A filtering algorithm based on peer-to-peer ad-hoc networks for GNSS-challenged environments

ICG WG-B Application SG Meeting
Location Based Services and Mass Market Applicatíons
Session 2

Pedestrian Indoor Navigation

- Convergence of personal navigation device and mobile phone
- Use of the smart phone for outdoor location-based services:

Find my friends feature of iOS developed by Apple, sharing of current location with other users

Google latitude

Allowing other user to view their current location on Google Maps

- Use of such services also indoors

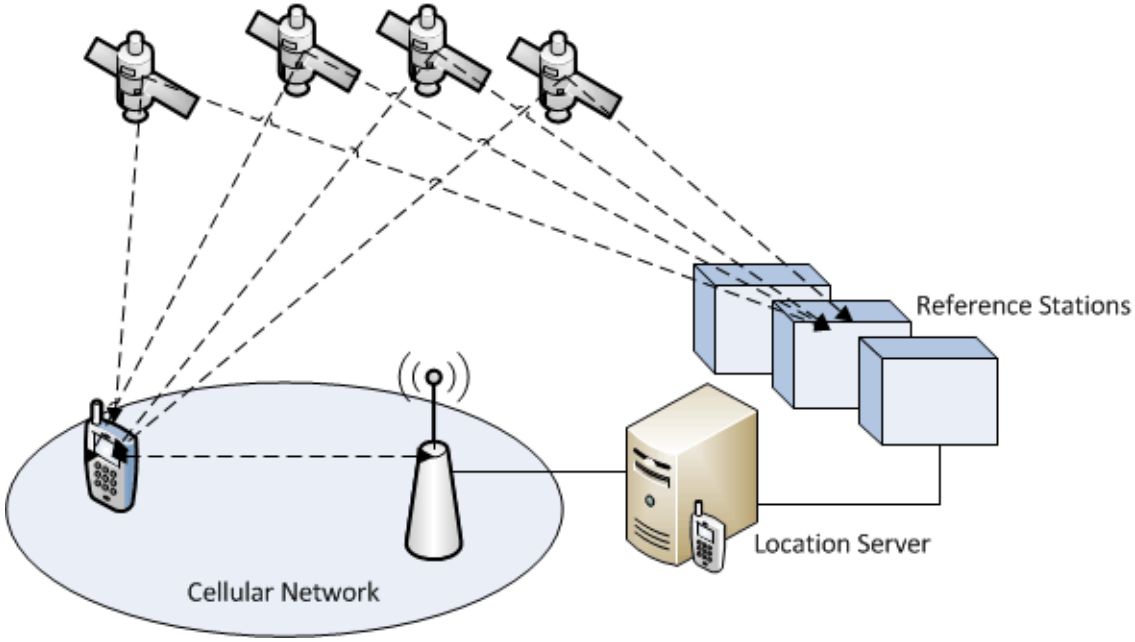
Pedestrian Indoor Navigation with GPS

- Attenuation of GPS signals by different materials:

Material	Attenuation in L1	
	[dB]	Factor
Drywall	1	0.8
Plywood	1 – 3	0.8 – 0.5
Glass	1 – 4	0.8 – 0.4
Toned glass	10	0.1
Timber	2 – 9	0.6 – 0.1
Iron	2 – 11	0.6 – 0.08
Brick	5 – 31	0.3 – 0.001
Concrete	12 -43	0.06- 0.00005
Armored concrete	29 – 33	0.001 – 0.0005

- GPS signals 20 to 30 dB weaker indoor than outdoor
- Navigation not possible

Pedestrian Indoor Navigation with A-GPS



- Obtaining satellite data via cellular network
- Indoor positioning partly possible but almost no navigation

We are navigation!

