Future trends in pervasive positioning

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Agenda

- Introduction
- Key trends in positioning
- Different positioning technologies and accuracy
  - GNSS, WLAN, inertial, visual, acoustic, LiDAR, RFID
  - Enhancements: sensor fusion, map matching, cooperation
  - Threats
- Conclusions
  - the future for reliable positioning

Introduction (1)

- The full capabilities of civilian Global Positioning System (GPS) were made public only around 15 years ago.
- Today, nearly every mobile app employs it.
- The total number of Global Navigation Satellite System (GNSS) devices in use is about 5,8 billion units (GNSS Market Report 2017, GSA), and it is predicted to grow to almost 8 billion by 2020 - more than one device per person on the planet.

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Introduction (2)

Satellite navigation market segments

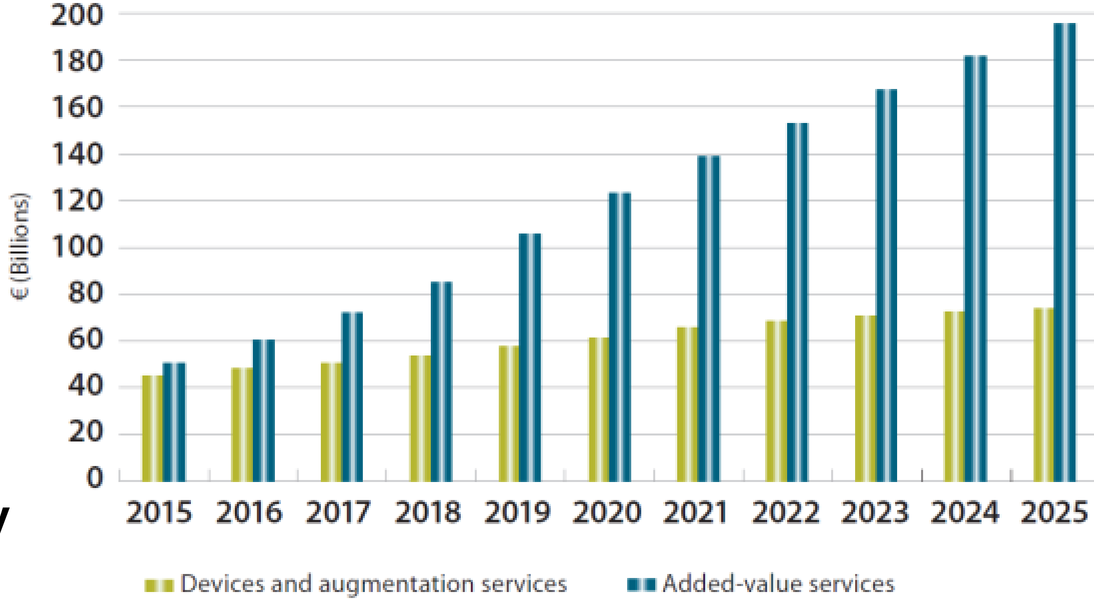
Source: European GNSS Agency's GNSS Market Report 2017

Introduction (3)

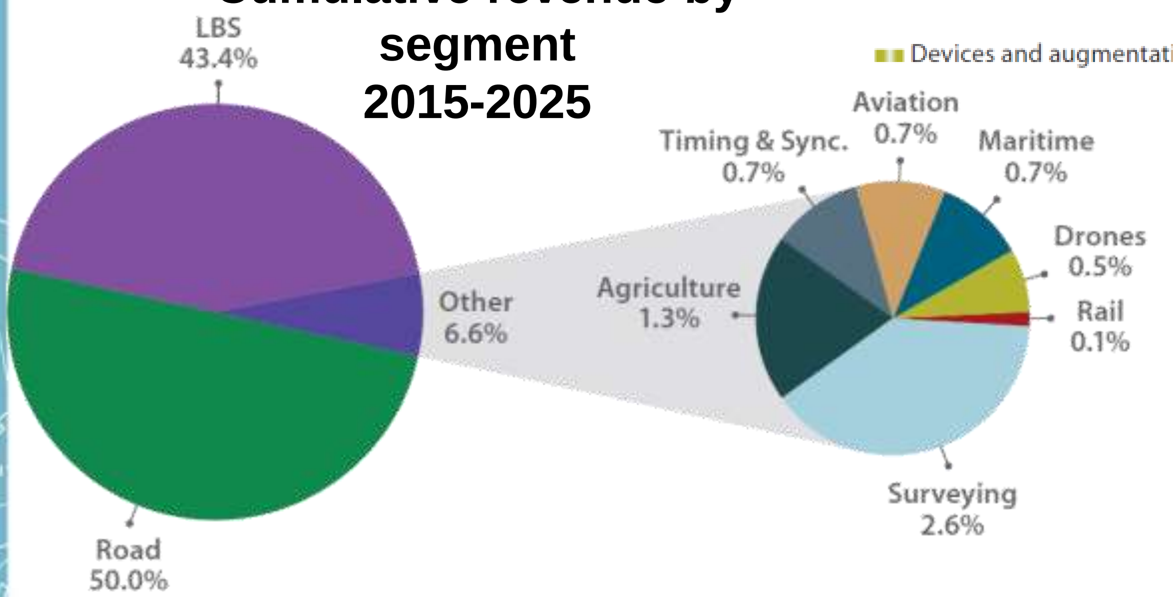
Satellite navigation related revenue

Source: European GNSS Agency's GNSS Market Report 2017

Global revenue by type



Cumulative revenue by segment 2015-2025



Different market segments have different operation environments and requirements for accuracy and reliability

