



Data collection workshop



IPIN 2019
TENTH INTERNATIONAL CONFERENCE ON
INDOOR POSITIONING
AND INDOOR NAVIGATION
30 September – 3 October 2019, Pisa, Italy

Dickson Phua
PHOTOGRAPHY

The Team

We will, we will teach you...



Outline

Introduction

IPIN Competition - Track 3

How to plan a data collection

Hands-on

Checking-data

How to Contribute

Introduction

Introduction to the workshop

Who we are

Technologies available for IP

Introduction

What is this workshop about?

DATA COLLECTION FOR USEFUL EVALUATION AND REPRODUCIBILITY

Introduction

Why this Workshop?

- Experiments in local facilities
- Custom data collection for experiments
- Length of tracks might be in some cases short
- Just one simple scenario considered
- Many different approaches to collect data
- We should use the approach of Machine Learning

Introduction

Why this Workshop?

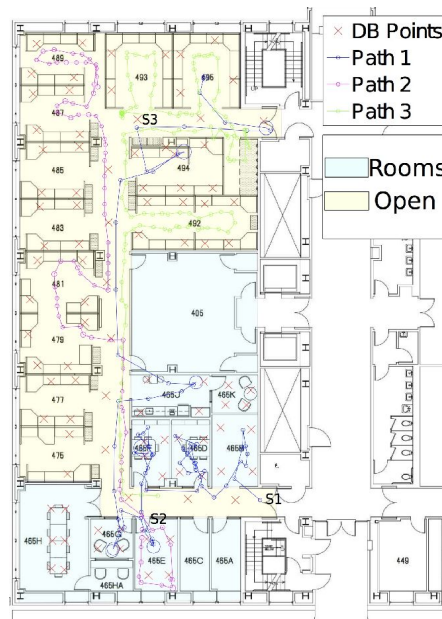


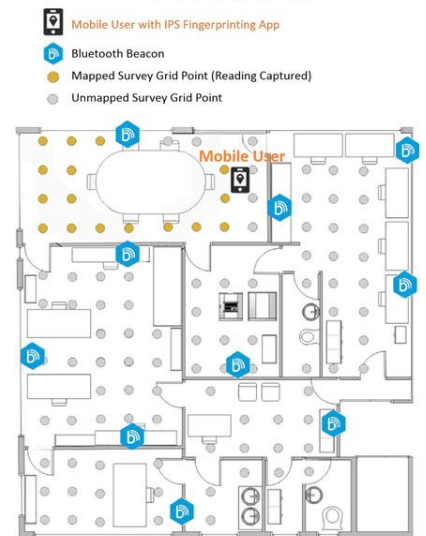
Figure 3. Database Points and Ground Truth Paths

<https://ai2-s2-public.s3.amazonaws.com/figures/2017-08-08/10f8c50ba88e728e10311b217fc9ded646950d3/6-Figure2-1.png>
<https://www.securityindustry.org/wp-content/uploads/2017/11/Figure-4-Grid-based-approach.jpg>

Figure 4. Grid-based approach to creating an IPS Bluetooth building fingerprint.

Creating a Building Bluetooth Fingerprint

By Surveying Building Spaces to
Capture Bluetooth Signal Readings



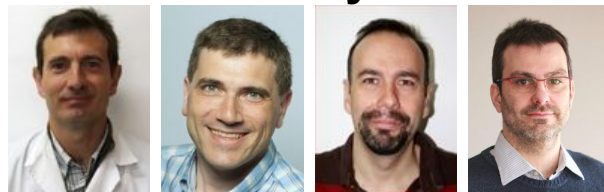
Source: Author, adapted from Sensors journal illustration. Ioizos Kanaris, Akis Kokkinis, Antonio Liotta, Stavros Stavrou, "Fusing Bluetooth Beacon Data with WiFi Radiomaps for Improved Indoor Localization", Sensors, 10 Apr. 2017, Figure 2.

Introduction

Who prepared this Workshop?

- Antonio R. Jimenez
- Antoni Pérez-Navarro
- Fernando Seco
- Joaquín Torres-Sospedra

Join us or create your network!



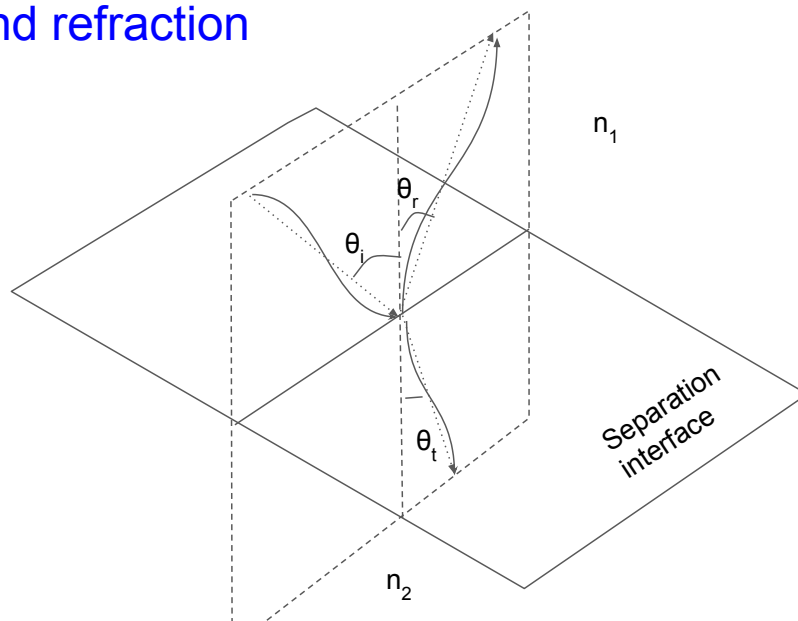
REPNI+,
TEC2017-90808-REDT

Introduction: WiFi theoretical background

- WiFi are electromagnetic waves and behave like them
- They are affected by the following phenomena:
 - Reflection
 - Refraction
 - Diffraction
 - Absorption

Introduction: WiFi theoretical background

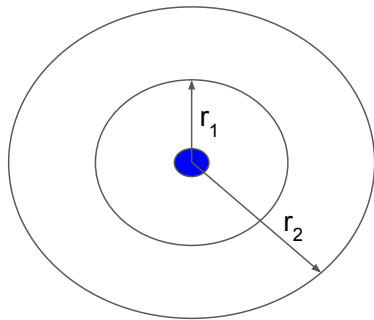
Reflection and refraction



$$\theta_i = \theta_r$$
$$n_1 \sin \theta_i = n_2 \sin \theta_t$$

Introduction: WiFi theoretical background

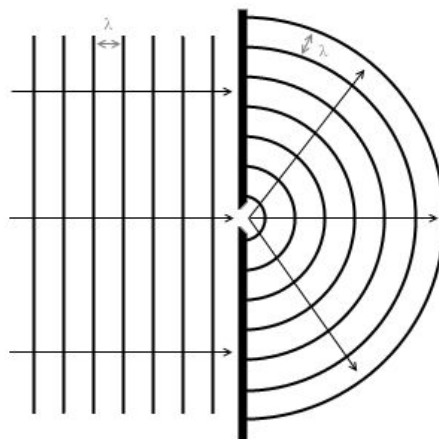
Geometrical attenuation



$$\begin{aligned} \text{Energy}_1 &= \text{Energy}_2 \\ I(r_1) \cdot 4\pi r_1^2 &= I(r_2) \cdot 4\pi r_2^2 \rightarrow \frac{I(r_2)}{I(r_1)} = \frac{r_1^2}{r_2^2} \end{aligned}$$

