Introduction

Me

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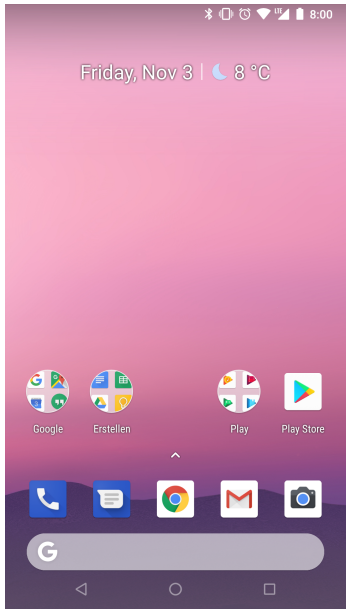
- Research interests:
  - Mobile and pervasive computing
  - Internet measurements

Topics

- Mobile and pervasive computing concepts
- Android programming
- Goal: students able to identify the most relevant design issues in mobile computing, programming Android app



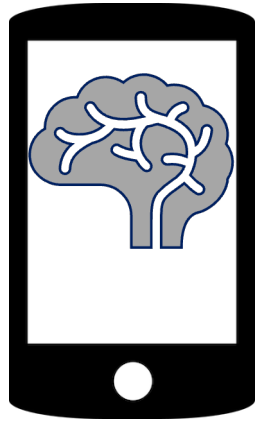
Mobile devices

- Smartwatches
- Smartphones
- Tablets
- Laptops

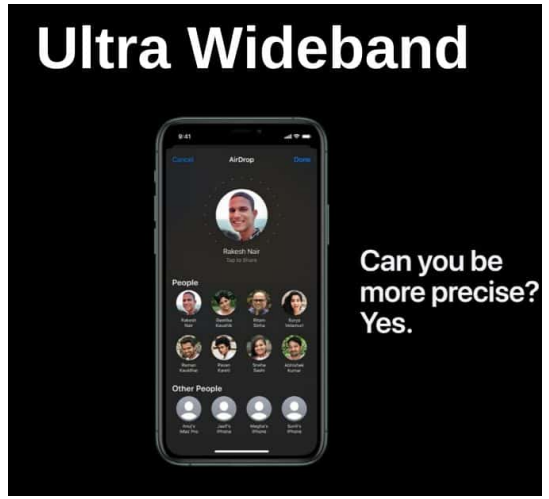
Smartphone

- Smart = Communication + Computing + Sensors
  - Communication: variety of technologies (wi-fi, cellular, bluetooth, NFC)
  - Computing: powerful processors (4-8 cores, GPU), able to execute VMs
  - Sensors: position, temperature, ambient light, pressure, camera, microphone

- Google Pixel 4:
  - octa-core 2,84 GHz + 1,78 GHz, 64 bit, 6 GB RAM
  - A PC in your pocket…

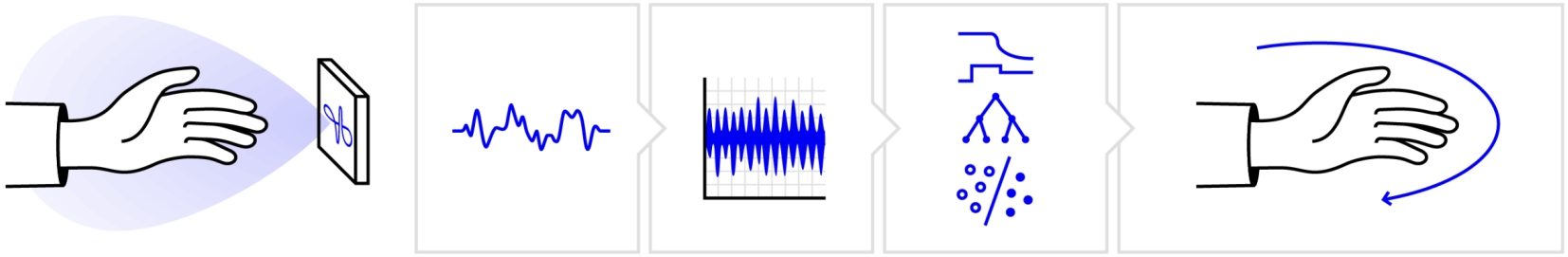


Source: apple.com



Sensors

- Sensors usually available:
  - GPS, microphone, ambient light, proximity, compass, camera
- Other sensors may be present:
  - Fingerprint, heart rate, pressure, temperature, motion sensing, UWB
- Information about the physical world -> Intelligent sensing apps
  - Example: amount of burnt calories by measuring physical activity



