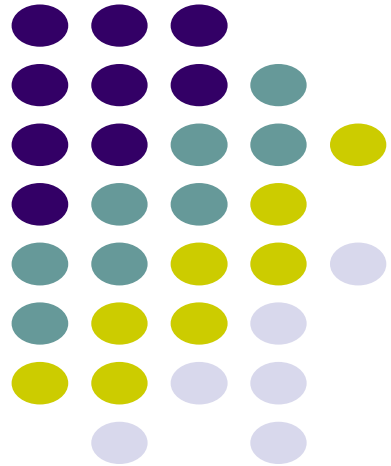
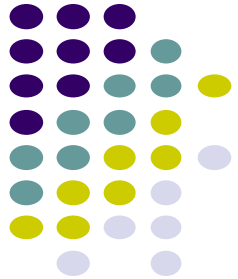
CS 528 Mobile and Ubiquitous Computing
Lecture 1a: Introduction

Emmanuel Agu

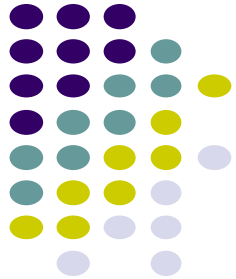


About Me

A Little about me

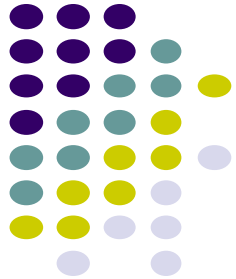


- WPI Computer Science Professor
- Research interests:
  - mobile computing especially mobile health, computer graphics
- Started working in mobile computing, wireless in grad school
- CS + ECE background (Hardware + software)
- Current active research: Mobile health apps
  - E.g: AlcoGait app to detect how drunk Smartphone owner is
    - https://www.youtube.com/watch?v=pwZaoKmfq8c



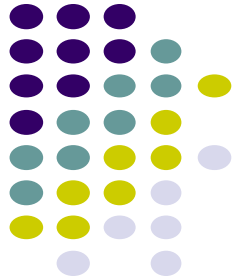
Administrivia

Administrivia: Schedule



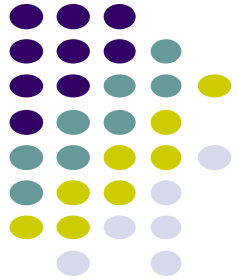
- ***Week 1-8:*** I will introduce class, concepts, Android (Students: Android programming, assigned projects)
  - **Goal:** Students acquire basic Android programming skills to do excellent project
  - Programming apps that use mobile & ubicomp components
- ***Week 9:*** Students will present final project proposal
- ***Week 9-14:*** Students work on final project
- ***Week 11:*** Students present on new mobile APIs, components
  - E.g. machine learning in Android, Augmented Reality
- ***Week 14:*** Students present + submit final projects
- Quizzes (5) throughout

Special Notes: This online offering



- Today's class recorded, video posted to canvas after class
- From lecture 2 on:
  - Videos posted days BEFORE class
  - Class: quick summary of key points, more interactive (Question and Answer), Quiz
  - Default: I'll assume all students can make it to class for quizzes
  - Please email me if you cannot. E.g. different time zone, illness, etc

Requirements to get a Grade

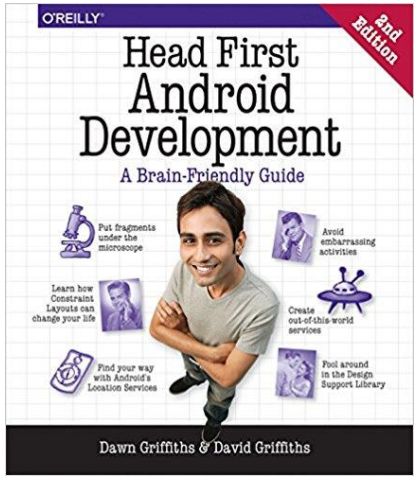


- **Grading policy:**
  - Presentation (tech topic) 15%, Assigned Projects 35%, Final project: 30%, Quizzes: 20%
- **Final project phases:** (See class website for deadlines)
  1. Pick partners, form project groups of 5 members
  2. Submit 1-slide of proposed idea (problem + envisioned solution)
  3. Present project proposal

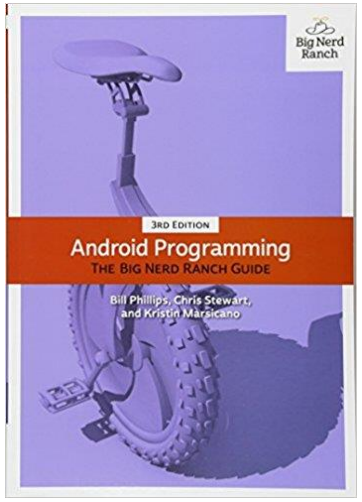
     + plus submit proposal (intro + related work + methodology/design + proposed project plan)
  4. Build app, evaluate, experiment, analyze results
  5. Present results + submit final paper (in week 14)
- **Degree of difficulty of project taken into account in grading rubric**

Course Texts

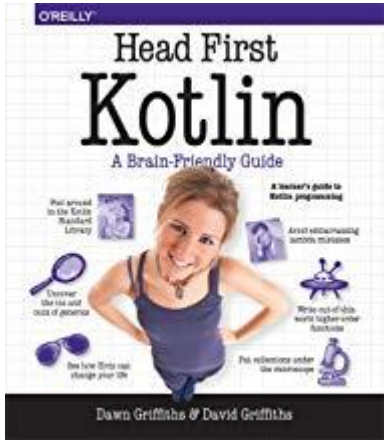
- **Android Texts:**
  - *Head First Android Dev, (2nd ed),* Dawn and David Griffiths, O'Reilly, 2017
  - *Android Programming: The Big Nerd Ranch (Third edition)*, Bill Phillips, Chris Stewart and Kristin Marsicano, The Big Nerd Ranch, 2017



Gentle, visual intro



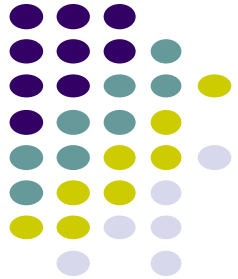
Bootcamp Tutorial



Visual kotlin intro

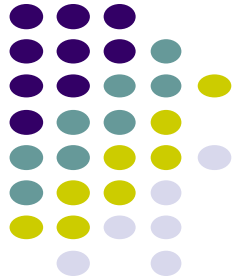
- Will also use official Google Android documentation
- Learn from research papers: Why not text?

Grader



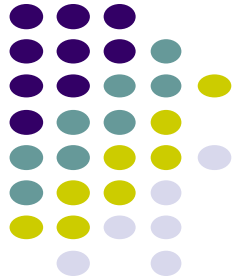
Will be hired

Class in 2 Halves

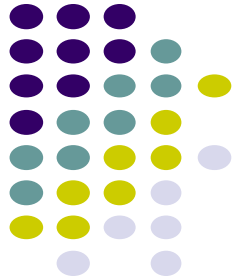


- 2 Halves: About 1 hour 15 mins each half
- Break of about 15 mins
- Talk to me **at the end of class NOT during break**
  - I need a break too

Poll Question



- How many students:
  1. **Own** recent Android phones (running Android 4.4, 5, 6 , 7, 8 or 9?)
  2. **Can borrow** Android phones for projects (e.g. from friend/spouse)?
  3. **Do not own and cannot borrow** Android phones for projects?
  4. **Cannot come to class** (e.g. in very different timezone?) Other constraints?