Introduction: WiFi theoretical background

Diffraction



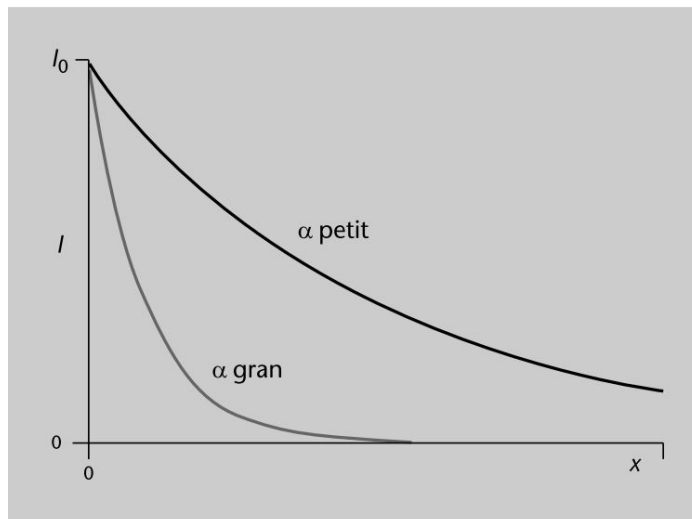
Introduction: WiFi theoretical background

Absorption

Intensity $\rightarrow I(x) = I_0 e^{-\alpha x}$ Attenuation coefficient

Penetration depth $\delta = \frac{1}{\alpha} = \frac{1}{\sqrt{\pi f \mu \sigma}}$

frequency f magnetic permeability μ conductivity σ

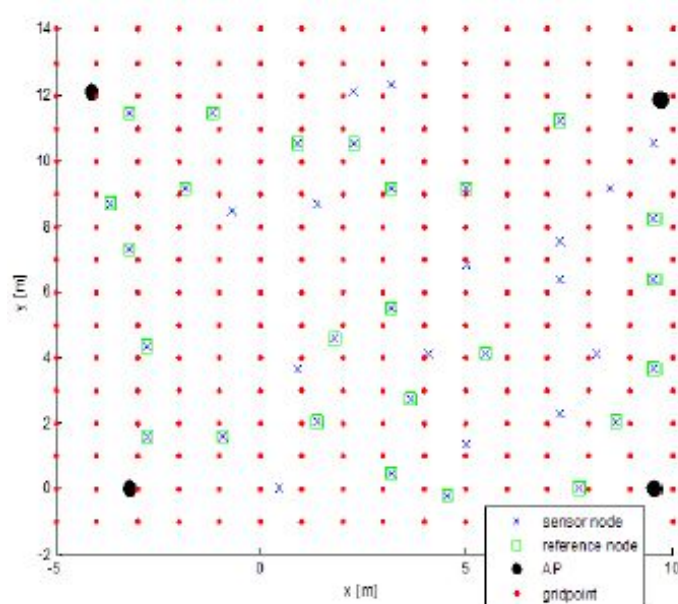


Introduction: WiFi theoretical background

- Fingerprinting:
 - Location of Wi-Fi APs might be unclear
 - We know the signature at given points
 - We look for similar fingerprints for position estimation



Introduction: WiFi theoretical background



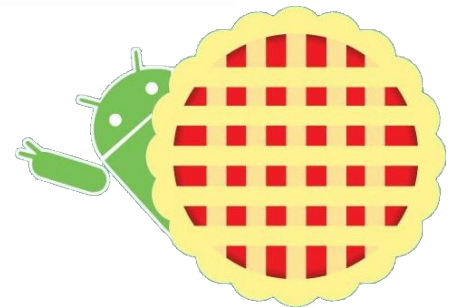
<http://www.rrrij.com/open-access/rss-based-indoor-localization-scheme-usinggrnn-and-virtual-gridpoints.php?aid=41585>

Introduction: BLE

- Fingerprinting:
 - Similar approach than Wi-Fi
 - New challenges: channel hopping, additional params.
- Centroid and advanced models
 - Positions of beacons are known
 - Range can be shorter
- Proximity

Introduction: WiFi theoretical background

4 scans
every 2 minutes

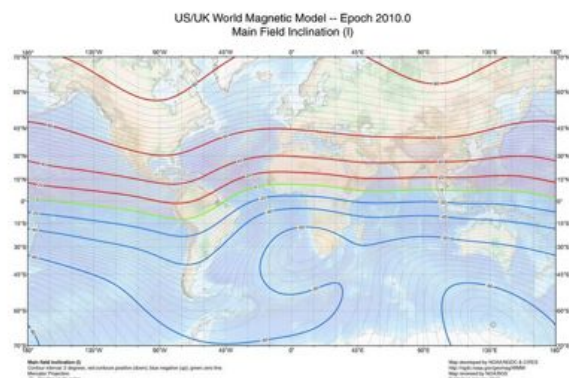


Introduction: Magnetic field theoretical background

Geomagnetic Field

- Geomagnetic field exists around Earth
- Metallic structures of buildings can distort it

Location ↔ Geomagnetic field distortion



Introduction: Magnetic field theoretical background

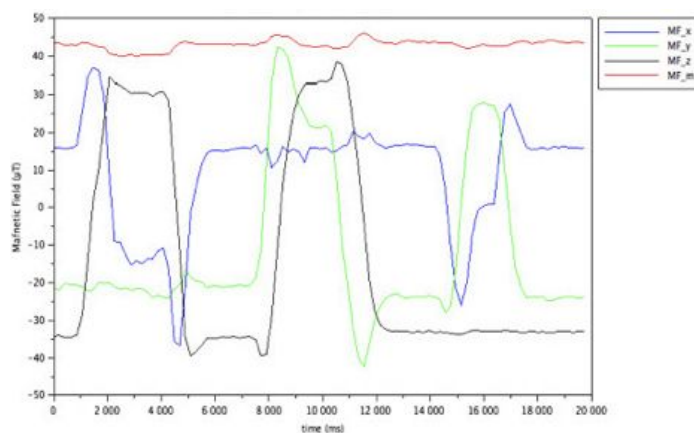
Artificial Magnetic Field

- Electric machines also produce magnetic field
- If they do not move:



Location $\leftrightarrow$ Geomagnetic field distortion + Generated magnetic field

Introduction: Magnetic field theoretical background

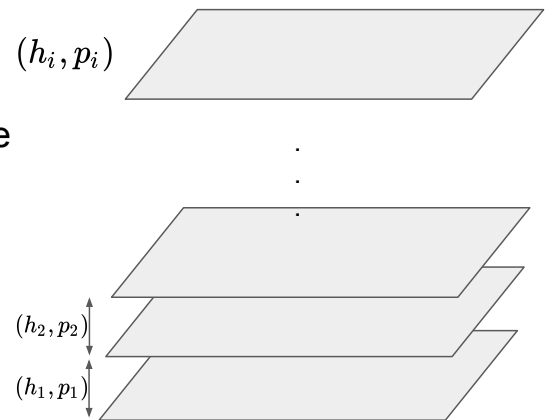


Location is given by the shape of the curve, and NOT by the value of magnetic field in a single point

Introduction: Height with the barometer

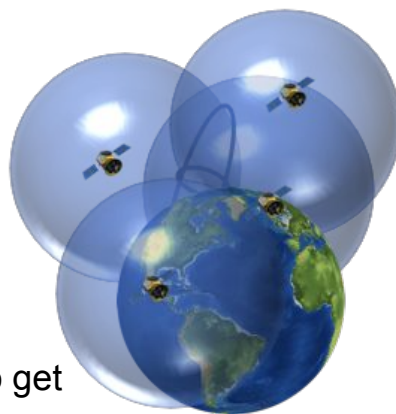
- Barometer measures differences of air pressure

$$h_i = \left(1 - \left[\frac{p_i}{1013.25} \right]^{1/5.255} \cdot \frac{288.15}{0.0065} \right)$$



Willemsen, T., Keller, F., & Sternberg, H. (2014). Concept for building a MEMS based indoor localization system. In *2014 International Conference on Indoor Positioning and Indoor Navigation (IPIN)* (pp. 1–10). IEEE. <https://doi.org/10.1109/IPIN.2014.7275461>

Introduction: Global Navigation Satellite Systems



A 4th satellite is needed to get high precision position

Introduction: Global Navigation Satellite Systems

- Indoors usually it is not possible to see 4 satellites
- In some situations, or next to the exterior walls, GNSS position still available
- Users can change outdoors and indoors, therefore, we need to know GNSS position when available
- Raw GNSS will be available in next versions of Android

