Maintenance and Emergency Management with an Integrated indoor/outdoor Navigation Support

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Context

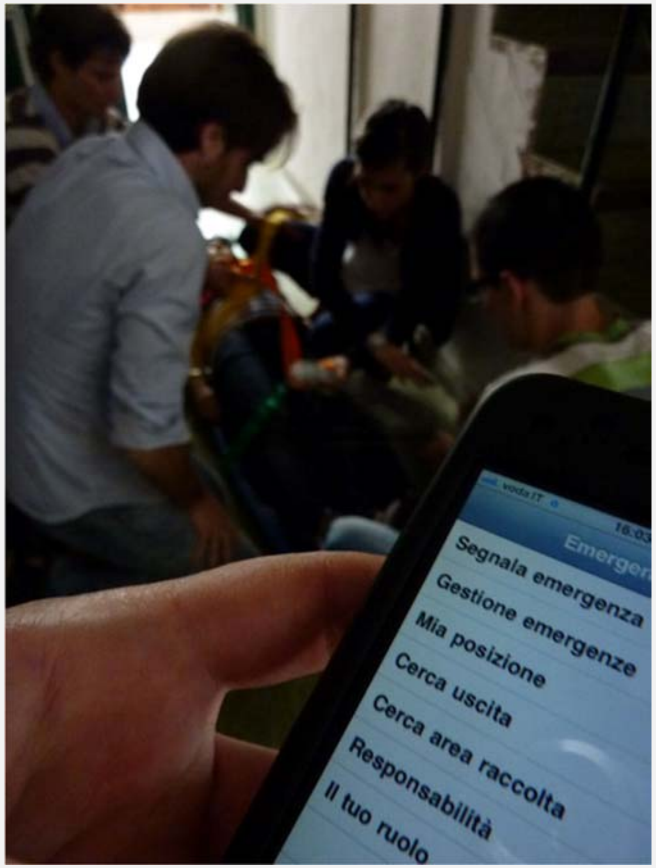
- Complex and large **systems of buildings** with activities of maintenance and emergency
  - implies movements of people in a non fully known environment.
  - Hospitals, industrial plan, airports, etc.
- **Personnel does not know** the position of every room and service device or tool (POI, Point of Interest) that can be needed to perform activities of rescue or maintenance
- **Conditions and positions can change**, and teams and people may be not aware about those changes in real time

State of the art

- Digital documentation → Aug. Reality, ..
- **Present solutions** for navigation
  - Tables and books for navigation
  - RFID, QR codes for making points and devices
  - Paper and wall maps for indoor navigation
  - Navigators for outdoor navigation
  - Pedometer for indoor inertial navigator
- **Lack of:**
  - integrated indoor/outdoor navigation
  - Precision in the indoor inertial navigation

Overview and aim of Mob Emerg.

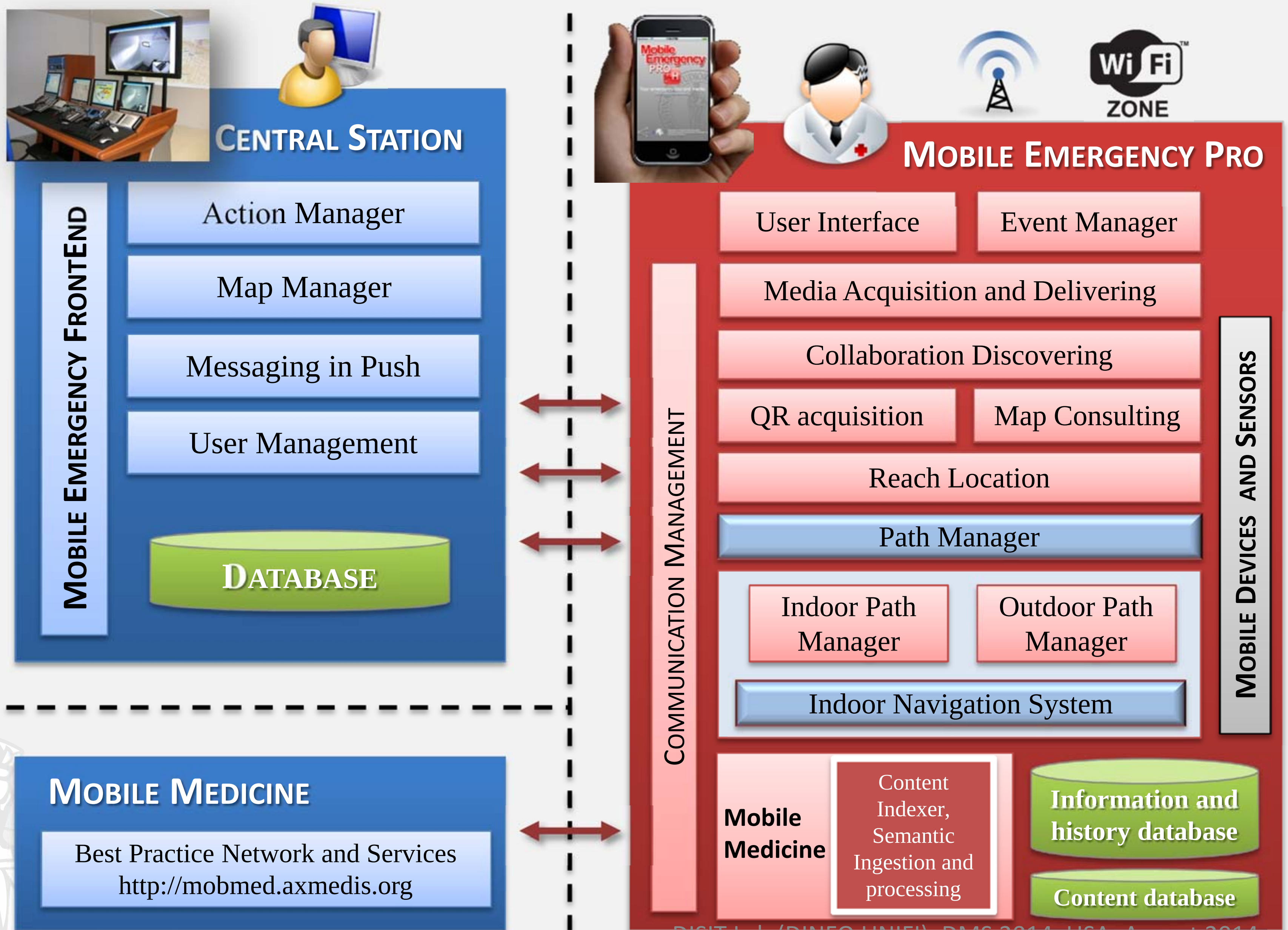
- **Managing team and singles**
  - Communication, collaborative work, access to on line documentation, recovering people, Creating Teams, etc.
- **Moving teams and singles**
  - pushing them towards meeting points, POI, emergency points, recalling them, etc.
  - help them to get the exists !!
- **Aim:**
  - *Reduction of Costs!!*
  - *Reduction of the intervention time!!*
  - *Access to updated information in real time!! (maps, manuals, guidelines, …)*