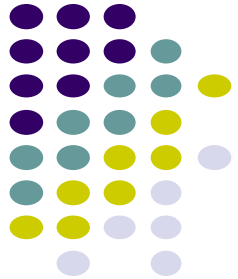


Mobile Devices

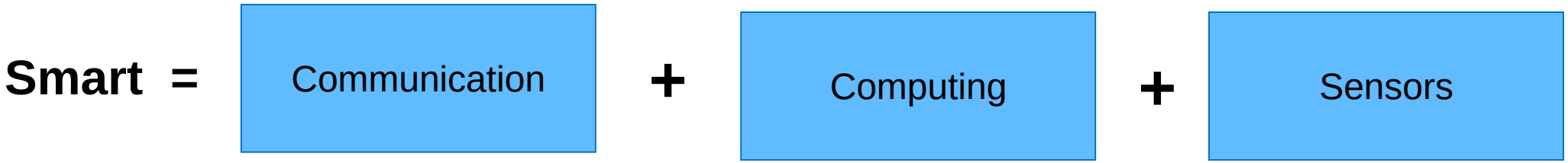
Mobile Devices

- Smartphones (Blackberry, iPhone, Android, etc)
- Tablets (iPad, etc)
- Laptops
- Smartwatches

SmartPhone Hardware



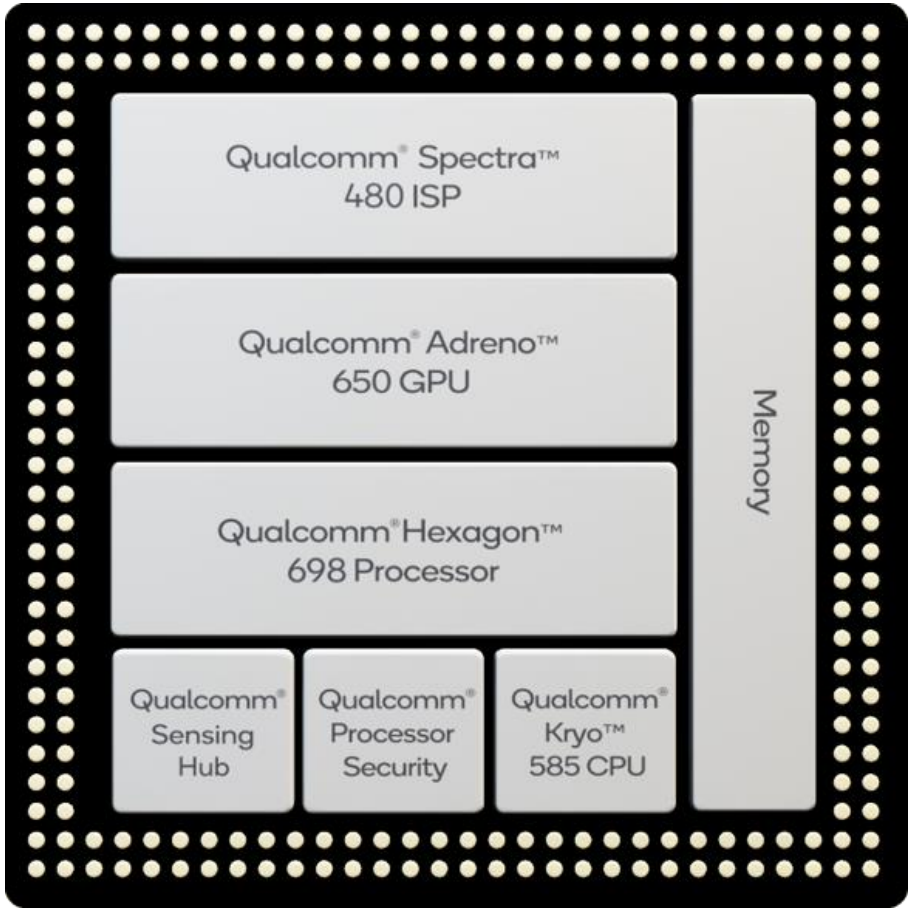
- Smartphones have capabilities beyond calling and texting (or feature phones)



  - **Communication:** Talk, SMS, chat, Internet access
  - **Computing:** Powerful processors, programmable operating system, Java apps, JVM, apps
  - **Sensors:** Camera, video, location, temperature, heart rate sensor, etc
- Example: Google Pixel XL 3 phone: 8 core 2.5 GHz/1.6GHz kryo CPU, Adreno 630 GPU, 128GB RAM
  - A PC in your pocket!!
  - Multi-core CPU, GPU, over 20 sensors (10 hardware sensors, over 10 soft sensors)
  - Linux OS, JVM, runs OpenGL ES, OpenCL and now Deep learning (Tensorflow)

Qualcomm SnapDragon System on a Chip (SoC)

- Core of most high end smartphones shipped in 2020
- **SoC:** Chip that integrates most computer components: CPU, GPU, memory, I/O, storage
- Ref: https://arstechnica.com/gadgets/2019/12/qualcomms-new-snapdragon-865-is-25-faster-comes-with-mandatory-5g/



Smartphone Sensors

- Typical smartphone sensors today
  - accelerometer, compass, GPS, microphone, camera, proximity
- Can sense physical world, inputs to intelligent sensing apps
  - E.g. Automatically turn off smartphone ringer when user walks into a class

Growth of Smartphone Sensors

- Smartphone generations have more and more sensors!!

