WHITE PAPER

People tracking and navigation

nextome

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Introduction

In Nextome Research, we have developed the most innovative Indoor Positioning and Navigation System with great field proven disruptive technology and patented in US/Europe/Singapore/Dubai IP (WO/2015/049660).

The innovative algorithms of **Nextome technology use advanced Artificial Intelligence (AI) techniques to receive, categorize, and analyse signals to identify the user's position in indoor area. Nextome technology is based on iBeacon or Eddystone Beacon compatible hardware indoors and GPS outdoors.** The solution is compatible with all kinds of smartphones, either iOS or Android, provided with Bluetooth® Low Energy (BLE) telecommunication technology.

At the same time, Nextome proposes a **fingerprinting-free solution**, with localization algorithms running locally, inside the smartphone, without making a continuous polling to a remote web server. As a matter of fact, Nextome technology does not require an Internet connection, thus making the indoor navigation possible even in those buildings that are not served with a backbone connection (Wi-Fi, Ethernet and/or cellular). As a such, no delays can be caused by a slow connection or by an excessive workload on the server side.

Practically speaking, fingerprinting is the most expensive phase for large indoor positioning projects. For the sake of clarity, mapping a 100.000 square meters building could be really demanding, since measuring Radio Frequency signals every second while moving with a one meter pace, will lead to a 2000000 measurements for a 20 seconds period. This implies 23148 days of full-time work without stops on a daily base (i.e., 24 hours). And this process must be repeated each time there are changes in walls or big furniture inside the environment.
In Nextome this time is 0.

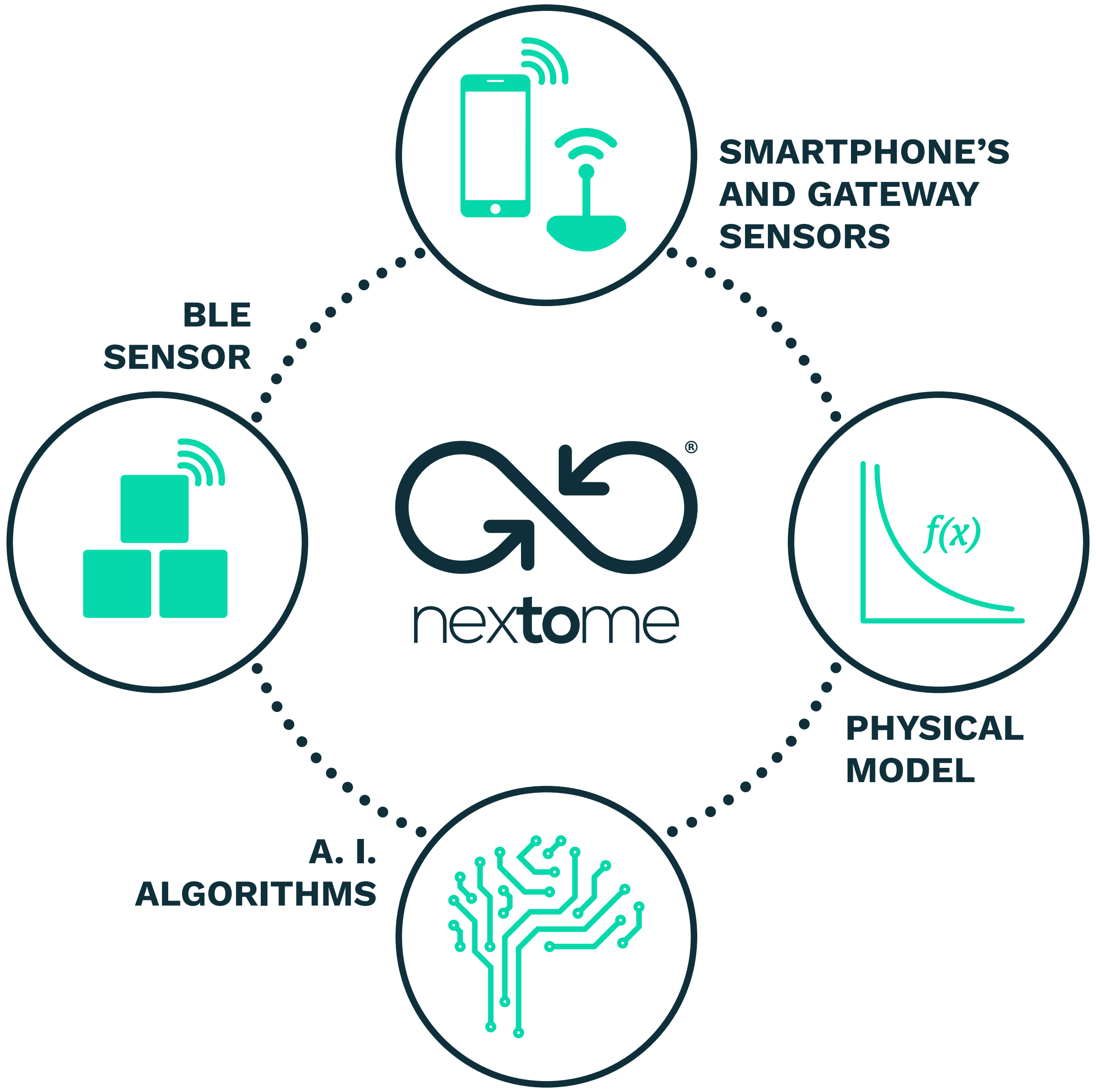


***Figure 1**: Nextome Technology.*

Nextome technology is the state of art technology in indoor positioning as reported by most important experts on indoor positioning: **Grizzly Analytics**[1], **GPS Business News**[2], and **ABI Research**[3].

