COMP90018 Mobile Computing Systems Programming (Mo)

Review/Mobile

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> Week 1 – All Slides Week 2 – All Slides Week 3 – All Slides Week 4 – All Slides Week 5 – All Slides Week 6 – RFID – Slides 1 to 39 Week 6 - Mobile Games – Slides 1 to 27 Week 7 – Location Privacy – Slides 1 to 34, 43 to 44, 46 to 47 Week 7 – Mobile GUIs – Slides 1 to 44 Week 8 - Wireless Sensor Networks – Slides 1 to 76 Week 9 - Mobile Networks – Slides 1 to 37 Week 10 – Advanced Topics – Not Examinable Week 11 - Not Examinable

L1

Technical Constraints

1. Disconnections
2. Bandwidth
3. Latency
4. Network heterogeneity
5. Security
6. Energy Usage
7. Risk to data
8. Memory
9. Processing power
10. Input/Output

Mobile application types

1. Native
2. Web
3. Hybrid

{speed, sensors, dev resources, dev speed, ux/ui, data transfer. updating, offline, monetisation(货币化)}

Mobile computing is about **Devices**, **Users**, **Agents**

Mobile device Types

- Luggable
- Portable
- Wearable
- Insertable

Design fiction

> The deliberate use of diegetic prototypes to suspend disbelief about change

- something that creates a story world
- has something prototyped in that story world
- does so in order to create a discursive space

L2 - UX research

UX

UX {User Experience Design} [Usability: A part of the User Experience]

HCI

HCI {Human Computer Interaction} [人机交互，交互设计]

Don Norman 三要素

[Don Norman 三要素]

1. **Visceral** Design (本能层设计): The subconscious reaction based on appearance. {Look, Feel, Sound}
2. **Behavioral** Design (行为设计): The reaction that stems from the ease of difficulty of use. {Function, Understandability, Usability, Physical feel}
3. **Reflective** Design (反思性设计): The reaction that derives from self-image, experience and memories.

[《情感化设计》的笔记-本能，行为，反思]

[情感设计中本能 、 行为 、 反思的解析与表达]

```
What are the three levels of processing that Don Norman proposes?
1. Visceral 2. Behavioral   3. Reflective
```

How do we know what to build

Understand the domain ⟶ Design ⟶ Build the App ⟶ Evaluation ⟶ *Understand the domain*

HCD

{Human Centered Design} 以人为本的设计

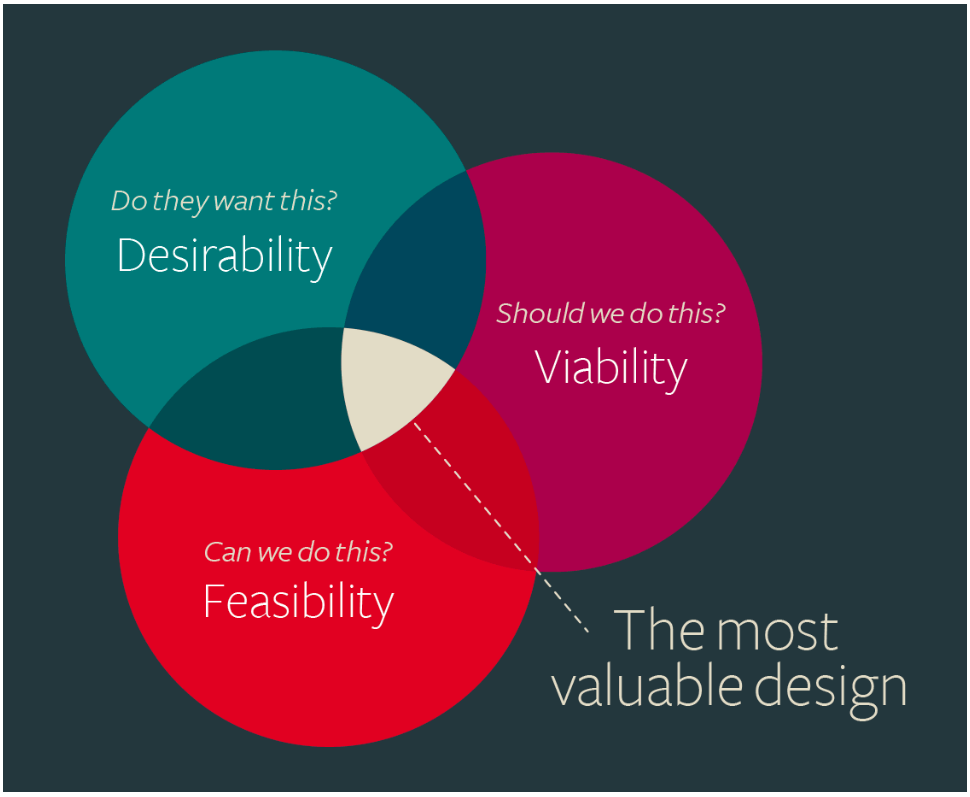
HCD is a creative approach to problem solving and the backbone. It's a process that starts with the people you're designing for and ends with new solution that are tailor made to suit their needs. HCD is all about building a deep empathy with the people you're designing for;generating tons of ideas;building a bunch of prototypes;sharing what you've made with the people you're designing for; and eventually putting your innovative new solution out in the world.

