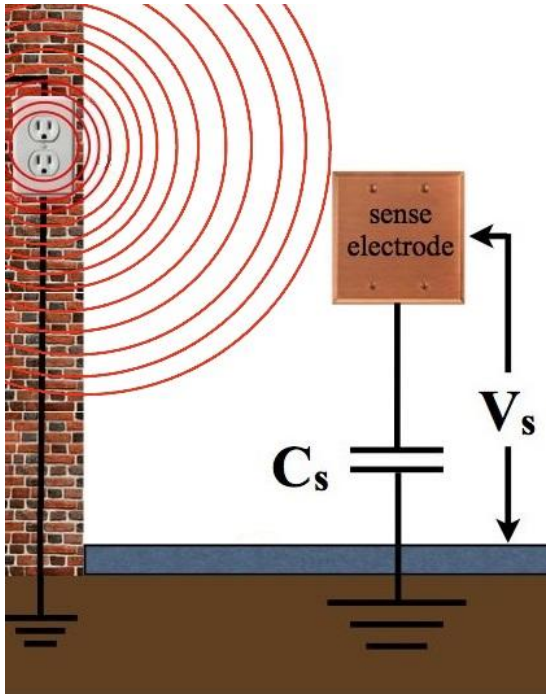
GestIC Electric Field



Active and Passive Electric Field Sensing

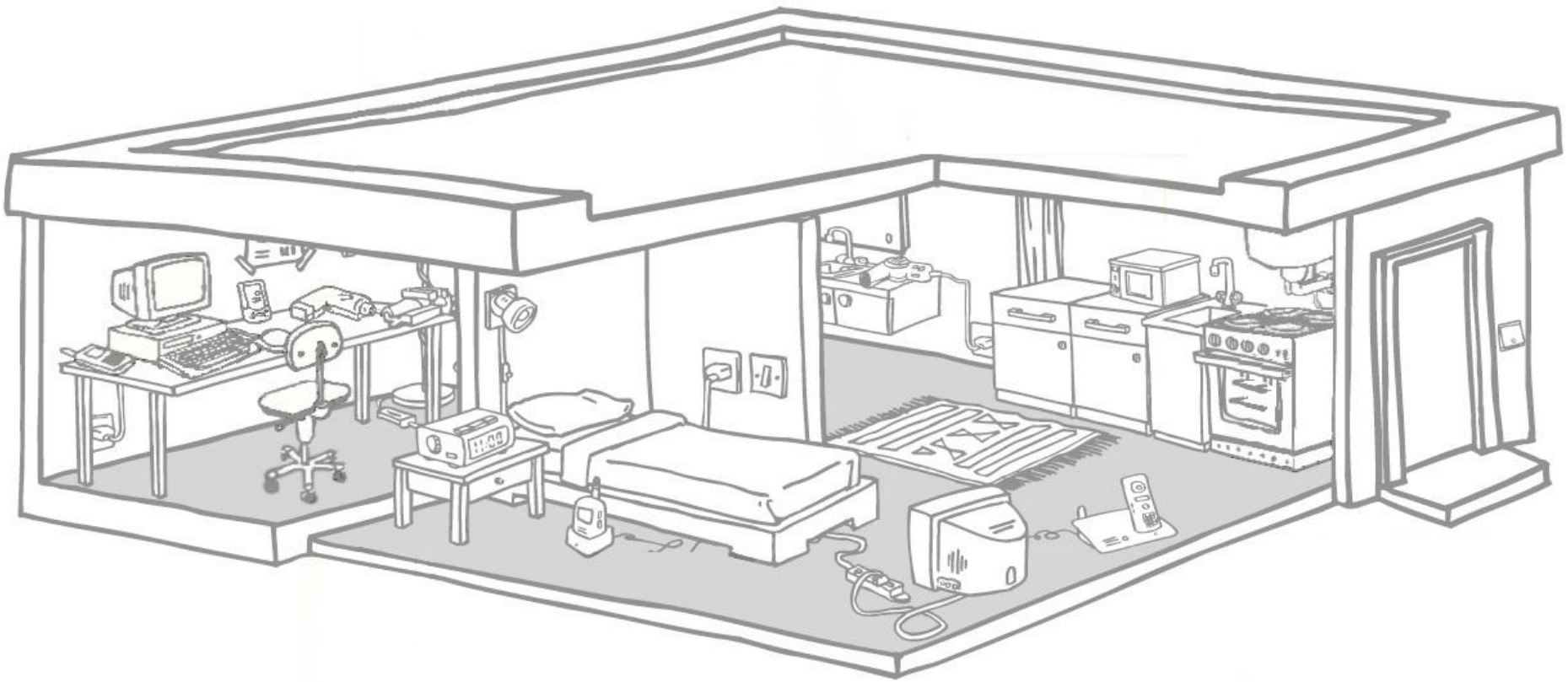


Actively emit field and sense distortion



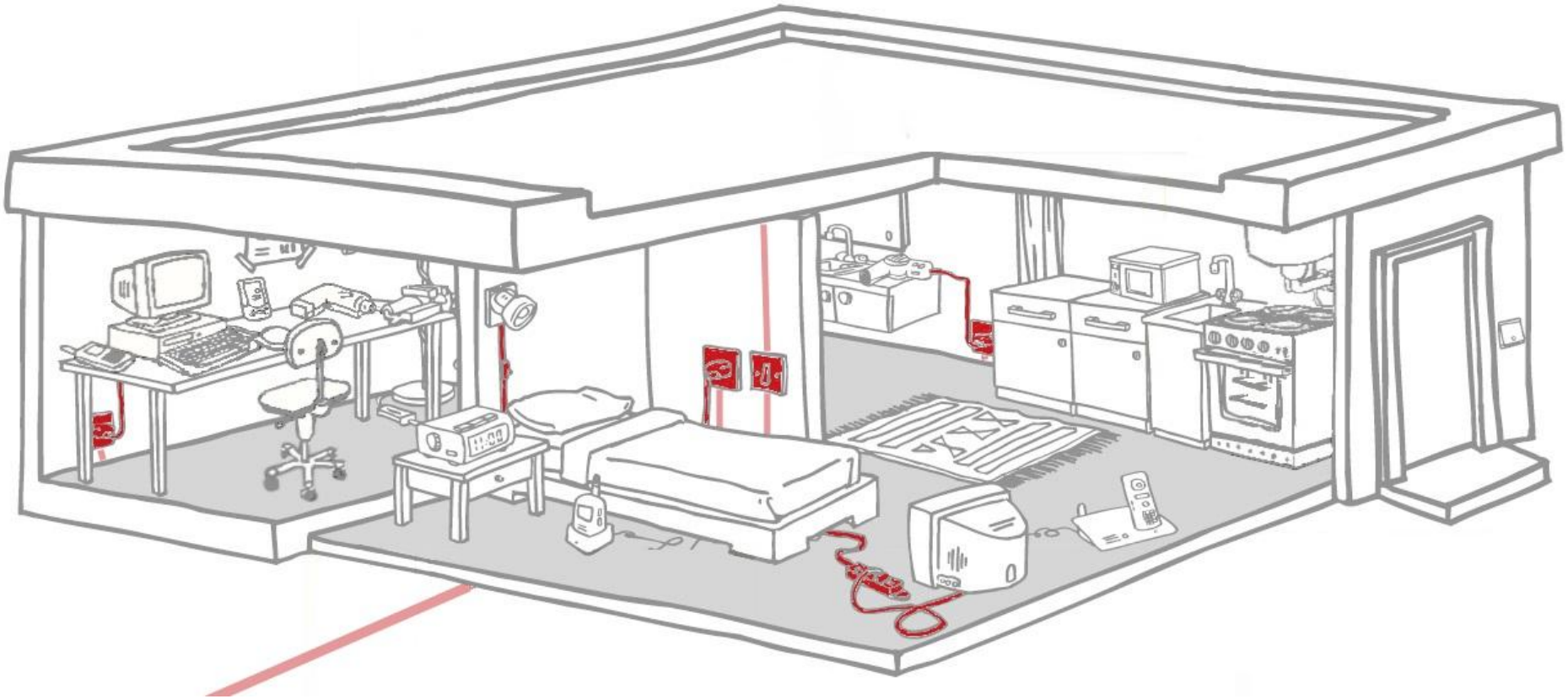
Passively sense fields from the environment