Source: google.com

Communication technologies

- Wi-Fi (IEEE 802.11)
- Cellular networks
- Bluetooth
- Near Field Communications (NFC)

Network Type	Speed	Range	Power	Common Use
WLAN	600 Mbps	45 m – 90 m	100 mW	Internet.
LTE (4G)	5-12 Mbps	35km	120 – 300 mW	Mobile Internet
3G	2 Mbps	35km	3 mW	Mobile Internet
Bluetooth	1 – 3 Mbps	100 m	1 W	Headsets, audio streaming.
Bluetooth LE	1 Mbps	100+ m	.01–.5 W	Wearables, fitness.
NFC	400 kbps	20 cm	200 mW	Mobile Payments

Table credit: Nirjoin, UNC

Mobile computing

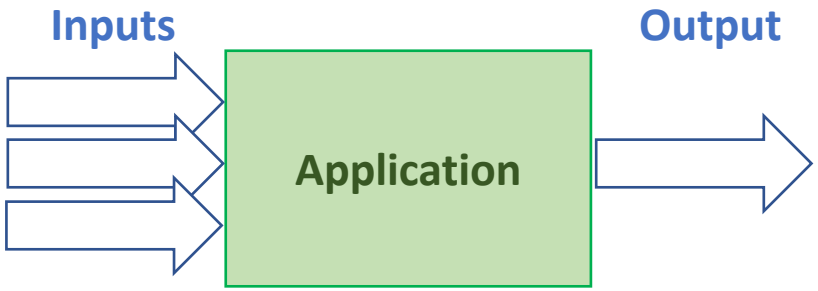
- Humans use a computing device while moving
  - Continuous network connectivity
  - Point of connection might change (Wi-Fi AP, cell tower)

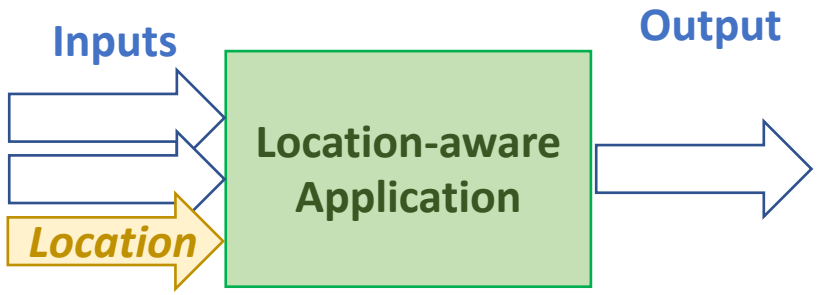
- From the user's perspective: same approach of desktop machines
  - User always initiates all activities (launching apps)
  - Examples:
    - Web browsing on a train
    - Chatting while walking
- No interaction with surrounding environment
- Infrastructure (network equipment) just for providing connectivity

http://www.leparisien.fr/societe/alerte-aux-smombies-ces-zombies-du-smartphone-qui-s-exposent-a-des-accidents-22-04-2019-8058333.php

Location-aware computing

- Mobile computing ≠ Location-awareness
- Location-aware: position must be one of the programs inputs
- Different position –> different output
- Examples:
  - Maps app
  - Museum app





Mobile apps not necessarily location-aware

- If behavior/output does not change when location changes -> not location-aware
- Application executed on smartphones just for convenience

- In some cases classification can be not so clear: ticket reservation app could use location to show the closest movie theaters

Major problem: energy efficiency

- During last decades resources increased significantly with the exception of energy

- Energy saving techniques:
  - CPUs able to adapt to the computational needs (most of the time smartphone is idle)
  - Turn off screen aggressively
  - Application specific methods: in video streaming reduce resolution
  - Make the user aware of remaining energy: with this battery level you can browse the web for 1h, or play music for 2h

