ETAI – AI Foundation

More precise indoor navigation: Deep Learning-based approach

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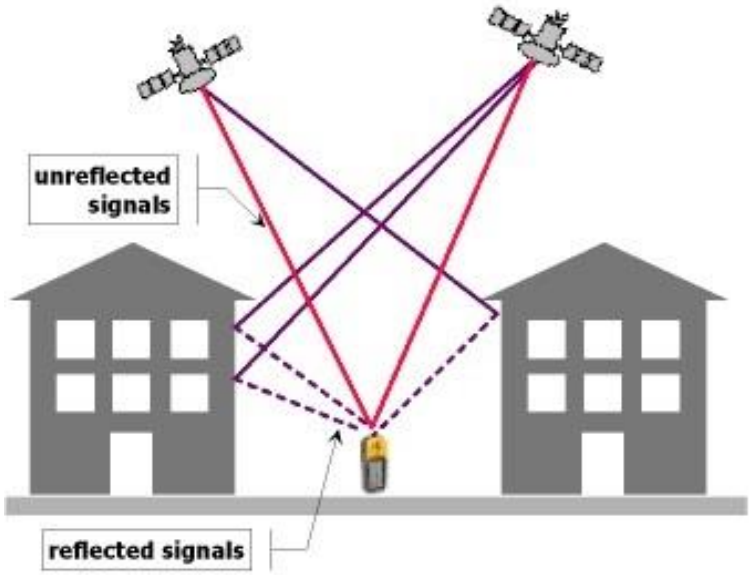
Indoor Positioning System (IPS)

Background

Indoor Positioning System (IPS)

Challenges



- Standards:

  "No unified standard exists for designing localization and proximity techniques" [1]

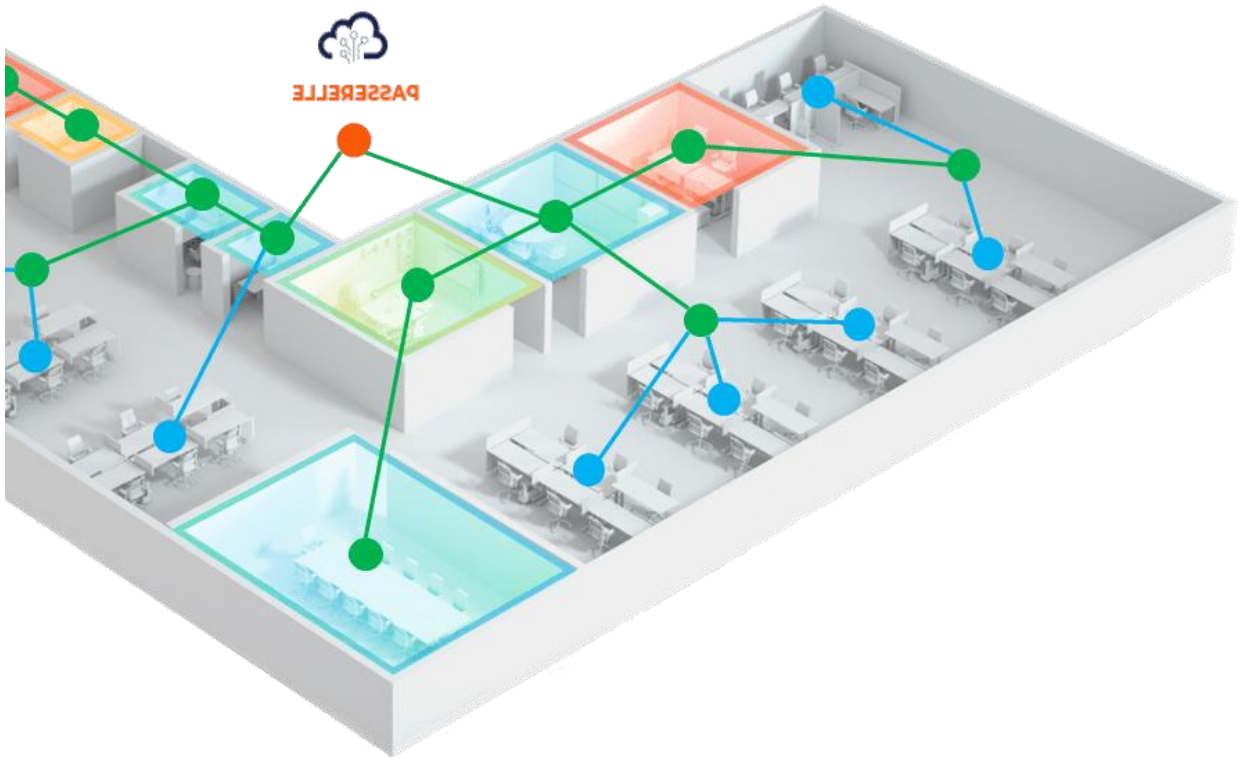
- Precision :

  Precision: Every indoor localization technology faces inherent limitations.

[1] Zafari, F.; Gkelias, A.; Leung, K. A Survey of Indoor Localization Systems and Technologies. IEEE Commun. Surv. Tutor. 2019, 21, 2568-2599.

Indoor Positioning System (IPS)

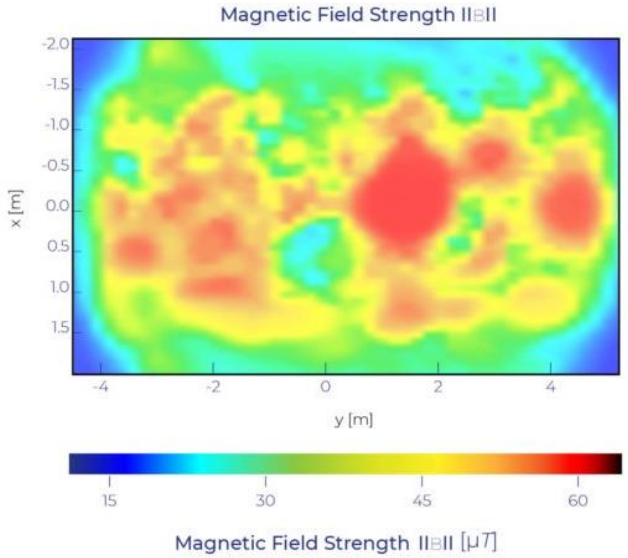
Approaches



Indoor Positioning System (IPS)