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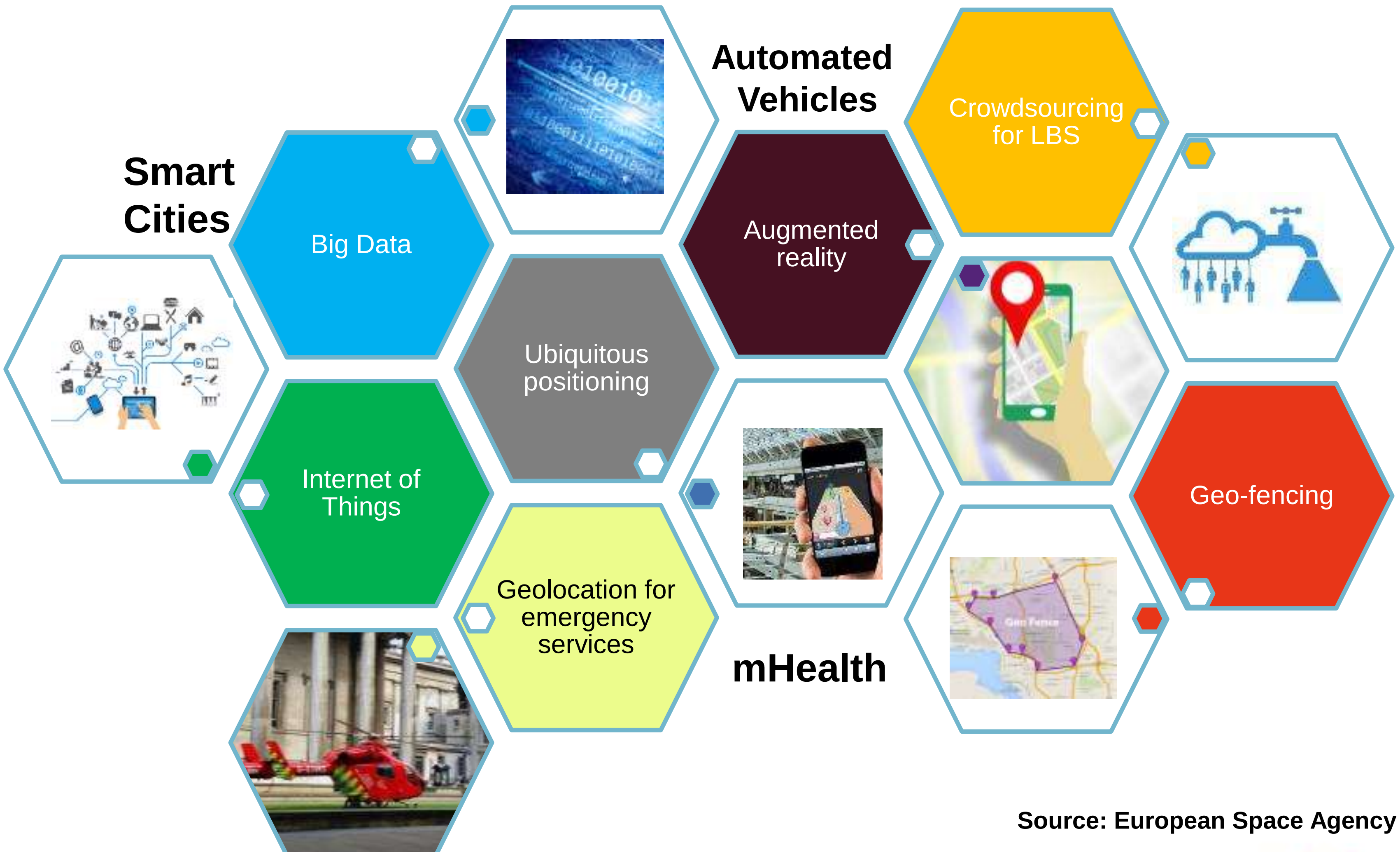
Positioning/timing play a key role in several broad technology trends



Source: European Space Agency

GNSS = Global Navigation Satellite Systems
PNT = Position, Location, Time

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New and emerging GNSS trends by market segment (1)

- **LBS**: More and more smartphones integrate multi-constellation GNSS
- **Road**: GNSS helps answers the need of Autonomous Driving (AD) for reliable and accurate positioning.

- **Aviation**: The aviation market continues to increasingly rely on GNSS, including rotocraft and unmanned vehicles
- **Search and Rescue (SAR)**: Beacon manufacturers are developing solutions for Aircraft Distress Tracking leveraging GNSS
- **Timing & Sync**: GNSS timing is at the core of many critical infrastructures, including telecoms, energy, finance

Source: European GNSS Agency

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New and emerging GNSS trends by market segment (2)

- **Rail**: GNSS-enabled solutions can offer enhanced safety for lower cost, e.g. in railway signaling
- **Maritime**: GNSS has become the primary means of obtaining PNT information at sea

- **Agriculture**: GNSS applications represent a key enabler for the integrated farm management concept
- **Surveying**: Falling device prices drive the democratisation of mapping