Introduction: Global Navigation Satellite Systems

GNSS Availables



GPS



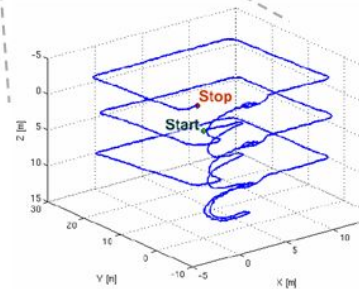
GLONASS



GALILEO

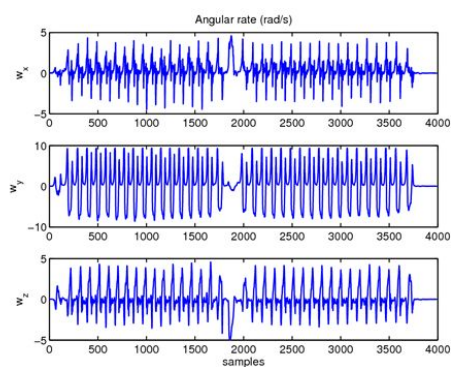
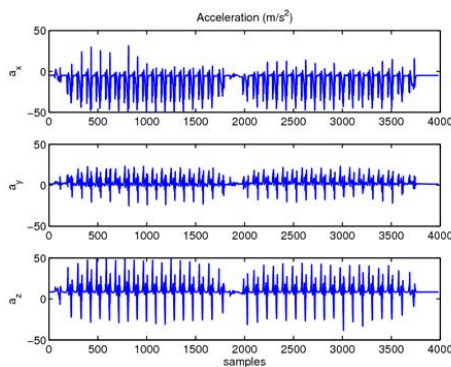
Introduction: PDR

- PDR is a method to:
 - estimate the user's trajectory**
(Position & Heading)
 - by **integrating inertial measurements**
- No need of external beacons: GPS, Cell-positioning, I (WiFi, BLE, UWB, US, Light,...)
- Assumes known initial conditions:
 - position and orientation
- Uses Inertial data:
 - Acceleration ($\text{m}\cdot\text{s}^{-2}$) & Angular rate ($\text{rad}\cdot\text{s}^{-1}$)



Introduction: PDR

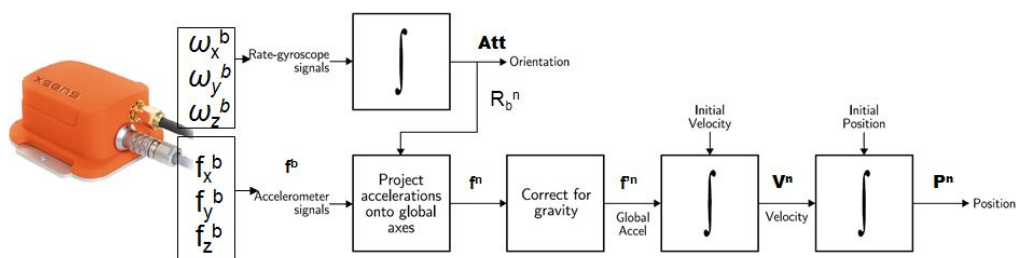
- «Acceleration & Angular rate» signals to integrate
 - Example: 60 meters walk
 - go (18 steps) + 180° turn (1 step) + return walk (18 steps)



Introduction: PDR

•Strap-down INS:

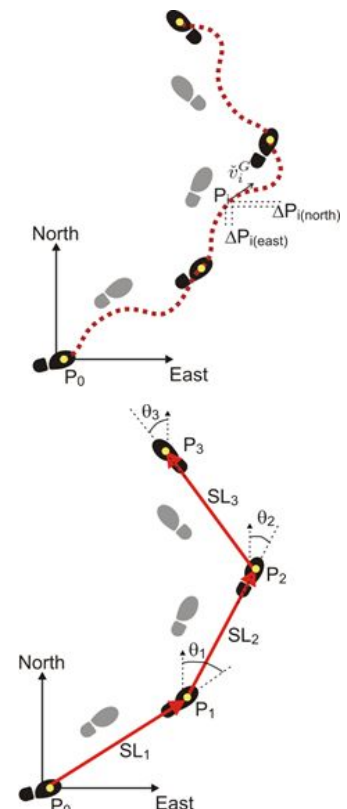
- –No stabilized platform. 3 Acc y 3Gyr fixed to the body.
- –Integrate angular rate (Gyro) to keep track of Attitude (R_b^n)
- –Transform specific force (f^b) measured by accelerometers in b-frame to n-frame (f^n) using Attitude.
- –Eliminate gravity (g) to that acceleration (f^n), obtaining: f^n
- Integrate f^n to obtain velocity (V^n), and again to get position (P^n)



Introduction: PDR

•There are 2 main types of PDR algorithms:

- “**INS-ZUPT**”: Integrates accelerations (INS) and correct velocities with zero velocity updates (ZUPT) at stance. IMU must be on foot.
- “**SL+Theta**”: Accumulates Stride Length (SL) estimations, along the Orientation angle (q) at foot stance. General purpose (IMU anywhere)



Introduction: UWB

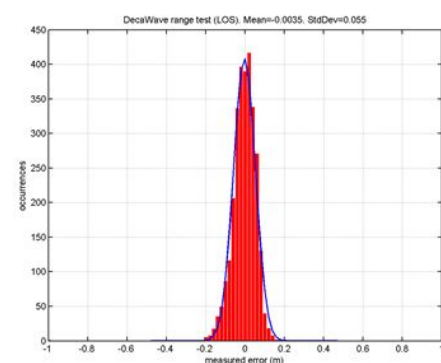
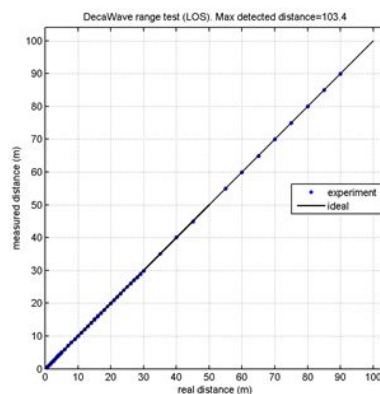
• UWB LPS:

- (+) centimeter accuracy (0.2 m in LOS)
- (+) can penetrate walls in buildings
- (+) large coverage & ranging (100 m in LOS)
- (+) can resolve individual multipath (BW)
- (+) Round-Trip range estimation (self-synchro.)
- (-) indoor operation & NLOS is a problem
- Ranging with large dispersion and outliers (>1 m)
- Maximum range indoors can be less than 10-15 m



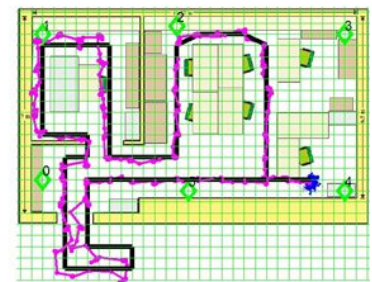
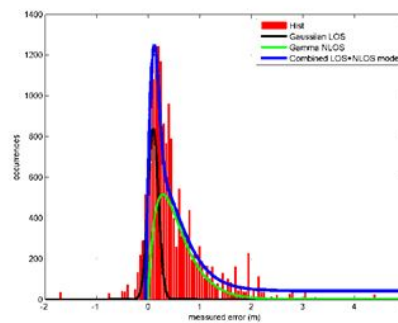
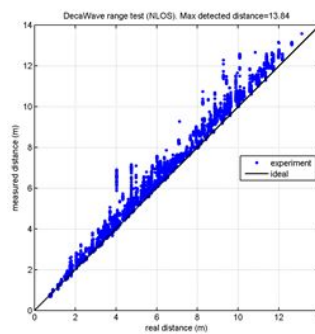
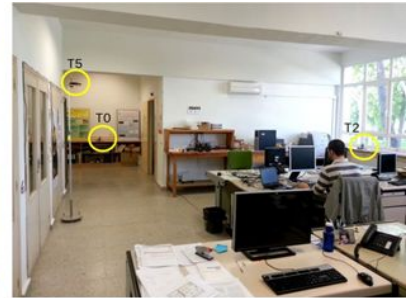
Introduction: UWB

UWB LOS Tests:



Introduction: UWB

UWB NLOS Tests:



Outline

Introduction

IPIN Competition - Track 3

How to plan a data collection

Hands-on

Checking-data

How to Contribute

IPIN Competition Track 3

Features

- Smartphone based competition
- Off-site - No need to be present in the competition area
- Collection of datasets with all the information
- Equal opportunities to all teams
- Any error in the data can be catastrophic

Based on accurate datasets

IPIN Competition Track 3

Features

- 2015: it was just Wi-Fi fingerprinting
- 2016: researchers from CSIC join the organization
- 2018: we used a large shopping mall as evaluation area
- 2019: we used a large research centre as evaluation area

Refining the procedures through the years!