How they use

- **Improving the coordination among personnel (medical and/or for maintenance)**
  - Sending instruction to form teams and join other colleagues
  - Signaling about critical conditions and intervention
  - Continuous connection and communication with the central station for monitoring and emergency
- **Delivering fresh and updated information**
  - Documentation, exits,
  - positions of POI and colleagues

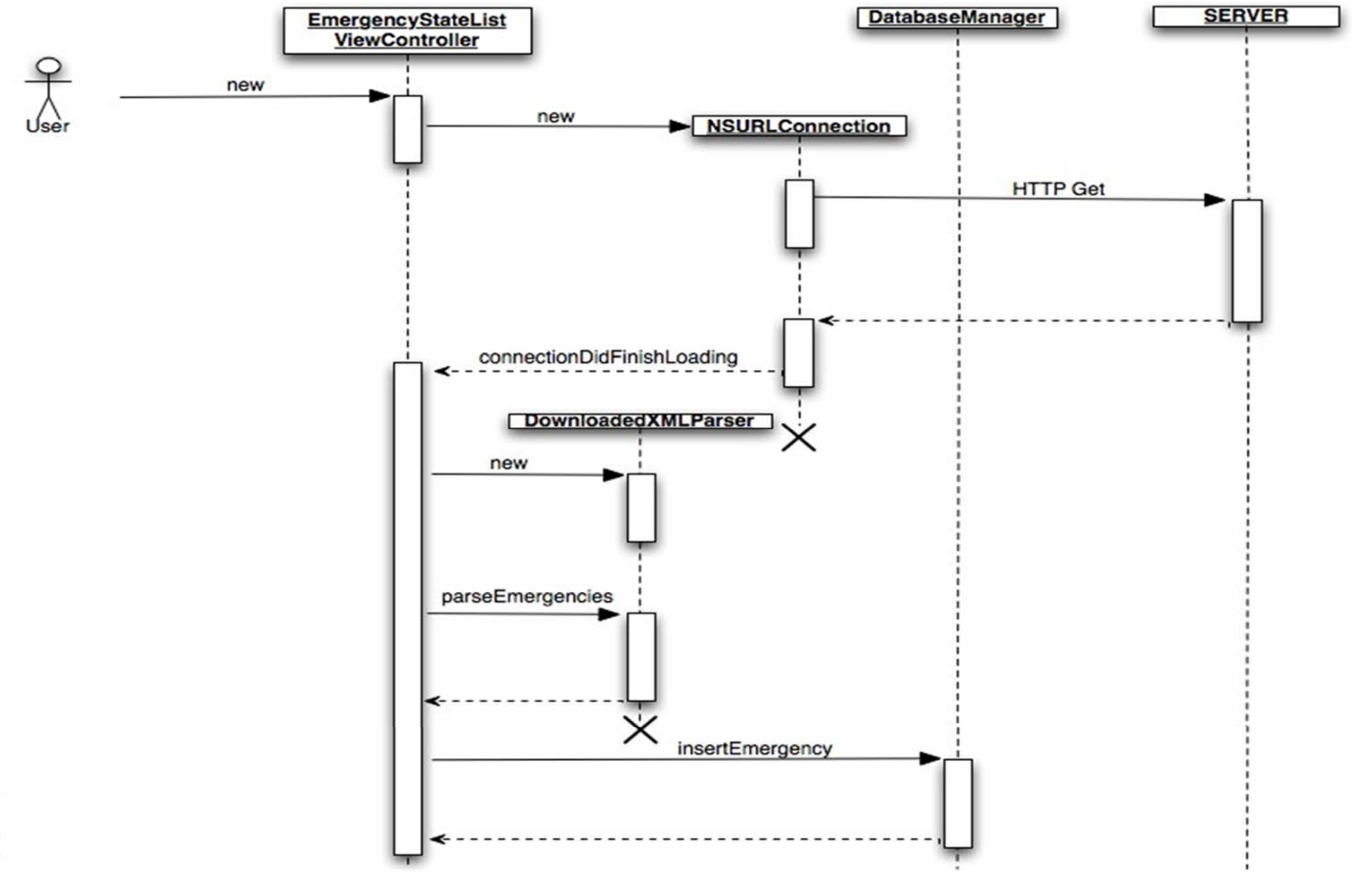