HCD consists of three phases

- **Inspiration** : you'll learn directly from the people you're designing for as you immerse yourself in their lives and come to deeply understand their needs
- **Ideation** : you'll make sense of what you learned, identify opportunities for design, and prototype possible solutions.
- **Implementation** : you'll bring your solution to life, and to market. And you'll know that your solution will be a success because you've kept people you're looking to serve at the heart of the process.

Shared Value 共同价值

- **Desirability** 愿望，客观需要 (Wishes of the stakeholder) — **Do they want this?**
    - Will this fill a need
    - Will they actually want it
    - Will this fit into their lives
    - Will it appeal to them
- **Feasibility** 可行性 (Your ability to deliver) — **Can we do this?**
    - Is the tech within reach
    - How long will this take
    - Can we make it happen
- **Viability** 行可能性 (whether you should start the project) — **Should we do this?**
    - Will this align with business goals
    - Does it fit the client's budget
    - What is the ROI/Opportunity cost



Shared Value

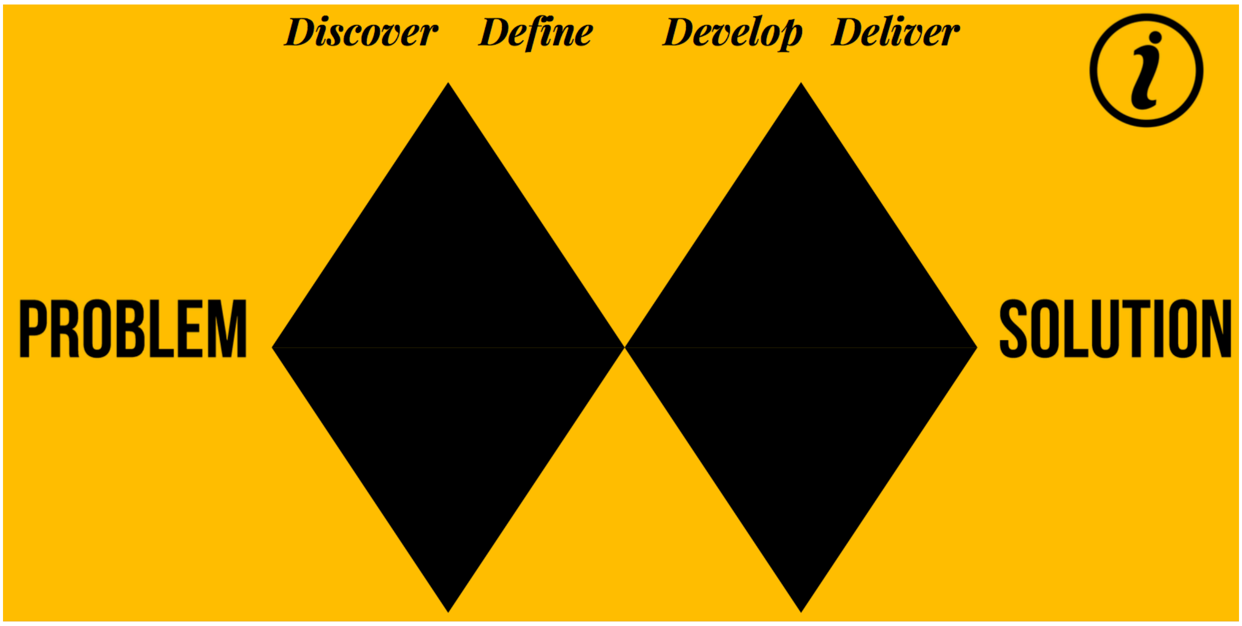
The Design Process: The Double Diamond

The design process: what is the double diamond

Problem __ divergent thinking (<-discover , develop->) __ Solution

_ convergent thinking (<-define, deliver ->) ___/

- **Discover** insight into the problem
- **Define** the area to focus upon
- **Develop** potential solutions
- **Deliver** solutions that work



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Brainstorming is a technique that involves __divergent__ thinking.
```

Interaction Design

[Interaction Design Sketchbook]

Hunch -> Hack -> Trial -> Idea =>> Design -> Prototype -> Test -> Principles -> Plans -> Product -> Market -> Paradigms

Reasearch Methods category

- **Looking**: Observational Methods
  - Ethnography It is a qualitative orientation to research that emphasises the detailed observation of people in natually occurring settings.
  - Shadowing The researcher accompanies the user and observes how they use the product or service within their natual environment.
  - Video Diary It collect quantitative data which is self-reported by participants over a period.
  - Case Study