IPIN Competition Track 3

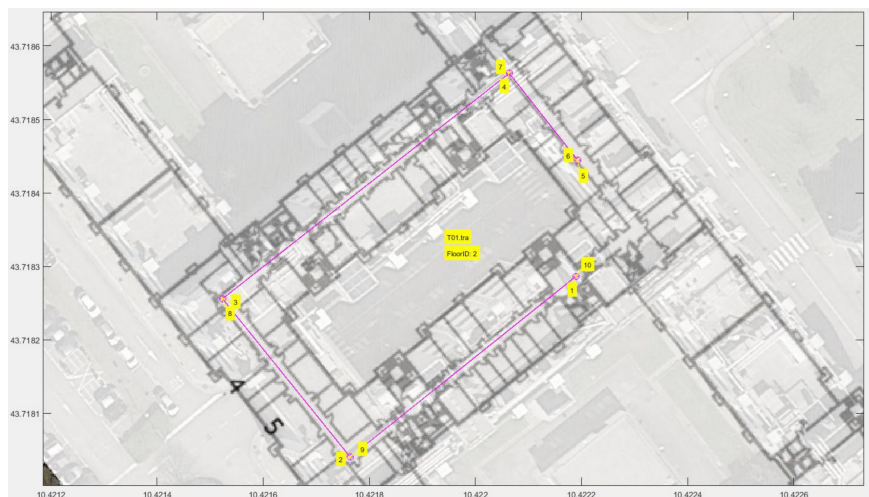
Features 2019

- 10 Training paths x 4 times (40 logfiles)
- 5 Training paths x 2 times* (10 logfiles)
- 9 Validation paths with few landmarks (9 logfiles)
- 1 Evaluation/Test blind logfile (92 validation points, 20 minutes)

Refining the procedures through the years!