General Architecture



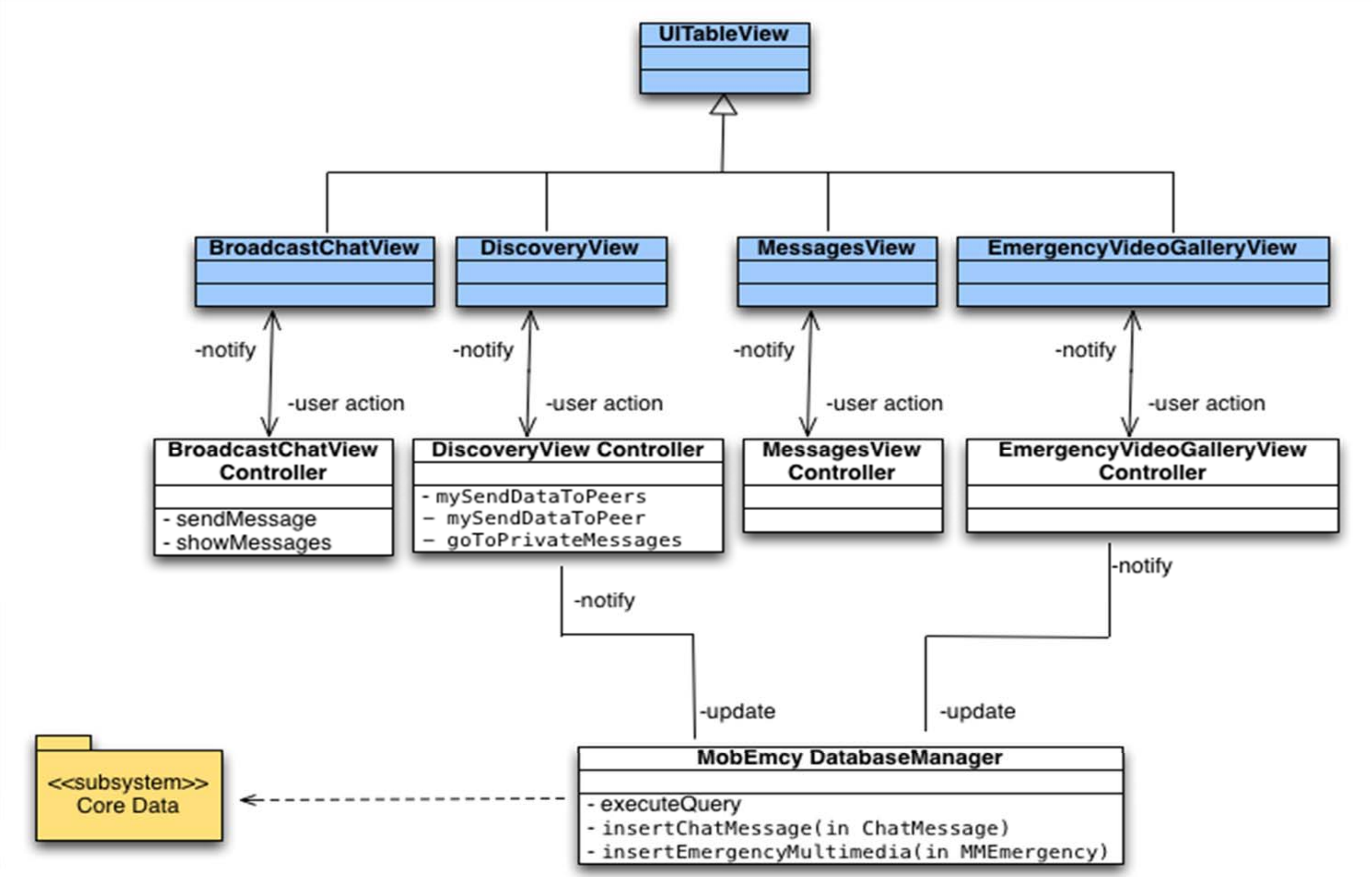
Central Station

- **receives alarms/requests** for intervention with a suitable protocol
- **supports people** involved in the event:
  - Providing: event status, viable exits, position of personnel, POIs,
  - Moving people and patients, moving materials, establishing teams
- **Sends messages** in push via APN, or polling to recall personnel, interrupts, etc.