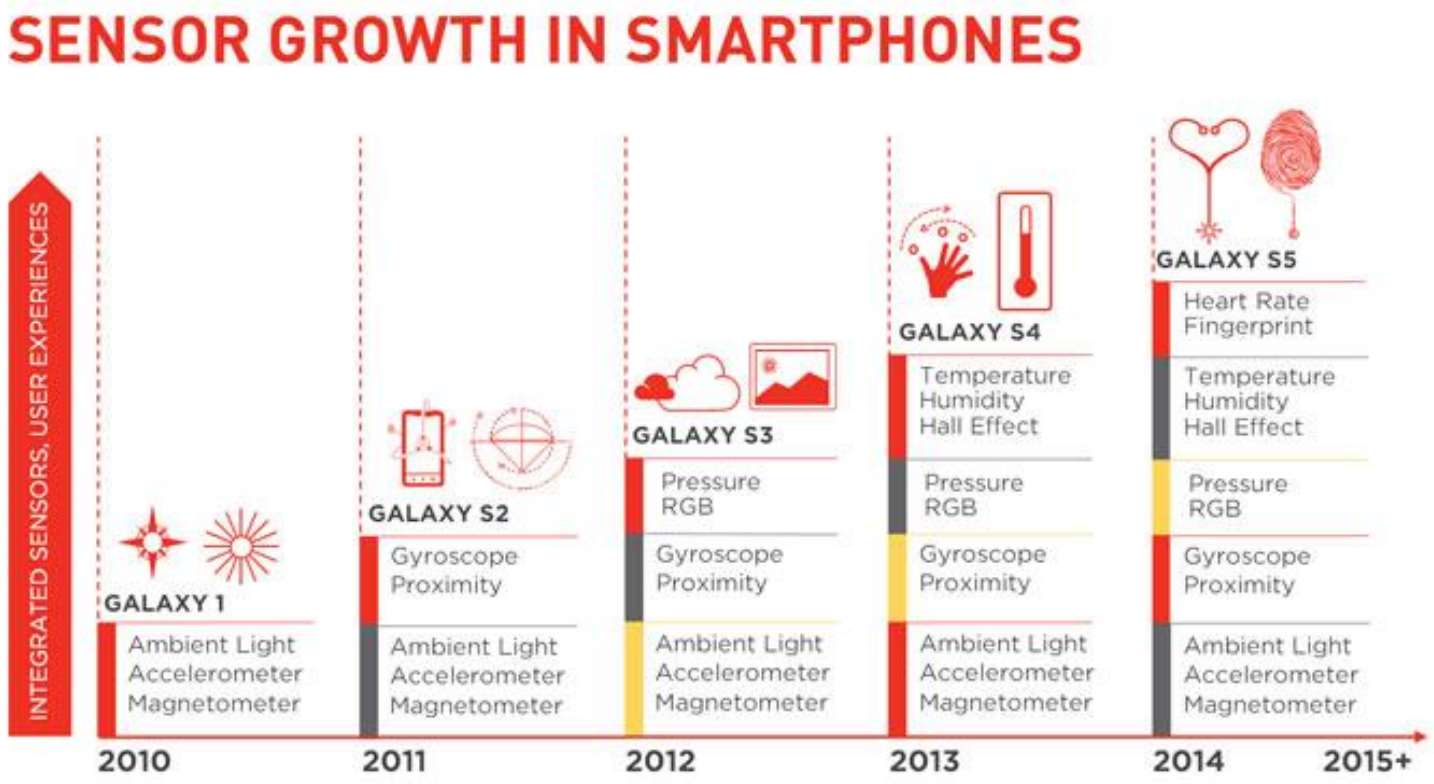
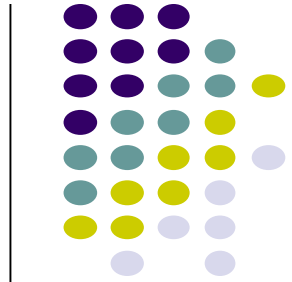


Image Credit: Qualcomm

Future sensors?

- Complex activity sensor,
- Pollution sensor,
- etc



Wireless Networks

Wireless Network Types

- **Wi-Fi (802.11):** (e.g. Starbucks Wi-Fi)
- **Cellular networks:** (e.g. T-Mobile network)
- **Bluetooth:** (e.g. car headset)
- **Near Field Communications (NFC)**

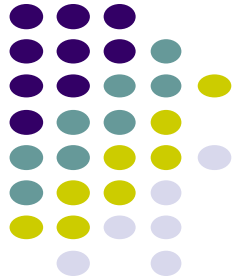
  e.g. Mobile pay: swipe phone at dunkin donut

Bluetooth

Wi-Fi

NFC

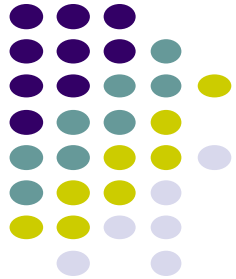
Wireless Networks Comparion



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

Different speeds, range, power, uses, etc



Mobile Computing

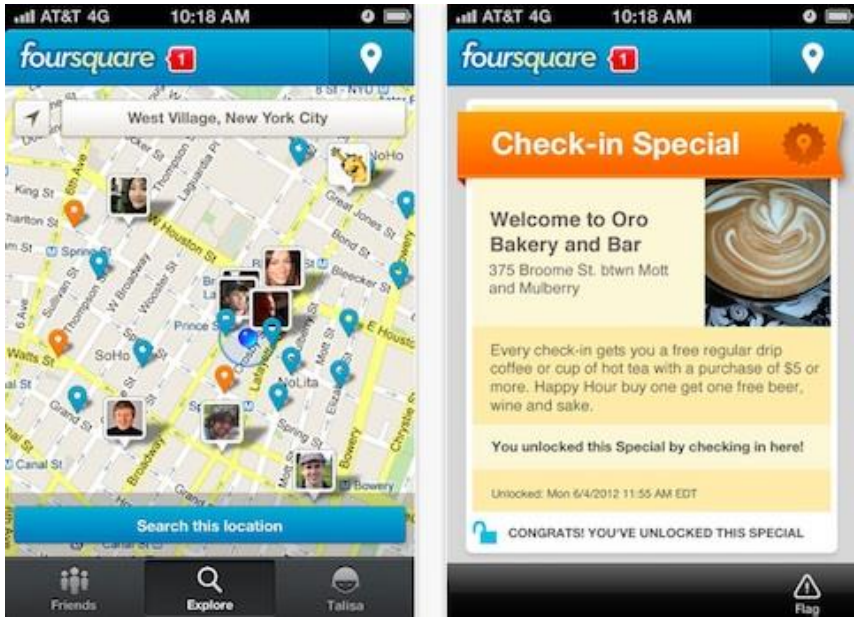
mo·bile

adjective
/ˈmōbəl,ˈmōˌbīl/

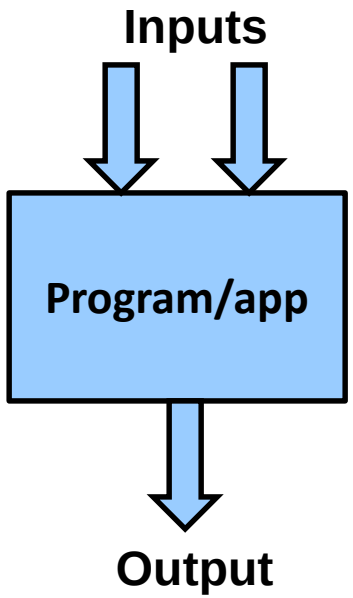
1. able to move or be moved freely or easily.
   "he has a major weight problem and is not very mobile"
   synonyms: able to move (around), moving, walking; motile; ambulant

Mobile Computing

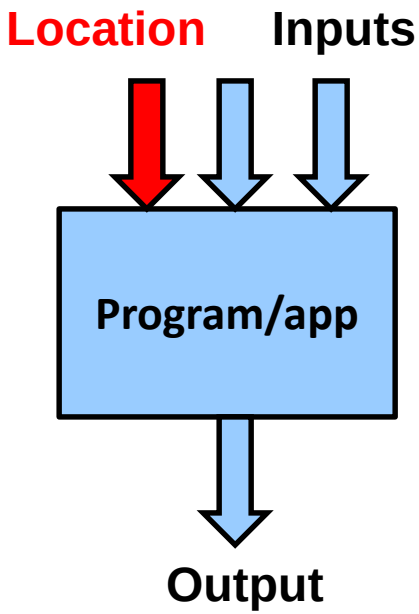
- Human computes while moving
  - Continuous network connectivity,
  - Points of connection (e.g. cell towers, WiFi access point) might change
- **Note:** Human initiates all activity, (e.g launches apps)
- Wireless Network is *passive*
- **Example:** Using *foursquare.com* on Smartphone