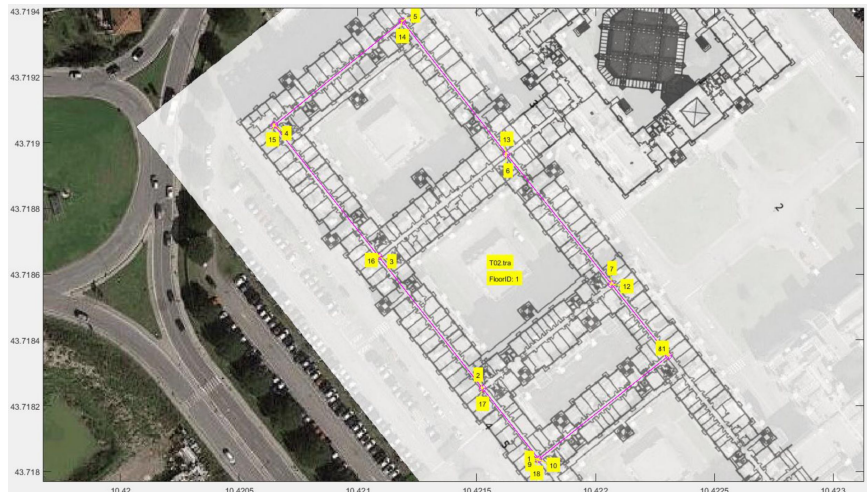
IPIN Competition Track 3

Features 2019



IPIN Competition Track 3

Features 2019



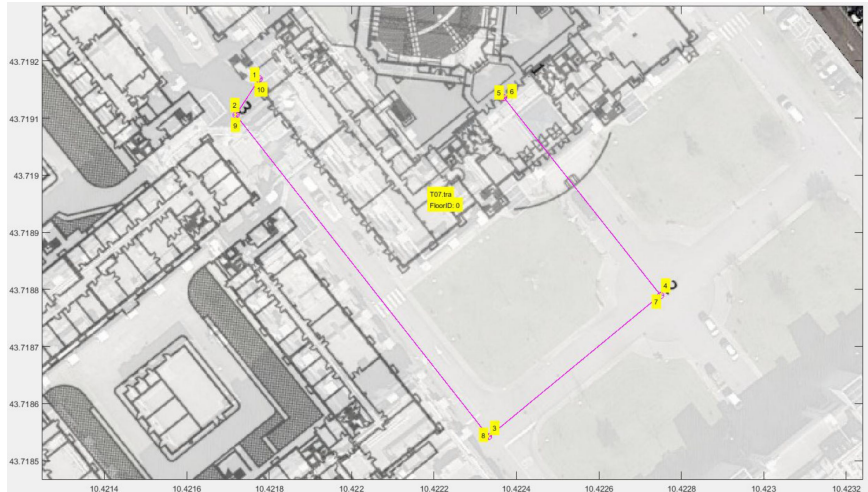
IPIN Competition Track 3

Features 2019



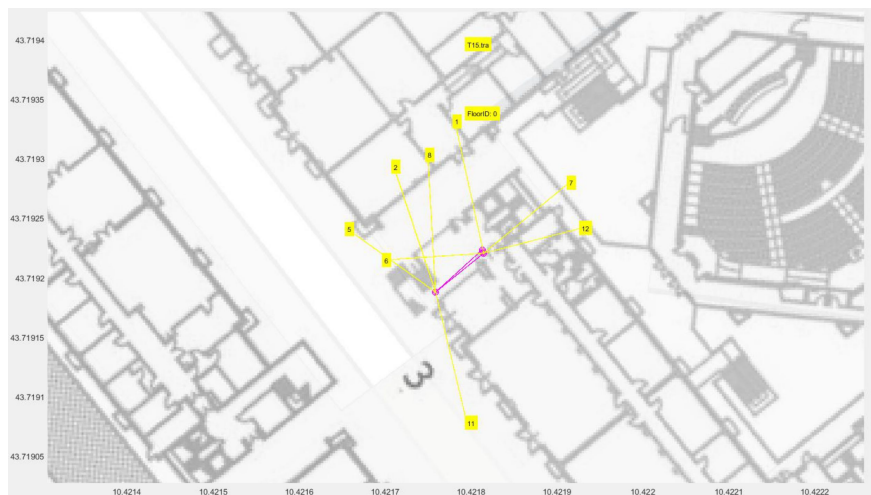
IPIN Competition Track 3

Features 2019



IPIN Competition Track 3

Features 2019



IPIN Competition Track 3

Features 2019



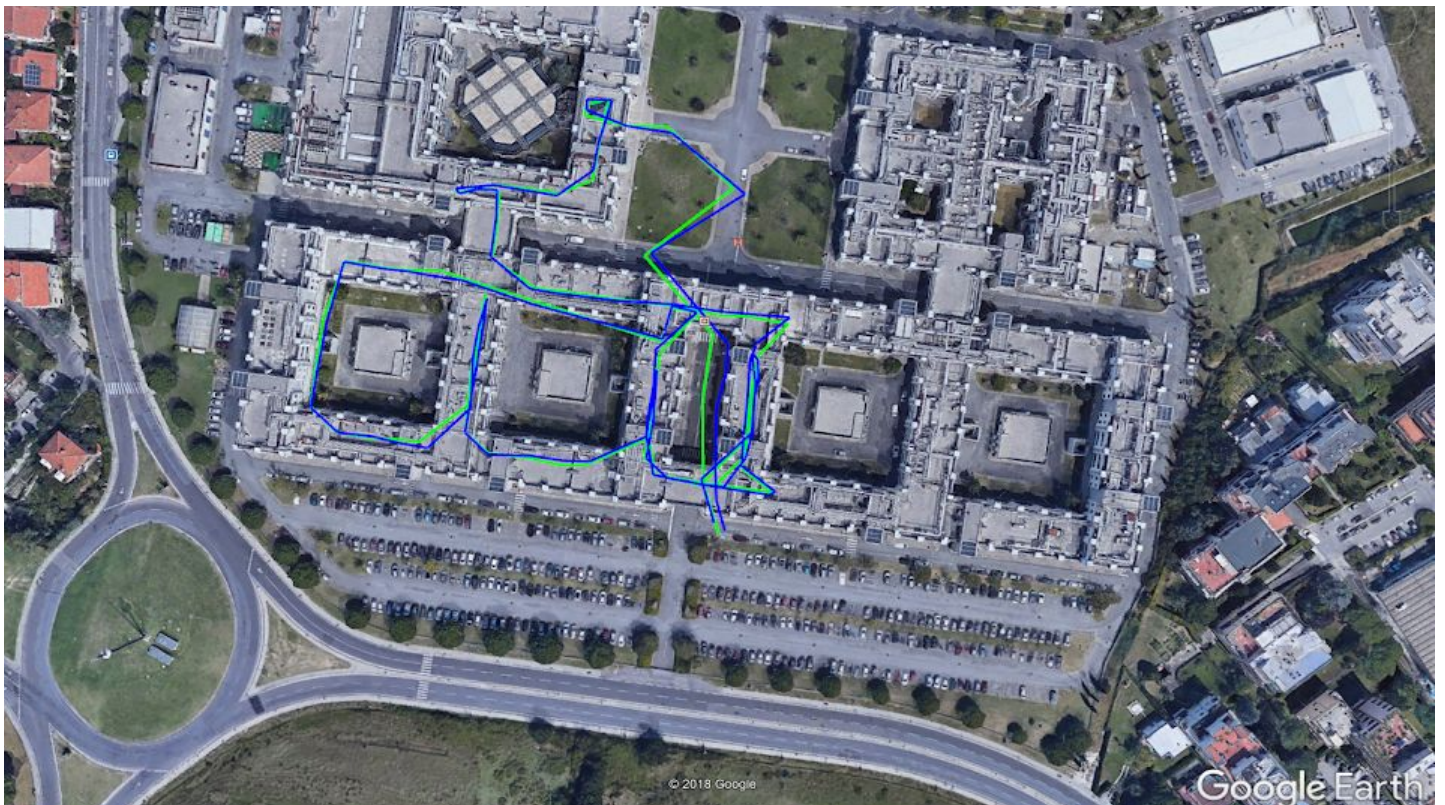
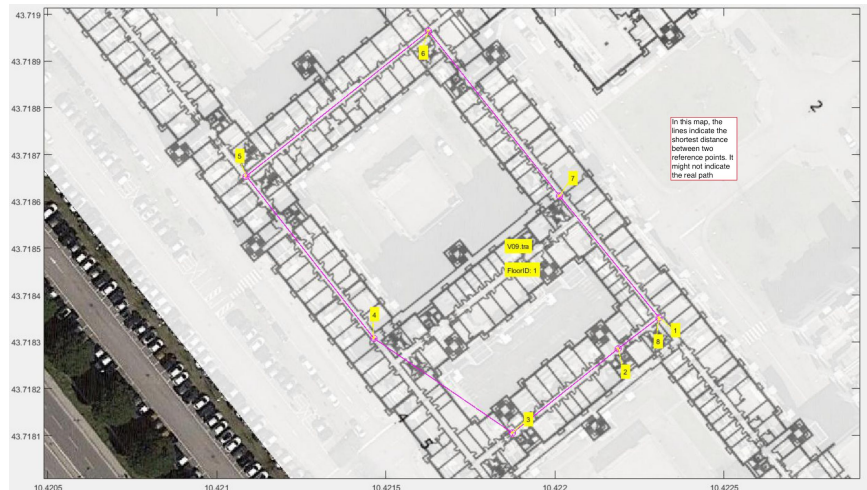
IPIN Competition Track 3

Features 2019



IPIN Competition Track 3

Features 2019



Outline

Introduction

IPIN Competition - Track 3

How to plan a data collection

Hands-on

Checking-data

How to Contribute

How to plan a data collection

We need:

1. A environment with a geo-reference map
2. A list of visiting landmarks
3. A list of training, validation and test routes
4. A phone & App to store sensor data (logfile creation)
5. Tools to visualize and check
6. Tools to do performance evaluation



How to plan a data collection

The GetSensorData App:

- Main screen shows different sensor available:

Green: Sensor detected

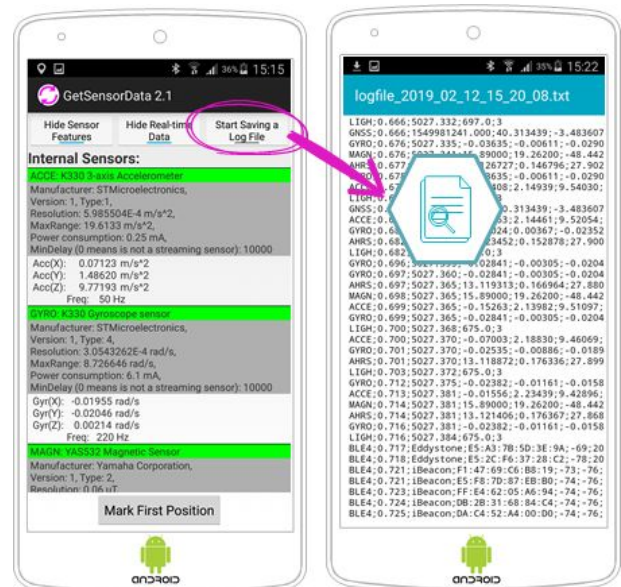
Red: Not available/connected



How to plan a data collection

The **GetSensorData** App:

- Saving a Logfile
 - Common format, which is independent of sensor type
 - Different sampling rates
 - Different accuracies



How to plan a data collection

Logfile data format (1/2):