Source: European GNSS Agency

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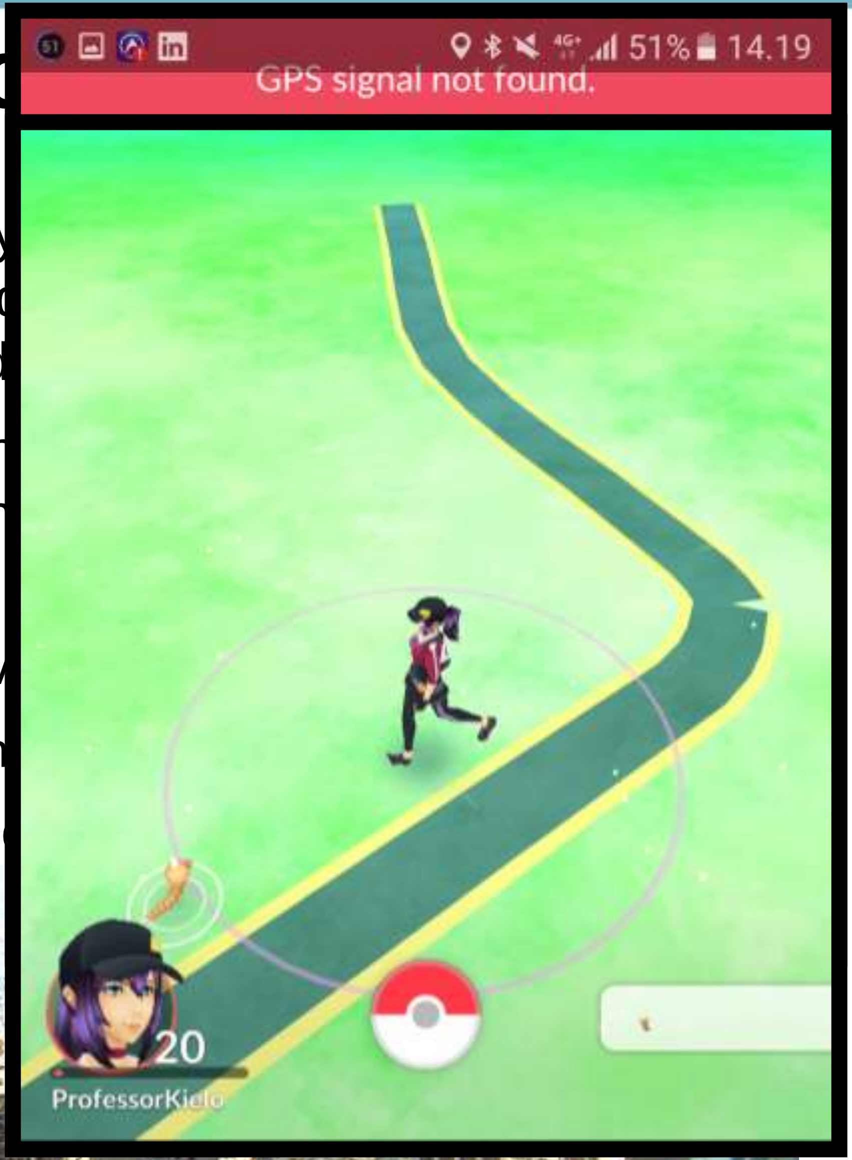
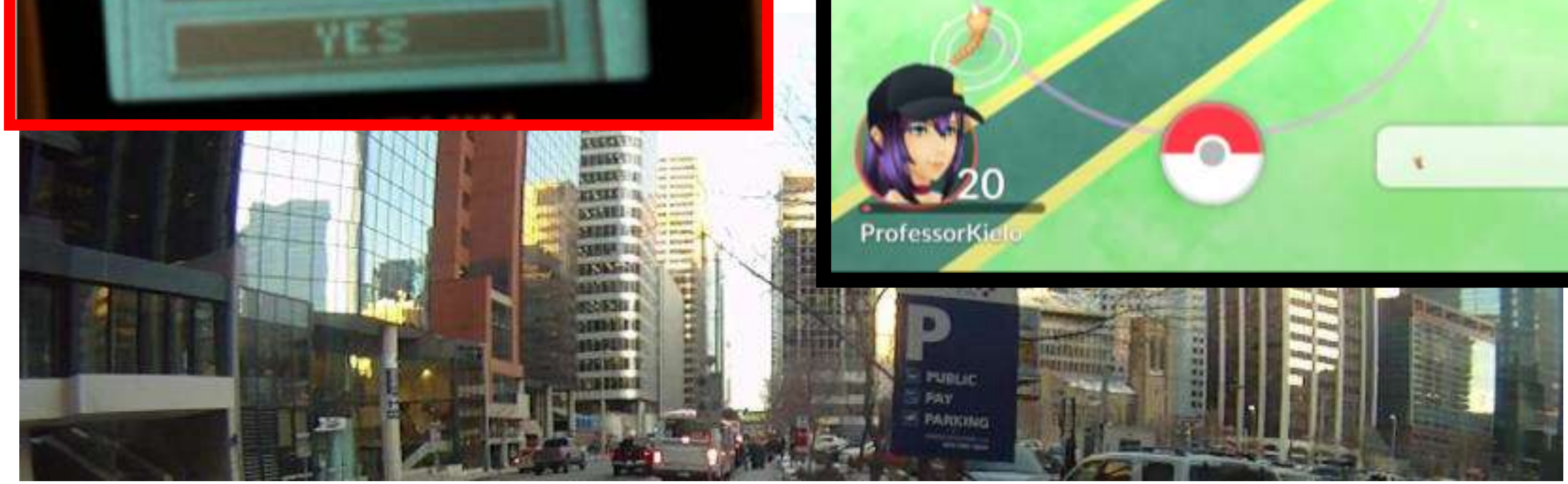
Positioning techno





Positioning technologies (2)

Reliable positioning is needed despite the situation

- Dense forests, urban and indoor environments



- While exposed to jamming or spoofing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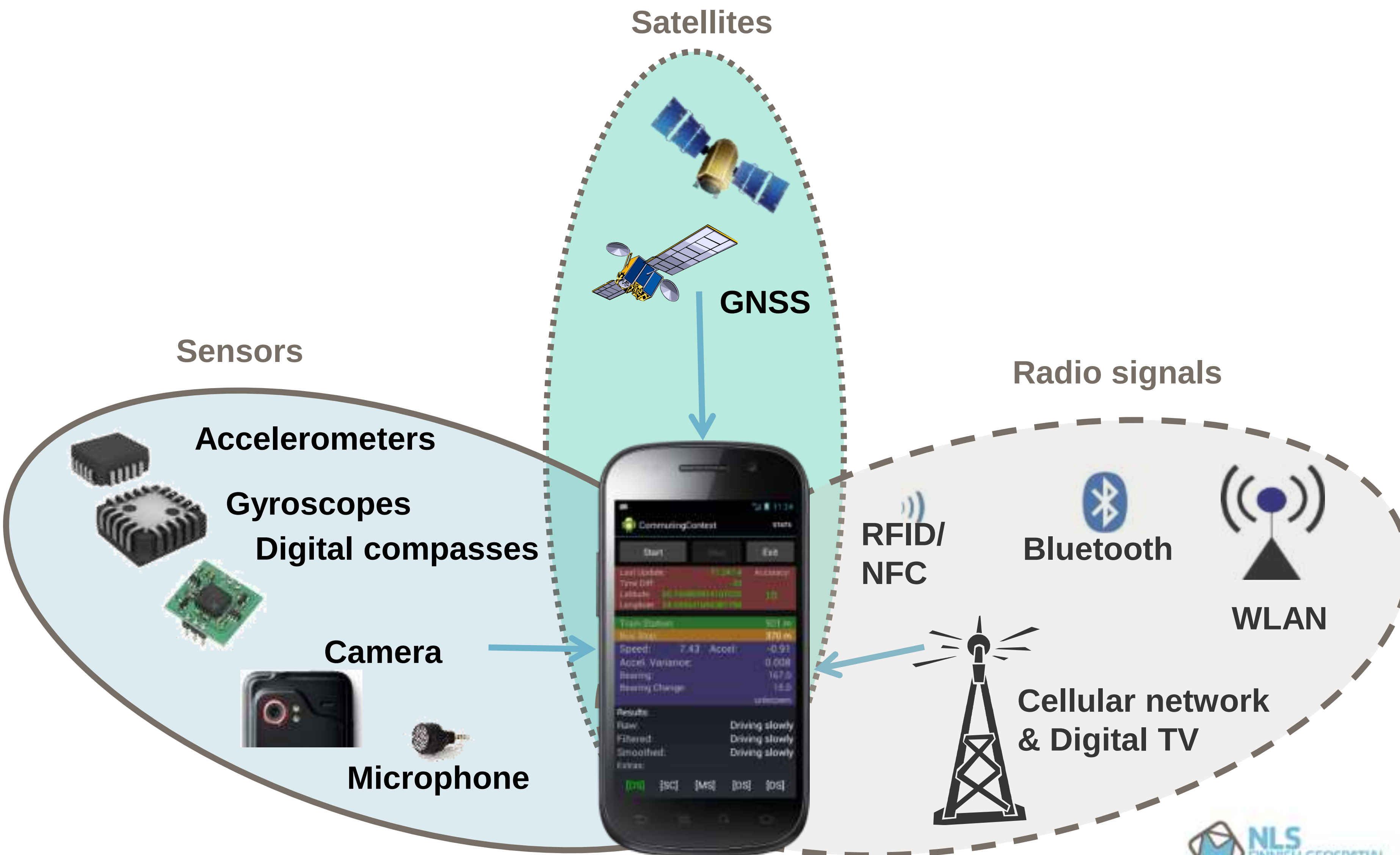
Positioning technologies (3)