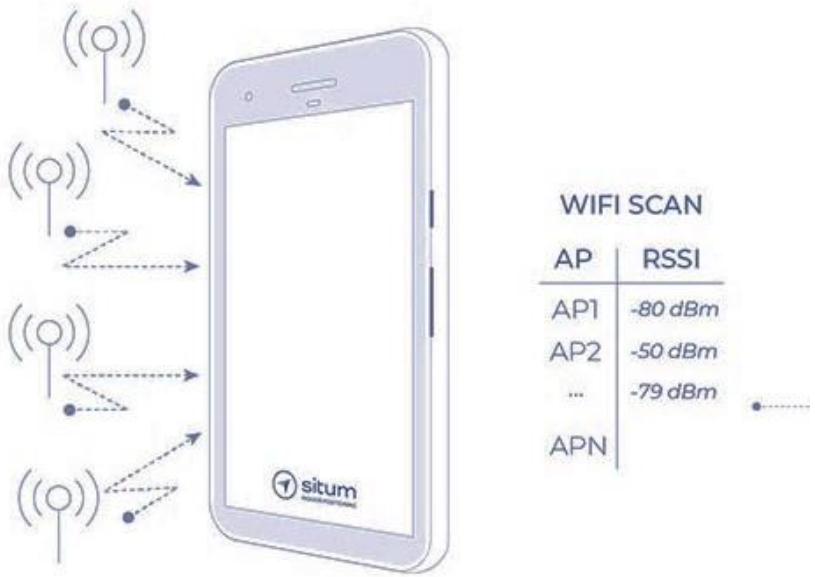
Technologies Utilized

- **GeoMagnetic field measurement (μT)**

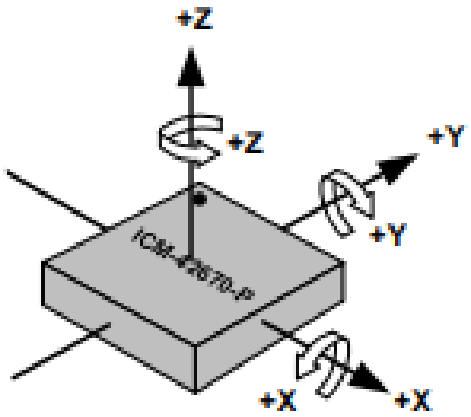


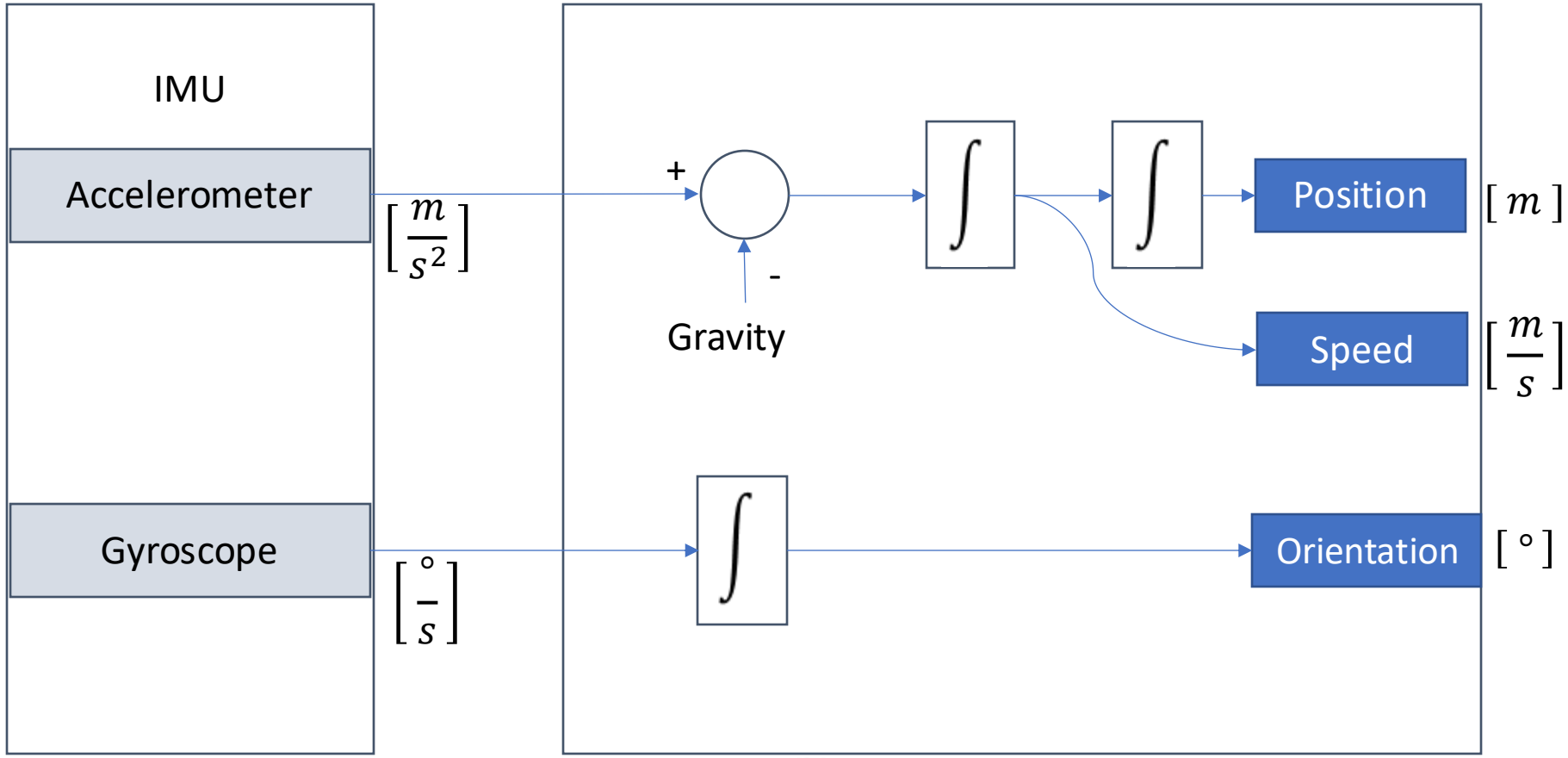
- **Wi-Fi :**

- **Received Signal Strength Indicator (RSSI):**
  - Measure of the sxtrength of the radio signal received by the device from an access point (AP) in dBm.