- **Learning**: Information gathering
  - Cultural Probes 文化探针研究
  - Technology Probes (the tech probes draw from **Social Science**, **Design** and **Engineering**)
  - Competitor Analysis (对竞争者应用的研究)
  - ```
    How are tech probes different to other prototypes or prodcut?
    1. They should only contain a handful of functions
    2. They should be instrumented to collect data from users
    3. They should be open for interpretation
    ```
- **Asking**: talking to people
  - Questionnaires
  - Interviews
  - Contextual Inquiry 情境调查
  - Guessability
  - Experience Sampling alerts
    - Random
    - Scheduled
    - Event-based
- **Prototyping**: learning by building
  - Sketching [📚: Sketching User Experiences & Sketching user experiences The workbook]
    ```

   - Task Flows {Tools: Marvel, balsqmiq, sketch}
      - Pads
      - Carousel
      - Wireframes
- **Testing**:
   - Discount usability 可用性
   - Eye tracking
   - Lab or In-The-Wild (Lab is better)

	Pons	Cons
Ethnography	in depth Better product	Not cheap Time consuming Observer effect Specific
Interview	Simple Cost cheaper Context	Forget Time-consuming You have not direct observation Formal
Experience sampling	Context timely Cheap Scale up Feeling	Insight Dirty hand Input

How to choose a method

research methods

1. What people do
2. what people say
3. Qualitative beats Quantitative

L3 - Mobile Interaction Design

Waves of Mobile computing

> Waves of Mobile computing

- **Portability**: Reducing the hardware size to make it possible to move them relatively easily
   - example: {Dynabook 1968}
- **Miniaturization**: Radically smaller, enabling usage on the move
   - example: {apple Newton 1992}
   - example: {palm pilot 1997}

- **Connectivity**: wireless data networks on the move
    - WAP: wireless application protocol
- **Convergence**: bringing device types together
- **Divergence**: specialised functionality rather than generalised ones
- **Apps**: There's an app for that
    - [Natural User Interfaces Are Not Natural]
- **Digital ecosystems**: Pervasive and interrelated technologies working together

Traditional phone VS Current phone

Traditional phone	Current phone
Tactile	Touch
Indirect	Direct
Key presses	Gestures
Single key press	Multi-touch
Portrait	Portrait or landscape

