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CARS and Beacons:

Context-aware Recommender Systems using Indoor Localization

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About me

- professor of computer science at Hochschule Hannover
  - cooperation with the AI group at URJC
- interested in Software Architecture, Intelligent Systems
  - especially in stream-based systems (Complex Event Processing)
  - Semantic Web, ontologies, data analysis
- recent projects: context-aware systems using CEP
  - application domains: M2M systems, RFID, iBeacons
- current work: mining data streams, infering CEP rules

Outline

A. CARS: Context-aware Recommender Systems

- Ramón Hermoso, Jürgen Dunkel, Jan Krause: Situation Awareness for Push-Based Recommendations in Mobile Devices, 19th Intern. Conf. on Business Information Systems (BIS) conference, 2016

B. Beacons and Indoor Localization

- W. Zimmermann: Indoor navigation with iBeacon Technology (master thesis)
- experiences of a student project using iBeacons
- experiences of two RFID research projects

A. CARS: Context-aware Recommender Systems

1. Motivation: CARS
2. Situation-aware Recommendation Process
3. Detailed Design
4. Conclusion

1. Motivation: CARS (Context-aware Recommender Systems)

- CARS make use of **context** to make individualized recommendations
  - context = situation of the user (age, gender, special interests…)
  - challenge: some type of context is frequently changing: user location, behaviour, …

- goal: **CARS architecture** providing **situation-awareness**

where to
go next ?

depends on:

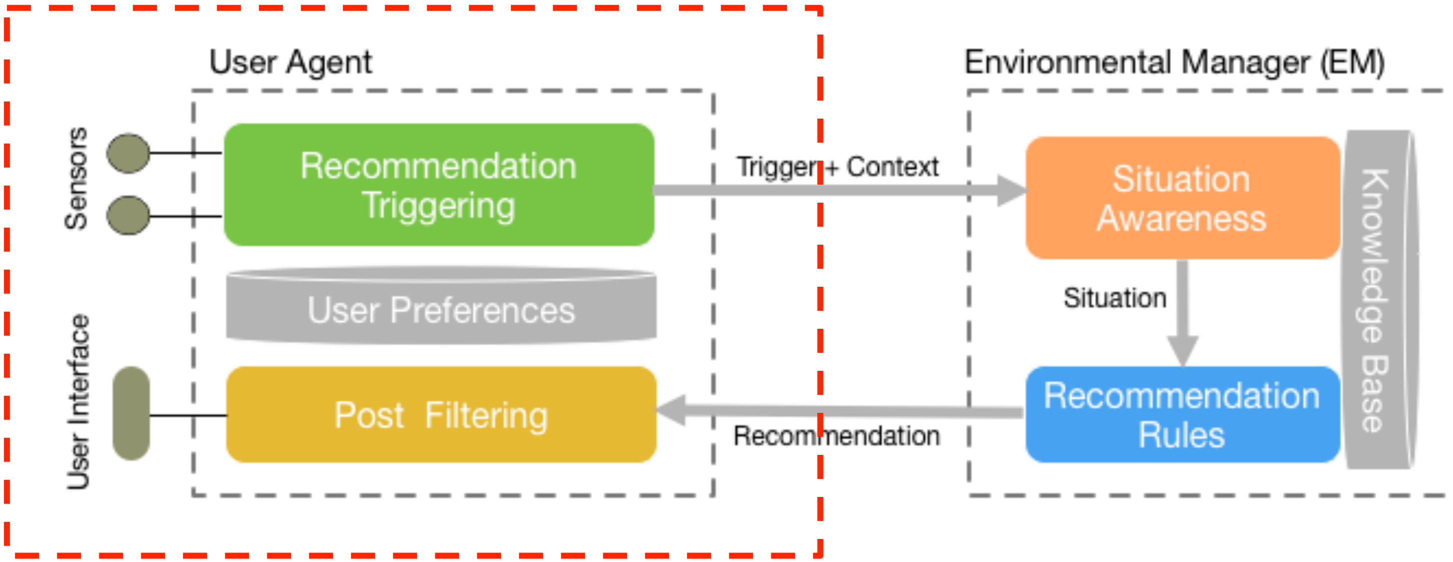
- visitor interests
- visitor **location**
- room **occupancies**

2. Situation-aware Recommendation Process

- User Agents (smartphone app)
  - knows user **preferences** (artists and art styles)
  - knows **user situation** (using GPS, iBeacons, acceleration sensors,…)
  - triggers recommendations

- Environmental Manager (server component)
  - **structural knowledge**:
    - about the museum: floor plan, location of artworks, beacons,…
    - about art: how to relate user preferences to certain artwork
  - **situational knowledge**: current situation of all users