- **Inertial measurement unit (IMU) :**

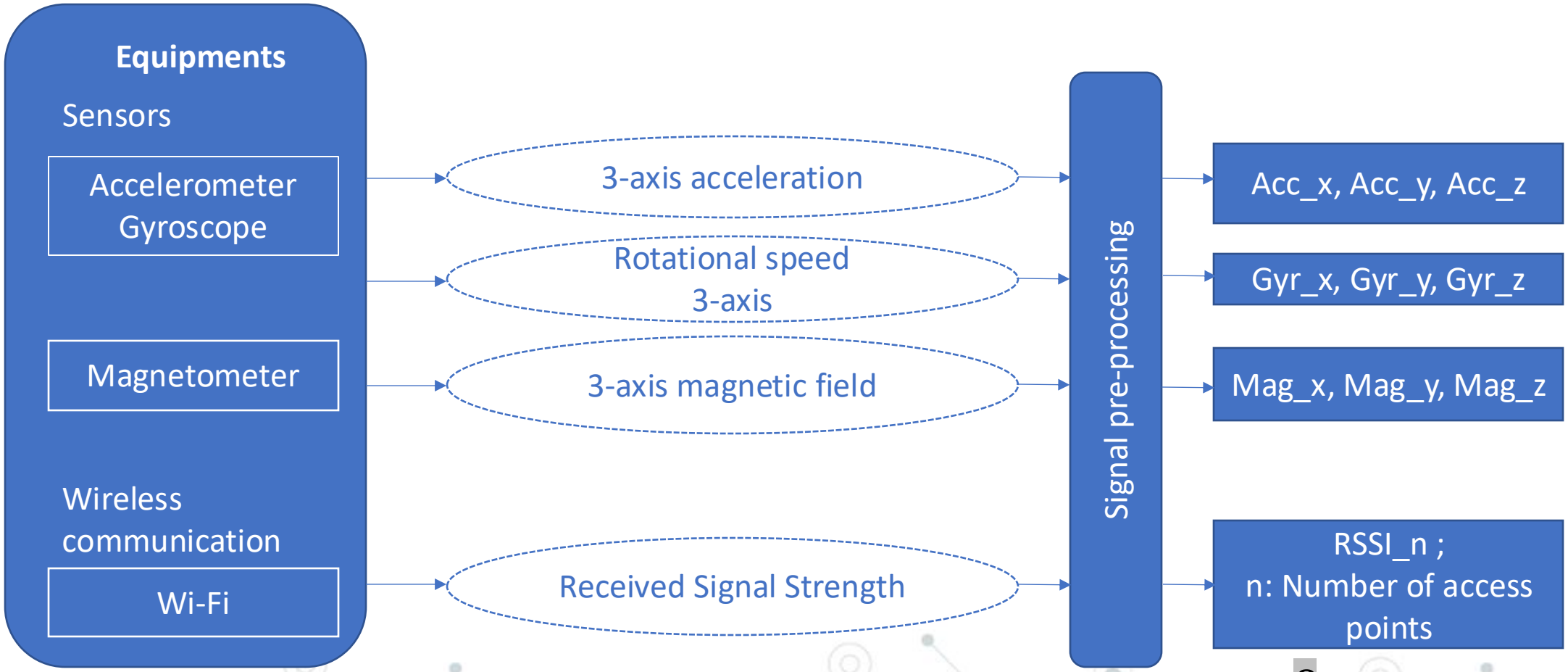




Technologies Utilized

- **a) Technologies :**
  - Geomagnetic field
  - IMU
  - Wi-Fi
- **b) Techniques :**
  - Supervised / unsupervised model ?
  - ML / DL ?
  - Regression / Classification / Clustering ?

- **Overall system architecture :**



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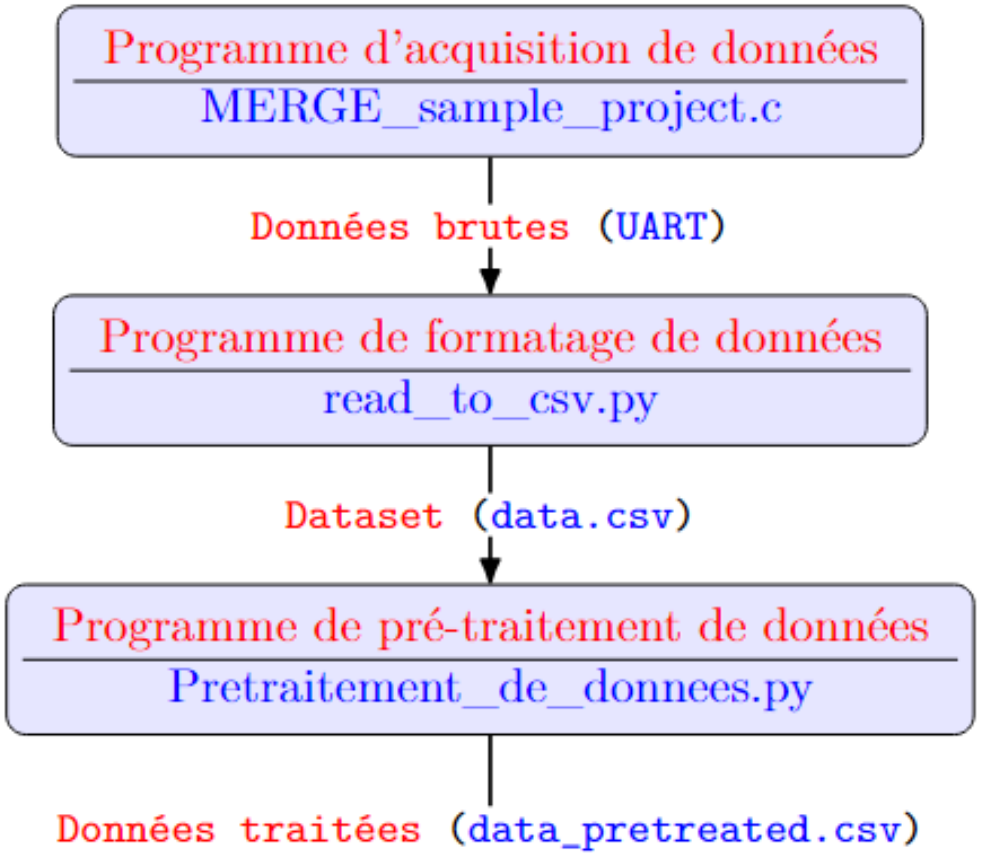
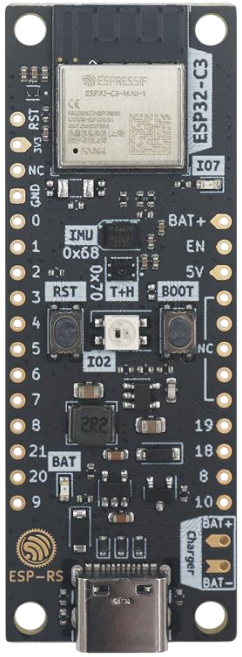
Background