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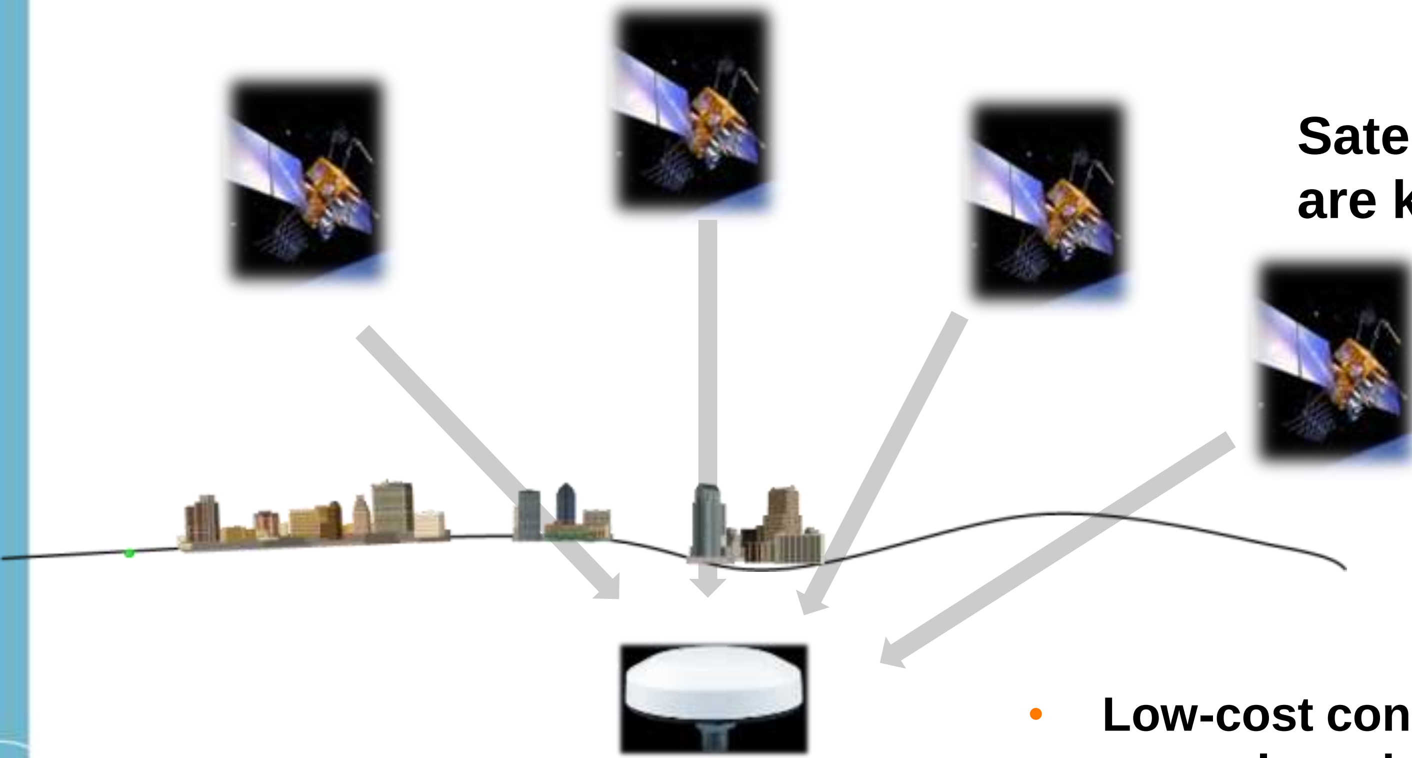
GNSS

Accuracy around 5 m with consumer-grade devices (code) and centimeter-level with professional devices and reference networks (phase)

Satellite locations are known



Position, Velocity, Time

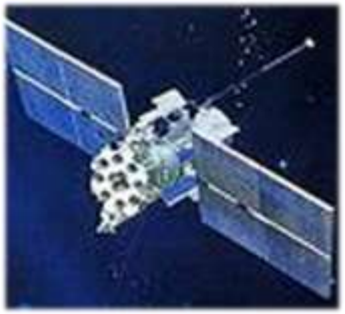
- **Low-cost consumer receivers use only code-based range for positioning**
- **Carrier phase observations and reference networks enable higher accuracy**

Next generation GNSS (1)

- The future European **Galileo**, the Russian **Glonass,** and the Chinese **BeiDou** are similar systems with the U.S. **GPS**
- Also **GPS** is being modernized: civil and military signals on new frequencies (L2 and L5)

GPS
May 2017: 31 SV operational

Galileo
May 2017: 9 SV operational



Glonass
May 2017: 24 SV operational

BeiDou2
20 SV operational in May 2017

Next generation GNSS (2)