Electrical Noise at Home



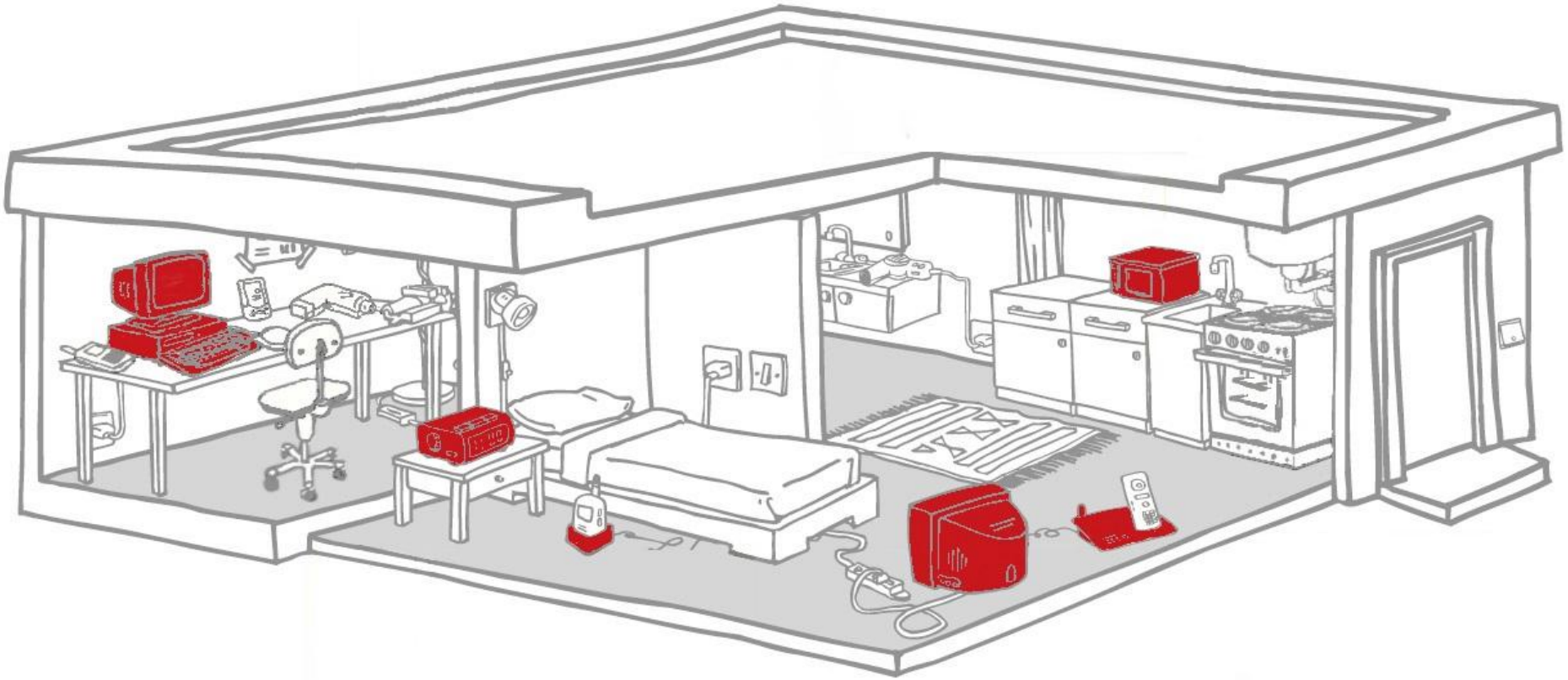
Electrical Noise at Home

- Power lines (AC and received noise)