Related Concept: Location-Awareness



Non-mobile app



Mobile app

- Mobile computing = computing while location changes
- **Location-aware:** Location must be one of app/program's inputs
  - Different user location = different output (e.g. maps)
- **E.g.** User in California gets different map from user in Boston

Location-Aware Example

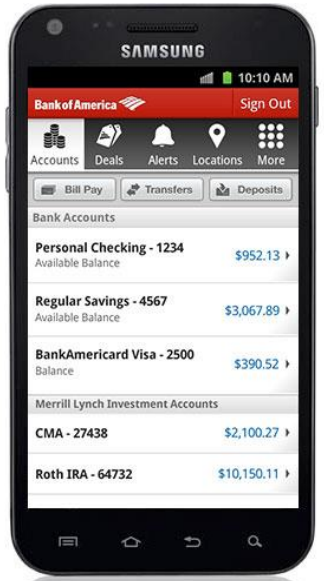
- Location-aware app must have different behavior/output for different locations
- Example: Mobile yelp
  - **Example search:** Find Indian restaurant
  - App checks user's location
  - Indian restaurants **close to user's location** are returned

Example of Truly Mobile App: Word Lens

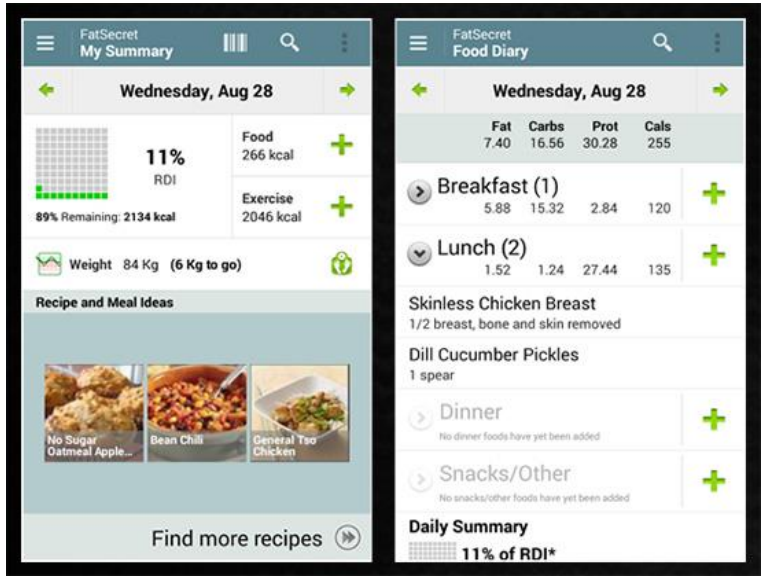
- Translates signs in foreign Language
- Location-dependent because location of sign, language? Varies
- Acquired by Google in 2015, now part of Google Translate

Some Mobile apps are not Location-Aware

- If output does not change as location changes, not location-aware
- Apps run on mobile phone **just for convenience**
- **Examples:**



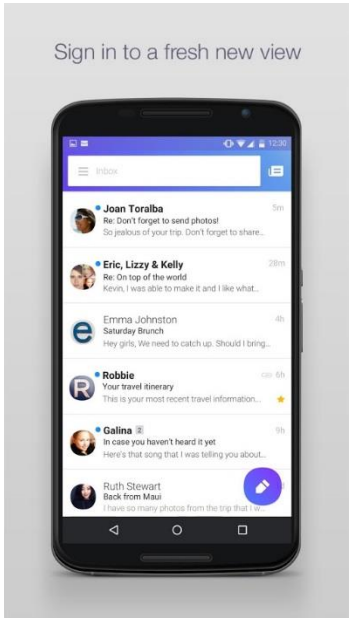
Mobile banking app



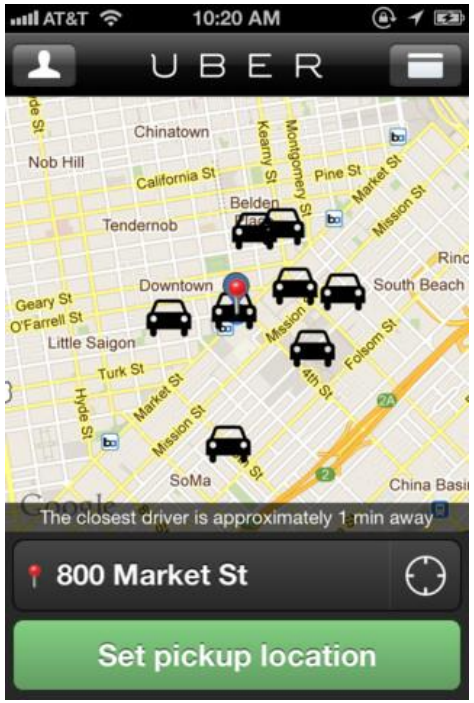
Diet recording app

- Distinction can be fuzzy. E.g. Banking app may display nearest locations

Which of these apps are Location-Aware?



a. Yahoo mail mobile



b. Uber app

Notable: Sharing Economy Apps

- **Idea:** Share resource, maximize under-utilized capacity
- **E.g.** Uber: share care, Airbnb: Share house
- **Question:** How is mobile/ubicomp used in sharing apps?

Mobile Device Issue: Energy Efficiency

- Most resources increasing exponentially *except* battery energy (ref. Starner, IEEE Pervasive Computing, Dec 2003)

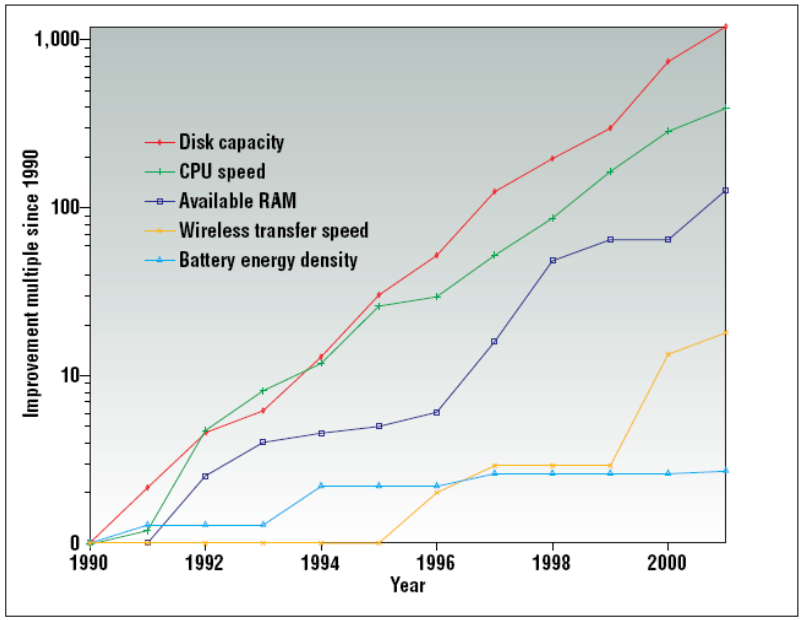
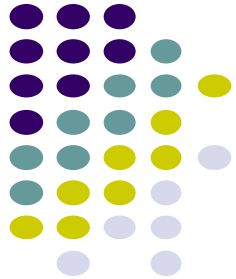
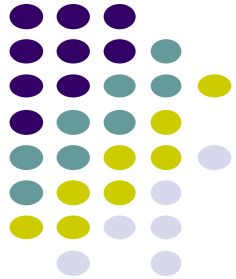


Figure 1. Improvements in laptop technology from 1990–2001.