- **Programs developed :**



- **Devices used :**

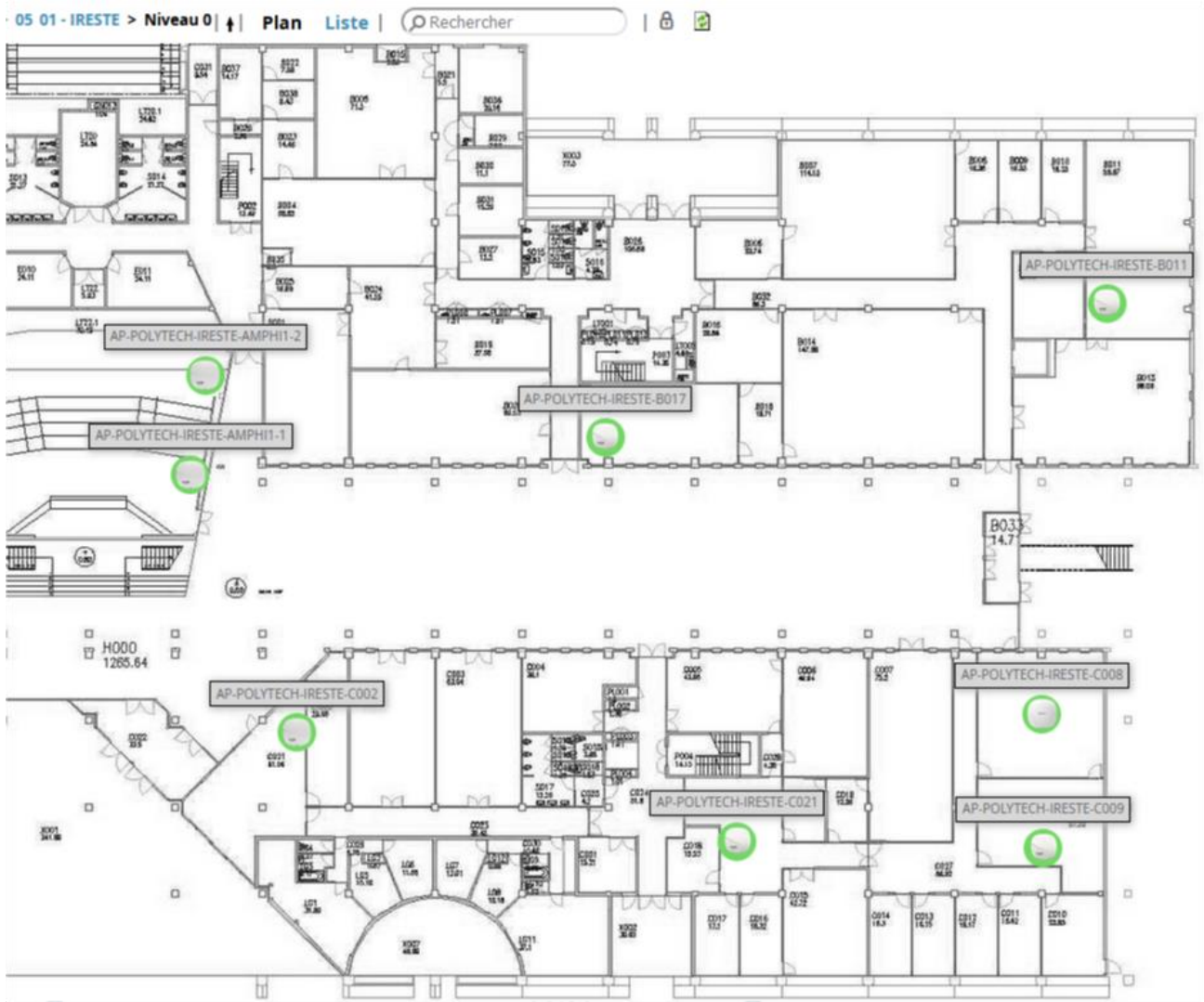


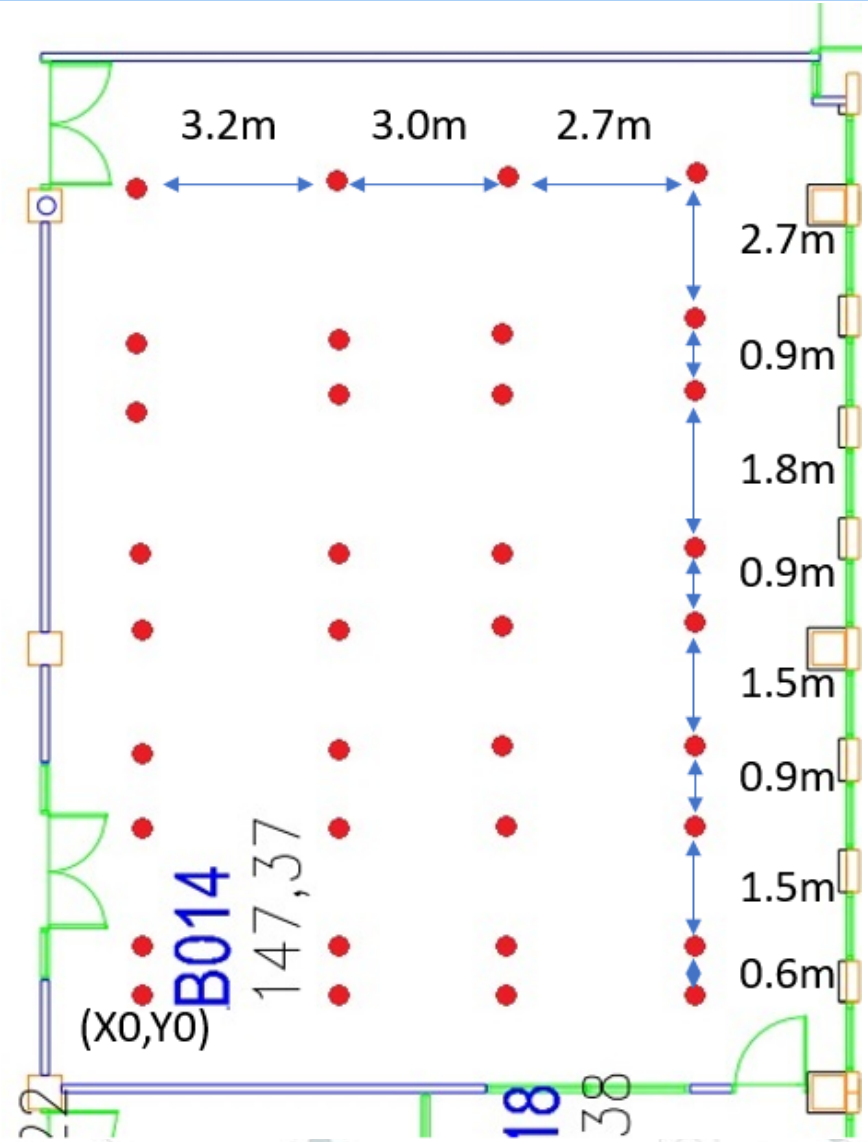