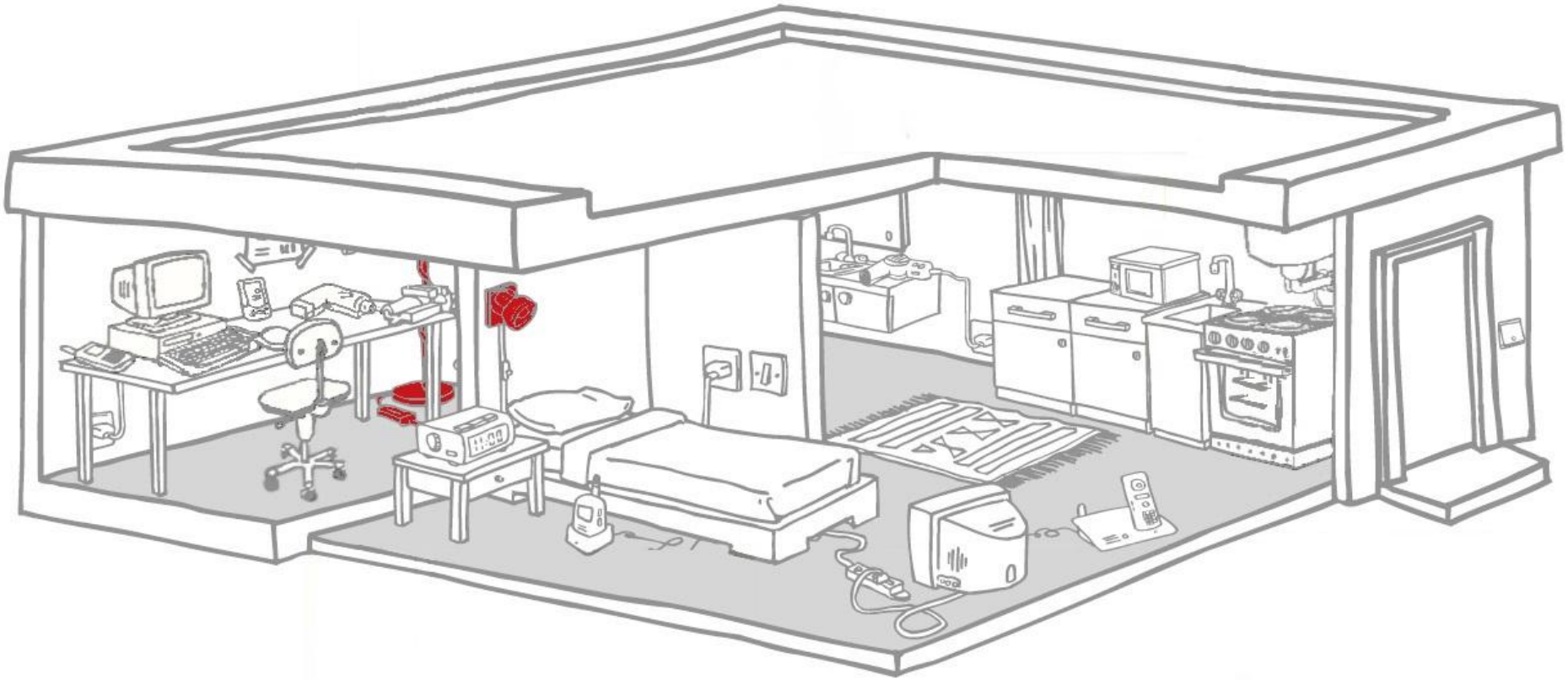
Electrical Noise at Home

- Switched-Mode Power Supplies



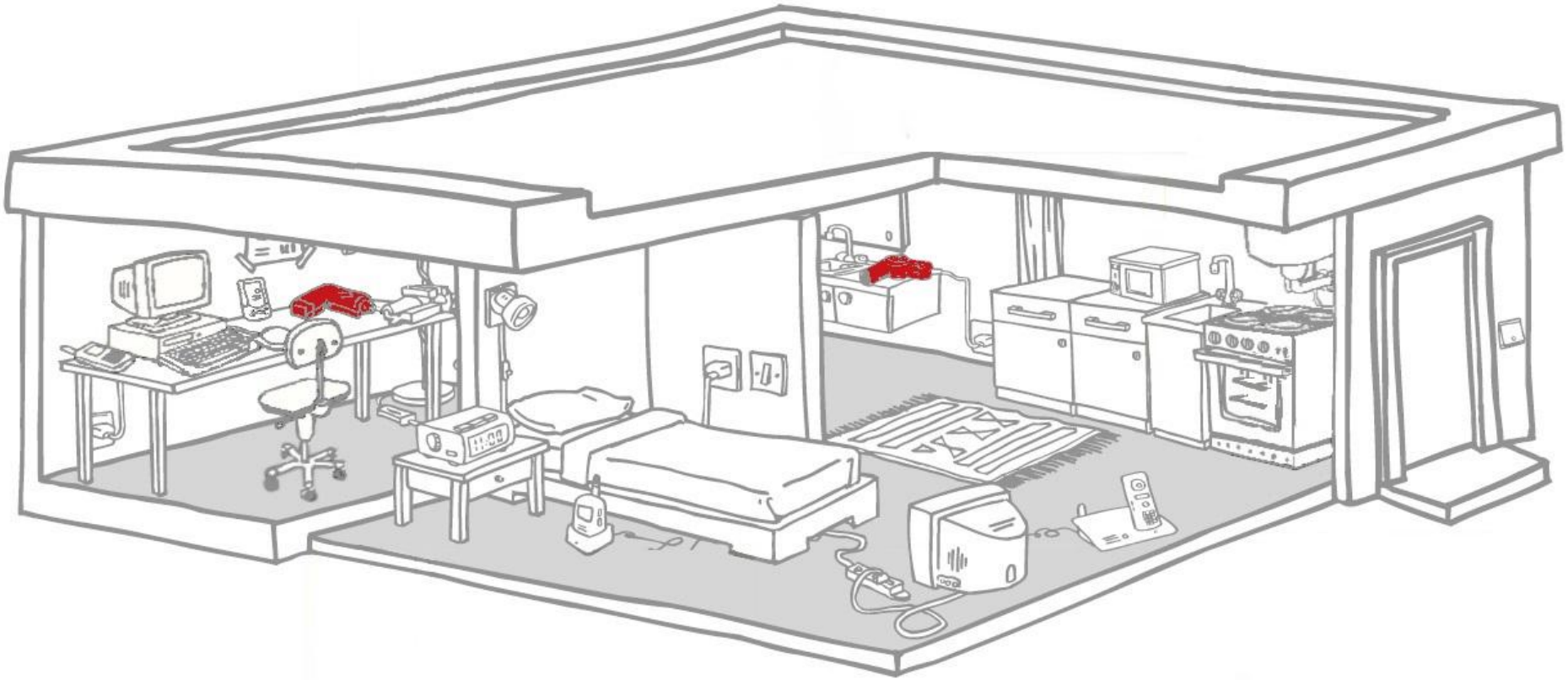
Electrical Noise at Home

- Dimmers

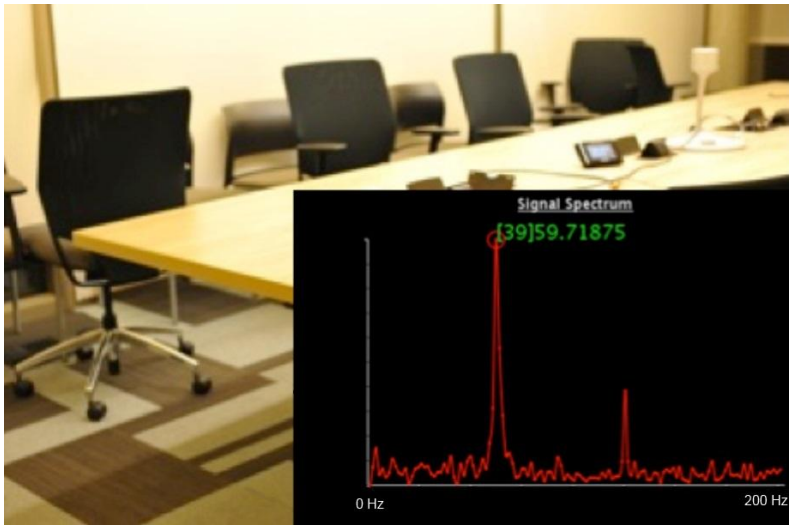


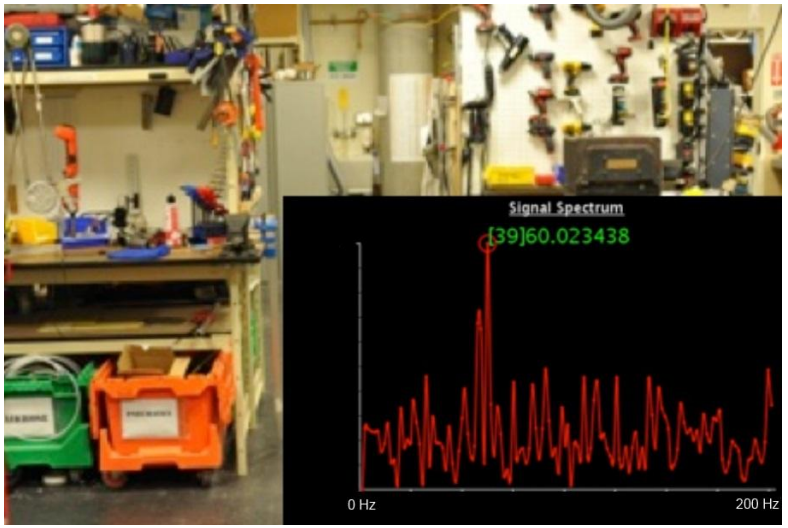
Electrical Noise at Home

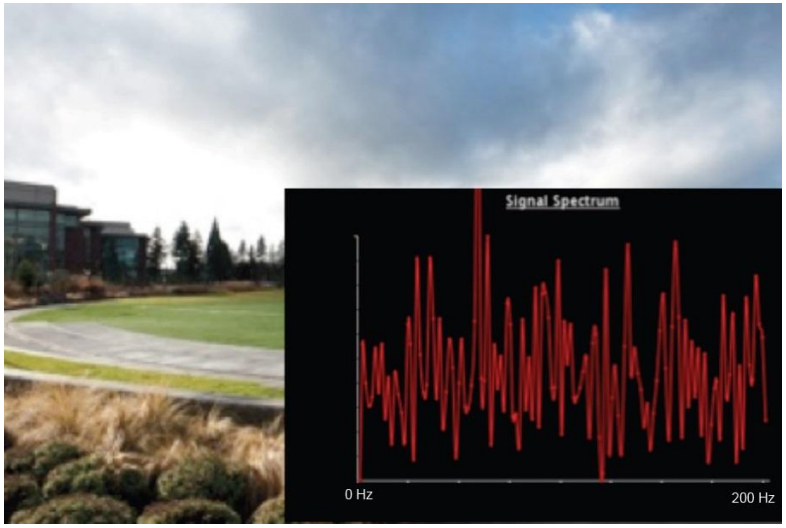
- Electric Motors

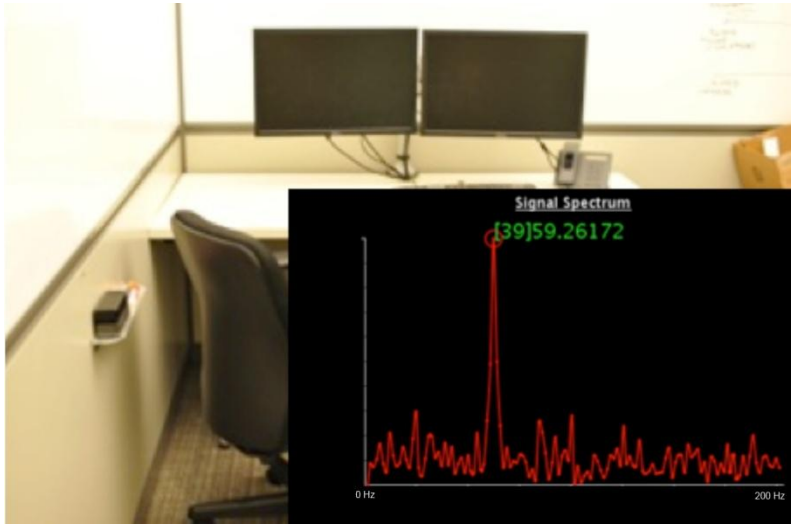


Electrical Noise in Different Locations



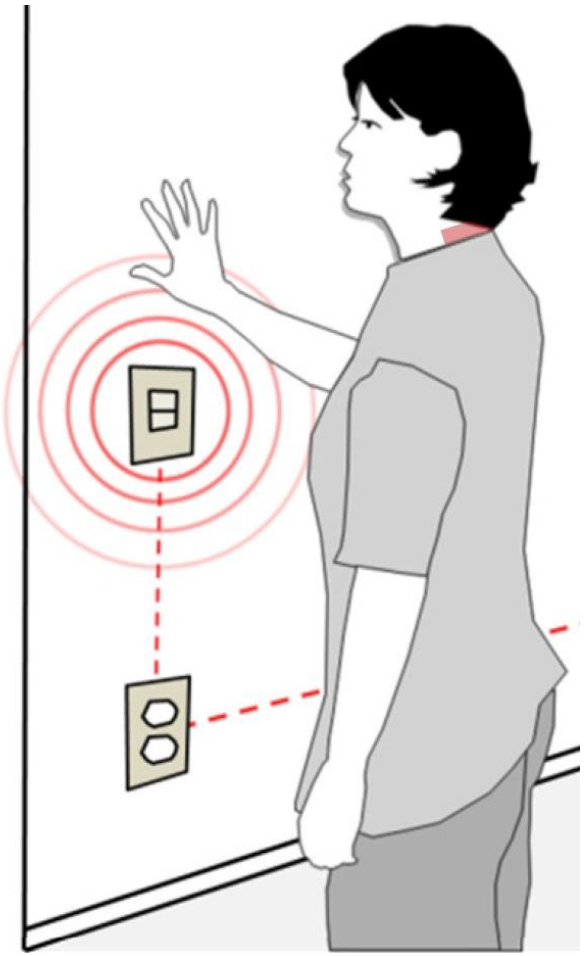






Your Noise Is My Command

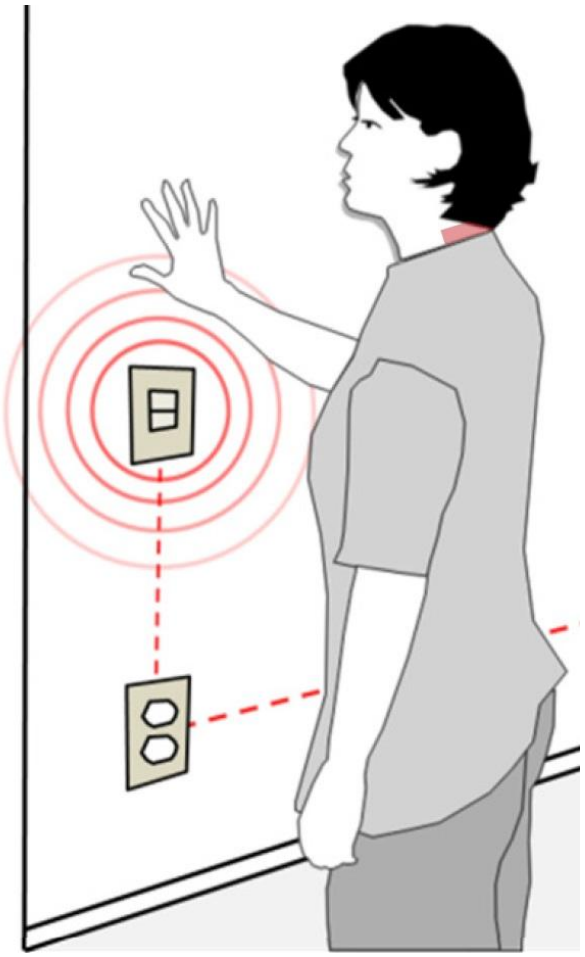
- Determine touch position on the wall
- Measure electric field that is received by the human body