	WIFI: the RSS (in dBm) received from a particular AP				
	<table border="1"> <tr> <td>Format</td> <td>WIFI:AppTimestamp(s);SensorTimeStamp(s);Name_SSID;MAC_BSSID;Frequency(Hz);RSS(dBm)</td> </tr> <tr> <td>Example</td> <td>WIFI:1.184;130.671;eduroam;00:0b:86:27:3f:b0;2472;-91</td> </tr> </table>	Format	WIFI:AppTimestamp(s);SensorTimeStamp(s);Name_SSID;MAC_BSSID;Frequency(Hz);RSS(dBm)	Example	WIFI:1.184;130.671;eduroam;00:0b:86:27:3f:b0;2472;-91
Format	WIFI:AppTimestamp(s);SensorTimeStamp(s);Name_SSID;MAC_BSSID;Frequency(Hz);RSS(dBm)				
Example	WIFI:1.184;130.671;eduroam;00:0b:86:27:3f:b0;2472;-91				
	MAGN: the local magnetic field, as measured by the 3-axis magnetometer in the phone				
	<table border="1"> <tr> <td>Format</td> <td>MAGN:AppTimestamp(s);SensorTimeStamp(s);Mag_X(uT);Mag_Y(uT);Mag_Z(uT);Accuracy(integer)</td> </tr> <tr> <td>Example</td> <td>MAGN:0.035;8902.708;-20.70000;-34.02000;-19.20000;3</td> </tr> </table>	Format	MAGN:AppTimestamp(s);SensorTimeStamp(s);Mag_X(uT);Mag_Y(uT);Mag_Z(uT);Accuracy(integer)	Example	MAGN:0.035;8902.708;-20.70000;-34.02000;-19.20000;3
Format	MAGN:AppTimestamp(s);SensorTimeStamp(s);Mag_X(uT);Mag_Y(uT);Mag_Z(uT);Accuracy(integer)				
Example	MAGN:0.035;8902.708;-20.70000;-34.02000;-19.20000;3				
	ACCE: the phone's acceleration, as measured by the 3-axis accelerometers in the phone				
	<table border="1"> <tr> <td>Format</td> <td>ACCE:AppTimestamp(s);SensorTS(s);Acc_X(m/s^2);Acc_Y(m/s^2);Acc_Z(m/s^2);Accuracy(integer)</td> </tr> <tr> <td>Example</td> <td>ACCE:0.034;8902.708;-1.80044;6.41646;7.17303;3</td> </tr> </table>	Format	ACCE:AppTimestamp(s);SensorTS(s);Acc_X(m/s^2);Acc_Y(m/s^2);Acc_Z(m/s^2);Accuracy(integer)	Example	ACCE:0.034;8902.708;-1.80044;6.41646;7.17303;3
Format	ACCE:AppTimestamp(s);SensorTS(s);Acc_X(m/s^2);Acc_Y(m/s^2);Acc_Z(m/s^2);Accuracy(integer)				
Example	ACCE:0.034;8902.708;-1.80044;6.41646;7.17303;3				
	GYRO: measures the phone's rotation, using the 3-axis orthogonal gyroscopes in the phone				
	<table border="1"> <tr> <td>Format</td> <td>GYRO:AppTimestamp(s);SensorTimeStamp(s);Gyr_X(rad/s);Gyr_Y(rad/s);Gyr_Z(rad/s);Accuracy(int.)</td> </tr> <tr> <td>Example</td> <td>GYRO:0.032;8902.705;-0.22846;-0.21930;-0.05498;3</td> </tr> </table>	Format	GYRO:AppTimestamp(s);SensorTimeStamp(s);Gyr_X(rad/s);Gyr_Y(rad/s);Gyr_Z(rad/s);Accuracy(int.)	Example	GYRO:0.032;8902.705;-0.22846;-0.21930;-0.05498;3
Format	GYRO:AppTimestamp(s);SensorTimeStamp(s);Gyr_X(rad/s);Gyr_Y(rad/s);Gyr_Z(rad/s);Accuracy(int.)				
Example	GYRO:0.032;8902.705;-0.22846;-0.21930;-0.05498;3				
	PRES: the atmospheric pressure				
	<table border="1"> <tr> <td>Format</td> <td>PRES:AppTimestamp(s);SensorTimeStamp(s);Pres(mbar);Accuracy(integer)</td> </tr> <tr> <td>Example</td> <td>PRES:0.038;8902.726;956.4289;0</td> </tr> </table>	Format	PRES:AppTimestamp(s);SensorTimeStamp(s);Pres(mbar);Accuracy(integer)	Example	PRES:0.038;8902.726;956.4289;0
Format	PRES:AppTimestamp(s);SensorTimeStamp(s);Pres(mbar);Accuracy(integer)				
Example	PRES:0.038;8902.726;956.4289;0				
	LIGH: for light intensity in Luxes				
	<table border="1"> <tr> <td>Format</td> <td>LIGH:AppTimestamp(s);SensorTimeStamp(s);Light(lux);Accuracy(integer)</td> </tr> <tr> <td>Example</td> <td>LIGH:0.032;8902.693;292.0;0</td> </tr> </table>	Format	LIGH:AppTimestamp(s);SensorTimeStamp(s);Light(lux);Accuracy(integer)	Example	LIGH:0.032;8902.693;292.0;0
Format	LIGH:AppTimestamp(s);SensorTimeStamp(s);Light(lux);Accuracy(integer)				
Example	LIGH:0.032;8902.693;292.0;0				

https://developer.android.com/guide/topics/sensors/sensors_overview#java

How to plan a data collection

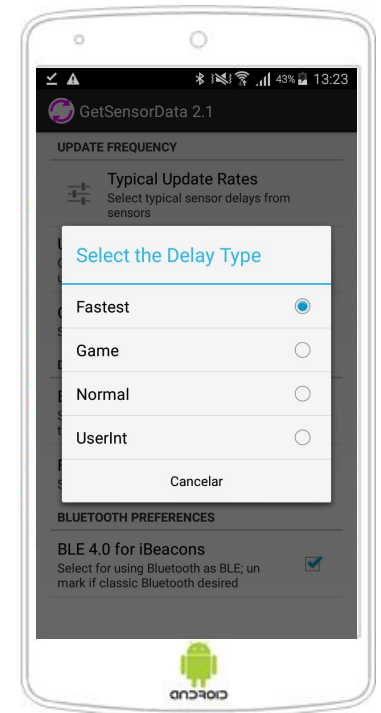
Logfile data format (2/2):

	SOUN: the sound pressure level in dB
	Format <code>SOUN:AppTimestamp(s):RMS:Pressure(Pa):SPL(dB)</code>
	Example <code>SOUN:0.248:594.57:0.01815:59.15</code>
	TEMP: the temperature in degrees Celsius
	Format <code>TEMP:AppTimestamp(s):SensorTimestamp(s):temp(°C):Accuracy(integer)</code>
	Example <code>TEMP:0.505:134.194:26.9:1</code>
	PROX: Proximity
	Format <code>PROX:AppTimestamp(s):SensorTimestamp(s):prox(1/0):Accuracy(integer)</code>
	Example
	HUMI: Humidity
	Format <code>HUMI:AppTimestamp(s):SensorTimestamp(s):humi(%):Accuracy(integer)</code>
	Example <code>HUMI:0.501:134.194:47.0:1</code>
	GNSS: the Latitude, Longitude and Height estimated from GPS/Glonass
	Format <code>GNSS:AppTimestamp(s):Latit(°):Long(°):Altitude(m):Bearing(°):Accuracy(m):Speed(m/s);UTCTime(ms):SatInView:SatInUse</code>
	Example <code>GNSS:0.611:40.313524;-3.483137:600.865:0.000:4.0:0.0:1358782729999;17,15</code>
	AHRS: the mobile phone 3D orientation in terms of pitch, roll and yaw
	Format <code>AHRS:AppTs(s):SensorTs(s):Pitch(X(°)):Roll(Y(°)):Yaw(Z(°)):RotVecX(I):RotVecY(J):RotVecZ(L):Accuracy(int)</code>
	Example <code>AHRS:0.033:8902.705:41.6550;11.7495;-124.0558;0.25038;-0.26750;-0.80406;-2</code>
	BLE4: Bluetooth Low Energy 4.0 data
	Format <code>iBeacon BLE4:AppTs(s):iBeacon:MAC:RSSI(dBm):Power:MajorID:MinorID:UUID</code>
	Example <code>BLE4:0.183:iBeacon:EA:2E:2A:D0:F5:18:-72:76:2016:9:b9407f30-f5f8-466e-aff9-25556b57fe6d</code>
	Form <code>Eddystone BLE4:AppTimestamp(s):Eddystone:MAC:RSSI(dBm):instanceID:OptionalTelemetry[voltage:temperature:uptime:count]</code>
	Example <code>BLE4:0.362:Eddystone:E5:A3:7B:5D:3E:9A:-82:201600000010:5968.23:0.22424:16687784</code>
	POST: ground-truth position (only in calibration files)
	Format <code>POST:Timestamp(s):Latitude(degrees):Longitude(degrees):floor ID(0,1,2,4):Building ID(0,1,2,3)</code>
	Example <code>POST:0.0330:41.12245678;-3.12355678:2:0</code>