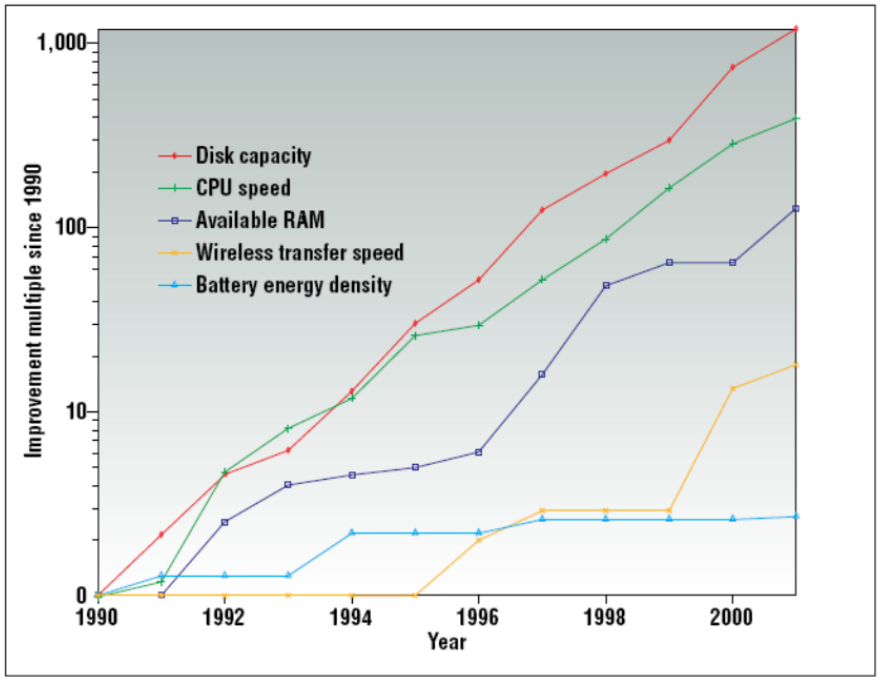


Figure 1. Improvements in laptop technology from 1990–2001.

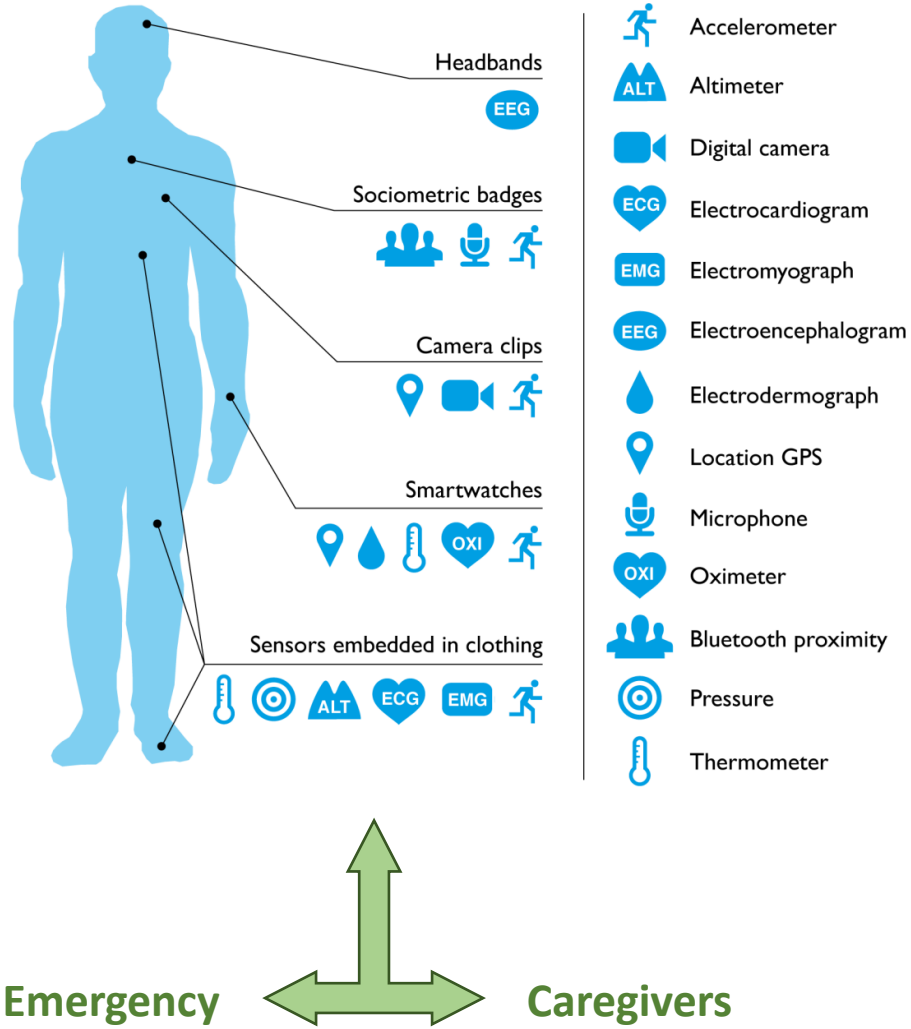
Starner, IEEE Pervasive Computing, Dec 2003