- Some energy saving strategies:
  - **Energy harvesting:** Energy from vibrations, charging mats, moving humans
  - **Scale content:** Reduce image, video resolutions to save energy
  - **Auto-dimming:** Dim screen whenever user not using it. E.g. talking on phone
  - **Better user interface:** Estimate and inform user how long each task will take
    - E.g: At current battery level, you can either type your paper for 45 mins, watch video for 20 mins, etc



Ubiquitous Computing



u·biq·ui·tous

/yo͞oˈbikwədəs/

adjective

present, appearing, or found everywhere.
"his ubiquitous influence was felt by all the family"
synonyms: omnipresent, ever-present, everywhere, all over the place, pervasive,

Ubiquitous Computing

- Collection of *active* specialized assistants to assist human in tasks (reminders, personal assistant, staying healthy, school, etc)
- App figures out user's current state, intent, assists them
- **How?** array of *active* elements, sensors, software, Artificial intelligence
- Extends *mobile computing* and *distributed systems* (more later)
- **Note:** System/app initiates activities, has intelligence
- **Example:** Google Assistant, feed informs user of
  - Driving time to work, home
  - News articles user will like
  - Weather
  - Favorite sports team scores, etc
- Also supports 2-way conversations

User Context

- Imagine a genie/personal assistant who wants to give you all the “right information” at the right time
  - Without asking you any questions
- Examples:
  - Detect traffic ahead, suggest alternate route
  - Bored user, suggest exciting video, etc
- Genie/personal assistant needs to passively detect user’s:
  - Current situation (Context)
  - Intention/plan

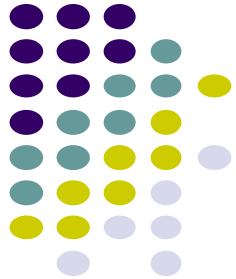
Vision

Current “personal assistant”

Smart Assistant/speaker

- User asks questions
- Answer questions, user requests
- Stream music, order a pizza,
- Weather, news, control smart home

Ubicomp Senses User's Context



- Context?
  - *Human:* motion, mood, identity, gesture
  - *Environment:* temperature, sound, humidity, location
  - *Computing Resources:* Hard disk space, memory, bandwidth
  - *Ubicomp example:*
    - *Assistant senses:* Temperature outside is 10F (environment sensing) + Human plans to go work (schedule)
    - *Ubicomp assistant advises:* Dress warm!
- Sensed **environment + Human + Computer resources** = ***Context***
- *Context-Aware* applications adapt their behavior to context

Sensing the Human

- Environmental sensing is relatively straight-forward
  - Use specialized sensors for temperature, humidity, pressure, etc
- Human sensing is a little harder (ranked easy to hard)
  - **When:** time (Easiest)
  - **Where:** location
  - **Who:** Identification
  - **How:** (Mood) happy, sad, bored (gesture recognition)
  - **What:** eating, cooking (meta task)
  - **Why:** reason for actions (extremely hard!)

5 W's + 1 H

- Human sensing (gesture, mood, etc) easiest using cameras
- Research in ubiquitous computing integrates
  - location sensing, user identification, emotion sensing, gesture recognition, activity sensing, user intent

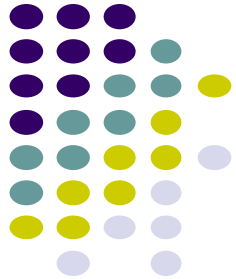
Sensor

- **Example:** E.g. door senses only human motion, opens
- **Sensor:** device that can sense physical world, programmable, multi-functional for various tasks (movement, temperature, humidity, pressure, etc)
- Device that can take inputs from physical word
  - Also includes camera, microphone, etc
- Ubicomp uses data from sensors in phone, wearables (e.g. clothes), appliances, etc.

(courtesy of MANTIS project, U. of Colorado)