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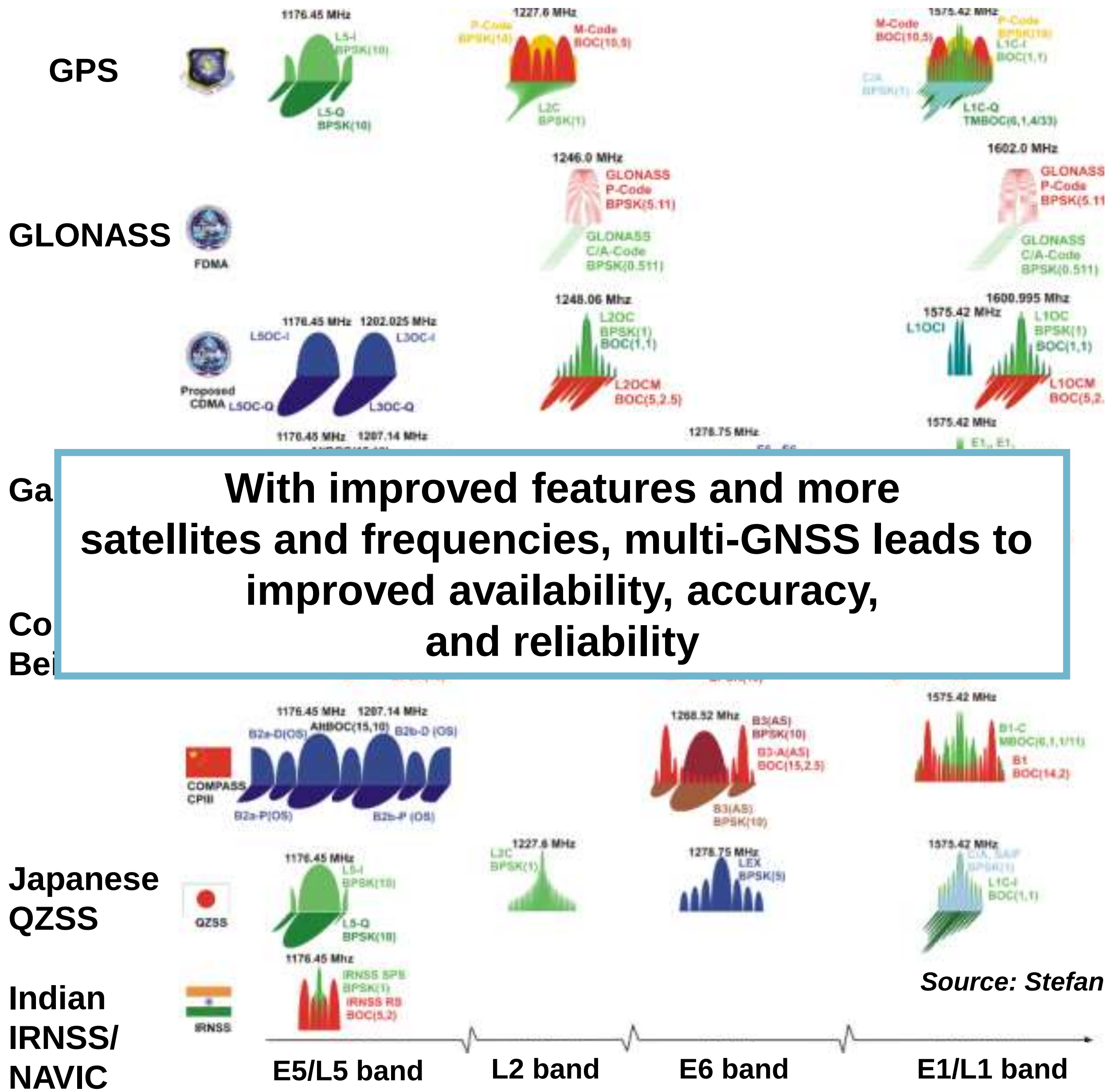

With improved features and more satellites and frequencies, multi-GNSS leads to improved availability, accuracy, and reliability

Source: Stefan Wallner

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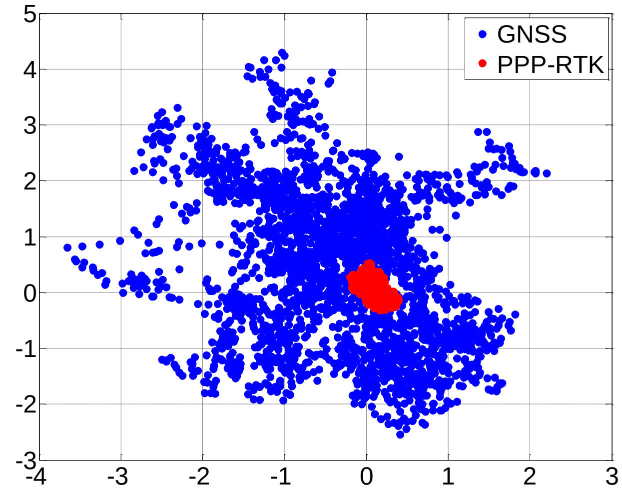
GNSS for Mobile Precise Positioning

FinnRef



	DGNSS	RTK	PPP with SSR
Professional Accuracy	0.5 m	Up to 0.05 m	~0.1 m
Mass-Market Accuracy	1 m	0.5 m	0.5 m
Key Benefits	Existing and freely available service	Well standardized in professional use	Improved privacy, low server load

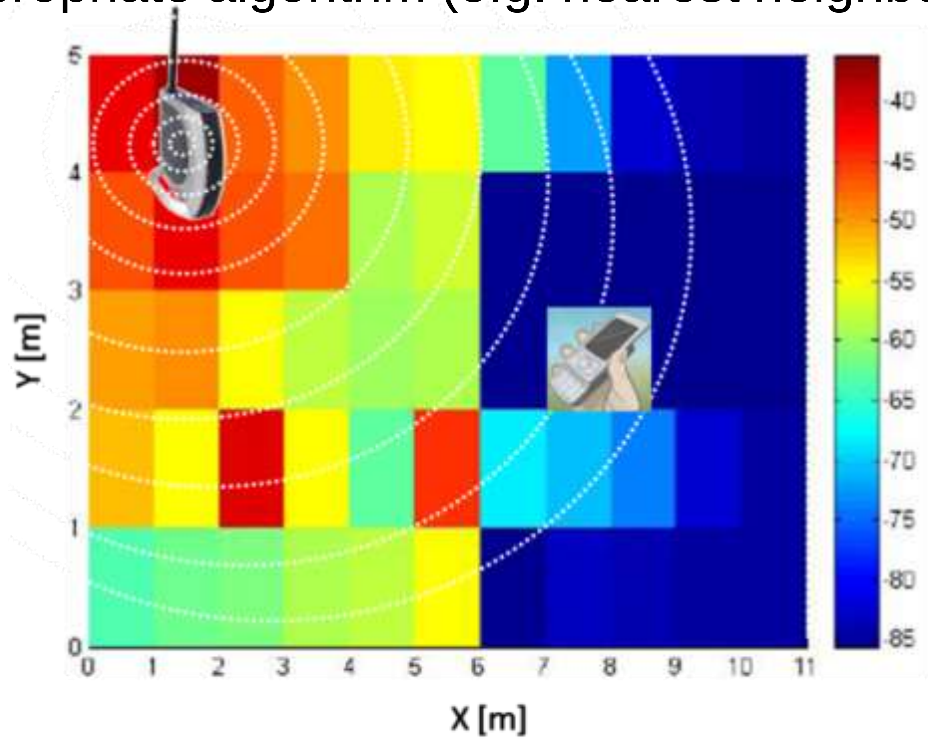
DGNSS = Differential GNSS
PPP = Precise Point Positioning
RTK = Real Time Kinematic
SSR = State Space Representation