2. Situation-aware Recommendation Process

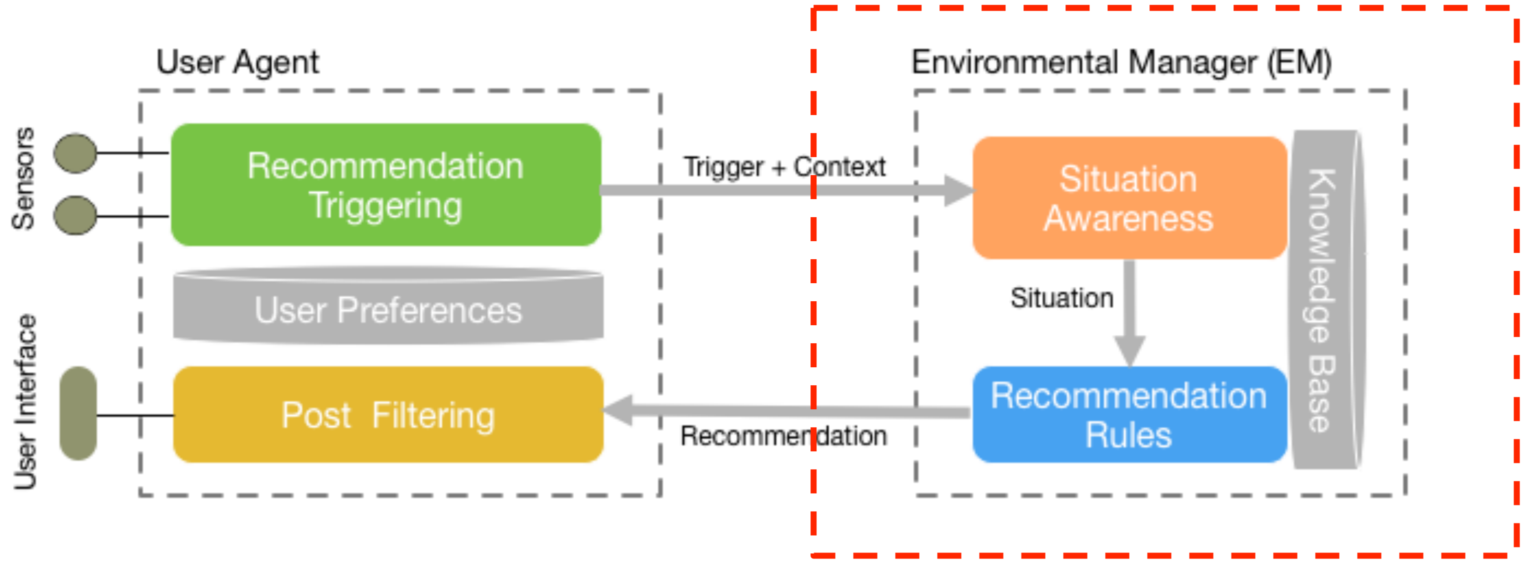


User Agents (UA): provide EM with current user situation

1. Recommendation **Triggering**
   - if the user is entering a new environment
   - if she is in an appropriate situation

2. Post **Filtering**
   - filters out received recommendation

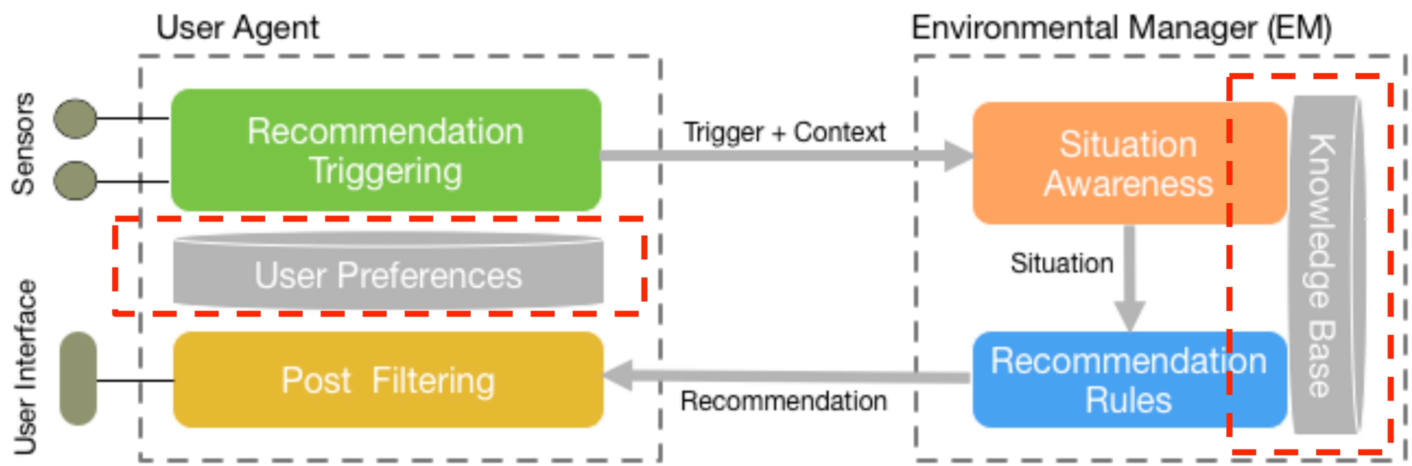
2. Situation-aware Recommendation Process



Environmental Manager (EM): makes recommendations

1. evaluates current **situation of all users**
2. infers the **global situation** of the environment
3. applies **recommendation rules**

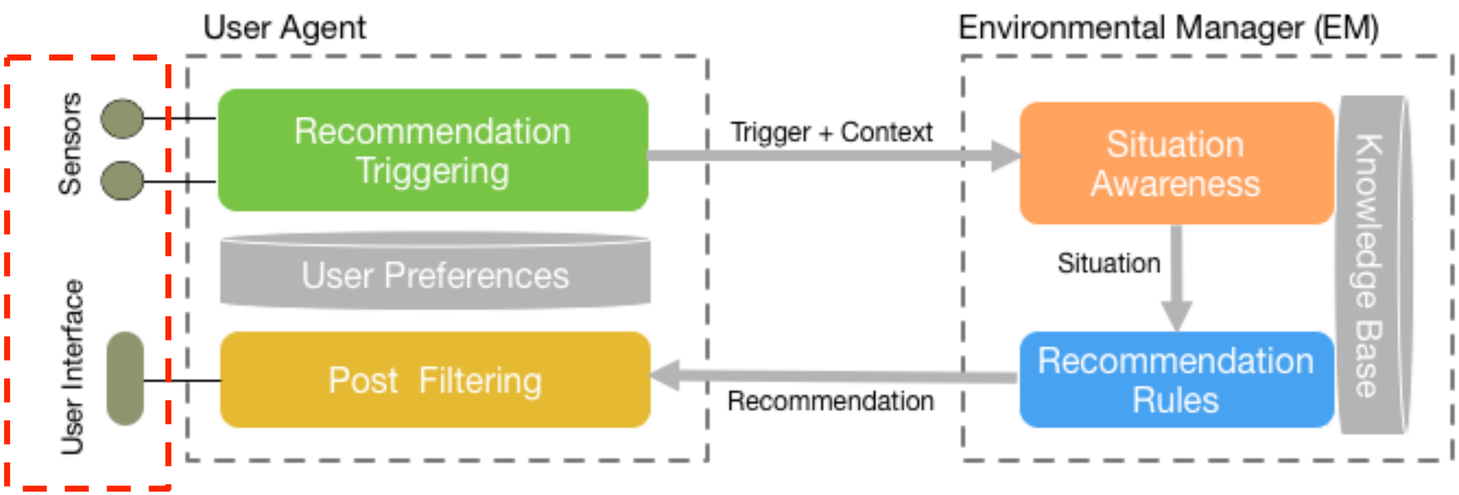
2. Situation-aware Recommendation Process



Structural Knowledge: expert knowledge about a domain

- using ontologies
- TBox: **conceptional** knowledge (=concepts)
- ABox: **assertional** knowledge (=facts)