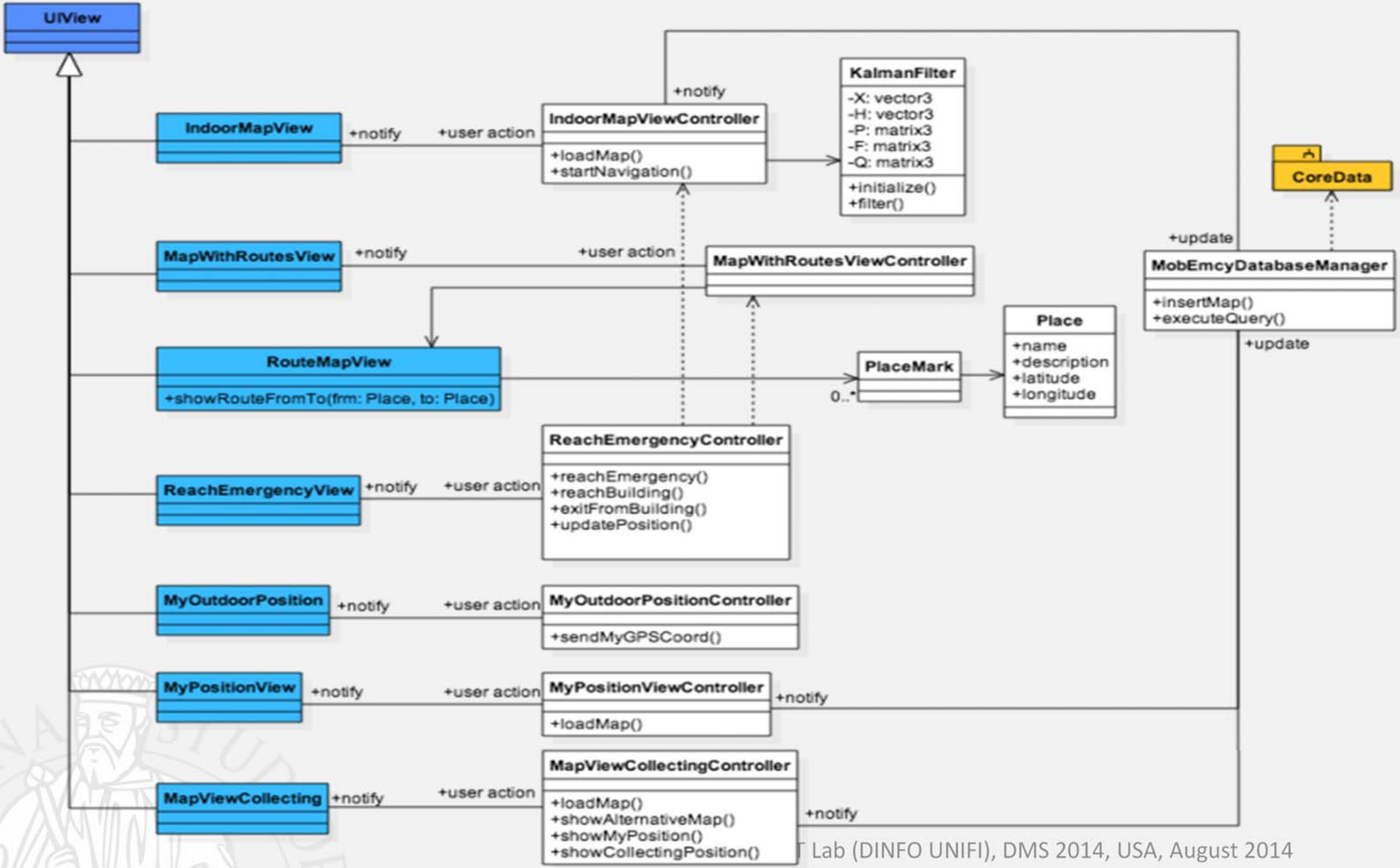
Recovering emergency status



collaboration discovering aspects

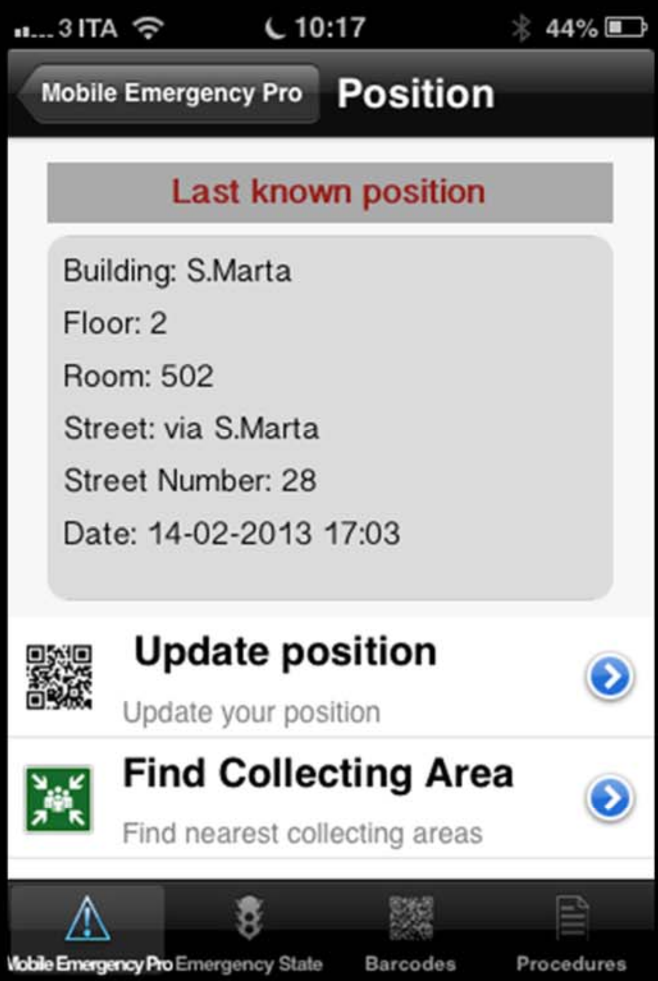


integrated navigation aspects



Mobile Emergency

Mobile Emergency



13.1 13.2 13.3

14.1 14.2 14.3

Indoor / Outdoor Navigation

- **Outdoor navigation** based on GPS: Google Map, Open Street view, etc.
- **Indoor navigation** based on Markers and Fields:
  – RFID, QR, Laser, Wi-Fi, images,..
- **Detection of Indoor/outdoor passages:**