Pedestrian Indoor Navigation with Inertial Sensors

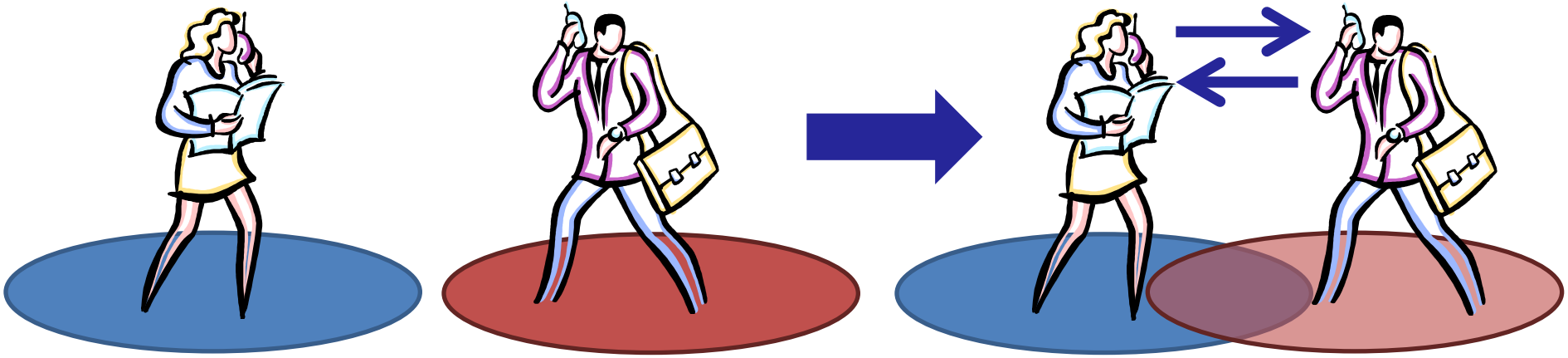
- Integrated MEMS (microelectro mechanical system) today in every smartphone
- Mostly accelerometer to extend user interaction with device; additonally magnetometer and gyroscopes

- Draws: Poor measurements and integrating error

We are navigation!

P2P Filtering Approach

- Combination of inertial navigation using integrated MEMS and peer-to-peer filtering algorithm



- Obtaining a better position solution for both peers

We are navigation!

Position estimation in deep-indoors

- Based on the last known GPS-position performing dead reckoning:

$$x_n = x_{n-1} + l \cdot \sin\theta$$
$$y_n = y_{n-1} + l \cdot \cos\theta$$

- Step detection and step length estimation based on accelerometer measurements
- Heading estimation based either on magnetometers or change of gyroscope based on the last known heading

Exchange of Position Data

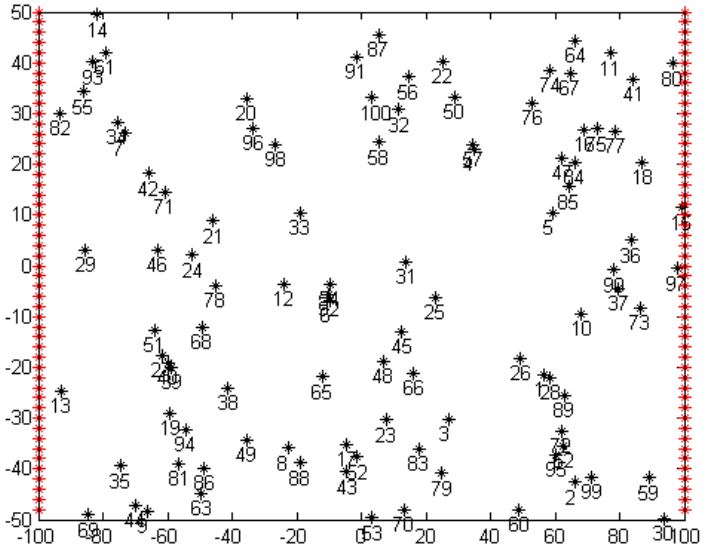
- Via wireless ad-hoc networks:
  - Bluetooth
  - WLAN / WiFi direct
  - ZigBee
- Mutual filtering of own position with received position of another peer
- Filtering realized by extended Kalman filter algorithm using incoming position as additional noisy measurement

Demands on the P2P Kalman Filter

- Autonomous navigation using either GPS / A-GPS, a combination of inertial sensor and GPS or only inertial sensors
- Enabling navigation also in deep indoor
- No surveying of building in advance and no addtional infrastructure needed
- Favoring local charge-free ad-hoc networks against regional costly server connections