How to plan a data collection

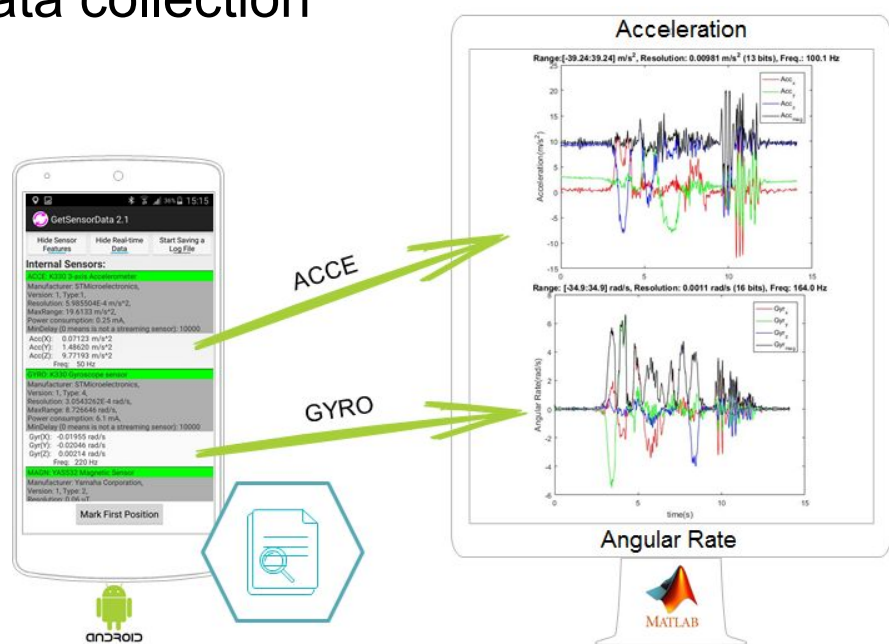
The **GetSensorData** App:

- Select Freq. rate
 - Fastest ~200Hz
 - Game ~100Hz
 - Normal ~50Hz
 - UserInt (Defined by the user)



How to plan a data collection

Parsing logfiles using
Matlab tools:



How to plan a data collection

Parsing logfiles using Matlab tools:

<http://indoorloc.uji.es/ipin2019track3/>

ReadLogFile

Competition LogFiles

How to plan a data collection

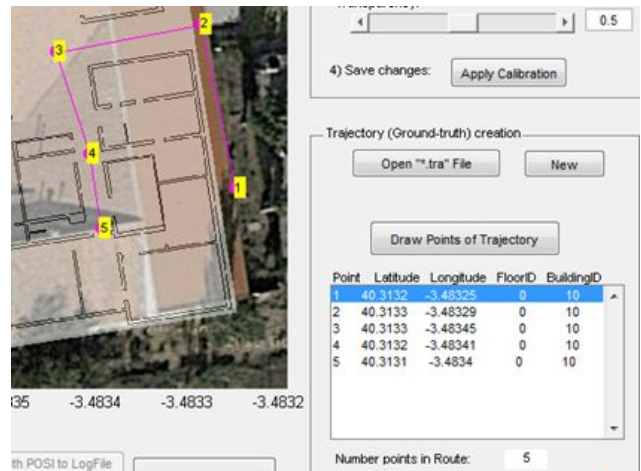
GUI for Ground-Truth definition & map calibr.:

- CAD maps are not usually georeferenced
- Graphical tool ('GUI_maps.m' Matlab) to:
 - 3. Geo-reference indoor maps of a building (several bitmaps for each different floor),
 - 4. Add sequences of points of ground-truth (GT) marks,
 - 5. Manipulate the sensorial LogFiles created with the "GetSensorData" app to fill the ground-truth 'POSI' marks



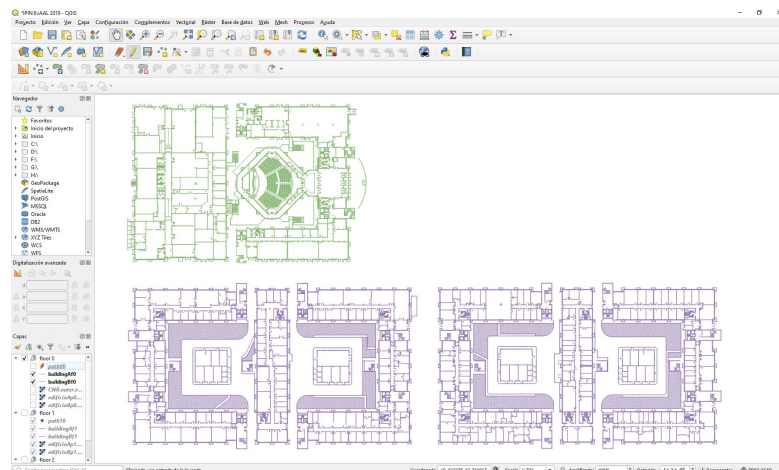
How to plan a data collection

- GT creation:
 - Insert list of ground-truth (GT) geo-referenced points
 - In a *.tra file
 - Modify/Insert/Delete
- POSI marks:
 - Assign GT trajectory as "POSI" lines in Logfile
 - Example:
'POSI; 30.341; 1; 40.31347091; -3.48315; 0; 10'



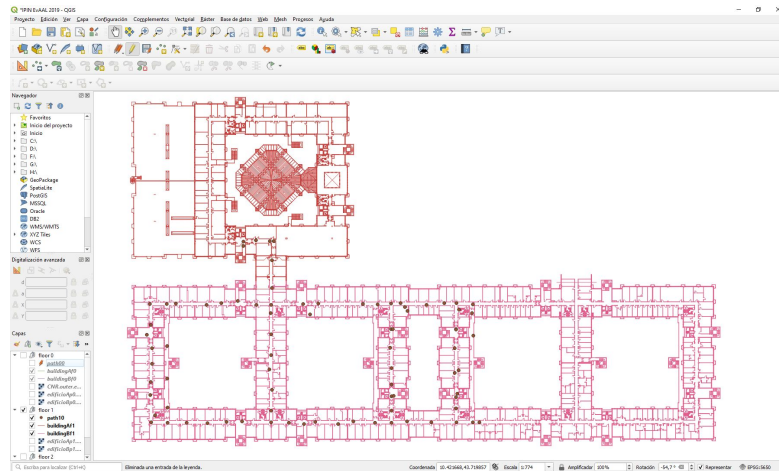
How to plan a data collection

- GT creation



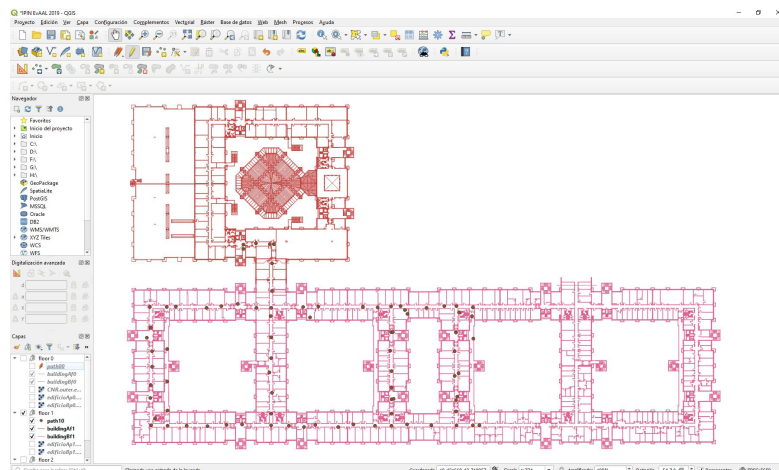
How to plan a data collection

- GT creation



How to plan a data collection

- GT creation

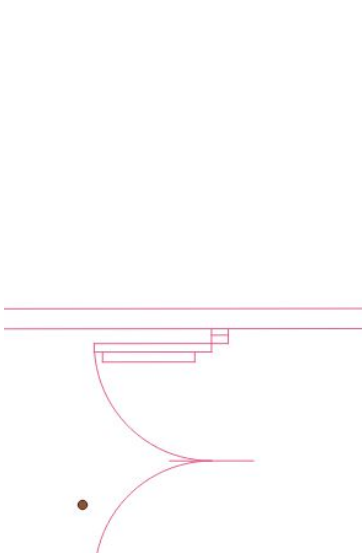


Export as WGS84,...