  – changes in signal power of GPS
  – presence of markers: QR, NFC (on android)
  – **Hyp**: Access to specific knowledge and maps integrating outdoor and indoor connected points (doors, windows, etc.)

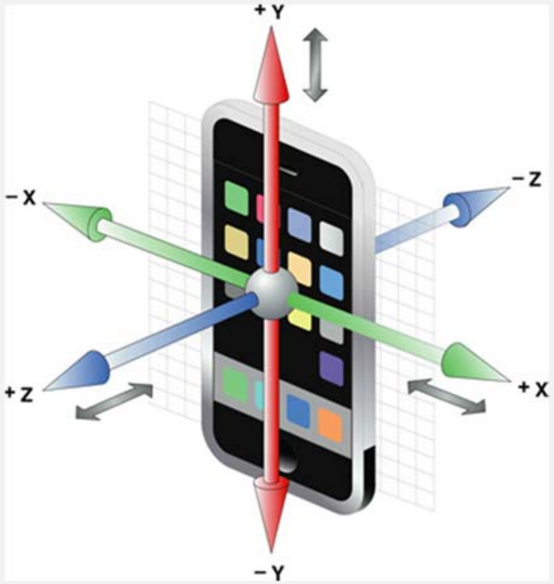
Get position

QR code aspect	Description and meaning of the QR code for location, an example	Map provided to standard QR readers
	"00039": position identifier of QR "n": control code based on SHA-1 algorithm. String BarCode: http://mobmed.axmedis.org/me/ID00039n	