[CHI 2011, Cohn et al]

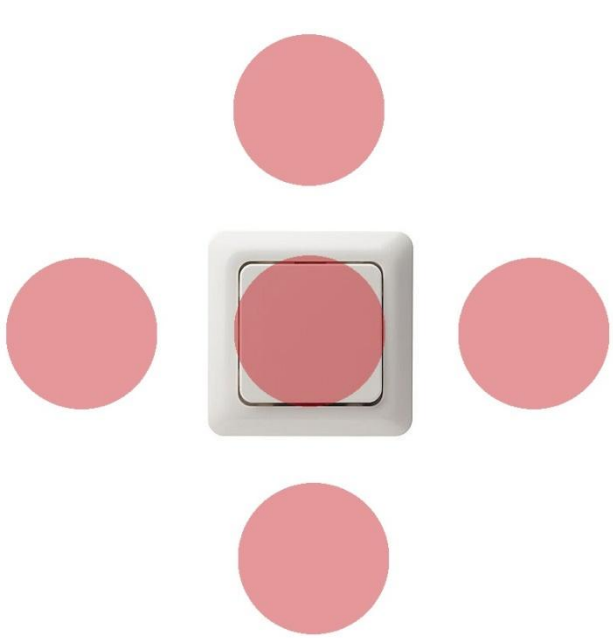
Your Noise Is My Command

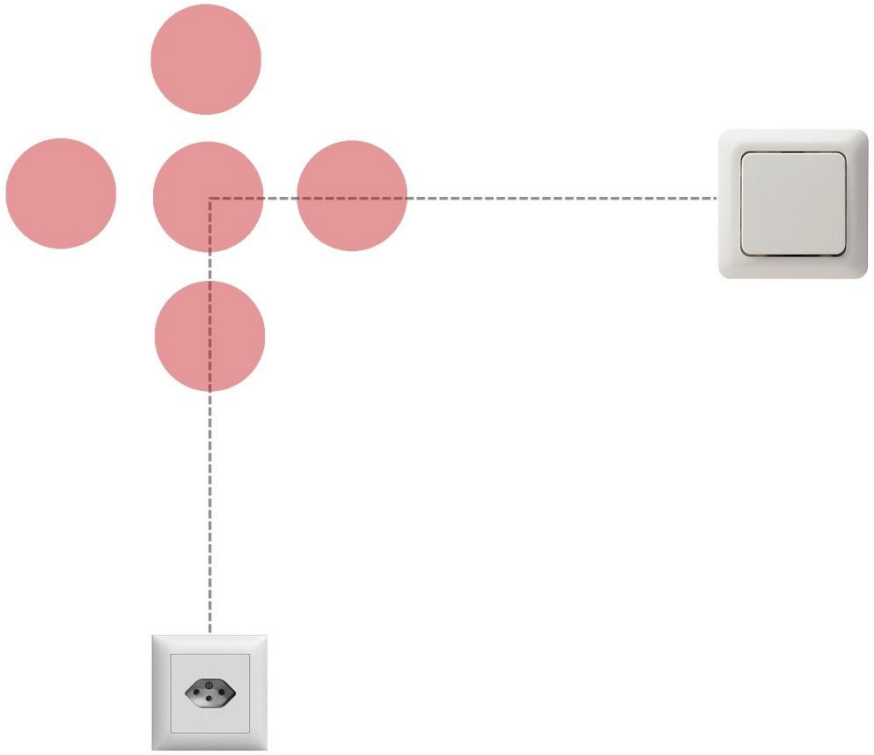
- Signal is measured at the neck
- Offline classification by trained program
- Changes in the environment are minimized



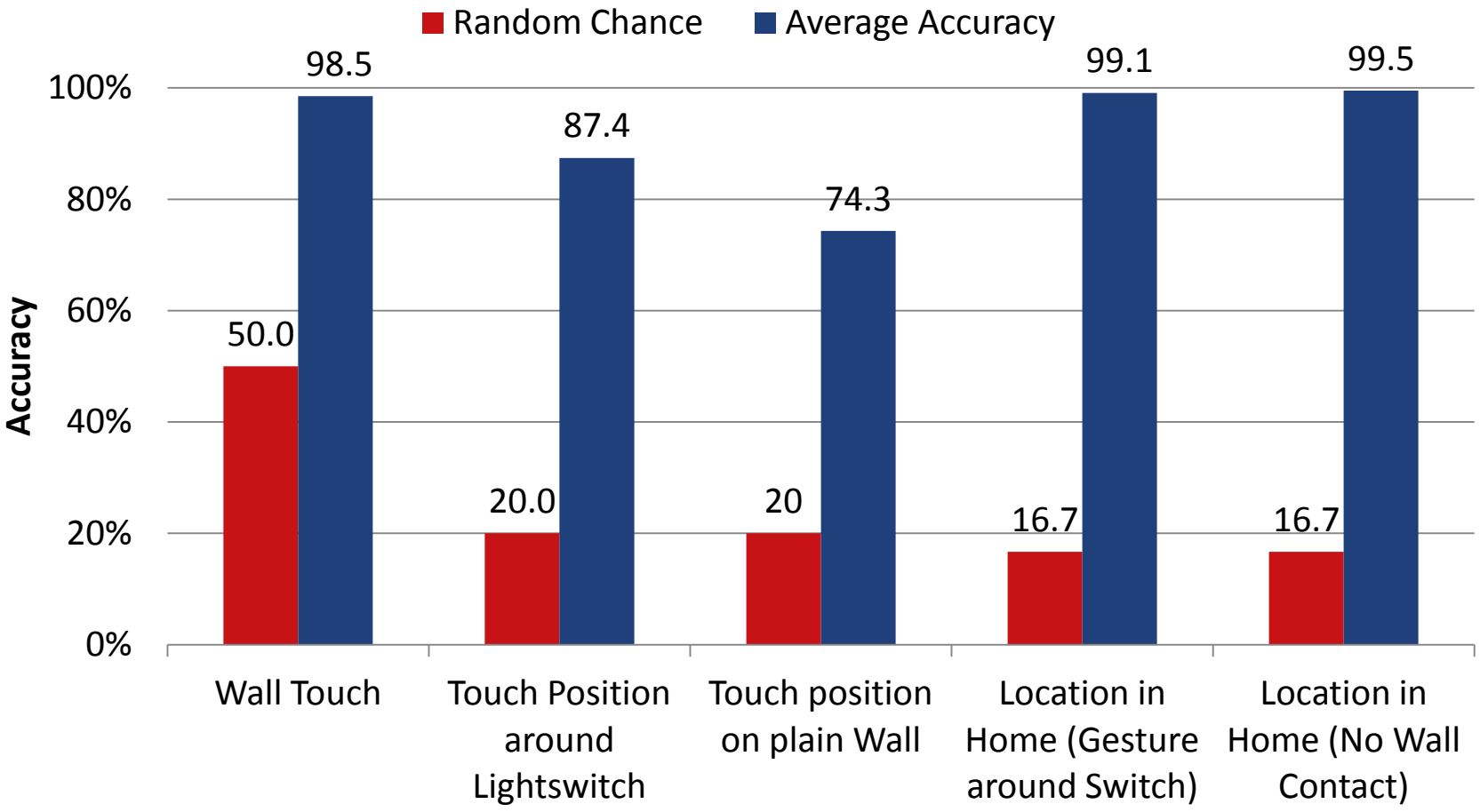
Your Noise Is My Command

Touch positions:

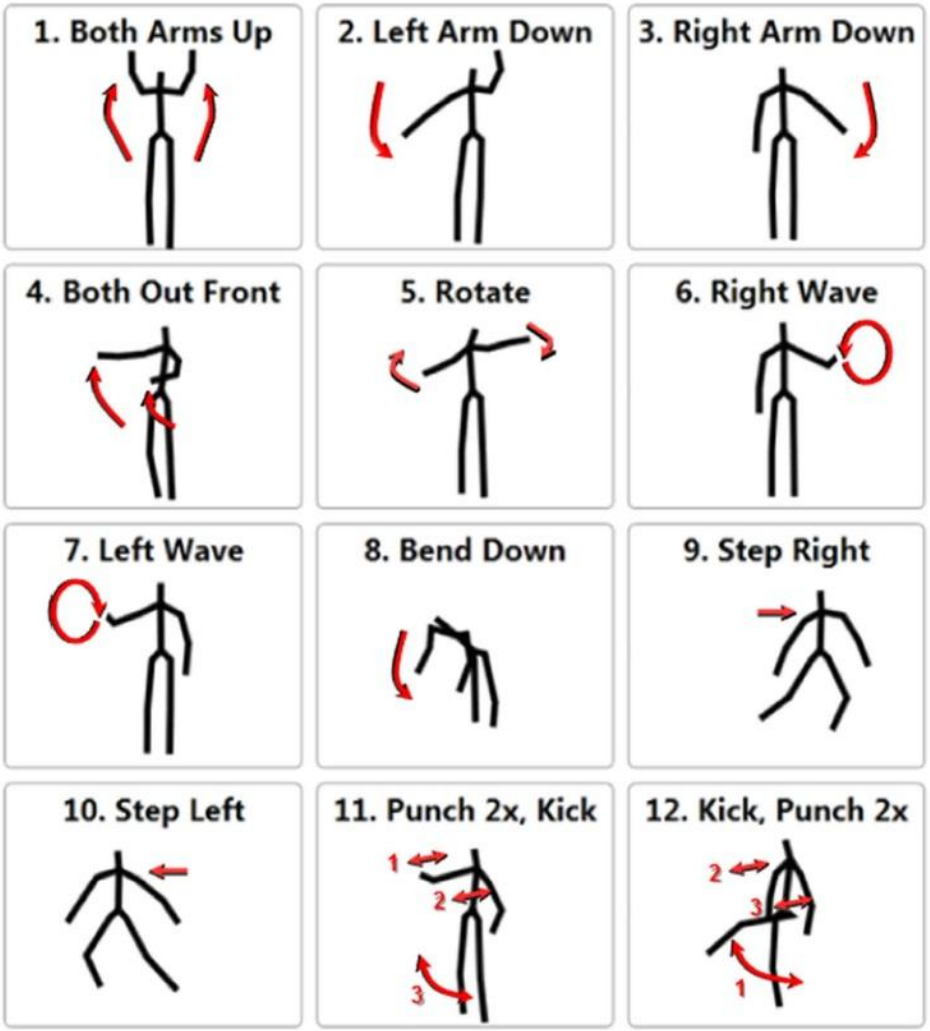




Your Noise Is My Command Results



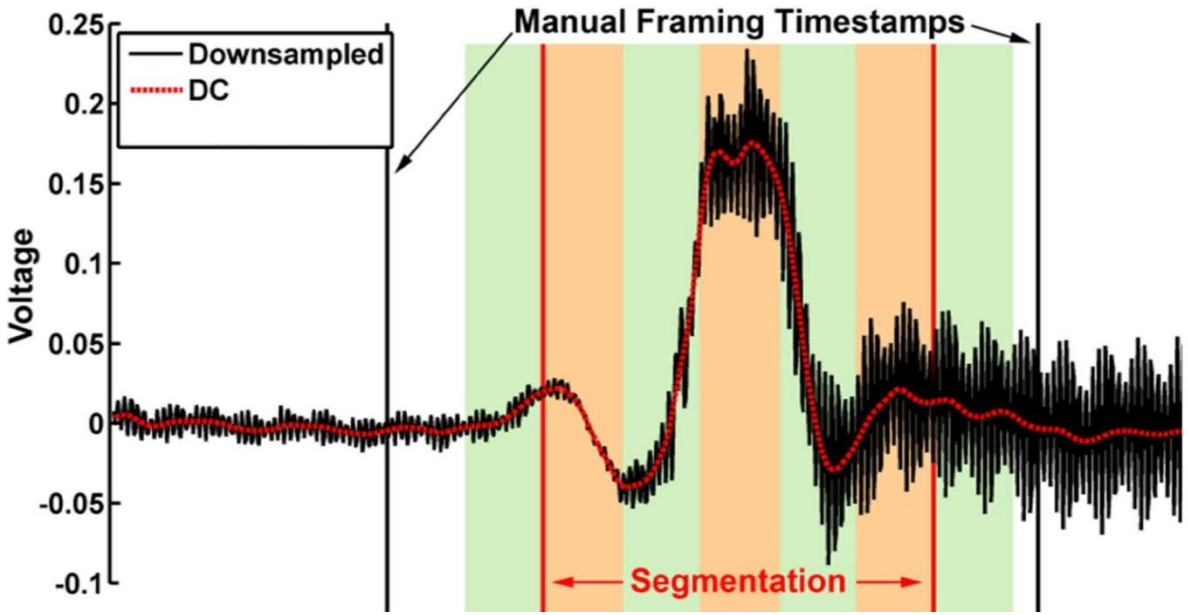
Humantenna



[CHI 2012, Cohn et al]

Humantenna Segmentation

- Coarse manual frame
- Determine exact frame from change of DC Voltage

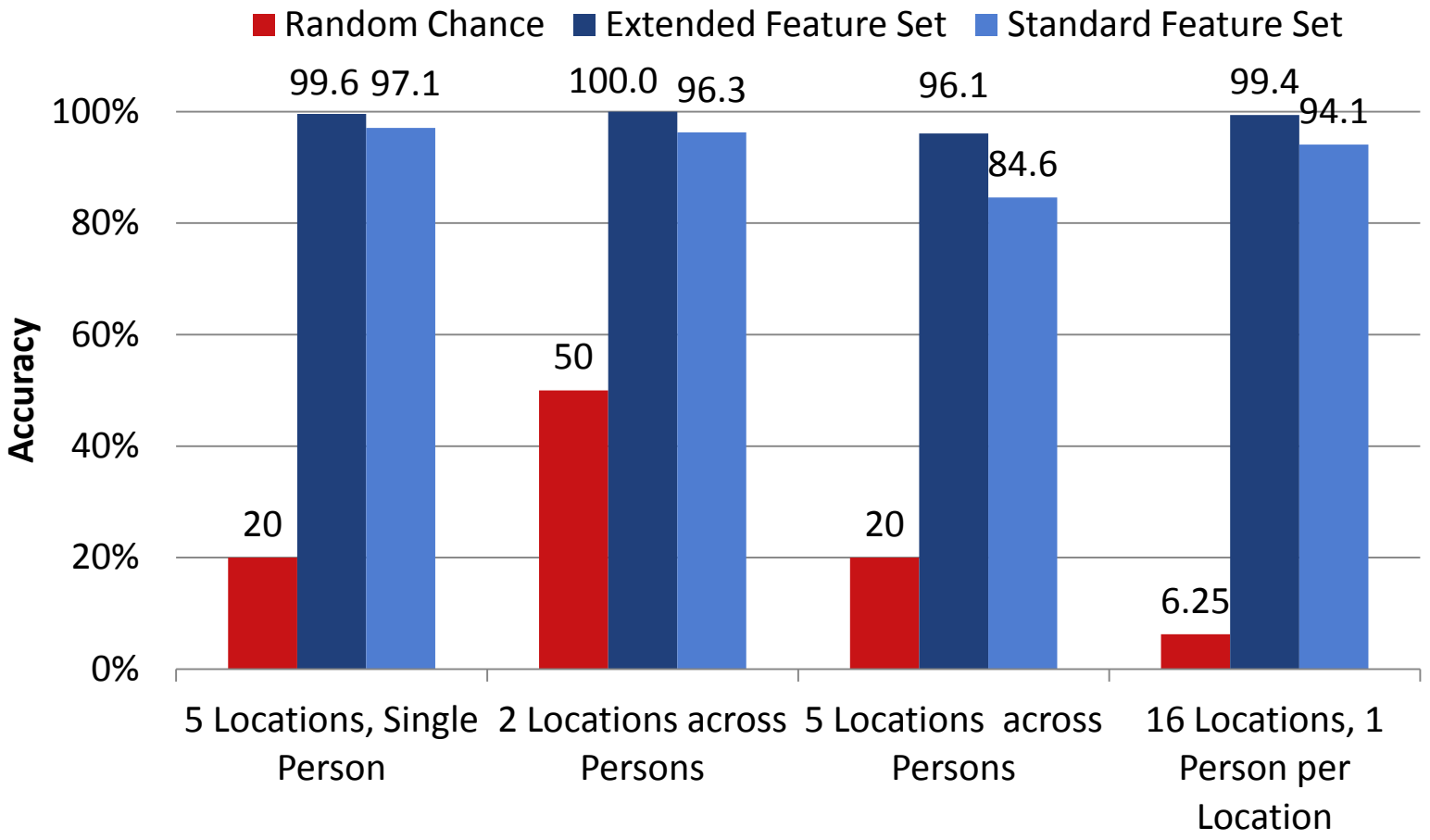


[Cohn et al (2012)]

Humantenna Results

Actual Gesture Performed	Classified Gesture											
	1	2	3	4	5	6	7	8	9	10	11	12
Both Arms Up - 1	94.2	0.6	0.5	0.9		0.9	0.6		0.5		0.6	1.1
Left Arm Down - 2	0.5	94.2	2.8	0.2		0.8	1.1		0.5			
Right Arm Down - 3	0.9	2.0	92.5	0.2		2.0	1.1		0.3	0.6	0.3	
Both Out Front - 4	0.8	0.5	0.2	95.2		1.1	1.3		0.3	0.5		0.3
Rotate - 5				0.2	99.7				0.2			
Right Wave - 6	0.8	0.5	1.4	2.0		79.2	14.1		0.9	0.8	0.2	0.2
Left Wave - 7	0.3	0.8	0.3	1.6		11.1	83.9		1.1	0.6	0.3	
Bend Down - 8								99.5	0.3		0.2	
Step Right - 9		0.3	0.2	0.8		1.9	1.4	0.3	93.6	1.4	0.2	
Step Left - 10	0.2	0.5	0.2	1.9		0.8	0.8	0.6	1.9	93.3		
Punch 2x, Kick - 11			0.2	0.2			0.2	0.3		0.2	92.8	6.3
Kick, Punch 2x - 12	0.5	0.6	0.3	0.3				0.2		0.3	4.1	93.8