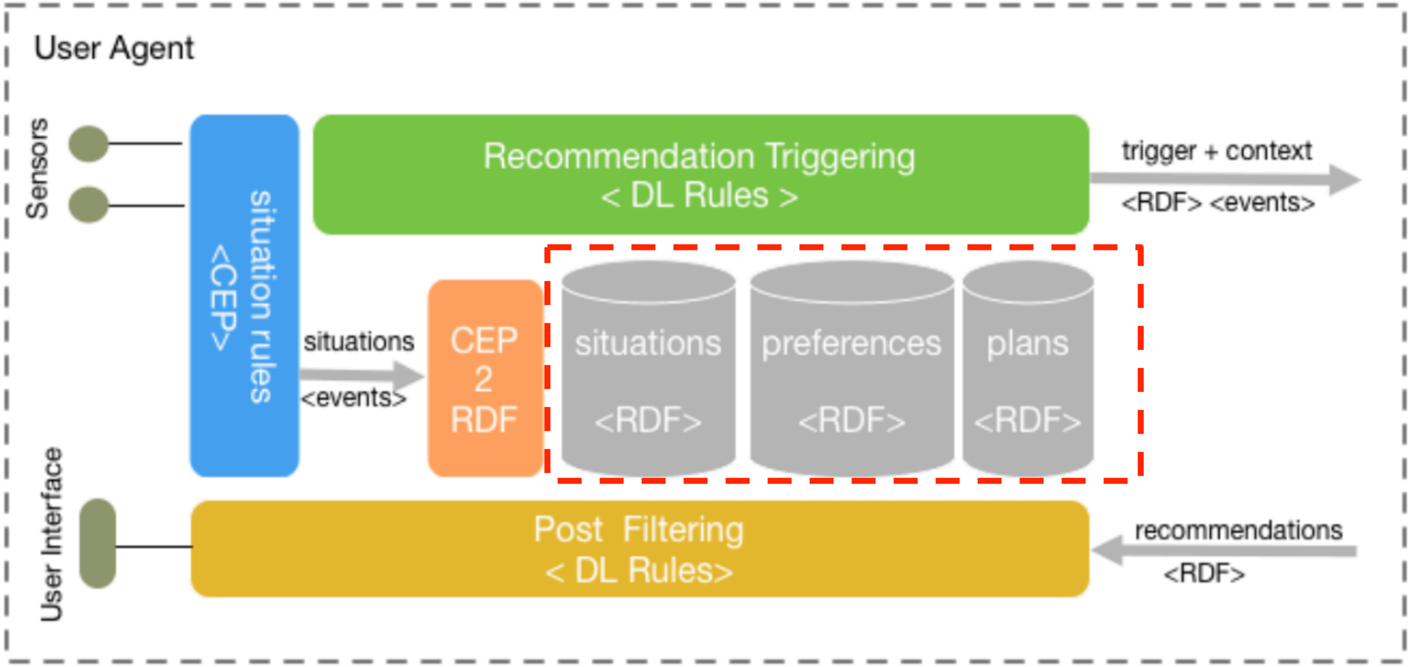
2. Situation-aware Recommendation Process



Situational Knowledge: current state in an environment

- exploiting live data (e.g. sensors)
- each data set corresponds with a particular event
- high change frequency

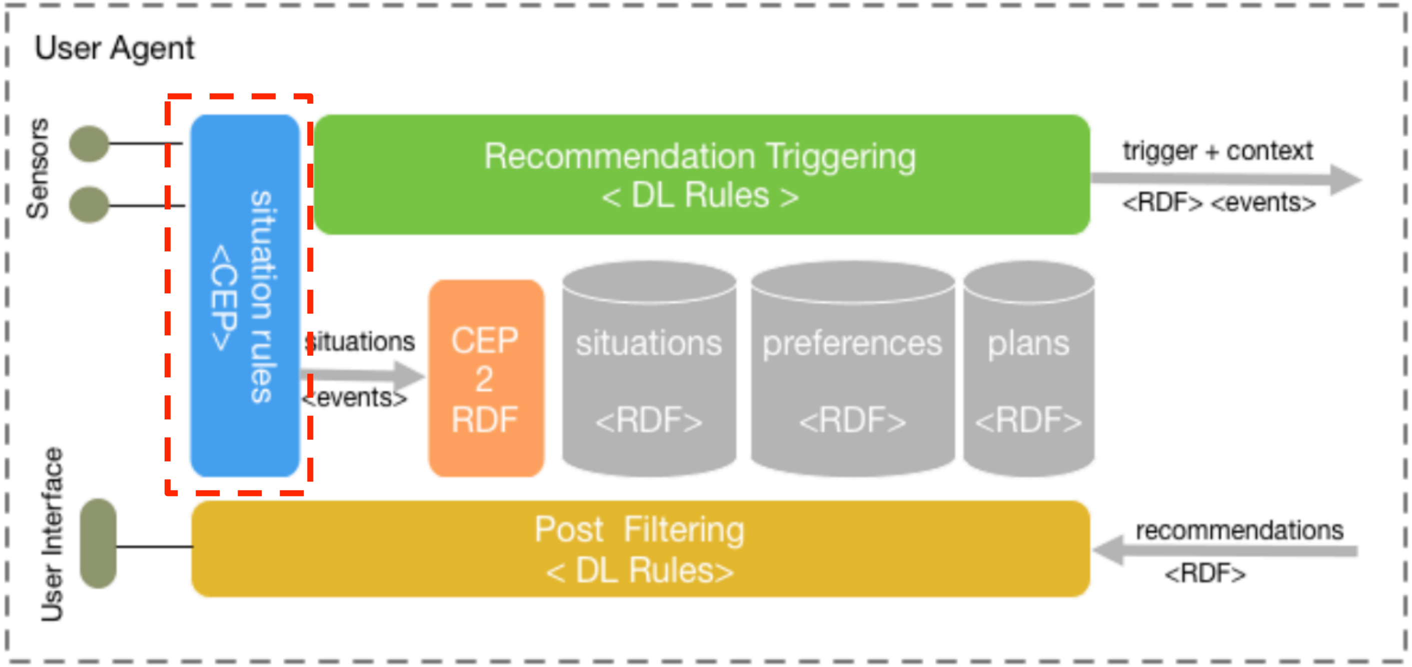
3. Design – User Agent



Knowledge base (RDF):

```
:User1  :likesArtist        :Kandinsky;
        :likesStyle         :Expressionism;
        :speaks             :Spanish;
        :isLocatedIn        :EntranceHall;
        :hasAppointmentAt   :"12:30".
```