ESP32-C3 microcontroller

Samsung A70

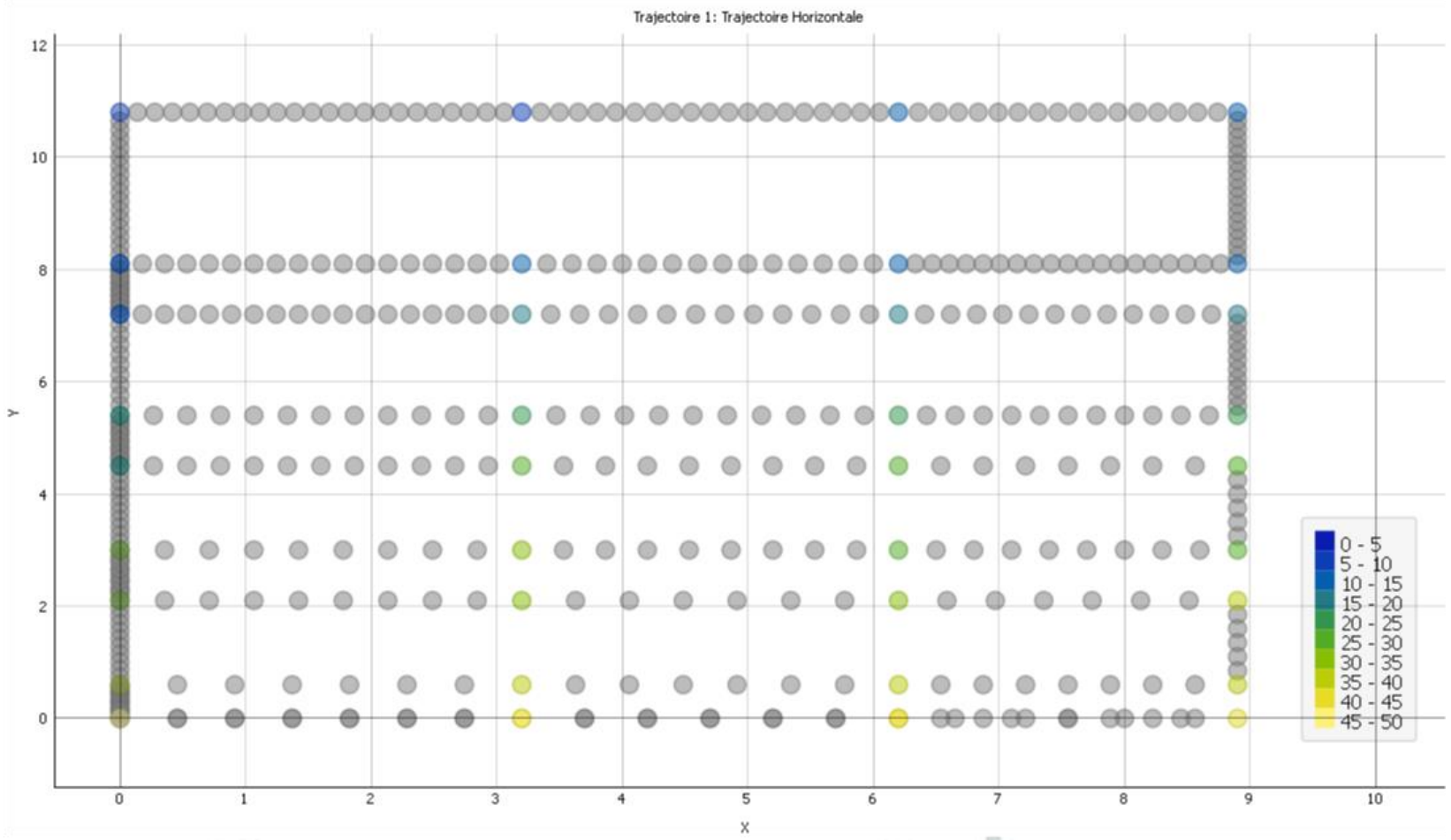
Indoor Positioning System (IPS)