WLAN fingerprinting (1)

Accuracy around 5-10 m (depending on the amount of available base stations)

- Positioning requires two steps:
  - Generation of a “fingerprint” database based on the statistical distribution of received signal strength indicators (RSSI)
  - Estimating the position the real-time RSSI measurements, database, and an appropriate algorithm (e.g. nearest neighbor search)

Colour = signal strength



WLAN fingerprinting (2)

Conferest localization app at #FIGWW2017 based on WLAN fingerprinting (HERE positioning technology)

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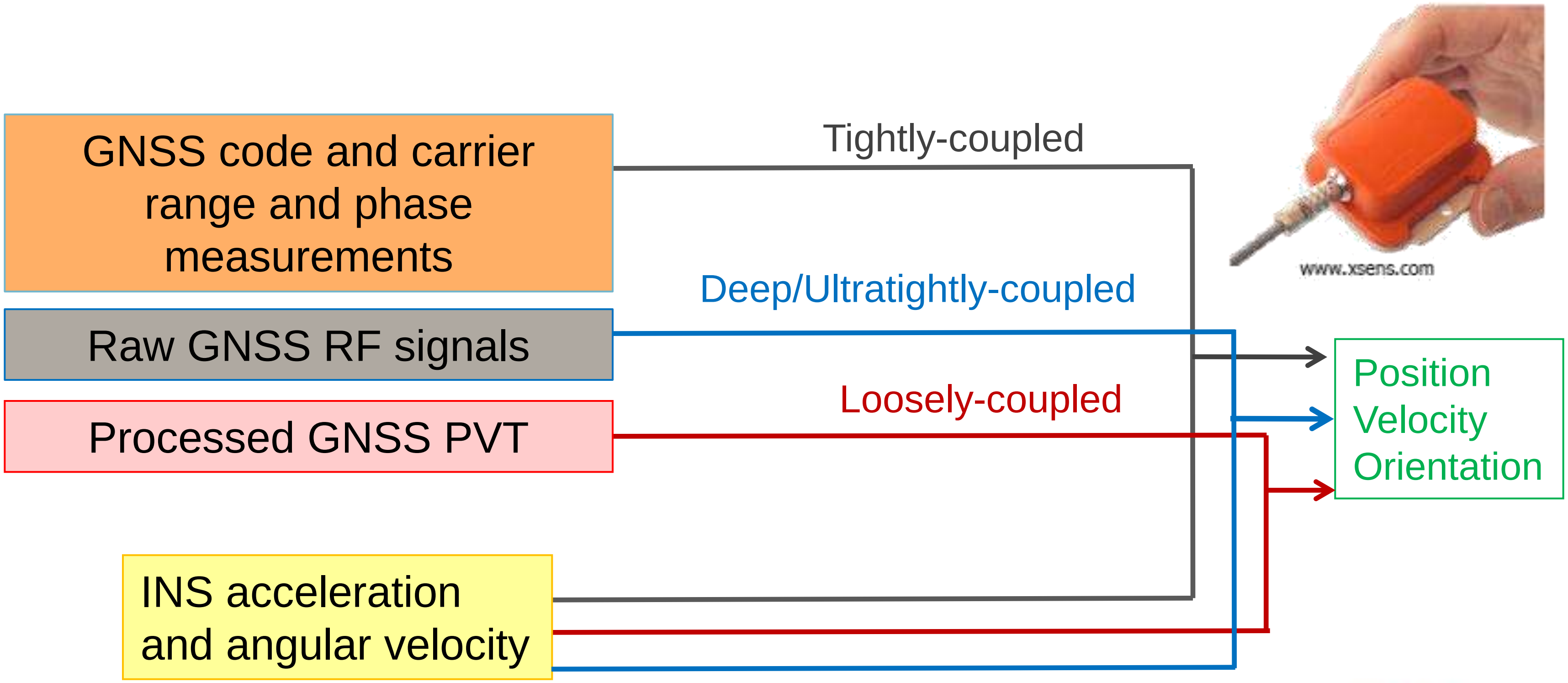
Inertial sensors

Accuracy varies: 1 cm - kms

- Inertial sensors continuously measure specific force (from which acceleration can be deduced) and rotation rates, from which position, velocity, and attitude can be derived.
- Inertial sensors need periodic updates from absolute positioning systems.



Visual Positioning

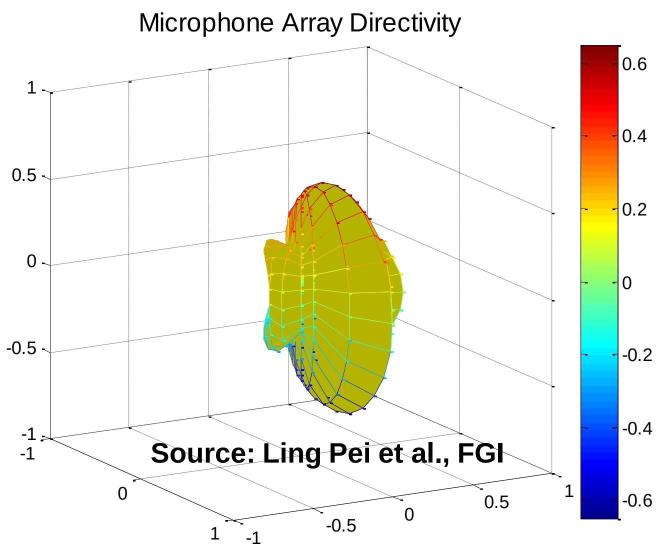
1. Image databases give an absolute position of the user:
   - Database of images attached with position information
   - Images matched to the images in database
   - When a match is found, the position is inferred.
2. User heading and translation/odometry can be observed from consecutive images
   - Heading+translation used to provide relative positioning (similar to inertial sensors)

Accuracy around 5 m (depending on the quality of database or lighting)