**You might have point
IDs that not to real IDs**

How to plan a data collection

- GT creation



Objeto espacial	Valor
path10	
Titulo	156
(Derivado)	
(coordenada X pinchada)	10.422319
(coordenada Y pinchada)	43.718274
ID de objeto	71
X	10.422319
Y	43.718275
(Acciones)	
id	156

10.4221019058735,43.7184139081452,"156"

10.4221236205715,43.7183955551767,"105"

10.4223193571129,43.7182747405179,"156"

10.4221295777743,43.71824083875,"155"

10.4221289000847,43.7182964201592,"154"

10.4221273695526,43.7182957480335,"193"

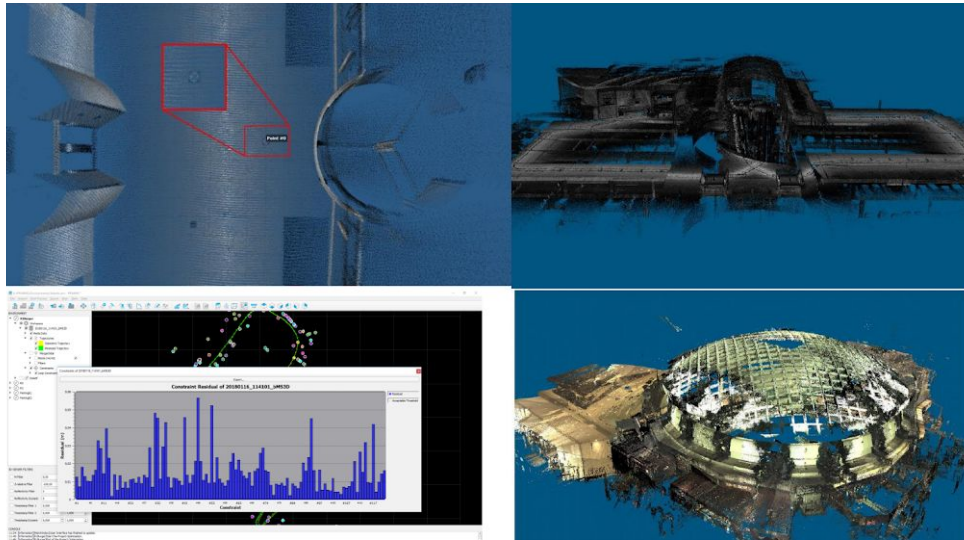
How to plan a data collection

- GT creation



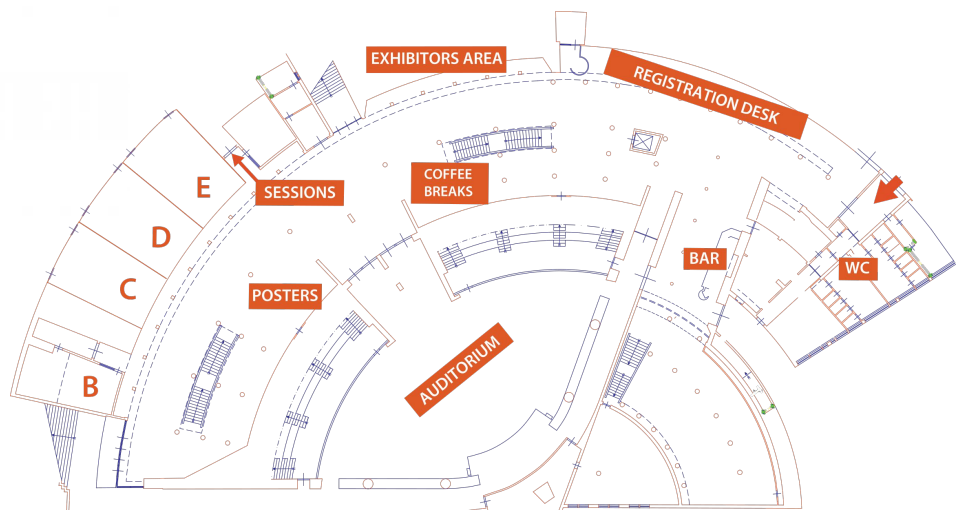
How to plan a data collection

- GT creation



How to plan a data collection

- GT creation



How to plan a data collection

- GT creation

There are many different ways!
Please, choose the most convenient

How to plan a data collection

Before collecting data

- Select representative point for reference and evaluation on the map
- Add a sticker next to the real point
- Document all reference points
 - Printed and Digital documents per point
 - Point identifier
 - Description of the location (e.g. main corridor, in front of Pot's office)
 - Detailed description
 - Picture
 - Approximate position on a floor plan
 - Pictures



How to plan a data collection

While collecting data

- Work in teams of, at least, two people: the data collector and the logger
- The data collector must annotate beforehand the sequence of points to visit and walk on the path to memorize the location of the reference points and their sequence
- The logger has to guide the data collector and independently check the sequence of points visited.
- An additional third actor should record a video of the collection procedure



Outline

Introduction

IPIN Competition - Track 3

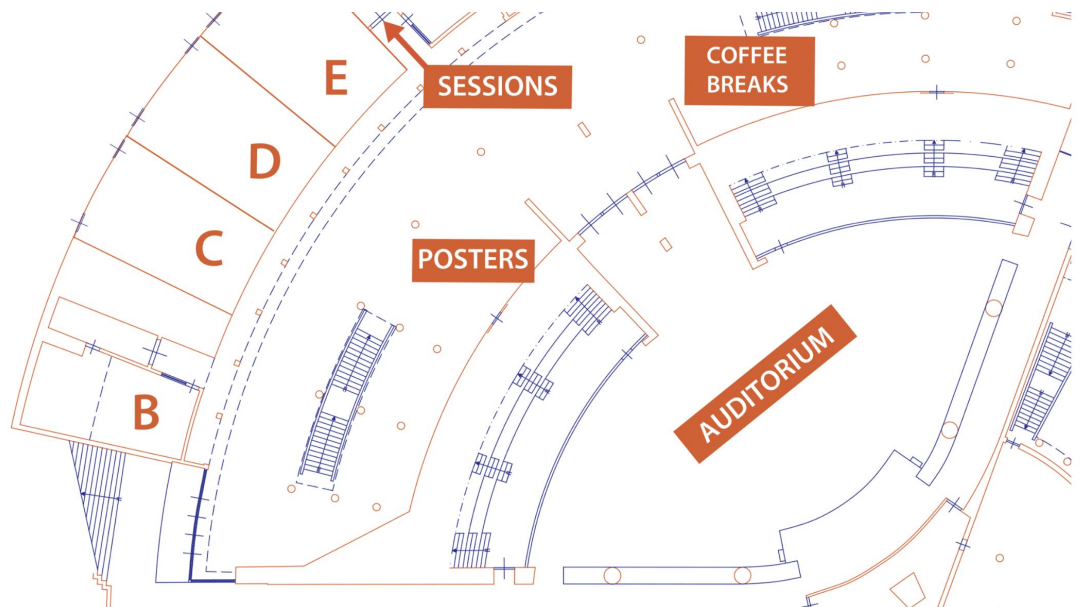
How to plan a data collection

Hands-on

Checking-data

How to Contribute

Hands on



How to plan a data collection

Before collecting data

- Select representative point for reference and evaluation on the map
- Add a sticker next to the real point
- Document all reference points
 - Printed and Digital documents per point
 - Point identifier
 - Description of the location (e.g. main corridor, in front of Pot's office)
 - Detailed description
 - Picture
 - Approximate position on a floor plan
 - Pictures



Outline

Introduction

IPIN Competition - Track 3

How to plan a data collection

Hands-on

Checking-data

How to Contribute

Checking data

email data to:

aperezn@uoc.edu

jtorres@uji.es

Outline

Introduction

IPIN Competition - Track 3

How to plan a data collection

Hands-on

Checking-data

How to Contribute

How to contribute

Participate in Competitions:

▶ Track 3 - 'Smartphone based Positioning (offsite)'



How to contribute

Participate in Competitions:



How to contribute

Participate in Competitions:

IPIN2021 in

BARCELONA



How to contribute

- Future improvements in Android & Matlab suite:
 - Contribute in Gitlab public repository to improve the Android and Matlab tools, or replicate for iPhone:
<https://gitlab.com/getsensordatasuite>
 - Add Raw GNSS measurements to the logfiles (GRAW header):
<https://developer.android.com/guide/topics/sensors/gnss>



How to contribute

- Create your own database
 - Use your facilities to provide new scenarios
 - Use multiple heterogeneous devices to collect data
 - Consider different occupancy levels
 - Add challenges: stairs, elevators, ...