Humantenna Location Results

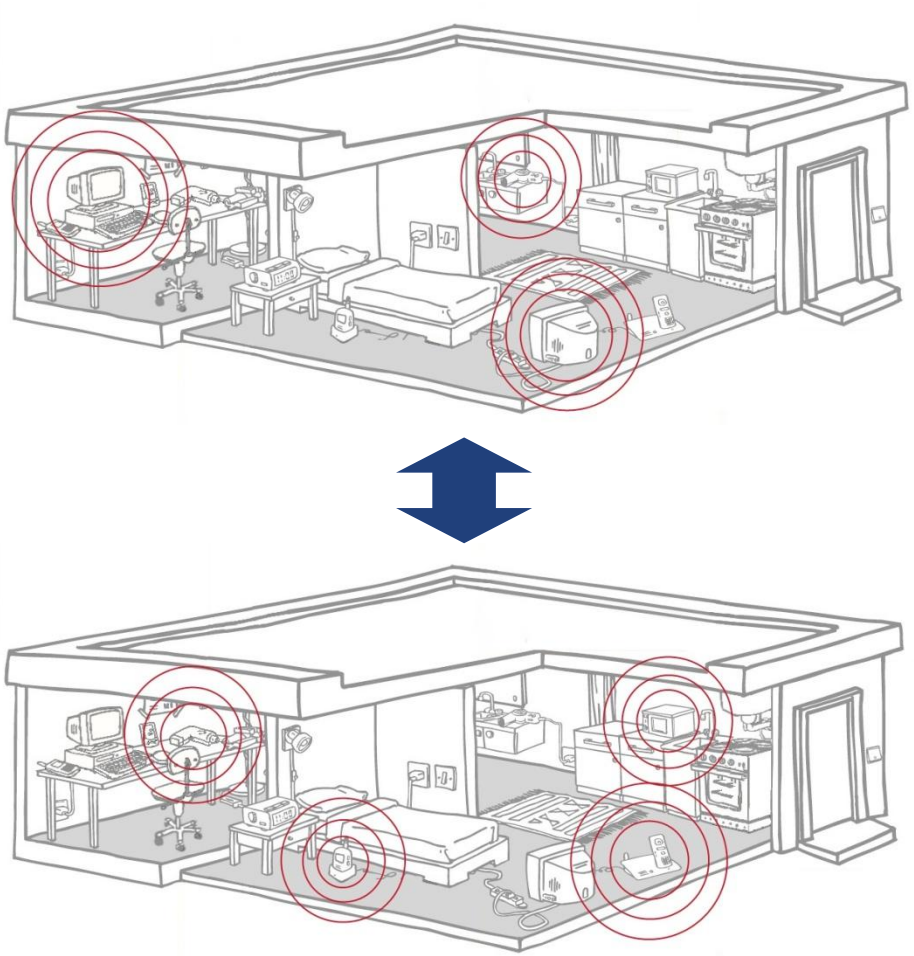


Humantenna Interactive System

- Lower sampling rate
- Apply static threshold to DC voltage change
- Consider short periods of inactivity as active
- Compute feature set in parallel to segmentation