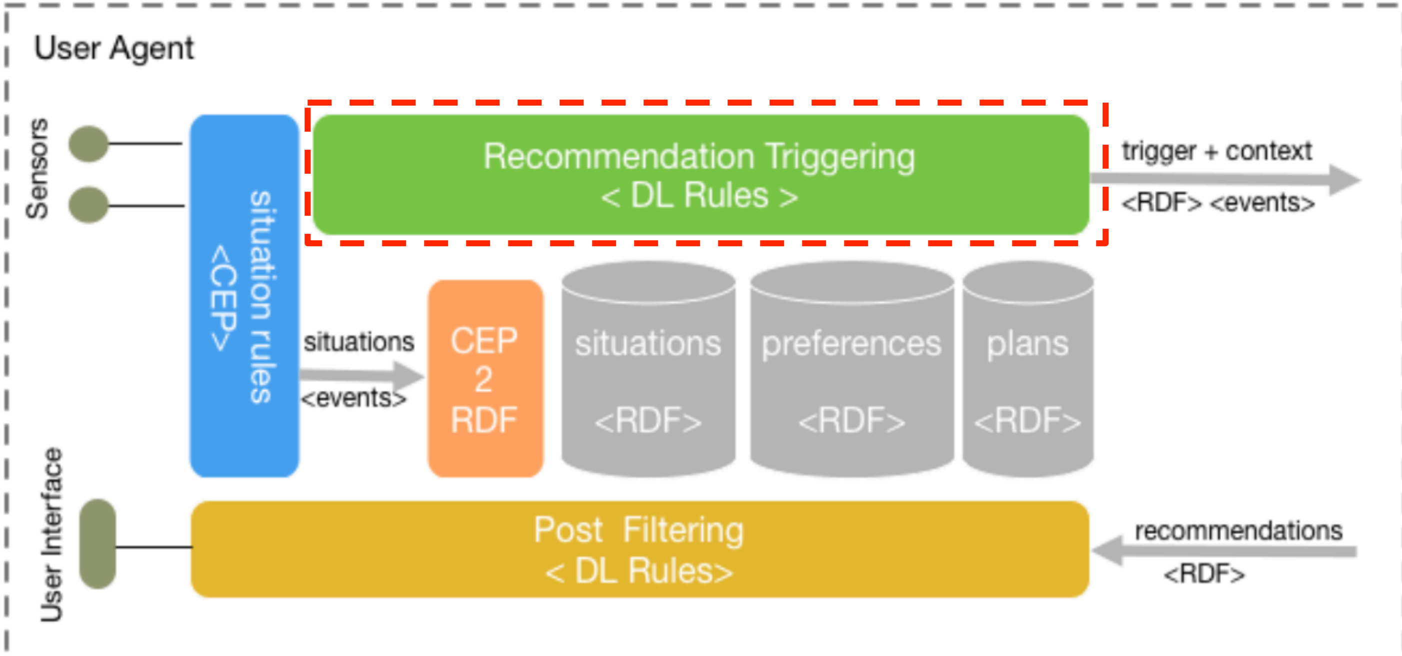
3. Design – User Agent



Situational Rules (CEP):

```
CONDITION: iBeaconEvent AS B1 → iBeaconEvent AS B2
           ∧ B1.id ≠ B2.id
   ACTION: create ChangedLocationEvent(from:=B1, to:=B2)
```

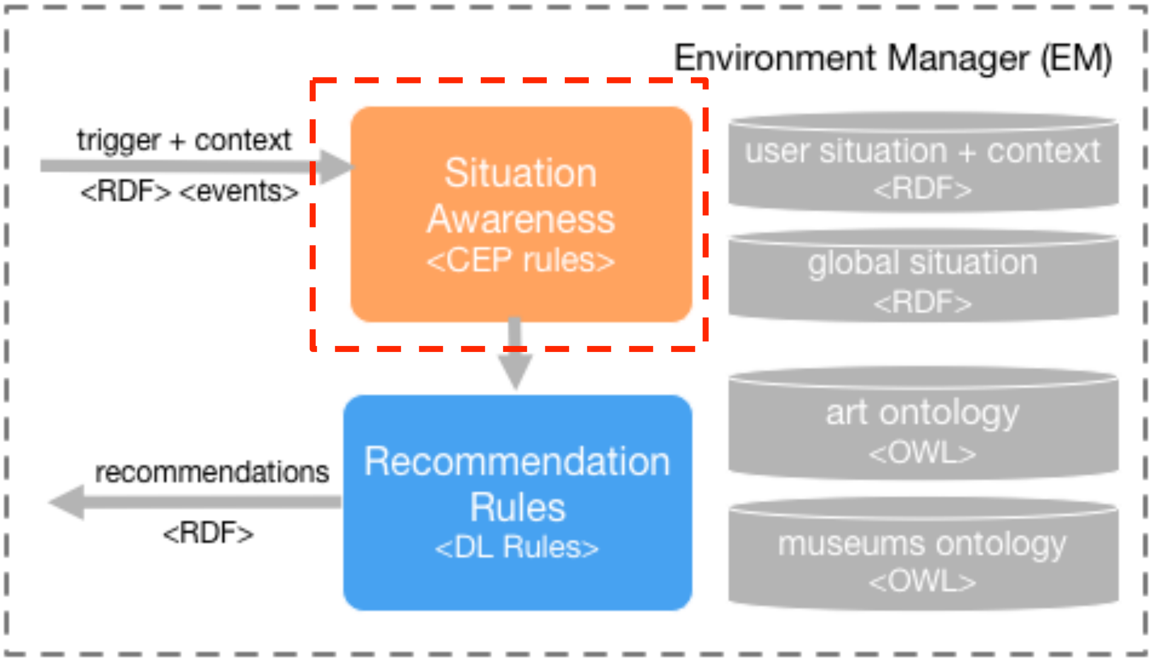
3. Design – User Agent



Recommendation Triggering (DL Rule):

```
IF currentTime>timeOfLastRecommendation+15min
   ∧ changeLocation(?user)
   ∧ notInMuseumShop(?user)
   ∧ noUpcomingAppointment(?user,currentTime+20min)
THEN triggerRecommendation(?user)
```

