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The Fourth Layer in Collaborative Navigation – Going Underground

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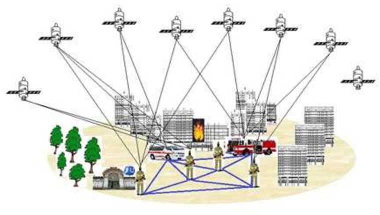
Principle of Collaborative Navigation

Ubiquitous positioning requirement in applications where a group of users has to be navigated led to the development of collaborative navigation

Integrated positioning solution employing multiple location sensors with different accuracy on different platforms for sharing of their absolute and relative localizations



after Grejner-Brzezinska and C. Toth, OSU, USA

Main goals:
- Robust multi-sensory navigation
- Seamless transition between different environments using different sensors, different platforms and different navigation approaches
- Optimal estimation of platform positions using sensor fusion of all currently available measurements

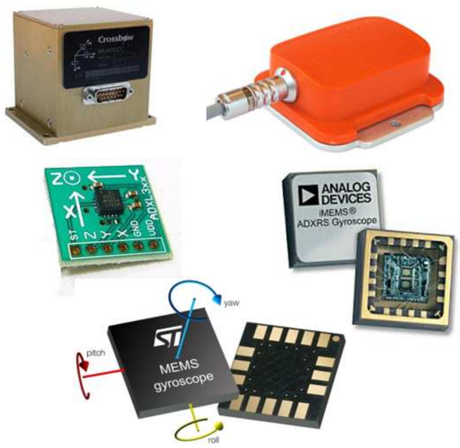
Application Fields and Sensors

Need for collaborative navigation and guidance in GNSS-challenged environments for:

- Dismounted soldiers,
- Emergency crews,
- Swarms of UAV's,
- Team of robots,
- ...

Sensor augmentation of GNSS:

- IMU's,
- Accelerometer,
- Magnetometer,
- Odometer,
- Compass,
- Gyroscope,
- Barometer,
- Optical systems,
- ...



Low-cost MEMS-based sensors (Micro Electro Mechanical Systems)

Sensors and Positioning Techniques

	SENSOR / TECHNIQUE	NAVIGATION INFORMATION	TYPICAL ACCURACY
RADIO FREQUENCY	GPS Position coordinates Velocity	X, Y, Z v_x, v_y v_z	~ 10 m (DGPS: 1 – 3 m) ~ 0.05 m/s ~ 0.2 m/s
	Pseudolites (e.g. Locata)	X, Y, Z v_x, v_y, v_z	comparable to GPS
	UWB	X, Y, Z	dm-level
	Wi-Fi Fingerprinting	X, Y	3 – 5 m
	RFID cell-based RFID Fingerprinting	X, Y X, Y	depending on cell size 1 – 3 m
INS	Accelerometer	a_{tan}, a_{rad}, a_z	< 0.03 m/s²
	Gyroscope	heading φ	0.5° – 3°
OPTICAL SYSTEMS	Image-based	X, Y, Z	few meters
	Optical sensor network	X, Y (Z optional)	few meters
	Laser	X, Y, Z	cm to dm
OTHERS	Digital compass / magnetometer	heading φ	0.5° – 3°
	Barometric pressure sensor	Z	1 – 3 m
	Temperature sensor	T	0.2° – 0.5° C

Extended excerpt from Retscher and Thienelt (2004) and Grejner-Brzezinska and Toth (2013)

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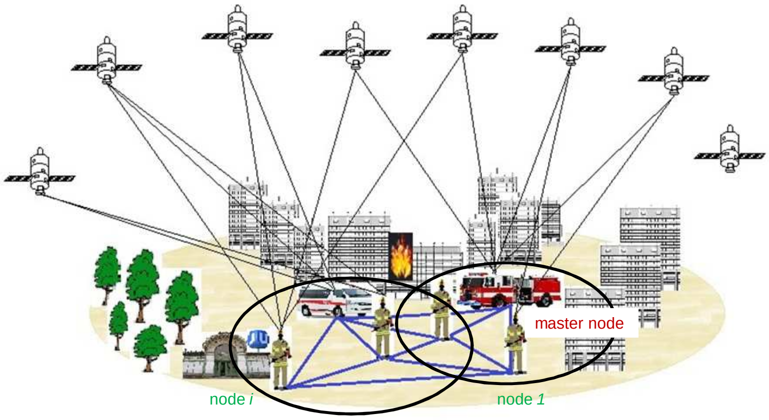
Emergency Scenario Concept