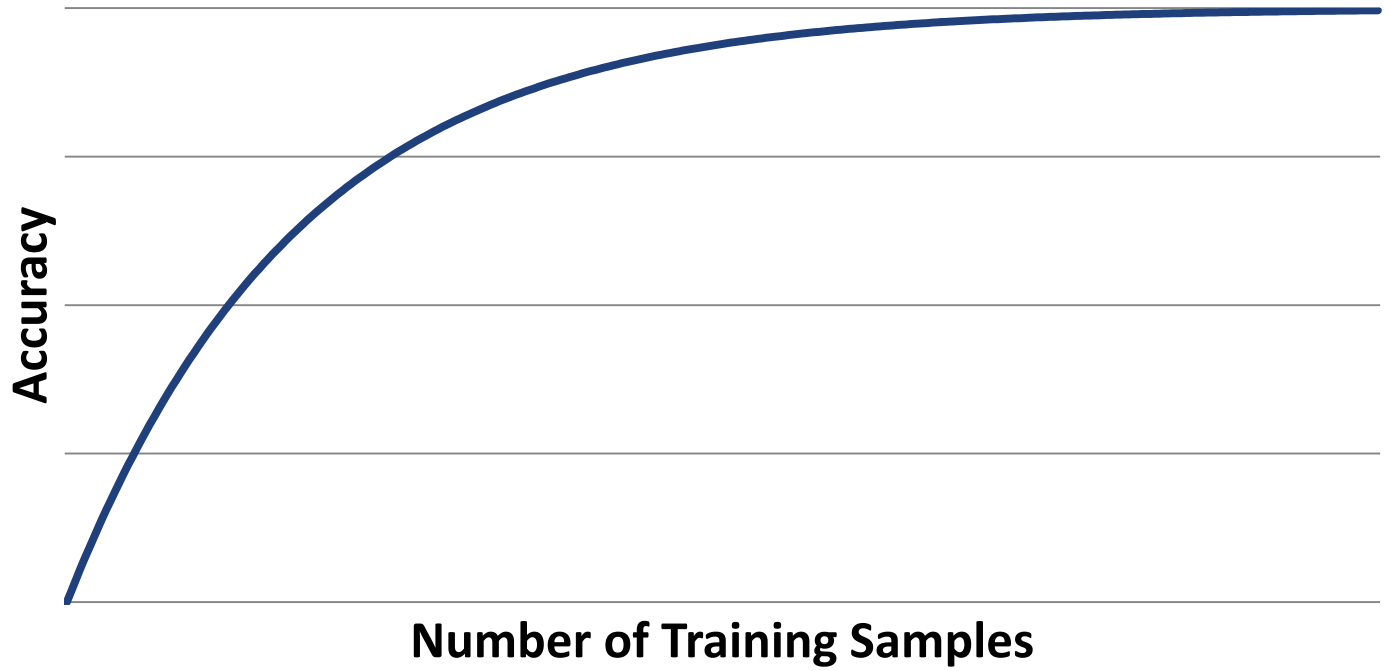
Limitations

- Sensible to changes in the (electric) environment



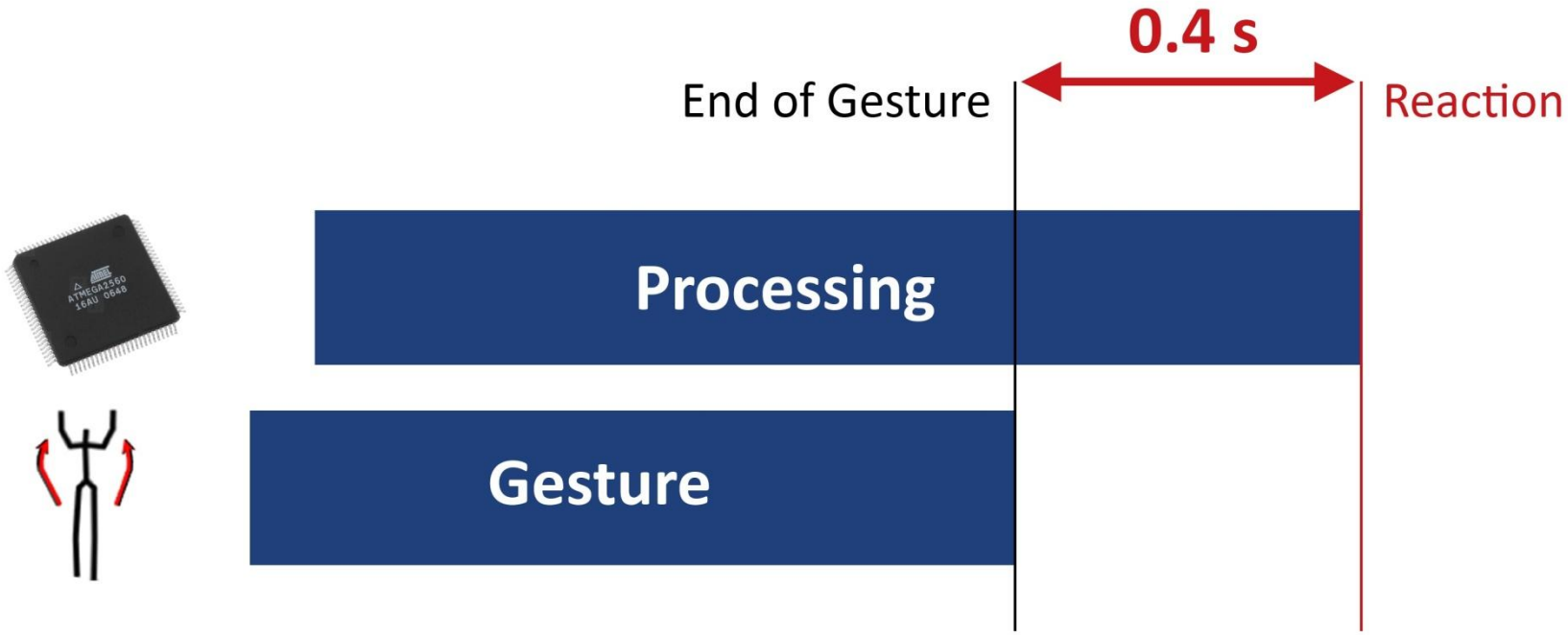
Limitations

- Needs to be trained



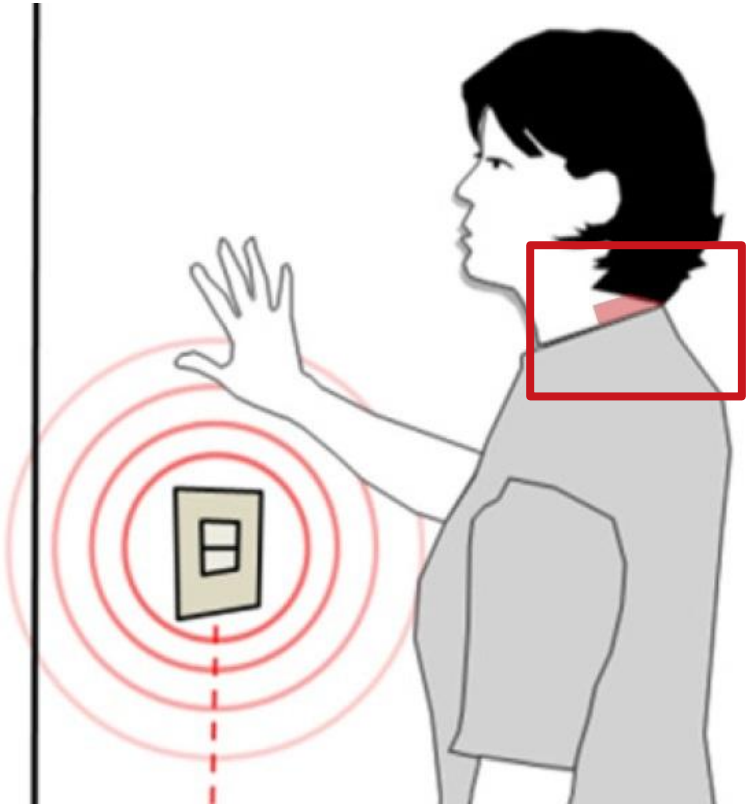
Limitations

- High latency in interactive system



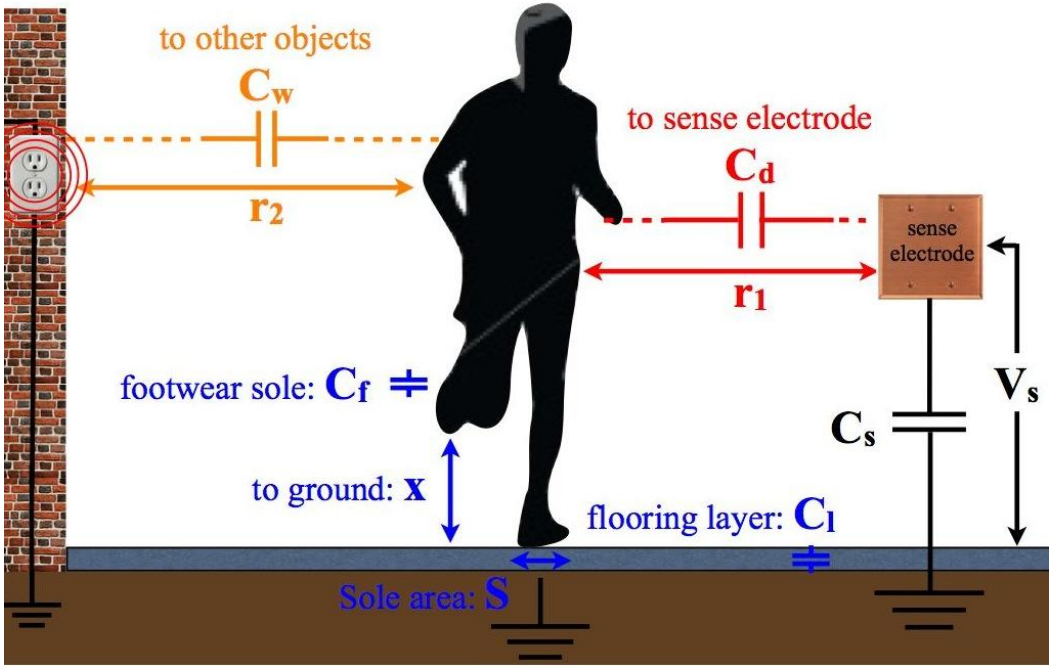
Limitations

- Needs sensors on body



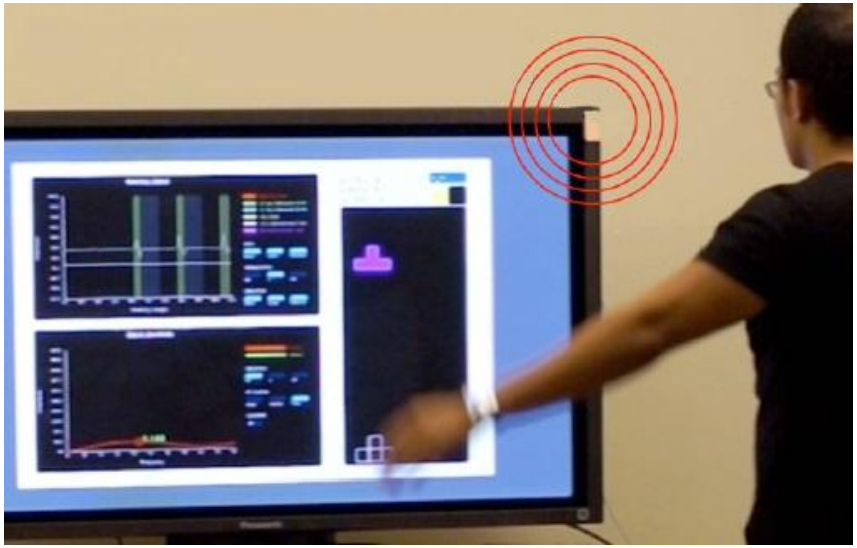
Mirage

- No body contact
- Detect distortion of electric field by human body



[UIST 2013, Mujibiya and Rekimoto]

Mirage



Peripheral-attached sensor

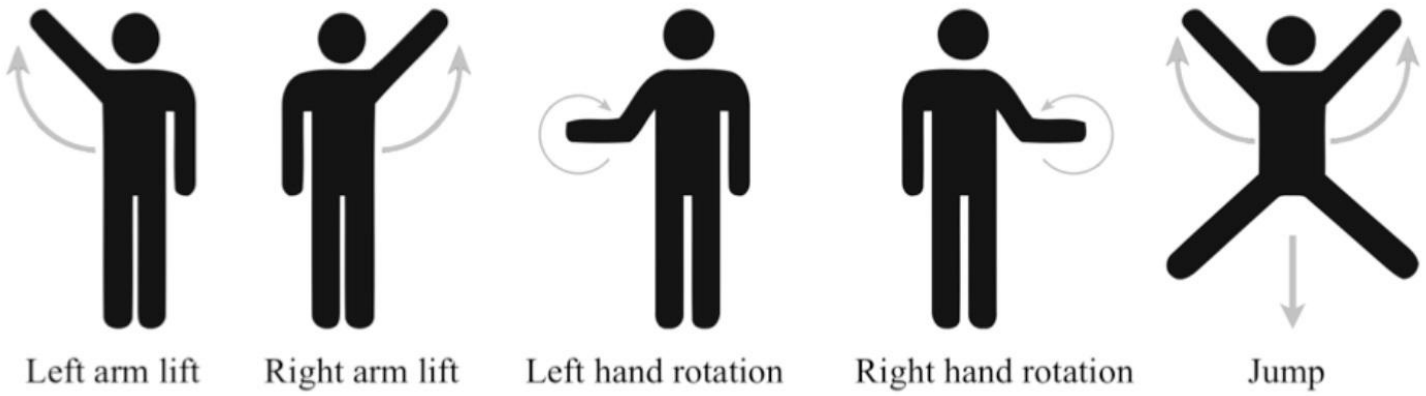
Mobile sensor

[Mujibiya, Rekimoto (2013)]