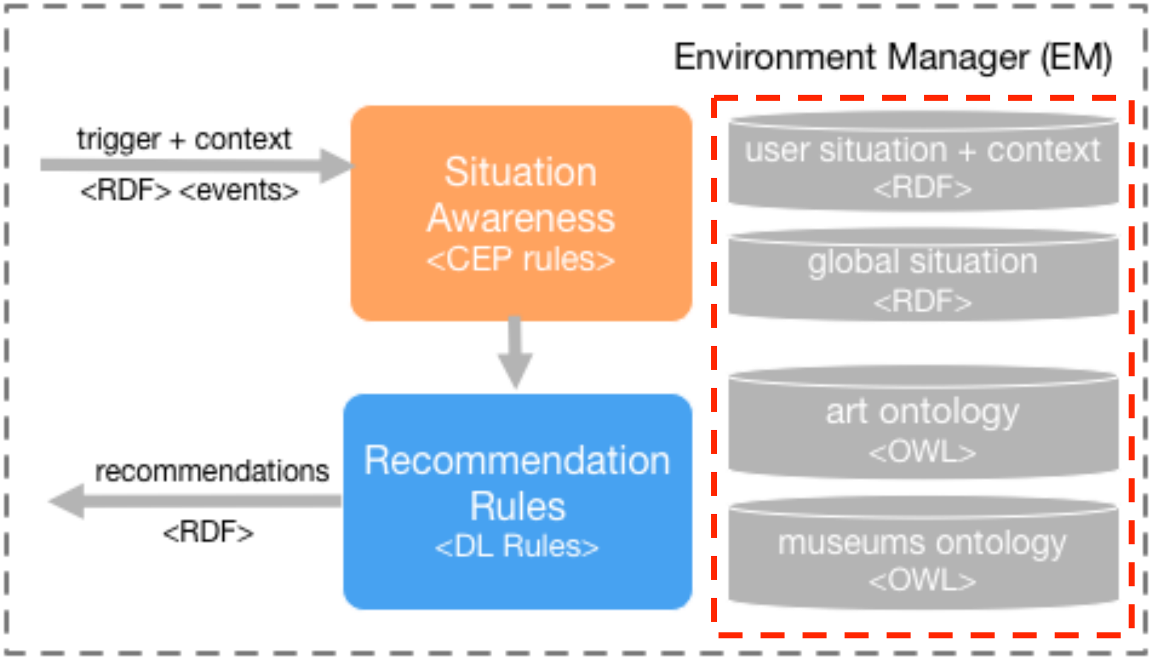
3. Design – Environment Manager



Situation Awareness (CEP rule):

```
CONDITION: (UserPositionEvent AS P )[win:time:5min]
           ∧ group_by(P.room_id)
           ∧ count(P) AS C
   ACTION: create RoomOccupancyEvent(room_id:=P.room_id,
                                     nb_users:=C)
```

3. Design – Environment Manager



Knowledge Base (OWL):

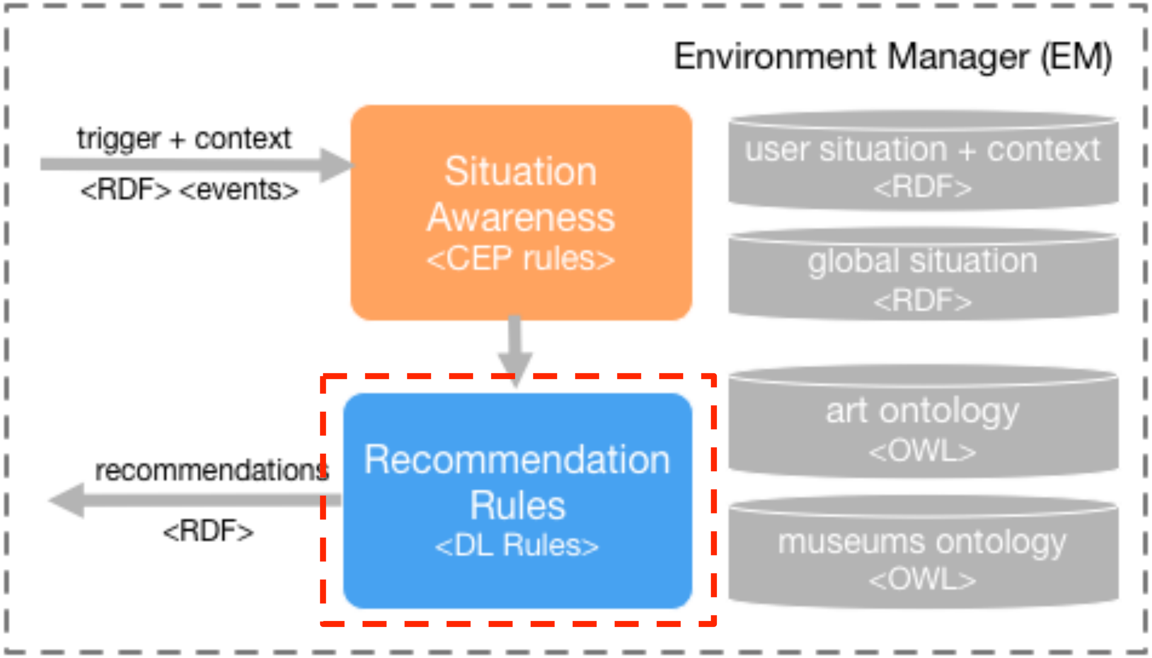
```
:Painter        rdfs:subClassOf :Artist.
:Expressionism rdfs:subClassOf :ModernArt.

:Kandinsky   :a          :Painter;
             :style      :Expressionism;
             :hasPainted :The_Rider.
```

```
:Macke :a          :Painter;
       :style      :Expressionism;
       :hasPainted :Promenade.

:The_Rider :hangingIn :Room_13.
:Promenade :hangingIn :Room_15.
```

3. Design – Environment Manager



Recommendation Rule (DL Rule):

```
IF likesArtist(?user, ?artist1)
   ∧ style(?artist1, ?style)
   ∧ style(?artist2, ?style)
   ∧ hasPainted(?artist2, ?painting)
   ∧ hangingIn(?painting, ?room2)
   ∧ located(?user, ?room1)
   ∧ nearBy(?room1, ?room2)
THEN recommend(?user, ?painting, ?room2)
```

4. Conclusion

- our approach for a CARS integrates
  - **CEP** to achieve situation awareness exploiting sensors
  - **ontologies** to describe structural domain knowledge
  - **semantic rules** for specifying individual recommendations

- key features
  - situation are referred in **real-time**
  - **high flexibility** due to rule-based approach
  - supports **privacy**: private information of the user is not revealed