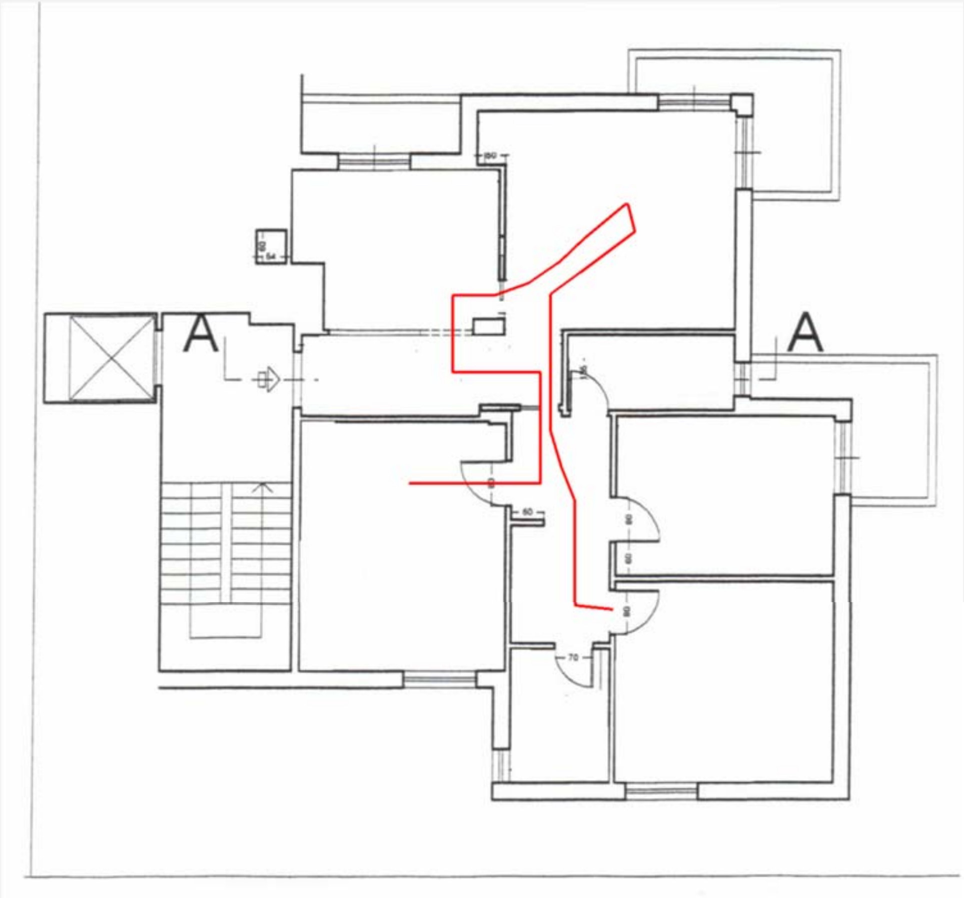
Indoor navigation

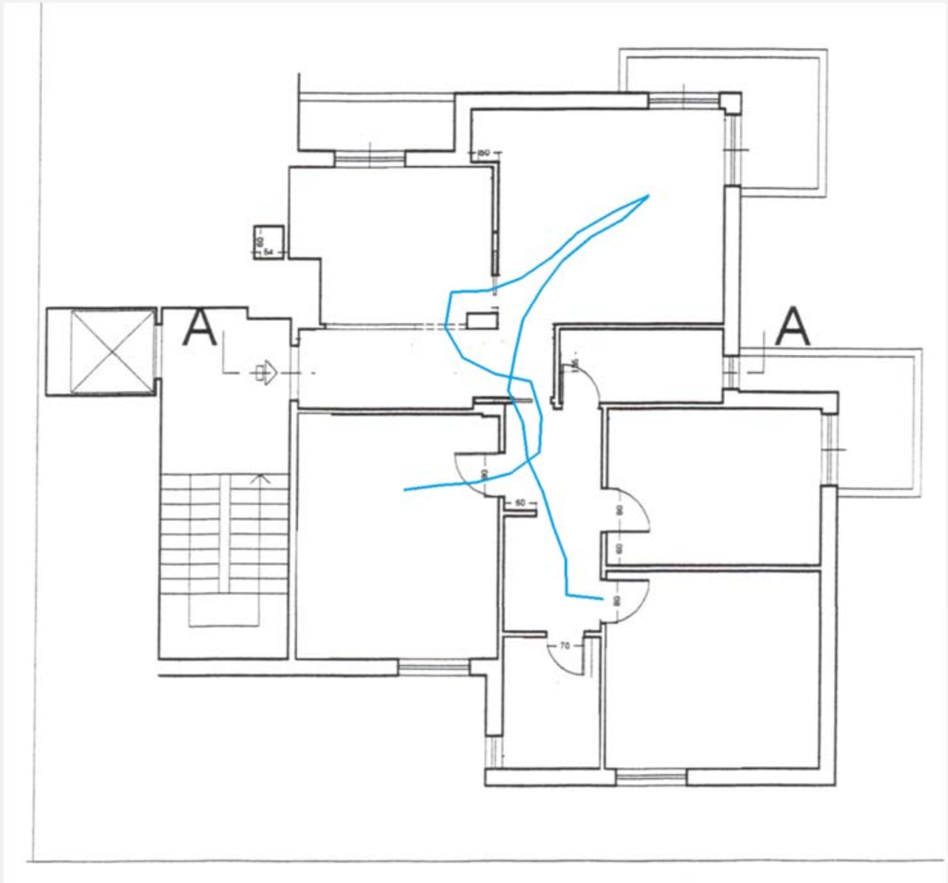
- Once marked a point in an indoor Map, a precise inertial navigation support is needed to reach the successive point,
  for example by using internal sensors of the mobile device:
  - gyroscopes, magnetic compass, accelerometers
  - as an ***Inertial Navigation System***

- ***→STOA lead to cumulative error in space and time:***
  - step counters, dead reckoning
  - traditional Kalman filter



Inertial Navigation





Kalman Filtering, in "*short*"

$$x_k = Ax_{k-1} + w_{k-1}$$ A = state transition model

$$z_k = Hx_k + v_k$$ H= observation model: true state space into observed space

- Wk, Vk model the noise of process and measure, respectively
- $p(w_k) \sim N(0, Q_k)$, $p(v_k) \sim N(0, R_k)$, white and normal distrib of noise
- Q and R are covariance of noise on state and measure, respectively

Predict, estimate next:

- state: $\hat{x}_{k|k-1} = A\hat{x}_{k-1|k-1}$
- covariance: $P_{k|k-1} = AP_{k-1|k-1}A^T + Q_k$ error covariance matrix

Update (a posteriori):

- gain: $K_k = P_{k|k-1}H^T(HP_{k|k-1}H^T + R_k)^{-1}$
- state: $\hat{x}_{k|k} = \hat{x}_{k|k-1} + K_k(z_k - H\hat{x}_{k|k-1})$
- covariance: $P_{k|k} = (I - K_kH)\, P_{k|k-1}$

$Q_k \rightarrow 0$ (full trust)
$Q_k \rightarrow \infty$ (no trust)
Q can be heuristically estimated or dynamically