Pervasive computing

- Ubiquitous computing, «The Computer for the 21st Century», M. Wiser
  - «The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistiguishable from it.»
- Pervasive computing = Ubiquitous computing
- Goal: to assist humans in tasks
  - Reminders, suggestions, ease interaction with the environment, well-being, health, …
- System needs to understand user's intention
- Sensors are generally used to collect information about the physical space
- System initiates activity, pro-active, user's explicit input may be not required
- Example: Google assistant
  - Driving conditions to home, work
  - Significant changes in weather conditions
  - Assist user in making phone calls
  - Automatic translation from different languages

Pervasive computing: wearable devices

- Wearables can provide patients with personalized health data, which could assist with self-diagnosis and behavior change interventions
- Examples of applications:
  - heart rate can be measured with an oximeter built into a ring
  - muscle activity with an electromyographic sensor embedded into clothing
  - stress with an electodermal sensor incorporated into a wristband
  - physical activity or sleep patterns via an accelerometer in a watch
  - a female's most fertile period can be identified with detailed body temperature tracking
  - levels of mental attention can be monitored with a small number of non-gelled electroencephalogram (EEG) electrodes
  - levels of social interaction (also known to affect general well-being) can be monitored using proximity detections to others with Bluetooth- or Wi-Fi-enabled devices



Piwek L, Ellis DA, Andrews S, Joinson A (2016) The Rise of Consumer Health Wearables: Promises and Barriers. PLoS Med 13(2)