Experimentations

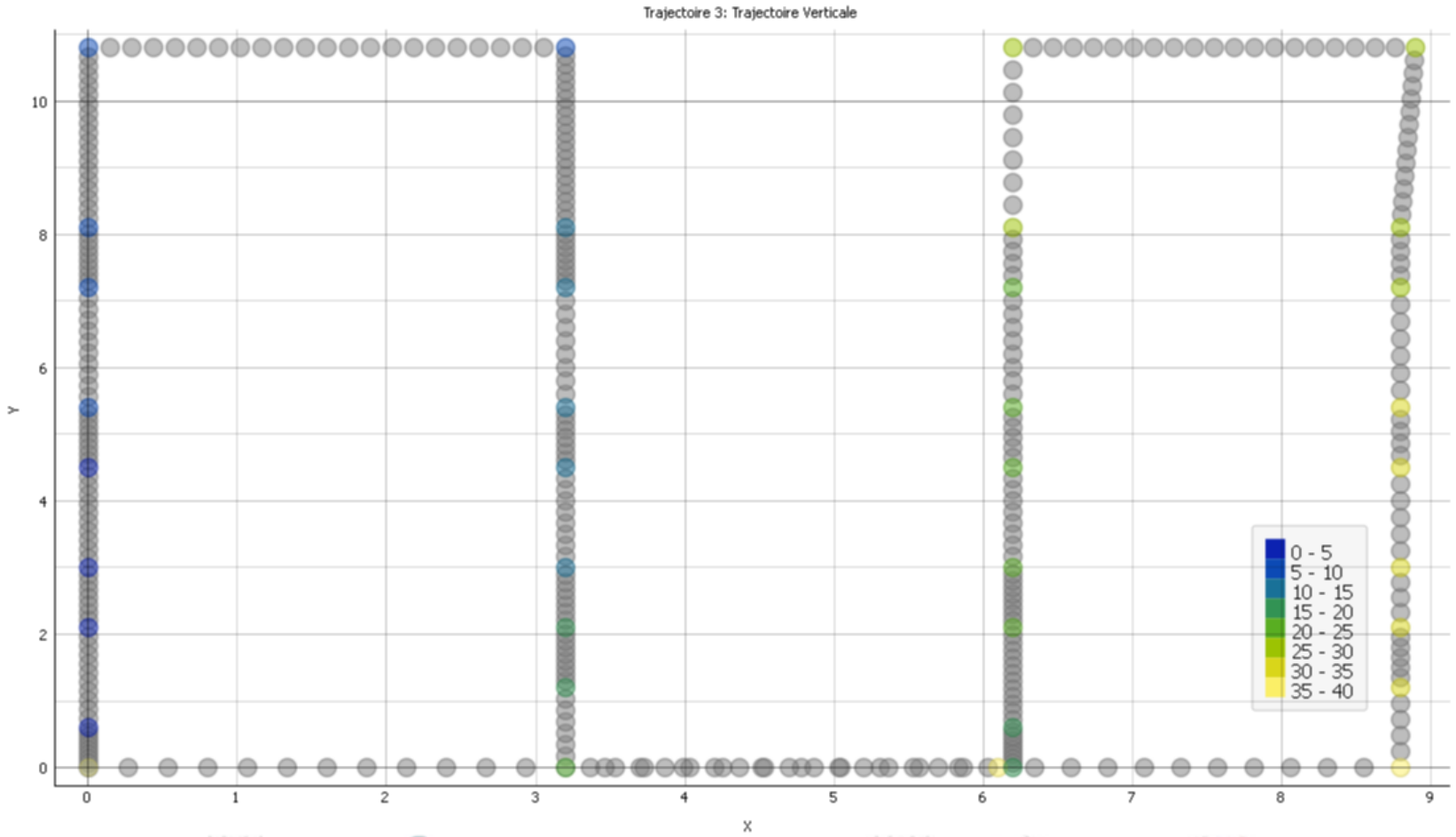




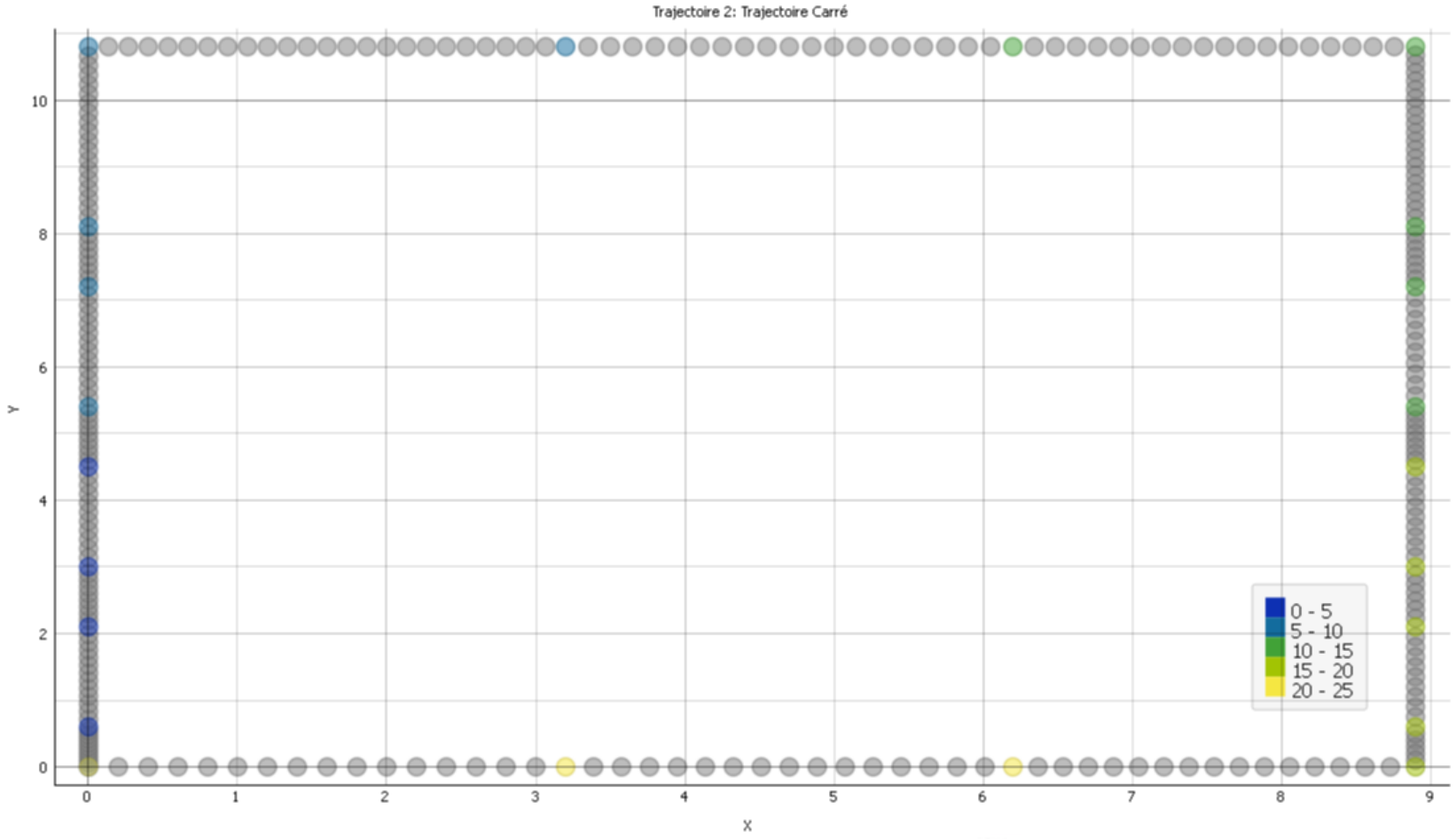
Path 1: Horizontal



Path 2: Vertical



Path 3: Square



Structure: X rows × 30 columns

Features:

1.Index: A unique identifier for each row in the dataset.

2.Timestamp: The time of measurement, recorded as a string (e.g., 02:25:31:93).

3.RefP: A reference point value; (e.g., stationary points in the environment).

4.X, Y: Positional coordinates; most entries are missing (NaN). To be filled

5.AccelX, AccelY, AccelZ:

- Readings from the accelerometer in the X, Y, and Z axes, representing linear acceleration in these directions.

6.GyroX, GyroY, GyroZ:

- Readings from the gyroscope in the X, Y, and Z axes, representing angular velocity in these directions.

7.MagnetoX, MagnetoY, MagnetoZ:

- Readings from the magnetometer in the X, Y, and Z axes, representing magnetic field strength in these directions.

8.WiFi Signal Features (Columns 14–37):

- Detected WiFi networks or access points, each column corresponding to a specific network identified by a name or MAC address (e.g., eduroam_c8:b5:ad:f3:69:c0, etn-scm-iot_b8:27:eb:29:0f:19, etc.).
- These features may represent signal strength, connection status, or other related metrics.

Indoor Positioning System (IPS) Project

Objective:

Develop a AI-based localization system capable of predicting positions (X, Y) based on sensors and WiFi signals data.

Instructions:

Step 1: Dataset Exploration

- Load and examine the dataset.