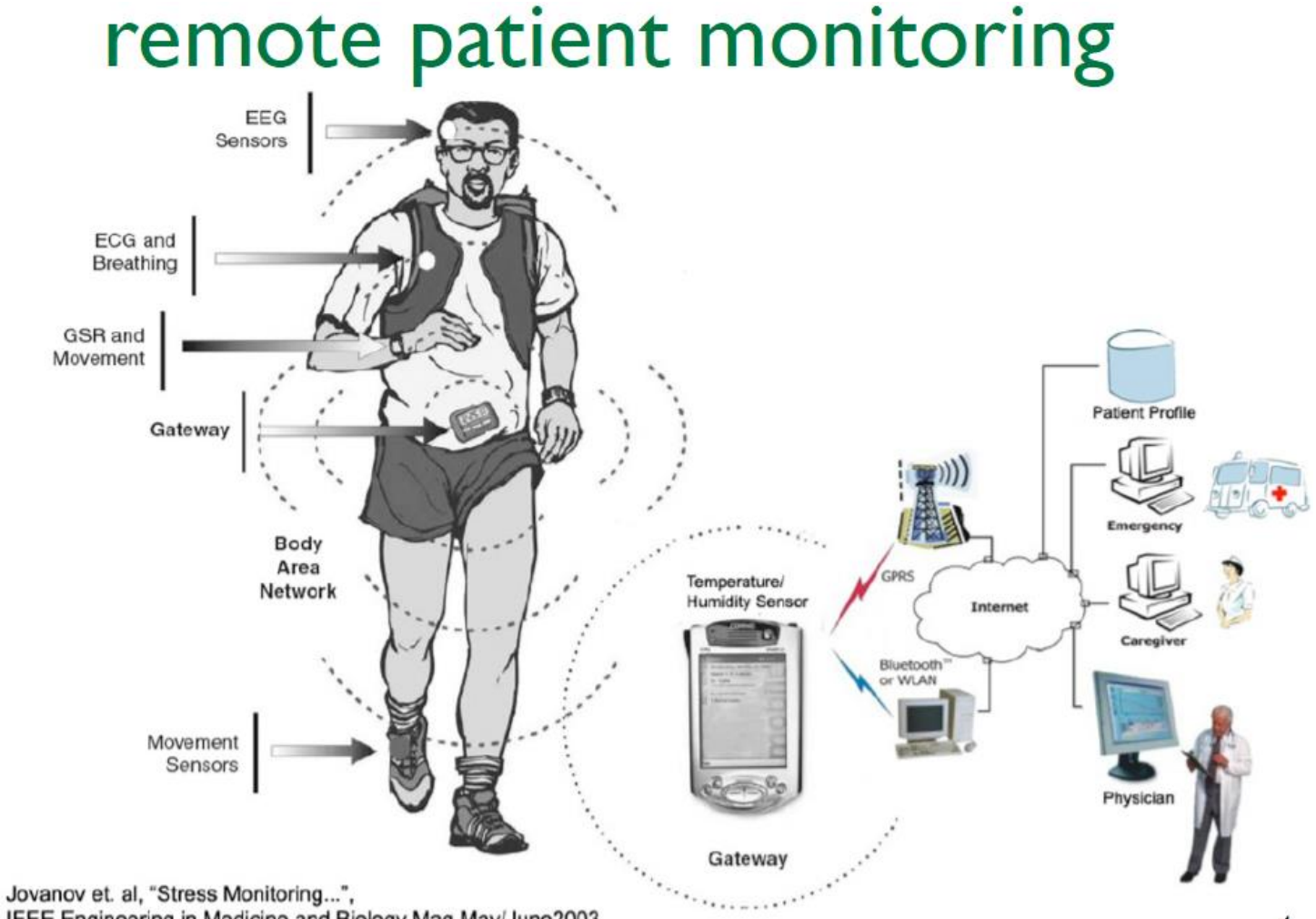
RFID tags

Tiny Mote Sensor, UC Berkeley



Ubiquitous Computing: Wearables

Ubiquitous Computing: Wearable Sensors for Health



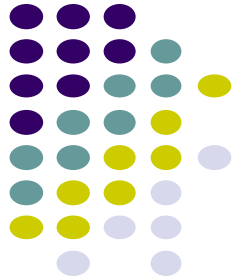
Jovanov et. al, "Stress Monitoring...", IEEE Engineering in Medicine and Biology Mag.May/June2003

UbiComp: Wearables, BlueTooth Devices

Body Worn
Activity Trackers

Bluetooth
Wellness
Devices

External sources of data for smartphone



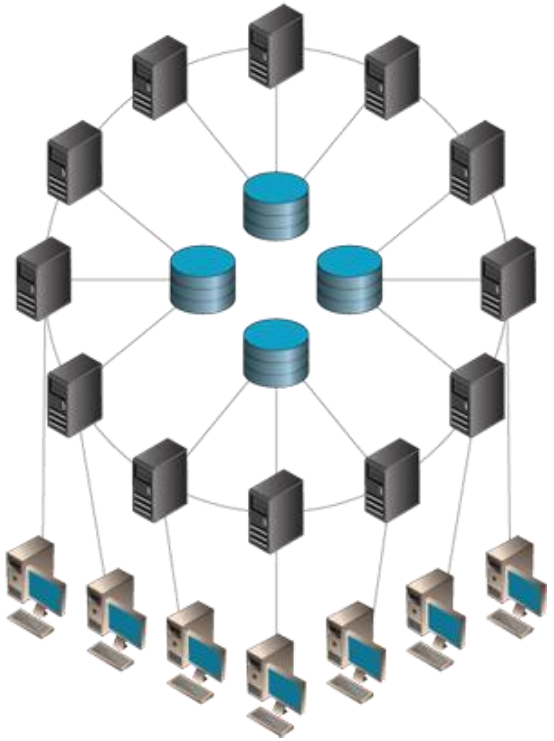
Definitions: Portable, mobile & ubiquitous computing

Distributed Computing

- Computer system is physically distributed
- User can access system/network from various points.
- E.g. Unix cluster, WWW
- Huge 70's revolution

- ***Distributed computing example:***
  - WPI students have a CCC account
  - Log into CCC machines,
  - Web surfing from different terminals on campus (library, dorm room, zoolab, etc).

- **Finer points:** network is fixed, Human moves



Portable (Nomadic) Computing

- **Basic idea:**
  - Network is fixed
  - device moves and changes point of attachment
  - No computing while moving

- ***Portable (nomadic) computing example:***
  - Mary owns a laptop
  - Plugs into her home network,
  - **At home:** surfs web while watching TV.
  - Every morning, brings laptop to school, plug into WPI network, boot up!
  - **No computing while traveling to school**

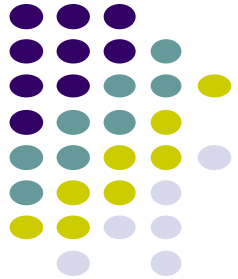
Mobile Computing Example

- Continuous computing/network access while moving, automatic reconnection

- ***Mobile computing example:***
  - John has SPRINT PCS phone with web access, voice, SMS messaging.
  - He runs apps like facebook and foursquare, continuously connected while walking around Boston

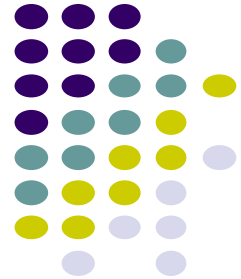
- **Finer points:**
  - John and mobile users move
  - Network deals with changing node location, disconnection/reconnection to different cell towers

Ubiquitous Computing Example



- ***Ubiquitous computing:*** John is leaving home to go and meet his friends. While passing the fridge, the fridge sends a message to his shoe that milk is almost finished. When John is passing grocery store, shoe sends message to glasses which displays “BUY milk” message. John buys milk, goes home.

- **Core idea:** ubiquitous computing assistants **actively** help John



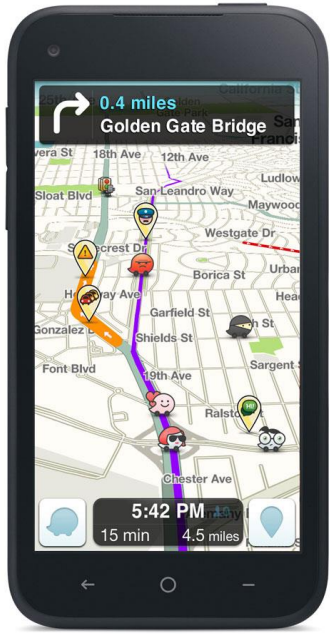
SmartPhone Sensing

Smartphone Sensing

- Smartphone used to sense human, environment

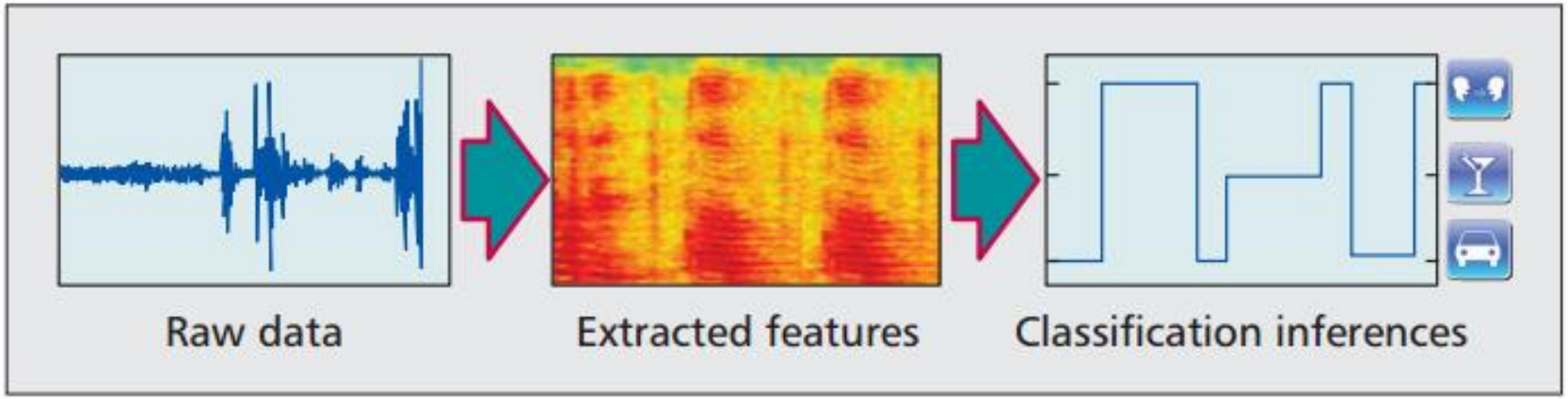
- ***Example:*** Human activity sensing (e.g. walking, driving, climbing stairs, sitting, lying down)