4C Framework for (Digital ecosystems)

- **Communality**: Sequential interaction involving several users.
    - Personalization
    - Generalization
- **Collaboration**: Simultaneous interation by many users.
    - Division:
    - Merging:
- **Continuity**: Sequential interaction involving several artifacts.
    - Sychronization:
    - Migration
- **Complementarity**: Simultaneous interaction with multiple artifacts.
    - Extension:
    - Remote Control:

	Many Users	**Many artifacts**
sequential (序列的)	**Communality** (集体性) * ***Personalization*** The artifact is personalized to each user {like Facebook} 个性化服务 * ***Generalization*** The artifact allows different users to immediately interact without any knowledge of their identity {like a ticket machine} 公众一致化服务	**Continuity** (连续性) * ***synchronization*** a user’s data is synchronized across artifacts {like “cloud-based” storage services like Dropbox} 在多个设备之间同步 * ***migration*** the state of a user’s activity is migrated from one artifact to another {like Apple’s AirPlay} 将正在进行的内容无缝转移到另个设备
simultaneous (同时的)	**Collaboration** (合作性) * ***division*** the artifact is divided into independent sections and each user can interact with it simultaneously {like split- screen views} 同屏幕分屏各自体验 * ***merging*** the artifact merges all users’ interaction {like a multi-user board game} 同屏不分屏多人体验	**Complementarity** (互补性) ***extension*** * interaction with an artifact is extended to another {Adobe’s Nav App moves selected tools in Photoshop onto an iPad} 用另个设备来扩展操控一个设备 * ***remote control*** one artifact is used to control another {control Apple TV with a app in iphone} 纯粹用另个设备当遥控器来远程操控

Case Study

- smart phone with smart watches
- phoneTouch

Augmenting the interaction with SENSORS

- Orientation sensor
- Flexcase
- table + pen
- Orbits (eye tracking)

L4 - Progessing Sensor Data

Challenges in Sensor Data

Most data will be like time serious, it's a funciton of time

1. The value of sensor data in time t will strongly influence sensor at time t+1. => GPS
2. Every sensor has sampling rate -> the data is disparate -> no idea of what happens between sampling rate.
3. Don't have enough data point.
4. Remove noise -> may lose some information of data.

Filter

> Mean and Median Filters, Kalman Filters, Particle Filters

$z_i = x_i$

z_i is the measurement from sensor, x_i is the actual value on ground truth

But the measurement may not equal to actual value

Therefore, we assume $z_i = x_i + v_i$

v_i is sensor noise, $v_i \sim N(0, \sigma)$

$$z_i = \begin{pmatrix} z_i^{(x)} \\ z_i^{(y)} \end{pmatrix} \textbf{ measurement}$$
$$x_i = \begin{pmatrix} x_i \\ y_i \end{pmatrix} \textbf{ actual value}$$
$$v_i = \begin{pmatrix} v_i^{(x)} \\ v_i^{(y)} \end{pmatrix} \sim \begin{pmatrix} N(0,\sigma) \\ N(0,\sigma) \end{pmatrix} \textbf{ Normal Dist}$$

Mean Filter

Create the window of a given size, wait till window full, each value will be replaced by the mean value in the given window.

Three problems:

- wait till window full -> delay of the computation.
- No sharp edges
- easy susceptible to outliers

Basic uniform Mean: if window size = 10. the weight that each value will have 0.1

Weighted Mean Filter: The old measurement still has effect, the newer, the larger effect.

Median Filter

Except for outliers. computing/pick the median. Always use the value exist on the window -> doesn't create the data. good for have the sharp edge (but if the window numbers are too much, the sharpness will be lost).