4. Future Lines of Research

- currently implementing the system for the Landesmuseum Hannover

- learning recommendations from the users behaviour
  - machine learning,
  - collaborative filtering,…

B. Indoor Navigation with iBeacons

1. Indoor Positioning in General
2. iBeacons
3. Positioning Methods
4. Indoor Navigation

1. Indoor Positioning in General

Different Technologies

- **GPS:** doesn´t work in buildings or is imprecise

- **WiFi**: estimating distance to WLAN access points using the signal strength
  - problems: high reach, but large distances difficult to estimate
- **Bluetooth**: Beacon technology
  - shorter reach than WiFi

- **RFID**: passive tags, different frequence bands (UHF, VHF)
  - expensive readers
  - imprecise

1. Indoor Positioning in General

	#Sender	*#Reader*	*Accuracy*
WiFi	few senders per floor	1 reader per person	low
RFID	1 sender per person	1 reader per room	medium
Beacon	many senders per room	1 reader per person	high

2. iBeacons

- Beacons are small devices
  - have batteries: send an ID during 1-2 years
  - up 70 meters
  - based on Bluetooth Low Energy (BLE)
  - are cheap (10-20 €)

- iBeacon standard from Apple (2013)
  - Apple defines a protocol: sending periodically a hierarchical ID

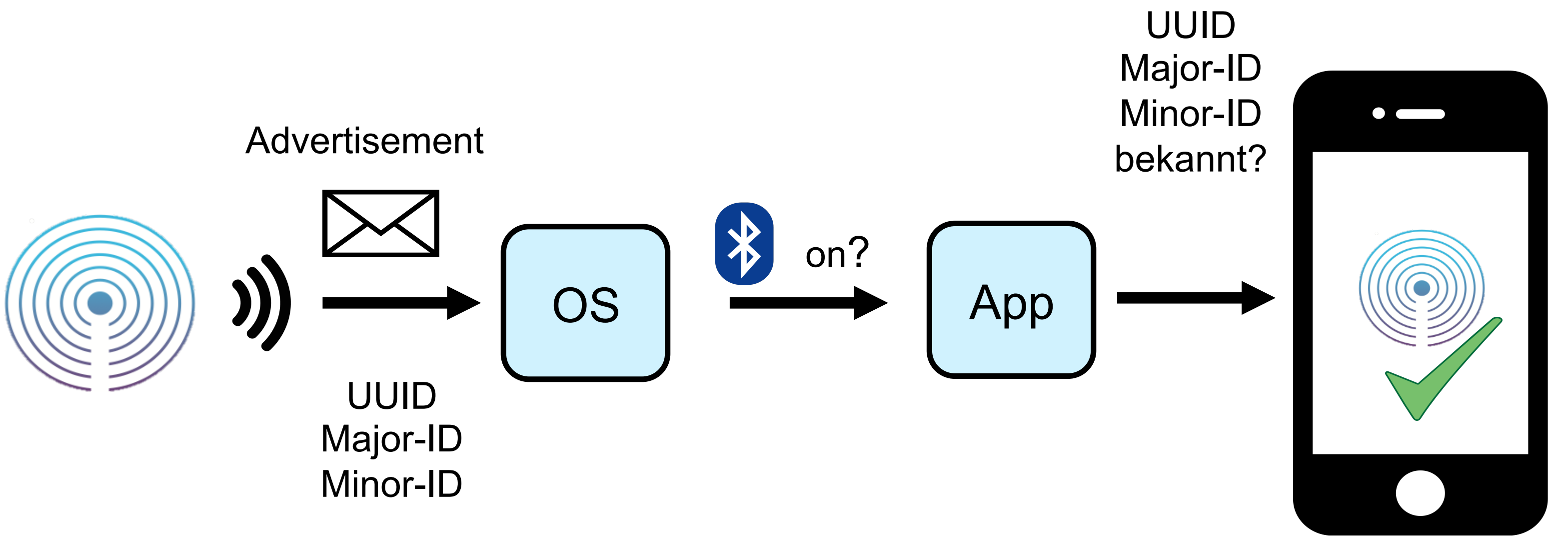
Manufacturer-specific data payload (from Type to Meas. Power)

Flags	Length	Type	Company ID	Beacon-Type	Proximity UUID	Major ID	Minor ID	Meas. Power
0x02-01-1A	0x1A	0xFF	0x00-4C	0x02-15				

iBeacon contents (from Proximity UUID to Meas. Power)

- **Eddystone**: similar standard from Google (2015)

2. iBeacons – Setup (1/2)



- Beacon signal can be read by every (mobile) devices understanding BLE
  - from iOS7 or AndroidOS 4.3
  - no expensive readers necessary

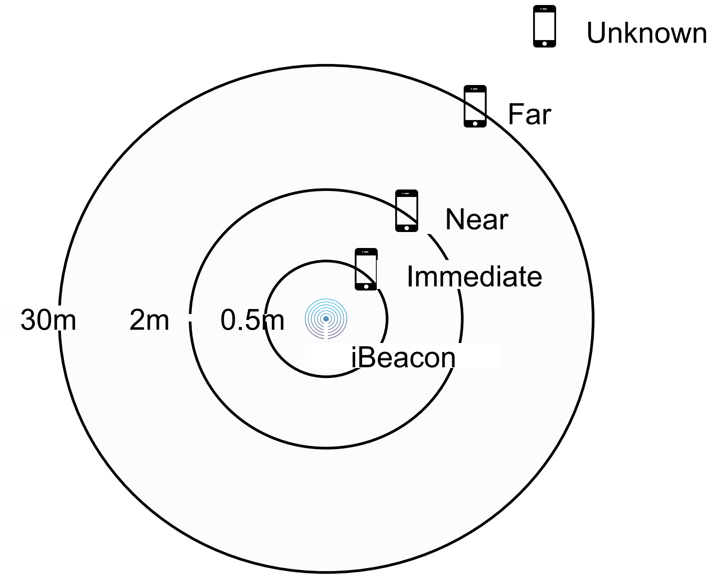
2. iBeacons – Setup (2/2)

Different Scenarios:

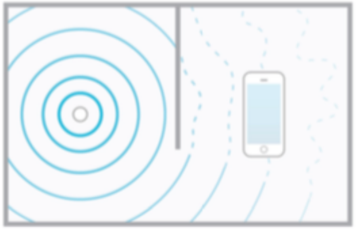
phones move

beacons move

2. iBeacons – Positioning with Beacons

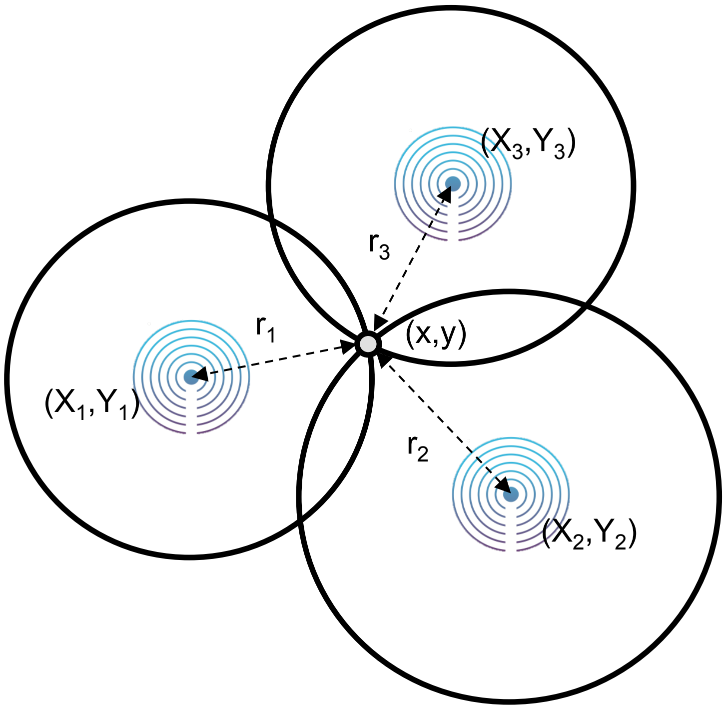


- **Monitoring**
  - scan Beacon IDs
  - system notification when a device enters or leaves the beacon region
- **Ranging**
  - estimates the proximity to an iBeacon
    - a) in iOS expressed by a proximity value: IMMEDIATE, NEAR, FAR, UNKNOW
    - b) RSSI (received signal strength indication) signal
  - problem: objects can reduce the signal strength



3. Positioning Methods – Trilateration

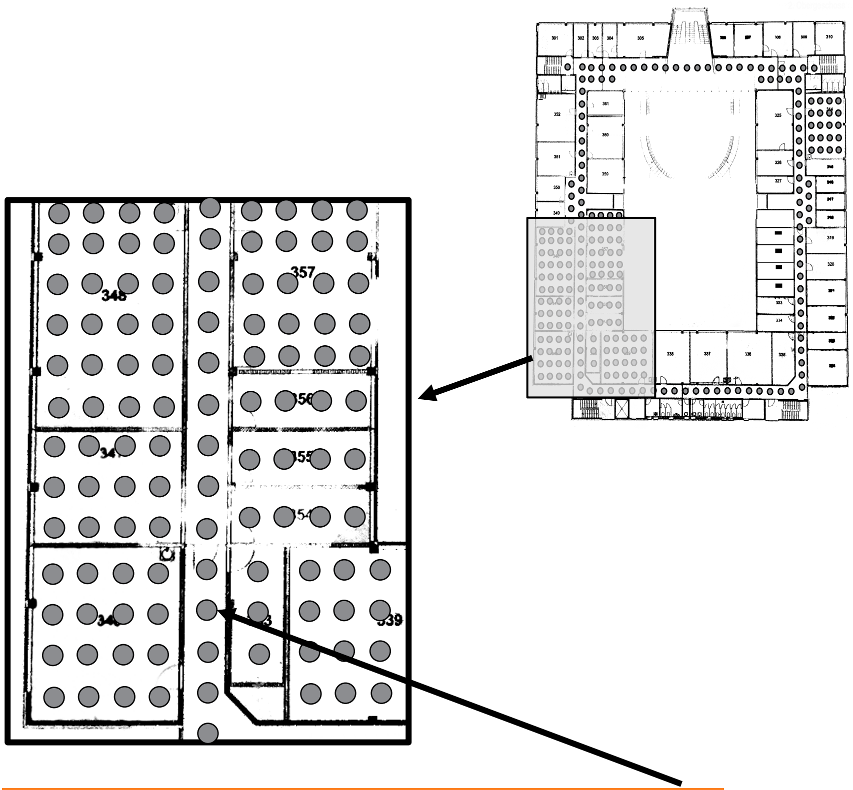
- estimating the position
  - by knowing the distance to 3 different location
  - intersection of three spheres



- advantage
  - easy to deploy
  - fast
- disadvantage
  - lack of precision

3. Positioning Methods – Fingerprinting

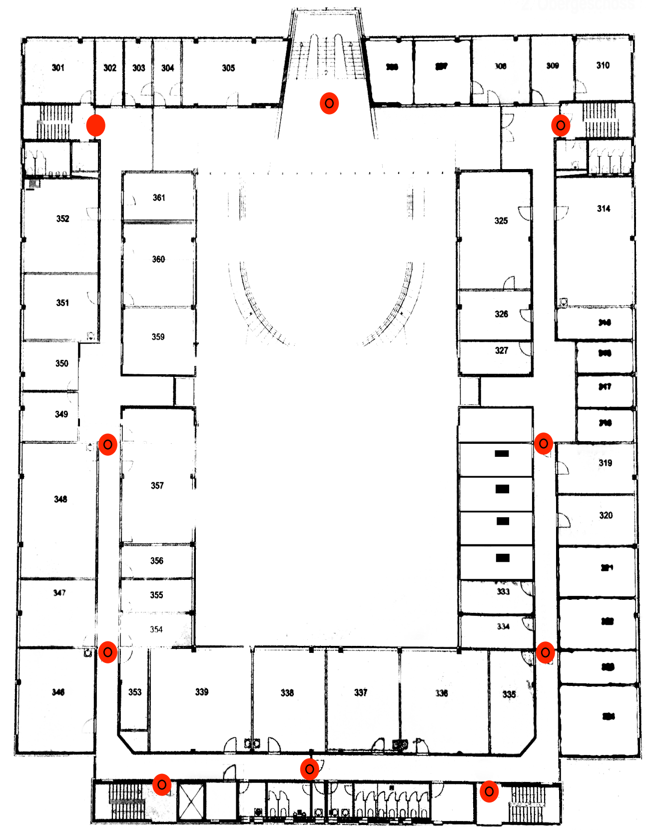
- constructing a map with the measured RSSI
  - offline phase
  - and online phase
- advantage
  - high precision
- disadvantage
  - high effort



UUID	Major	Minor	dBm
FF..	10033	35	-76
FF..	10033	36	-88
FF..	10033	37	-92
...	...	...	...