Mirage

Detect…

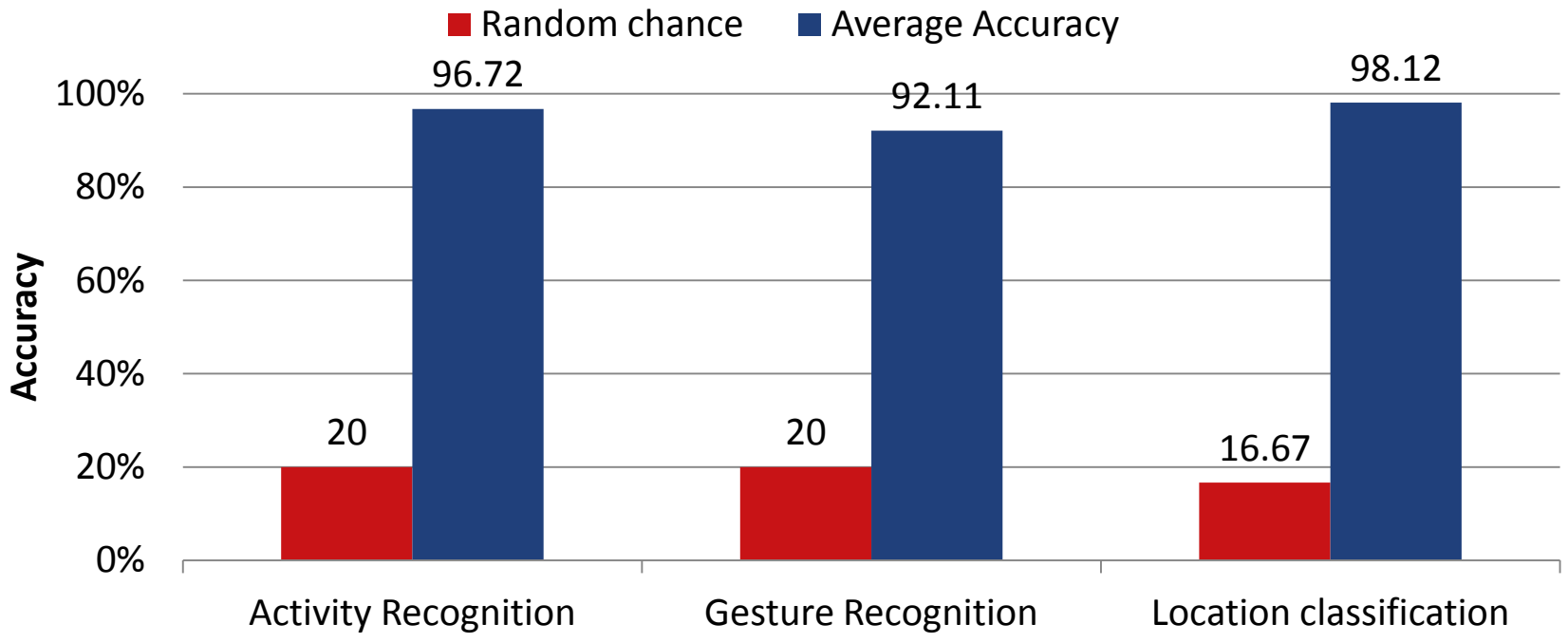
- … single gestures
- … continuous activity (walking, running, ...)
- … repeated events (single steps, …)



[Mujibiya, Rekimoto (2013)]

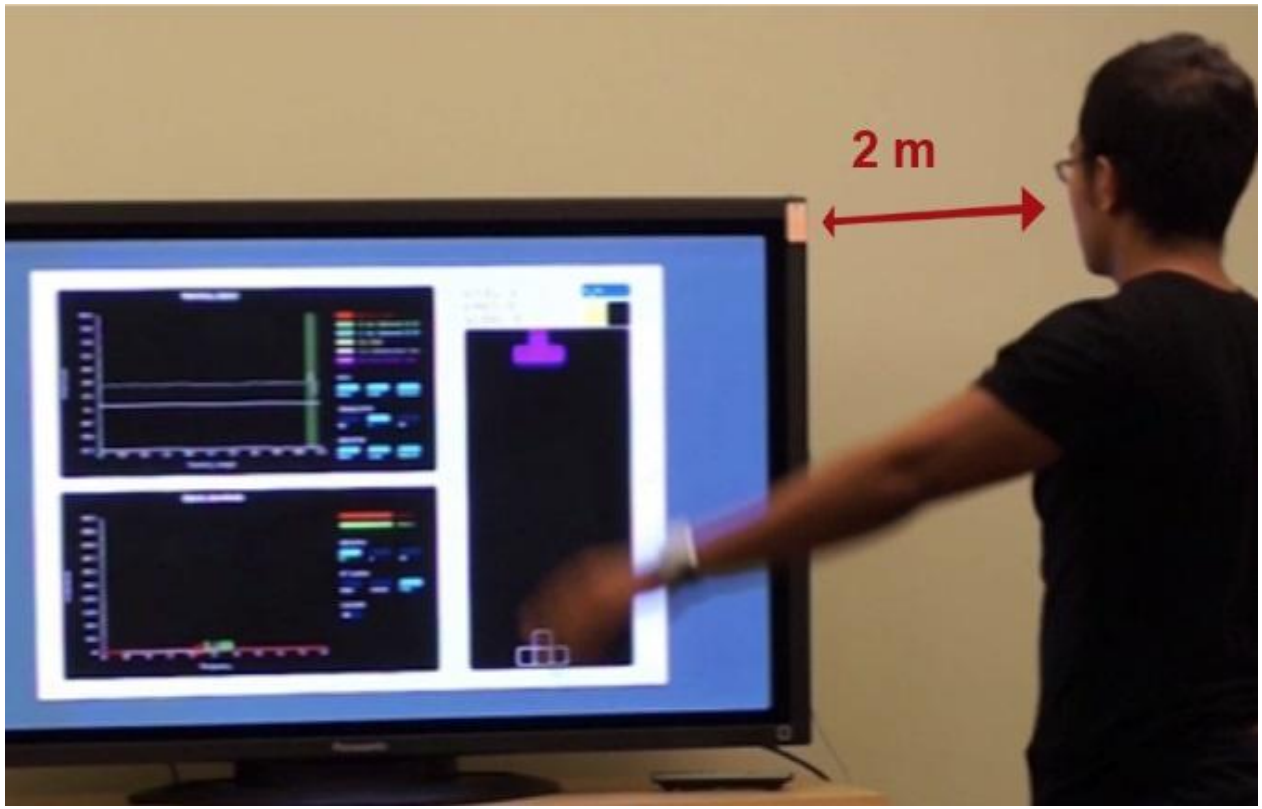
Mirage Results

- Low error in event counting (8.41 %)



Limitations

- Limited distance

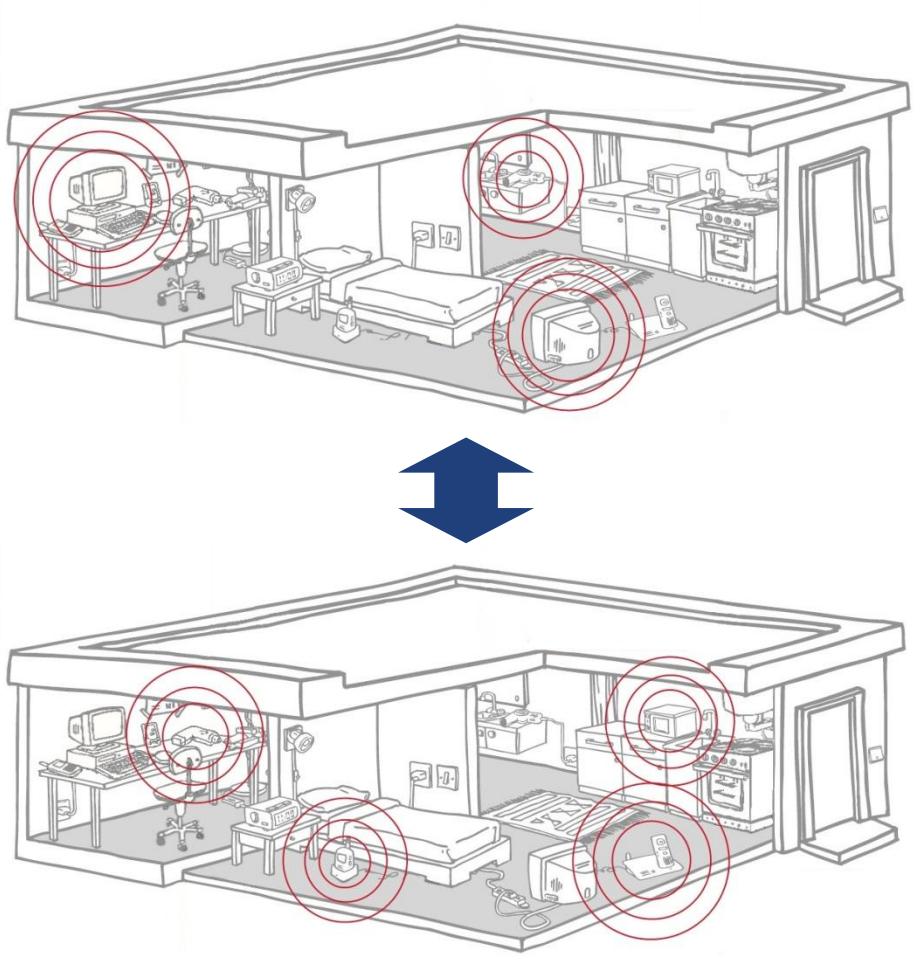


Limitations

- Sensible to different footwear

Limitations

- Sensible to changes in the (electric) environment



Applications

- Gesture Detection for Mobile Devices

Applications

- Indoor Localization

Applications

- Virtual Switches



Applications

- Intruder Detection

Conclusion

Electric Field Sensing is…

- …accurat in gesture/activity recognition
- …accurat in location classification
- …energy efficient
- …cheap
- …sensible to changes in the (electric) environment

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Thank you for listening!