- less susceptible to outliers
- still need wait till window full
- Does not make up data

Both pros and cons for mean/median filter

Pros:

- easy to implement
- efficient
- great cost benefit

Cons:

- Laggy
- No dynamic model

trajectory smooth

Kalman FIlter

> underlying velocity

$$z_i = \begin{pmatrix} z_i^{(x)} \\ z_i^{(y)} \end{pmatrix}$$

$$x_i = \begin{pmatrix} x_i \\ y_i \\ v_i^{(x)} \\ v_i^{(y)} \end{pmatrix} \text{ contain posiitons and velocities total 4 dimensions}$$

$$\text{Therefore } z_i = Hx_i + v_i$$

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

$$v_i \sim N(0, R_i)$$

$$R_i = \begin{bmatrix} \sigma^2 & 0 \\ 0 & \sigma^2 \end{bmatrix}$$

modelling the dynamics

$$x_i \leftarrow x_{i-1}$$

$$\because x_i = x_{i-1} + v_{i-1}\Delta t \text{ and } v_i = v_{i-1}$$

$$\begin{pmatrix} x_i \\ y_i \\ v_i^{(x)} \\ v_i^{(y)} \end{pmatrix} = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_{i-1} \\ y_{i-1} \\ v_{i-1}^{(x)} \\ v_{i-1}^{(y)} \end{pmatrix} + Noise$$

$$\begin{pmatrix} x_i \\ y_i \\ v_i^{(x)} \\ v_i^{(y)} \end{pmatrix} = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_{i-1} \\ y_{i-1} \\ v_{i-1}^{(x)} \\ v_{i-1}^{(y)} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ N(0,\sigma_s) \\ N(0,\sigma_s) \end{pmatrix}$$

$$\phi_{i-1} = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$w_{i-1} = \begin{pmatrix} 0 \\ 0 \\ N(0,\sigma_s) \\ N(0,\sigma_s) \end{pmatrix}$$

$$w_{i-1} \sim N(0, Q_i)$$

$$Q_i = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma^2 & 0 \\ 0 & 0 & 0 & \sigma^2 \end{bmatrix}$$

$$\text{Therefore, Measurement matrix is : } H = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

$$\text{Measurement noise is : } v_i \sim N(0, R_i)$$

$$\text{Therefore, Dynamics of states is : } \phi_{i-1} = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Dynamic noise is : } w_{i-1} \sim N(0, Q_i)$$

$$\text{All together}$$

$$\text{Initial state estimate: } x_o = \begin{pmatrix} x_0 \\ y_0 \\ v_0^{(x)} \\ v_0^{(y)} \end{pmatrix} = \begin{pmatrix} z_0^{(x)} \\ z_0^{(y)} \\ 0 \\ 0 \end{pmatrix}$$

$$\text{Initial estimate of state error covariance :}$$

$$P_0 = \begin{bmatrix} \sigma^2 & 0 & 0 & 0 \\ 0 & \sigma^2 & 0 & 0 \\ 0 & 0 & \sigma_s^2 & 0 \\ 0 & 0 & 0 & \sigma_s^2 \end{bmatrix}$$

$$\text{STEP 1: PREDICT}$$

$$x_i^{predicted} = \phi_{i-1} x_{i-1}^{corrected}$$

$$\text{Extrapolate the state error covariance:}$$

$$P_i^{predicted} = \phi_{i-1} P_{i-1}^{corrected} \phi_{i-1}^T + Q_{i-1}$$

$$\text{STEP 2: MEASURE}$$

$$\text{Compute the Kalman gain:}$$

$$K_i = \frac{P_i^{predicted} H_i^T}{H_i P_i^{predicted} H_i^T + R_i} = H_i^{-1} \frac{H_i P_i^{predicted} H_i^T}{H_i P_i^{predicted} H_i^T + R_i}$$

$$R_i \text{ is the uncertainty from the measurement}$$

$$H_i P_i^{predicted} H_i^T \text{ is the uncertainty propagated by the model}$$

$$\text{Update extrapolations with new measurements:}$$

$$x_i^{corrected} = x_i^{predicted} + K_i (z_i - H_i x_i^{predicted})$$

$$p_i^{corrected} = (I - K_i H_i) P_i^{predicted}$$

1. Make prediction most like value based on dynamic model.
2. measure use sensor data to correct the prediction.

Pros and Cons for Kalman filter

Pros:

- Dynamic model of the system
- no lag
- Tunable trade-off between model and measurement
- Uncertainty estimate

cons:

- Parameters are not intuitive
- Overshooting

Kalman and Particle

- Kalman is cheap to run
- Particle is general

Kalman	Particle
Bayesian	Bayesian
Gaussian	Gaussian or not
Linear	Linear or not
Online	Online

Particle Filter

Generate hypotheses -> compute weights -> resample

Pros:

1. General -> because it doesn't make any assumptions
2. Continuous or discrete values is available
3. Great result

Cons:

1. Lots of memory
2. Very slow

L5 - Context & Activity RECOGNITION

Elements of the user's context

- Location
- User's identity
- Time of the day
- Sound levels
- Light levels
- User's motion

Context awareness (activities)

> Who What Where When Why

- context **Display** (e.g. GPS can track where you are)
- contextual **augmentation** (e.g. google photo use location and time to create augment info)
- **context-aware configuration** (configure how devices are used)
- **context- triggered actions** (changing brightness when light changes)
- **contextual adaptation of the environment** (turn on heating when go to sleep)
- **contextual mediation** (based on the limited and needs of the context)
- **context-aware presentation** (e.g. switch Portrait to landscape)

Characteristics of Human Activity Recognition (HAR) Systems

- **Execution** (the timing of the execution of the recognition)
  - **online**: process data in real time. e.g. human-computer interaction
  - **offline**: records the sensor data first. The recognition is performed afterwards. e.g. health monitoring
- **Generalisation**
  - **user independent**: working with everyone
  - **user specific**: single person data. Performance is usually higher than in the user-independent case, but does not generalise as well to other users.
  - **temporal**: both cases.
- **Recognition**
  - **continuous** : stream of data. The system automatically “spots” the occurrence of activities or gestures in the streaming sensor data.
  - **segmented** : The system assumes that the sensor data stream is segmented at the start and end of a gesture by an oracle.
- **Activities**
  - **periodic** : Activities or gestures exhibiting periodicity, such as walking, running, rowing, biking, etc. Sliding window segmentation and frequency-domain features are generally used for classification.
  - **sporadic** :The activity or gesture occurs sporadically, interspersed with other activities or gestures. Segmentation plays a key role to isolate the subset of data containing the gesture.
  - **static** : The system deals with the detection of static postures or static pointing gestures.
- **System model**
  - **stateless** : The recognition system does not model the state of the world.
  - **stateful**: The system uses a model of the environment, such as the user’s context or an environment map with location of objects.

```
Imagine an app that analyses your shopping lists and suggests at the end of the week recipes with a better nutriotional value based on the ingredients of that list. Check all characteristics that apply to this app.
Offline, User-specific, Periodic
```

The processing pipeline

- sensor

Choosing a sensor

- what is it measuring

- Accuracy and precision
- range of the sensor
- resolution or sensitivity of the sensor
- sampling rate or frame rate
- cost

Preprocessing

- Interpolation
- downsampling

Segmentation

- sliding window
    - Non-overlapping sliding window
    - overlapping sliding window
- energy based
- additional context sources

Feature extraction

- Min
- Max
- Range
- Skewness
- Mean
- Energy
- Kurtosis
- Variance

Classifiers

- Hidden Markov Models
- Dynamic Time Wraping
- kNN
- AdaBoost
- Support Vector Machines
- Random Forest

Reporting performance

What proportion of the labelled items were correct?