3. Positioning Methods – Proximity

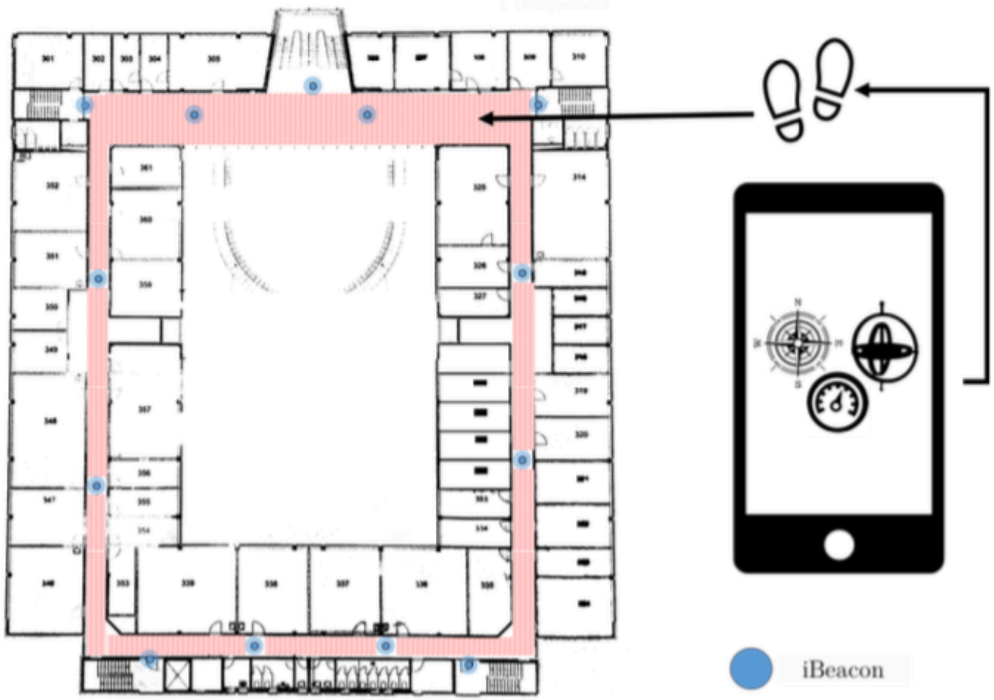
- reading the proximity
  - position of the iBeacon is the user position
  - using proximity NEAR means user is within a range of 2 meters



- advantage
  - easy to deploy

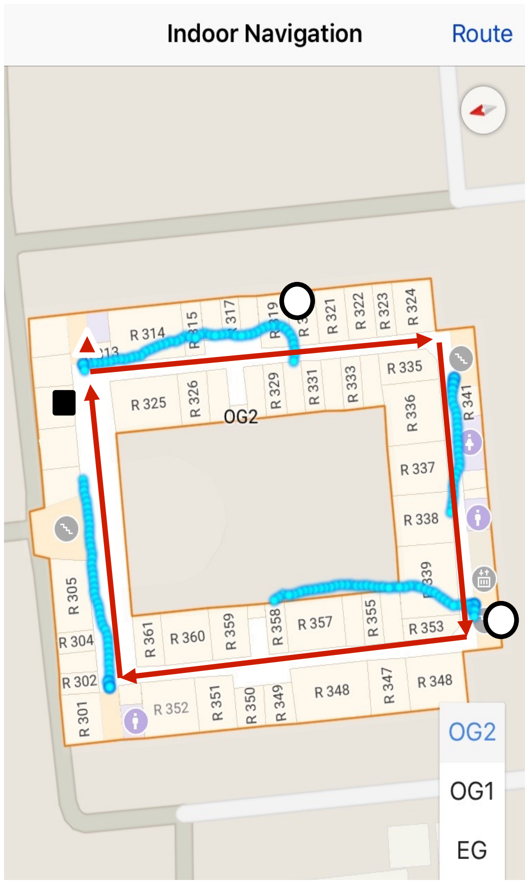
- disadvantage
  - many beacons necessary

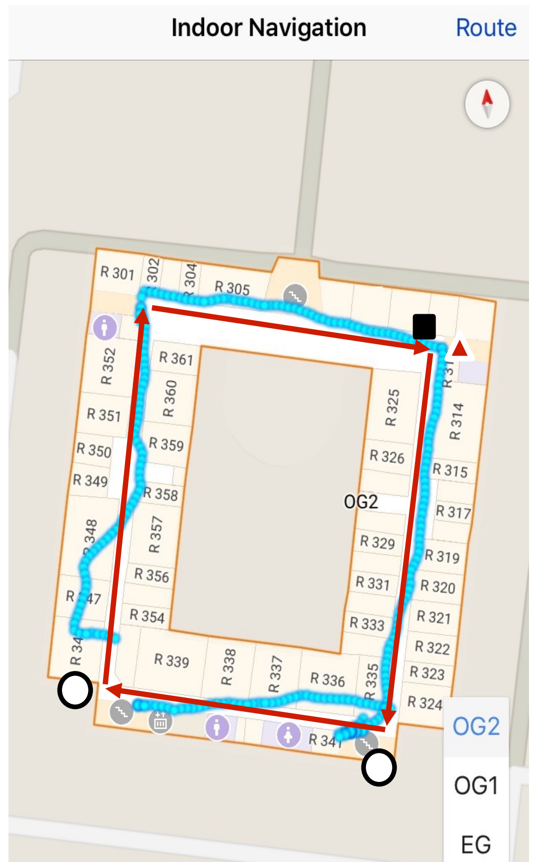
4. Indoor Navigation



- approach in the master thesis
  - combining proximity and smartphone sensors
  - interpolation approach: detecting steps and the direction (using smartphone compass)

Experiment Results





- Start
- Destination
- Real track
- Estimated Track

4. Indoor Navigation – Experiences

- Setup:
  - beacons located in 2 meter height
  - proximity NEAR (=2 meter)

- Problems
  - difficult to estimate the direction of footsteps with the compass

- Solution approach
  - taking more sophisticated domain knowledge into account
  - floor layout!: what are the areas a user can walk, what are steps she cannot do, …..

Thank you!