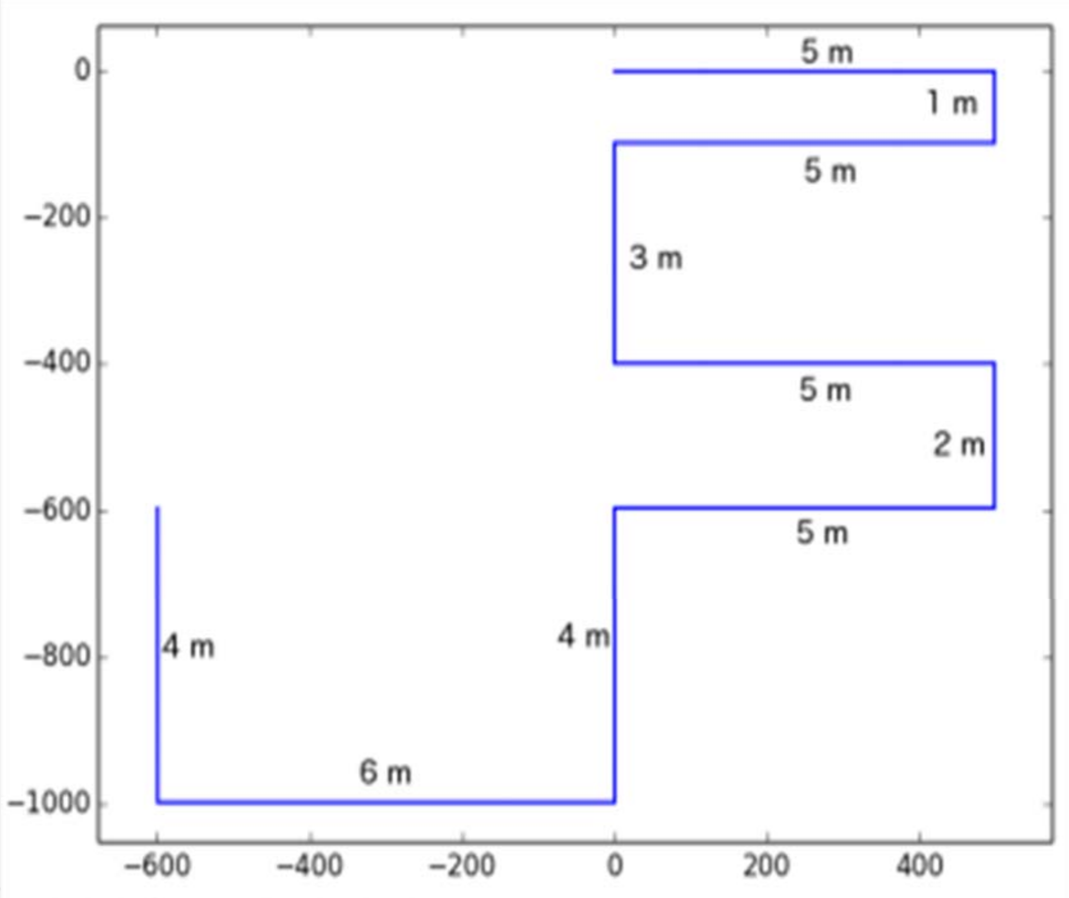
notes

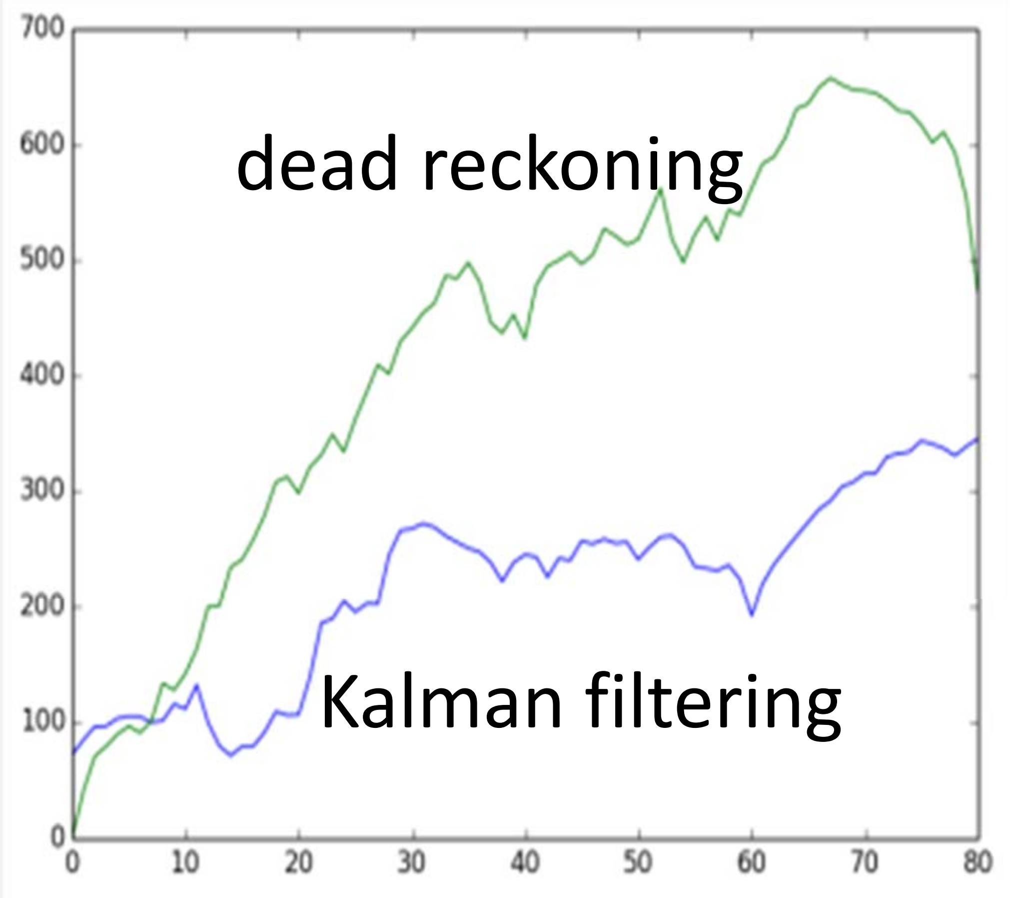
- Once derotated
- two Kalman filters have been applied for the accelerations along the x and y axes
- State vector are the positions, velocity and accelerations
- Hyp. acceleration is constant A →