Simulation Configuration for P2P filtering

- Simulation of an rectangular indoor area with reference position and varying amount of peers:

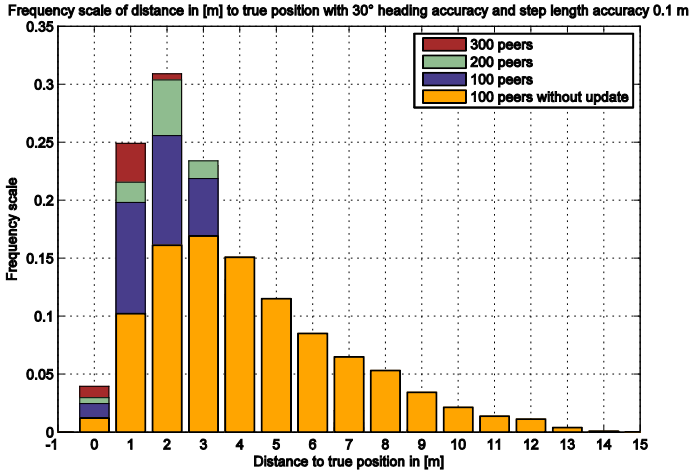


- Variation of several variables:
  - Measurement accuracy of sensors
  - Number of peers
  - Maximum distance to other peer

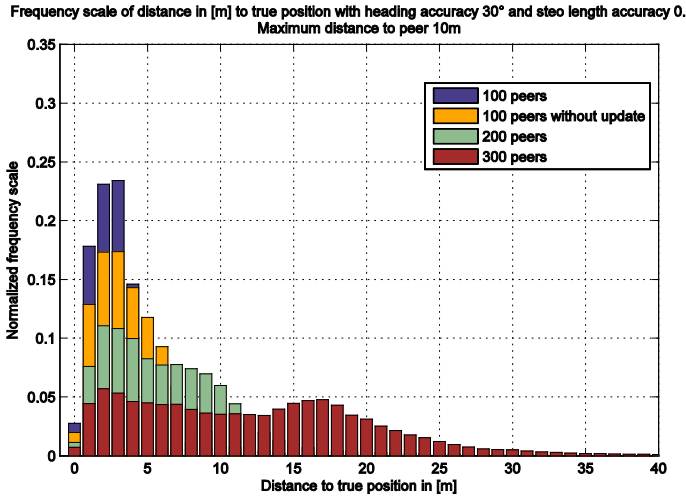
We are navigation!

Results of of P2P filtering approach

- Maximum distance to other peer 5m: Increasing position accuracy related to the number of peers
- Maximum distance to other peer 10m: Decreasing position accuracy



Maximum distance to other peer 5m



Maximum distance to other peer 10m

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Peer-to-Peer network standards

Bluetooth	WiFi direct	ZigBee
IEEE 802.15.1	IEEE 802.11	IEEE 802.15.4
Founded 1998 as Special Interest Group by five companies	Founded 1999 as consortium of more than 300 companies	Founded 2002 as an open non-profit association
Working in the 2.4 GHz ISM frequency band	Working in the 2.4 GHz ISM and the 5 GHz frequency band	Working in the 2.4 GHz ISM frequency band
Establishment of Piconets (~5m) or scatternets	Establishement of IBSS with a size of 100 m	Establishment of star-topology or peer-to-peer topology networks (~8m)

Demands on the network protocol

	Bluetooth	WiFi direct	ZigBee
Large Acceptance	+	+	−
Small transmission area (~5m)	+	−	+
Fast network establishment	+	+	+
No user interaction required	−	?	?
Estimating distance to other peer	−	?	?

We are navigation!

Summary

- Increasing position accuracy by enabling peer-to-peer filtering
- Only possible when distance to other peers kept below a certain threshold
- Two main demands on peer-to-peer networking:
  - Easy way to estimate the distance between two peers
  - Avoiding user interaction and enabling security protocol to hide position information of other users
- Future work: Implementation of a prototype and improving of dead reckoning algorithm