- ***Example 2:*** Waze crowdsourced traffic



Sensor 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



What Can We Detect/Infer using Smartphone Sensors

Smartphone Sensing!!

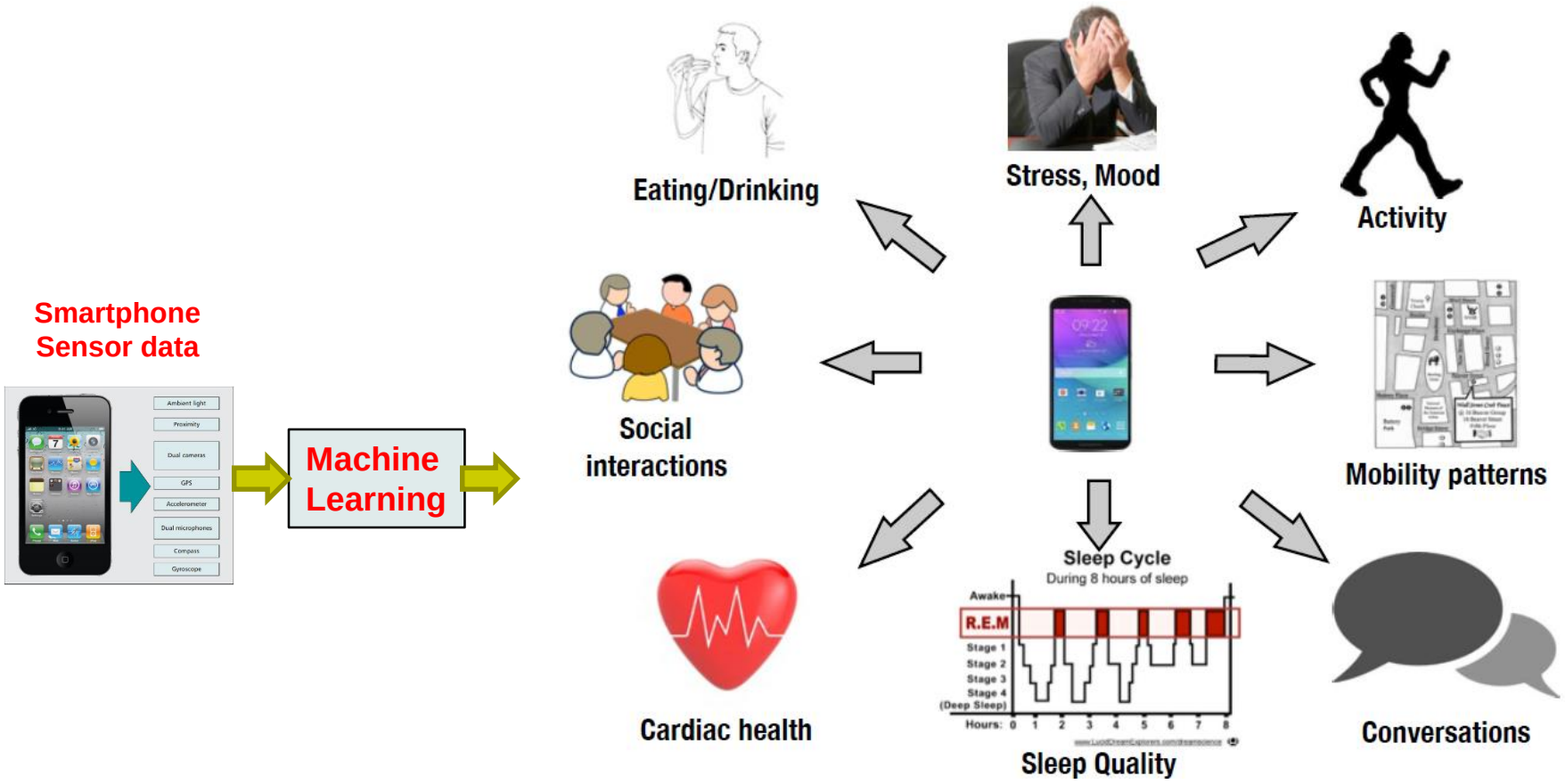
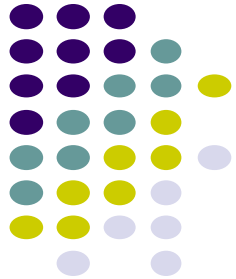


Image Credit: Deepak Ganesan, UMass

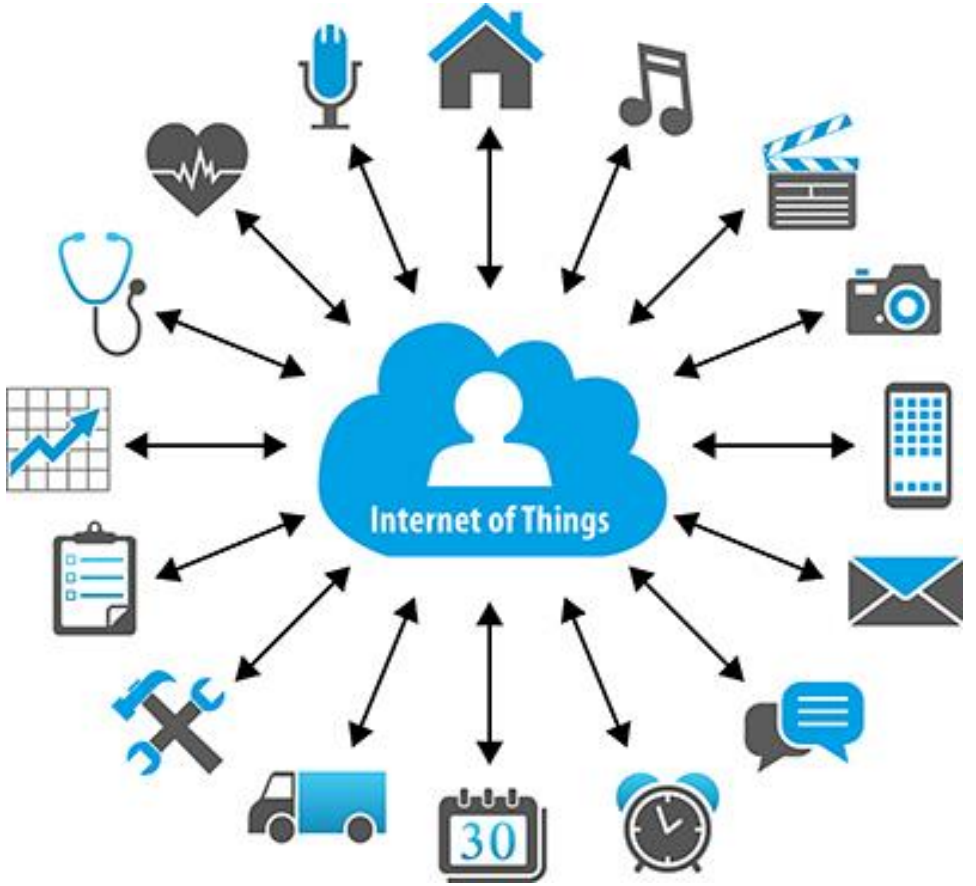


Internet of Things (IoT)