- Visualize the features (e.g., AccelX, GyroY) to understand their distributions and relationships.
- Investigate missing values, focusing on X and Y where RefP is missing.

Step 2: Data Preprocessing

- **Label Missing X, Y Values:**
  - Use interpolation or modeling to estimate positions for rows where RefP is not set.
  - Incorporate sensor data (acceleration, gyroscope, etc.) and WiFi signal strength as inputs for position labeling.

Instructions:

Step 3: Model Development

• Design a DNN architecture with:

- Input: Sensor features (AccelX, GyroY, etc.) and WiFi signal strengths.
- Output: Predicted positions (X, Y).

•Experiment with hyperparameters like the number of layers, neurons, and activation functions.

Step 4: Training and Validation

• Split the dataset into:

- Training set: For model fitting.
- Validation set: For hyperparameter tuning.
- Testing set: For final performance evaluation.

• Define and use a loss function and optimizer and train the model.

• Regularly evaluate performance using Mean Absolute Error (MAE).

Step 5: Evaluation and Reporting

- **Visualizations:**
  - Plot predicted vs. actual positions (X, Y).
  - Analyze error distributions to identify patterns.

Deliverables:

1. Analysis Report:

- Dataset exploration results.
- Steps taken for preprocessing and labeling missing data.

2. DNN Model:

- Code and documentation for the localization system.

3. Evaluation Results:

- Performance metrics (MAE).
- Visualizations comparing predicted and actual positions.

4. Conclusion:

- Discussion on system performance and possible enhancements.