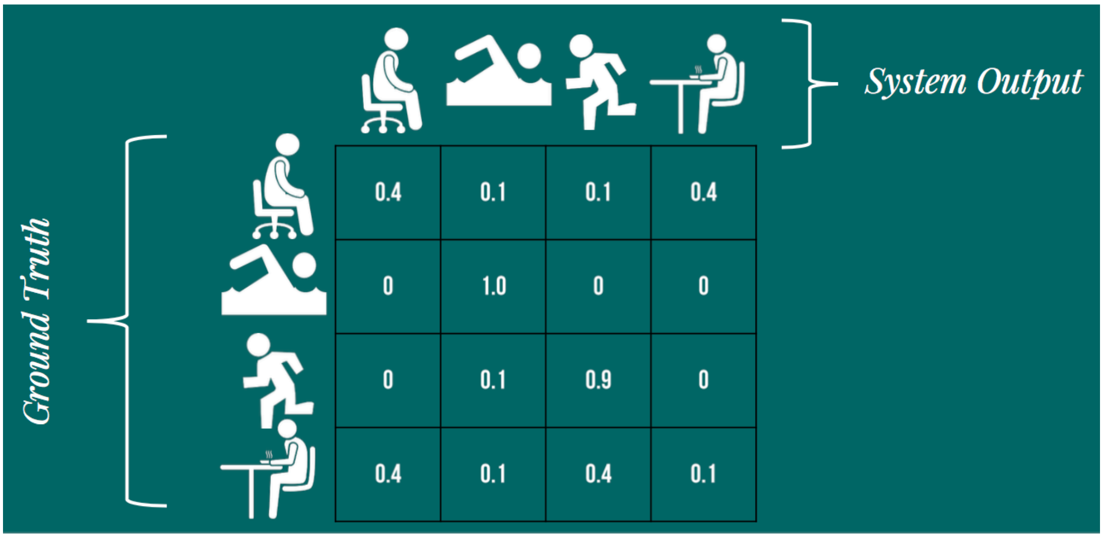
- **Precision** = True positives / (True positives + False positives)

What proportion of the windows with that activity were recognised?

- **Recall** = True positives / (True positives + False negatives)

F1 Score = $\frac{2}{\frac{1}{\text{Recall}} + \frac{1}{\text{Precision}}} = 2\frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$

Confusion Matrix



L6 - RFID

RFID technology

Tag

- Microchip connected to an antenna
- can be passive, semi-passive, active
- No battery: passive
- Semni-passive: circuit is battery-powered except communication
- secure
- query tags via radio signals

Reader

- Query tags via radio signals

> Example: Visa payWave, payPass

RFID (radio frequency identification)

- Proximity-based technology: determine the tag location by measuring the signal's time of flight (in theory)

Pros:

- Cheap, high volume, large variety
- Long industry experience
- scanning even with high speeds
- no maintenance, simple to manage

Cons:

- No quality of service
- Only passive data acquistion

Characteristics

- No line-of sight necessary
- Resist environmental conditions: frost, heat, dirt, ...
- RFID tags with read & write memory
- Smartcard functionality (JavaCard): cryptographiccomputations for personal contact cards

Passive RFIDs

- Do not need an internal power source
- Operating power is supplied by the reader

Features

3m, cheap

Active RFIDs

- Own power source (battery life expectancy: up to 10 years)

Features

cheap, samll, 100m, combination with sensors

RFID Frequencies

- LF: low frequency
  - good penetration of materials including water and metal
  - widely adopted
  - No collision protocol available
  - Range: 30cm
- HF: high frequency
  - Provides anti-collision protocols
  - 1m
- UHF : ultra-high frequency
  - Difficult to penetrate of water and metal
  - range: 3m
- Microwave
  - range: 2m
  - high data rate

EPC - pass

Anti-collision & Singulation

Problem

- RFID tags are simple and cannot communicate with other tags
- High probability that two tags in communication rangerespond simultaneously
- Collision

Anti-collision and singulation protocols

- Algorithms to identify all tags
- Anti-collision: trade time for the possibility to interrogate alltags
- **Singulation**: identify (iterate through) individual tags

ALOHA Protocol

“Tag-Talks-First” behavior: tag automatically sends its ID (and data) if it enters a power field.