IoT: Definitions

- Internet extended to connect Devices
- New technology paradigm
- Internetworked smart machines and devices can
  - Interacting with each other
  - Exchanging information
  - Can be controlled over the Internet

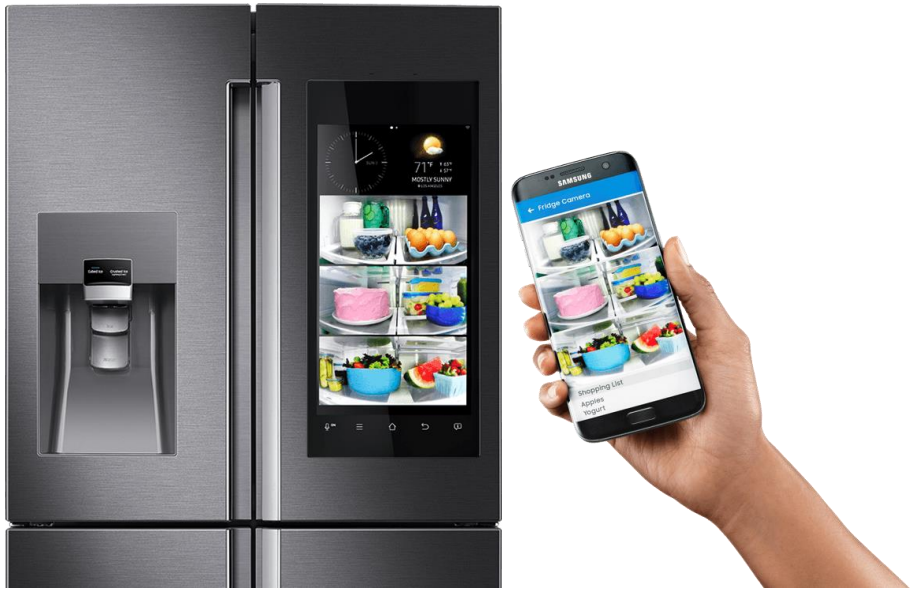
Lee, I. and Lee, K., 2015. The Internet of Things (IoT): Applications, investments, and challenges for enterprises. Business Horizons, 58(4), pp.431-440.



IoT: Networked Smart Things (Devices)

- Smart things: Can be accessed, controlled over the network, learns users patterns

Nest Smart thermostat
- Learns owners manual settings
- Turns down heat when not around



Smart Fridge
- See groceries in fridge from anywhere

Other Ubicomp Systems

- **Smart Homes:** ambient intelligence, sensing, context-aware services, enable remote home control

  Alam, M.R., Reaz, M.B.I. and Ali, M.A.M., 2012. A review of smart homes—Past, present, and future. *IEEE trans sys. man, and cybernetics, 42*(6), pp.1190-1203.

  - Example: Falls kill many old people who live alone
  - Smartphone continuously monitors elders living in smart home, automatically dials 911 if elder falls or ill

- **Smart buildings:** intelligently improve comfort and energy efficiency

  Wang, Z., et al (2012a), "Integration of plug-in hybrid electric vehicles into energy and comfort management for smart building", Energy and Buildings, Vol. 47, pp. 260-266.

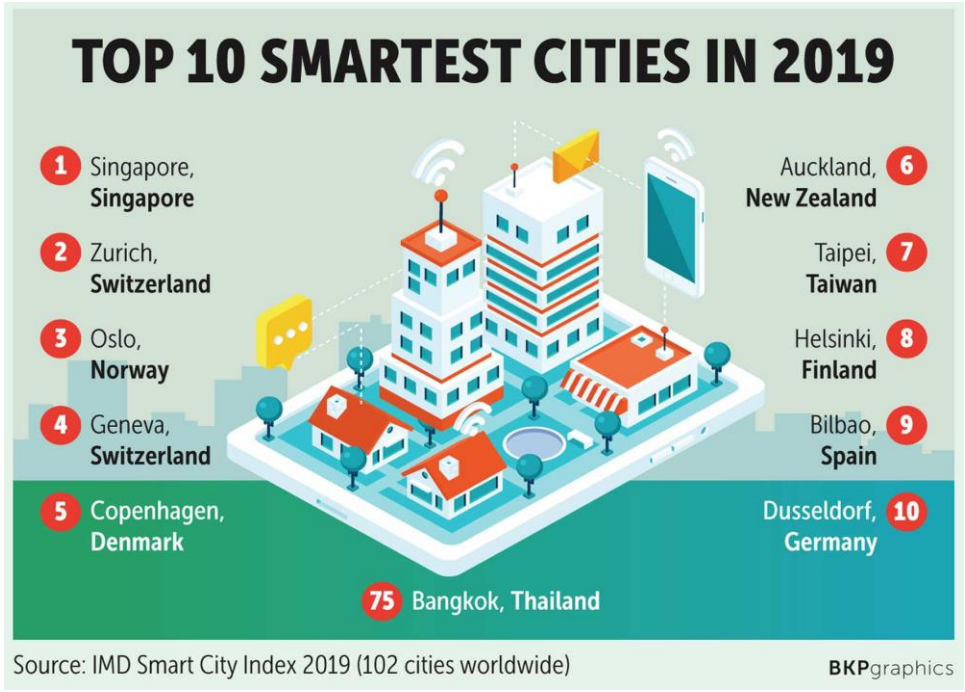
  - Senses presence of people, ambient temperature, people flow, dynamically adjusts heating/cooling
  - Up to 40% savings energy bill

Other Ubicomp Systems

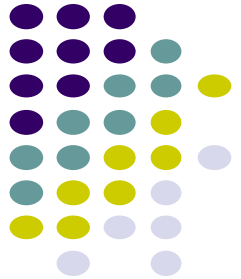
- **Smart Cities:** intelligently improve citizens' quality of life, transport, traffic management, environment, economy and interaction with government

  Ismagilova, E., Hughes, L., Dwivedi, Y.K. and Raman, K.R., 2019. Smart cities: Advances in research—An information systems perspective. *International Journal of Information Management*, *47*, pp.88-100.

  - Example: About 30% of traffic jam caused by people hunting for parking
  - Real time data from Sensors embedded in street used to direct drivers to empty parking spots



References



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