Source: Laura Ruotsalainen, FGI

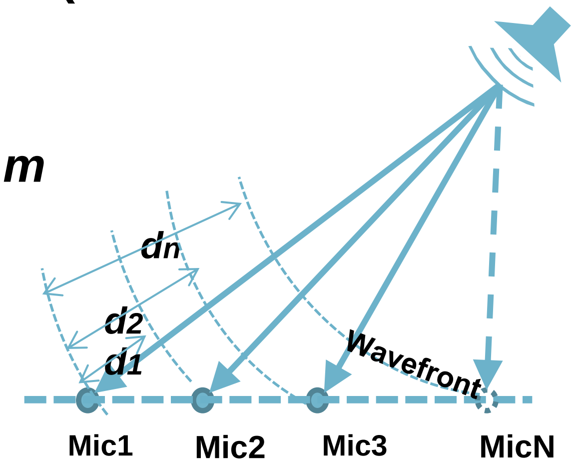
Acoustic Positioning

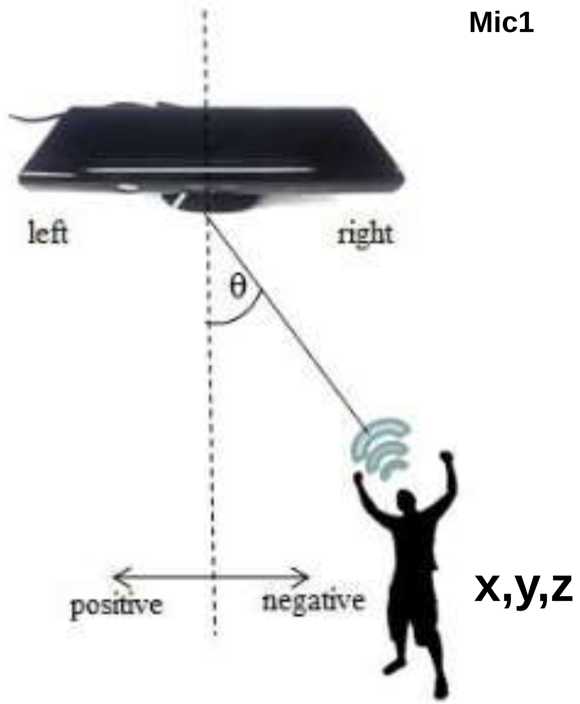
Transmitter (x,y,z)
(near-field sound source)



Source: Ling Pei et al., FGI

Accuracy around 1 m





LiDAR for improved positioning

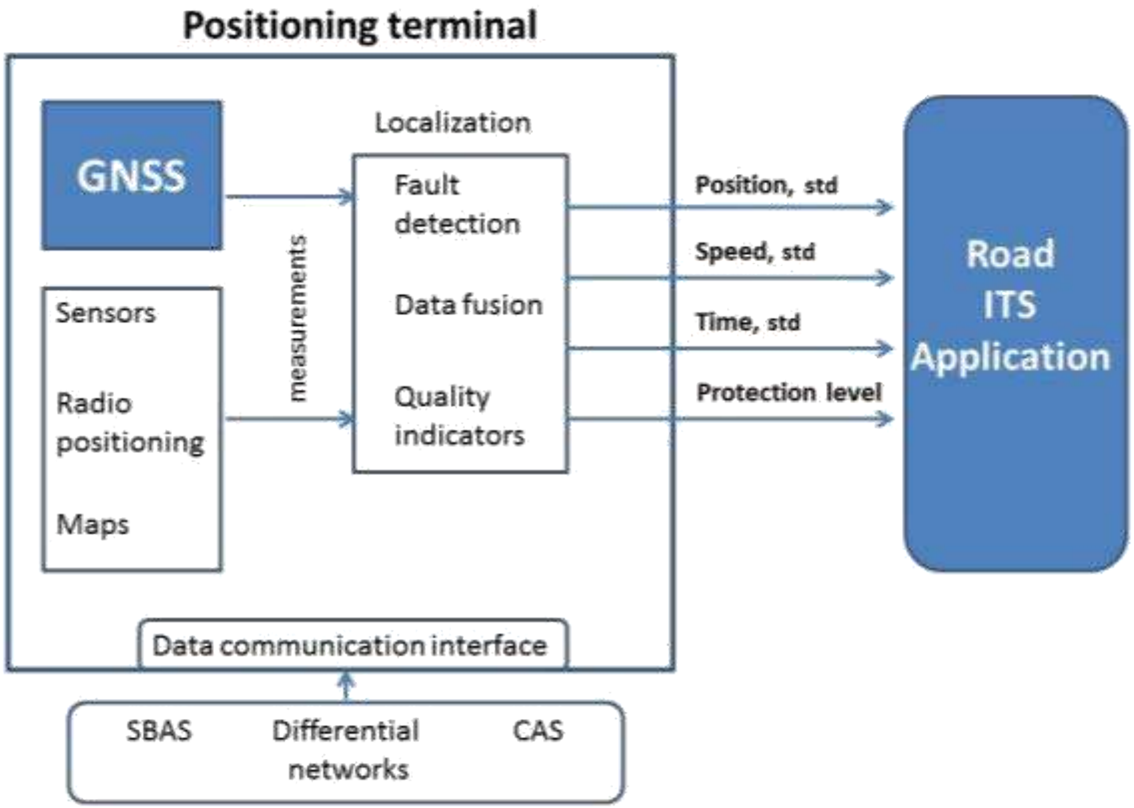
- Light Detection And Ranging (LiDAR) has high accuracy in ranging, wide area view and, low data processing requirements.
- Transmitting a laser pulse and calculating distance to surrounding constructions based on the signal return time.
- Reliability is highly dependent on the distance and reflectivity of different objects
- Robust to light conditions
- Increasingly found in vehicles
- Cost a significant drawback

RFID in positioning

- Radio Frequency Identification (RFID) is a wireless radio technology
- Provides information about RFID tag's proximity, carried by the user, to the RFID reader => requires infrastructure
- Can be used locally as complementary positioning technology in some specific points (e.g. tunnels)
- Positioning performance is dependent on the RFID technology used and of the density of the RFID reader network

Sensor Fusion

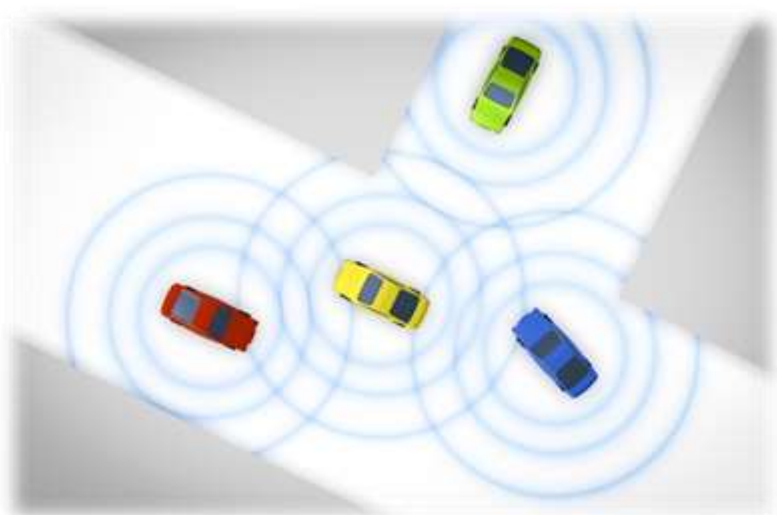
- Data fusion = mathematical tools for combining measurements