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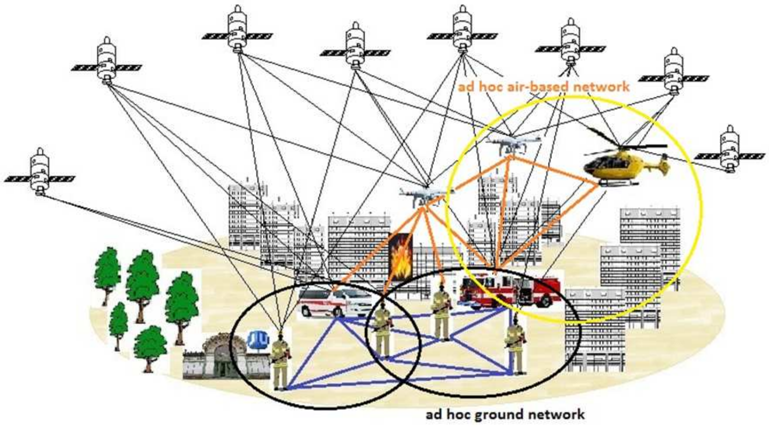
Inter-nodal Range Measurements

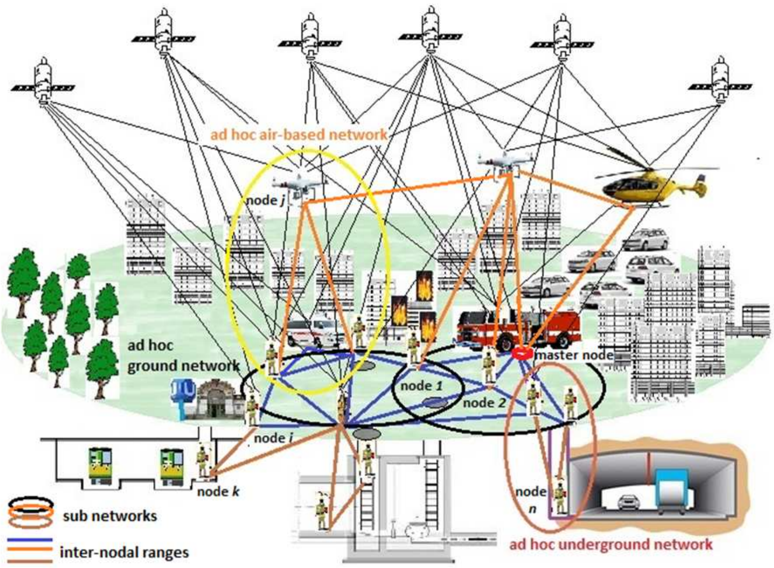
TYPE	OBSERVATION	CHARACTERISTICS
RADIO FREQUENCY SIGNALS IN WIRELESS SENSOR NETWORKS	Received signal strength RSS	Channel attenuation which increases with distance Computed from known position of transmitters and the received power Cell-based positioning (Cell-of-Origin CoO), lateration or location fingerprinting
	Time of Arrival ToA	Distance is computed by signal's travel time as long as the network is synchronized
	Time Difference of Arrival TDoA	Time difference of ToA Hyperbolic positioning method
	Angle of Arrival AoA	Angle between the propagation direction of an incident wave and some reference direction
RANGING BASED ON OPTICAL SENSORY DATA	Laser ranging	High accuracy but high power requirement
	Computer vision-based estimation	Detection of land marker or distinct feature in the image facilitates the distance measurement

Modified excerpt from Grejner-Brzezinska et al., 2010

Inclusion of UAVs in a 3rd Layer



Underground as 4th Layer



RFID Positioning Scenarios

Strategy 1:

RFID readers are installed at specific locations or waypoints of interest

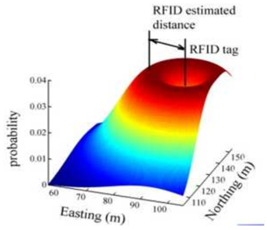
User is equipped with an RFID tag and can be located in a certain section between two waypoints

Strategy 2:

Tags are mounted at certain known locations of interest (i.e. active landmarks)

The mobile user is equipped with a reader

The tag's ID and 3-D coordinates can be retrieved in the given read range if the user passes by



Positioning in Underground Networks: 2^{nd} strategy

Cell-of-Origin CoO

Concluding Remarks

Advantages

- Collaborative Positioning can bridge GNSS signal losses successfully and enables navigation in otherwise challenging environments
- Higher positioning accuracies, availability and reliability if tight integration of all sensor observations is performed

Challenges

- Sensor calibration required
- Time synchronisation between sensors and nodes essential

Call for international collaboration

Further tests are initiated investigating the use of the underground layer

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FIG WORKING GROUP 5.5 / IAG WORKING GROUP 4.1.1
Ubiquitous Positioning Systems

Collaborative Navigation with Ground Vehicles and Personal Navigators

International Collaboration with:
Allison Kealy and Azmir Hasnur-Rabiani
University of Melbourne, Australia
Dorota Grejner-Brzezinska and Charles Toth
Ohio State University, USA
Terry Moore and Gethin Roberts
University of Nottingham, UK and China
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National Technical University of Athens, Greece
Andrew Dempster and Nima Alam
University of New South Wales, Australia

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