$$A = \begin{pmatrix} 0 & \Delta T & \frac{1}{2}\Delta T^2 \\ 0 & 1 & \Delta T \\ 0 & 0 & 1 \end{pmatrix}$$

- H = (0,0,1) observation model
- R = 0.00064 measured observing sys. of meas.
- Q initially supposed to be constant diagonal matrix
- $Q_0 = 15$ heuristically estimated → adaptive

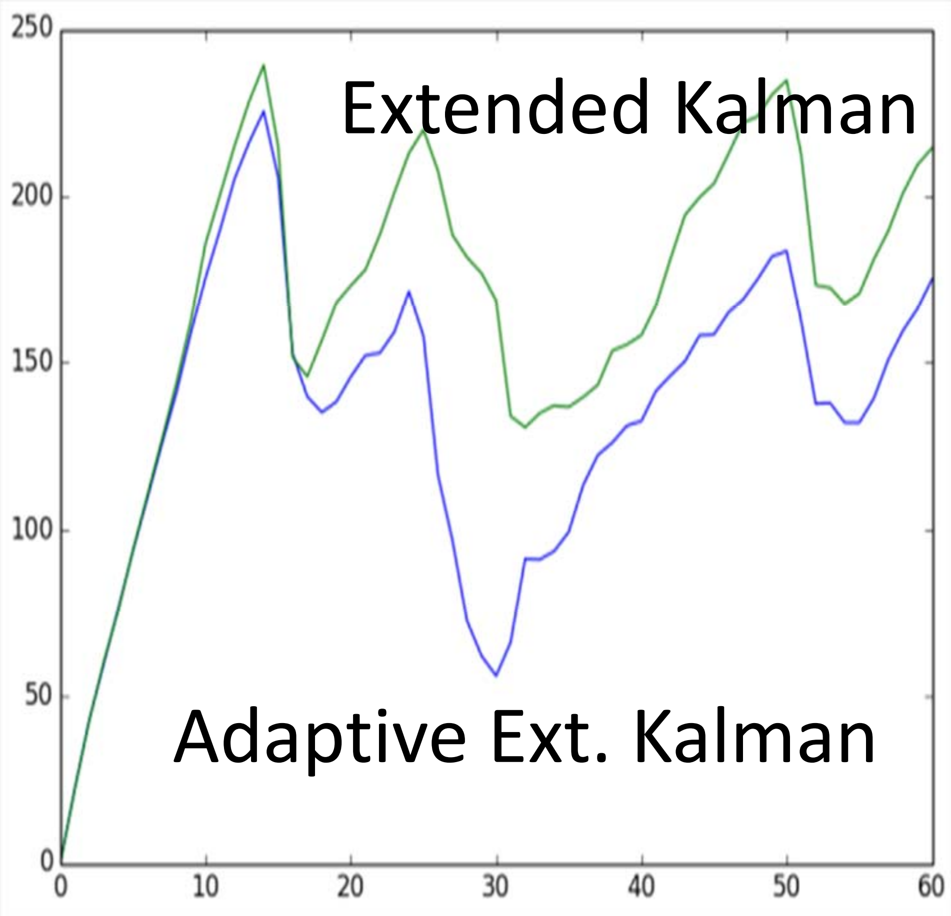
Dear Reckoning vs Kalman filtering





Extended Kalman Filtering

- First Kalman was with costant Q
- Extended Kalman addresses the non linearity
- Adaptive Ext. Kalman adapted Q using
  - *Q* at the previous time instant and a corrective scale factor (estimated on the basis of the ratio from the innovation covariance and the predicted value)
  - Q reported at Qo when singularity are detected.



Conclusions

- A solution for **integrated indoor/outdoor inertial navigation** has been proposed, addressing
  - map and knowledge modeling
  - adaptive Extended Kalman filtering
- **Compared with state of the art** solutions, the proposed solution obtained
  - errors < 20 cm at the end of the path, 40mt.
  - saving 18% in time to reach the target point for team that do not know the area

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Thank you!

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