If a message collides with another transmission, try resending it later after a random period

Collision types: Partial & complete

Reducing collisions in ALOHA

- Switch-off
    - After a successful transmission a tag enters the quiet state
- Slow down
    - Reduce the frequency of tag responses
- Carrier sense
    - Use ACK signal of the reader in communication with another tag
    - Reader broadcasts a MUTE command to other tags if itinterrogates one tag

Partial overlap leads to maximum throughput of a 18.4%

Slotted ALOHA protocol

- “Reader-Talks-First”: use discrete timeslots SOF (start-of-frame) and EOF (end-of-frame)
- A tag can send only at the beginning of a timeslot
- Leads to complete or no collision
- Increased maximum throughput of 36.8%

Frame-slotted ALOHA

- Group several slots into frames
- Only one tag transmission per frame
- Limits frequently responding tags
- Adaptive version: adjust the number of slots per frame

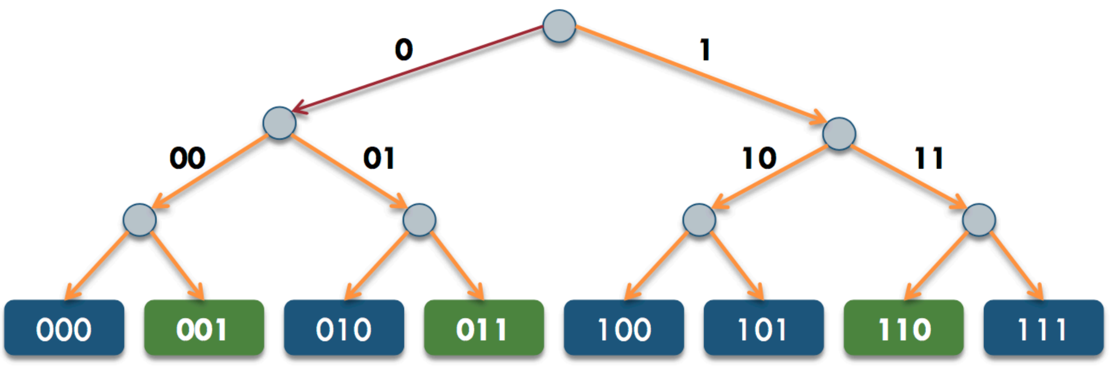
Protocol	+	-
ALOHA	Adapts quickly to changing numbers of tags Simple reader design	Worst case: never finishes Small throughput
Slotted ALOHA	Doubles throughput	Requires synchronization Tags have to count slots
Frame-slotted-ALOHA	Avoids frequently responding tags	Frame size has to be known or transmitted similar to slotted ALOHA

Binary Tree Protocol I

- DFS
  - "Reader-Talks-First" behavior: reader broadcasts a request command with an ID as a parameter
  - A sub-tree T is searched by an identifier prefix
  - Only tags with an ID lower or equal respond
  - An interrogated tag is instructed to keep quiet afterward
  - Repeat algorithm until no collision occurs or all tags are quiet

Binary Tree Protocol II

- Each sub-tree T corresponds to an identifier prefix
- Reader searches T by sending prefix, interrogating tags for their next bit
  - If all "0" search Left(T)
  - If all "1" search Right(T)
  - If both "0" and "1" search Left(T) and Right(T)



RFID Applications

- E-passports
  - Security risk: forgery
- Transportation payment

- Electronic toll collection
    - Security risk: denial of service
- Vehicles : Smart key
- Supply chain & inventory management
- Preventation
- product tracking
    - privacy risk: tracking
- Human implants

Status Quo of RFID Systems

- No authentication
    - Readers are blind: if tag does not reply, reader does not know about it
    - Tags are promiscuous and reply to any reader
- No access control
    - Malicious reader can link to a tag
    - Malicious tag can spoof a reader
- No encryption
    - Eavesdropping possible (especially for the reader)
- Man-in-the-middle-attack

Privacy Concerns

- Unauthorized surveillance
    - simple RFID tags support no security mechanisms
    - Permanent RFID serial numbers can compromise privacy
- Potential risks
    - Tags in goods might be a potential risk
    - Threat: scanning of assts of high value

RFID Tag Privacy

`TODO`