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Dataset Overview

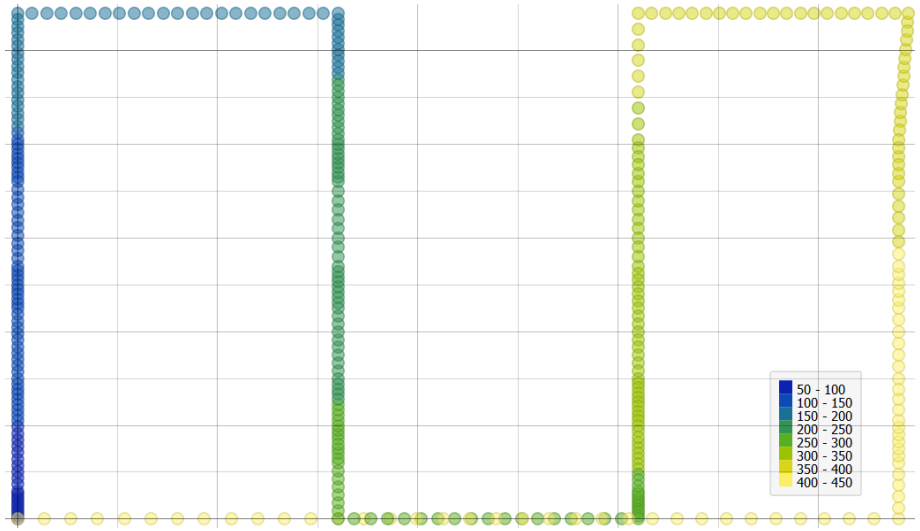
- **Structure:** X rows × 30 columns
- **Key Columns:**
  - *Index:* Row identifier.
  - *Timestamp*: Time of data collection.
  - *RefP*: Reference points (e.g., stationary points in the environment).
  - *X*, *Y*: Positional coordinates.
  - *AccelX*, *AccelY*, *AccelZ*: Acceleration in X, Y, Z axes.
  - *GyroX*, *GyroY*, *GyroZ*: Angular velocity in X, Y, Z axes.
  - *MagnetoX*, *MagnetoY*, *MagnetoZ*: Magnetic field strength in X, Y, Z axes.
  - *WiFi Signal Strength* Columns (e.g., eduroam_*, TP-Link_*, etc.): Indicate signal strength for various networks.

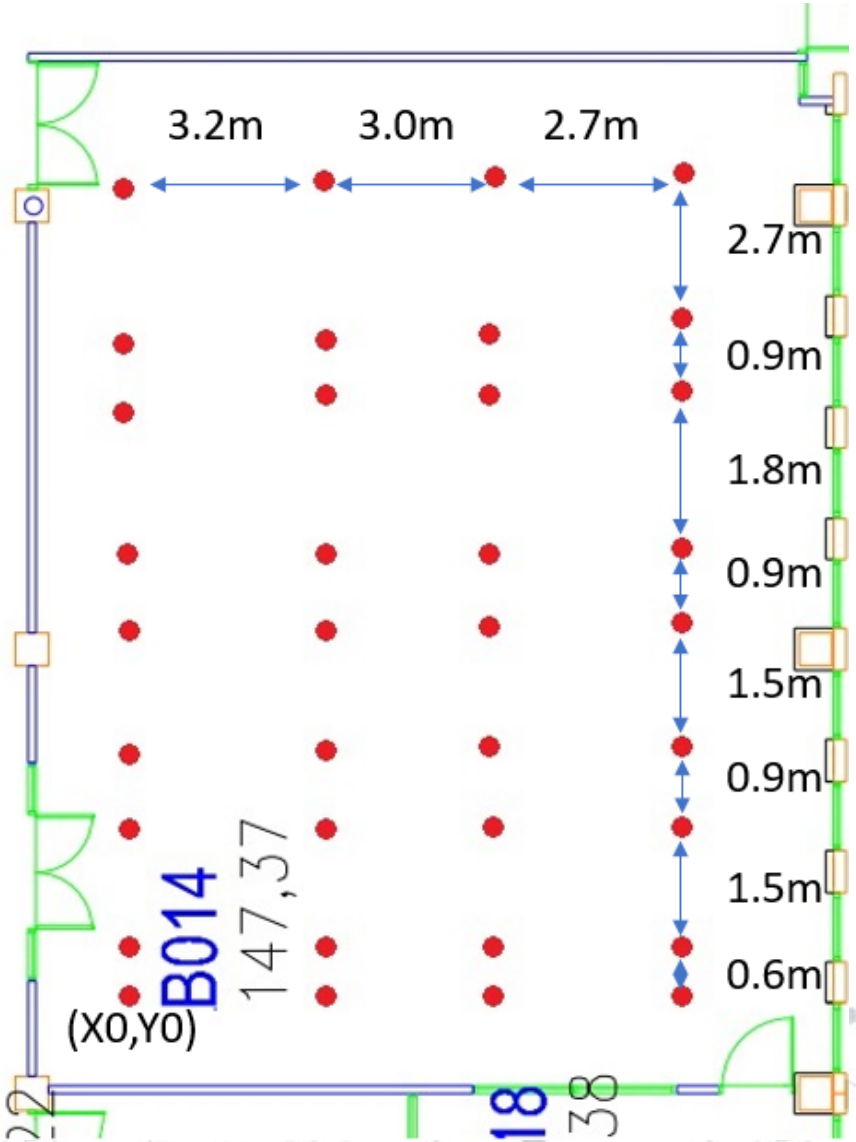
Introduction

TO DO

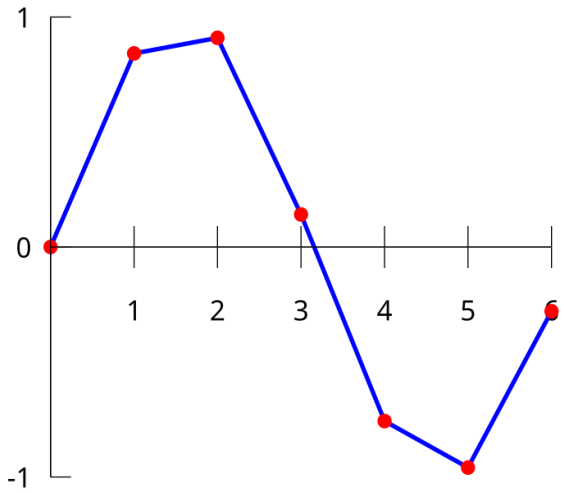
- **1 : Labelling:**

Trajectoire : Verticale





- **Labelling:**
  - **Assigns specific labels or information to a dataset.**
  - **Coordinate labeling by Linear Interpolation**



Caractéristiques du modèle LSTM proposée	
Entrées	Magnétomètre, IMU, RSSI, coordonnées antérieures
Sorties	Coordonnées actuelles
Nombre de couches cachées	3
Nombres des unités par cachées	192 / 128 / 64
Optimisateur	Adam
Evaluation	MSE
Taille de la fenêtre	W = 3
Nombres des répétitions	5
Nombres des datasets	4