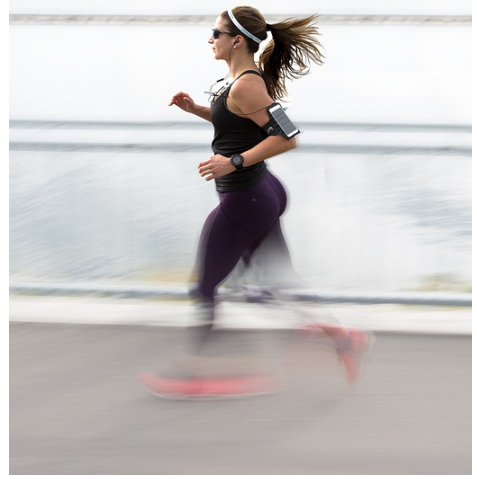
Wearable devices

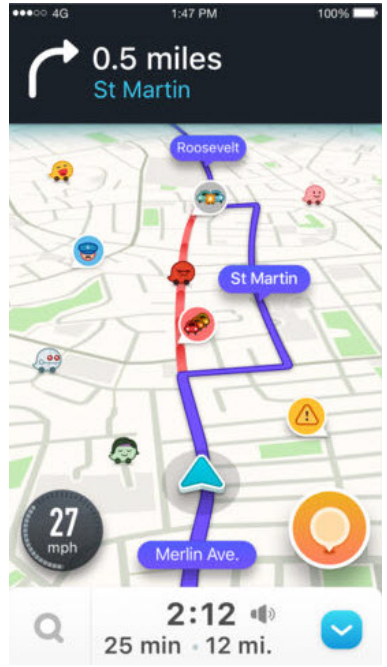
- Pedometers increased physical activity among older people
- Surveys showed that 32% of users stop wearing these devices after six months, and 50% after one year
- Useful as “secondary" diagnostic tool: For chronic conditions, wearables could effortlessly provide detailed longitudinal data in order to monitor patients’ progress
- Apple Watch can trigger an emergency SOS call if it detects a hard fall and subsequent inactivity
- Smart-shoes provide useful info for sport professionals (stride length, pace)

Credits: UnderArmour

Smartphone sensing

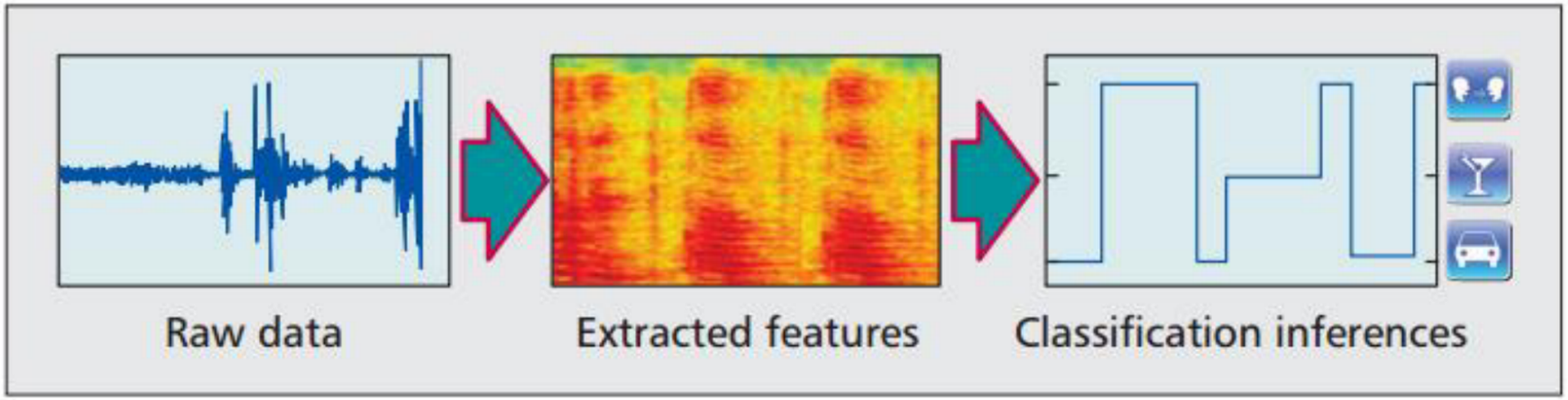
- Smartphones turned many pervasive applications into reality
- Smartphone used to sense the user or surrounding environment
- Example:
  - Human activity sensing (e.g. walking, driving, climbing stairs, sitting, lying down)
  - Waze crowdsourced traffic





Processing

- Machine learning commonly used to process sensor data
  - Action to be inferred is hand-labelled to generate training data
  - Sensor data is mined for combinations of sensor readings corresponding to action
- Example: Smartphone detects user's activity (e.g. walking, running , sitting,) by classifying accelerometer sensor data



Other pervasive systems

- **Smart Homes**: Continuously monitors elders who live in smart home, automatically dials 911 if elder ill, fall
  - Falls kill many old people who live alone
- **Smart Buildings**: Senses presence of people, ambient temperature, people flow, dynamically adjusts heating/cooling
  - Can save significant fraction of energy bill
- **Smart Cities**: Real time data from sensors embedded in street used to direct drivers to empty parking spots
  - Reduce traffic jam caused by people looking for parking

References

- CS 528, Mobile and Ubiquitous Computing, WPI, Prof. E. Agu
- Piwek L, Ellis DA, Andrews S, Joinson A (2016) The Rise of Consumer Health Wearables: Promises and Barriers. PLoS Med 13(2)