Peyret F. (2013), Standardization of performances of GNSS- based positioning terminals for ITS (Intelligent Transport System) applications

Cooperative positioning

- Peer-to-peer and cooperative positioning bring together capabilities of Satellite Navigation and Communication Systems
- Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication are key enablers



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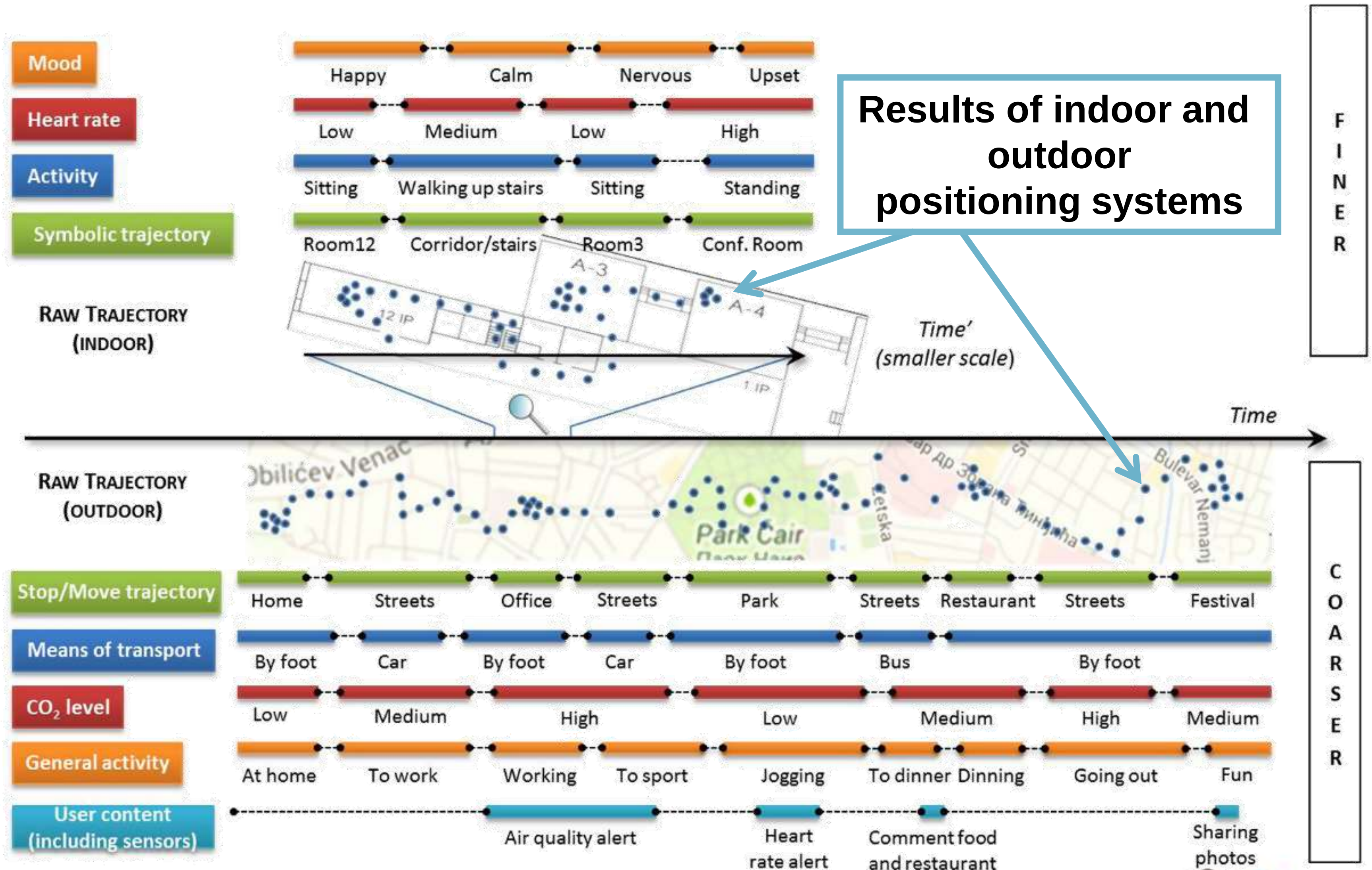
More than just position information…



S. Ilarri, D. Stojanovic, C. Ray (2015), "Semantic management of moving objects: A vision towards smart mobility", *Expert Systems with Applications*, Elsevier, 42:3, 2015, pp. 1418-1435.

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Threats to positioning

GNSS Vulnerabilities

- Jamming: Broadcast of an interference signal.
- Spoofing: Broadcast of synthetic GNSS signals to try to trick a GNSS receiver.
- Meaconing: Re-broadcast of real satellite signals after a brief delay in order to create errors in the GNSS receiver.
- Un-intended narrowband and wideband interferences.

Non-GNSS Vulnerabilities

- Database intentional and unintentional corruption: many non-GNSS positioning methods rely on some training databases; outliers or fake data in such databases can corrupt the location estimate.
- User privacy: most network-centric location solutions make the user vulnerable to various privacy leaks or theft of location information.
- Other malicious attacks on the physical or virtual infrastructure of the localization engine.

Conclusions – reliable navigation in the future (1)

- Means for navigation and positioning:
  - Signals intended for navigation
    - Multi-GNSS
    - Other radio navigation systems
      - Dedicated WLAN, Bluetooth, RFID tags and UWB emitters
    - Self-contained sensors
  - Signals of Opportunity
    - Not intended for positioning but freely available
      - WLAN, Bluetooth, Cellular, DTV, AM, FM, (5G?)
  - Natural signals
    - Magnetic field, gravity
    - Landmarks

Conclusions – reliable navigation in the future (2)

- Accuracy, availability and reliability
  - Sufficient accuracy to support autonomous vehicles
    - Carrier-phase utilization of GNSS
    - Inertial measurement units
  - Interference resilience
    - Backup-systems
  - Seamless positioning from outdoors to indoors
- Interoperability among different location-based services and providers
  - Mobile users should receive useful information services independently of their current location and LBS provider
- Protection of personal location information and information security of localization

Thank you!

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