Nextome solution has a proven accuracy[4] in the range from 0.8 meter to 1.5 meter and we have often reached up to 0.5 meter of error in field pilots when a larger number of beacons are deployed.

Every time a user moves from indoors to outdoors and vice versa, the system chooses whether to use Nextome technology or GPS thanks to its seamless indoor/outdoor positioning: an automatic switching Nextome/Google Maps is provided, so it is not needed to open a second App. Nextome is the unique solution for indoor positioning to guarantee this functionality to date.

In addition, Nextome guarantees:

- **unlimited scalability because of the whole computation of the position is made on the smartphone making it possible to use Nextome also offline.**
- **easy configuration thanks to its advanced configuration system that allows users to load low-detail map, and the algorithm automatically detects walls, rooms, pillars, and furnishings, as well as not accessible areas by identifying different colours and borders.**

Indoor localization and navigation to points of interest are guaranteed functions even without an internet connection. In cases where mobile phones are connected to an internet network, it is possible to store the positions anonymously and perform post-hoc analysis on the data through multiple intelligent business dashboards.

1 *http://www.grizzlyanalytics.com*
2 *http://www.gpsbusinessnews.com/Nextome-Bluetooth®-Indoor-Location-Made-in-Italy_a5322.html*
3 *https://www.abiresearch.com*
4 *https://opusresearch.net/wordpress/2015/06/11/place-conference-new-york-2015-agenda-presentations/*

The Technology

Reference Architecture

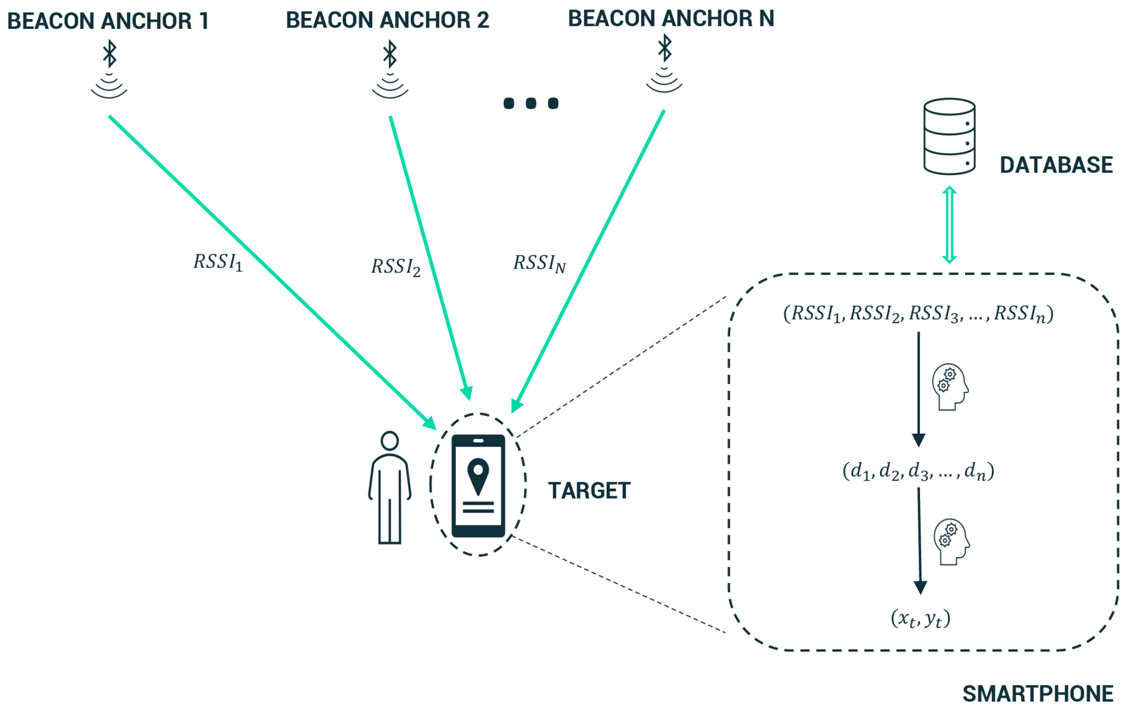


Figure 2*: Overview of the reference architecture.*

Figure 2 depicts the reference architecture of the Nextome technology. Nextome technology is based on the iteration between a certain number of Beacons, which work as transmitter sensors, and the smartphone on which the Nextome application is installed. The position of the smartphone is the target position to be calculated.

The **Beacon transmitter sensors** are installed in the indoor environment and **create a network of reference points** on which the calculation of the target position is based. These beacons, also referred to as anchors, transmit Bluetooth® signals which are detected by the smartphone scanner, to further process them. **The Nextome application is installed on the smartphone that you want to track**, and uses the set of detections of the signal transmitted by the Beacon to calculate:

- **The structure inside which the mobile phone is present.**
- **The floor of the structure in which the mobile phone is present.**
- **The room inside the floor.**
- **The coordinates (x, y) of the position are expressed in pixels on the map file.**

If the smartphone is equipped with an Internet connection, and the user requests it, the positions can be saved on the database to allow subsequent analysis. Gathered data are anonymized according to privacy regulations.
It is possible to have access to the database through dedicated API calls.

A focus on hardware

One of the advantages of Nextome technology is that it is standard-compliant, and it is not vendor-dependent. Therefore, the system will be set up and running with Beacons that are compliant with Bluetooth® Low Energy (BLE) v4.1, or newer. According to the reference market, we are currently employing Blueup BlueBeacon Maxi, or similar.

The choice is motivated by the compliance to the standard, since they work in the ISM 2.4 GHz band, between 2.402 and 2.480 GHz, and they integrate a Nordic nRF51822 System on Chip (SoC). One of the most interesting features that motivates the choice among the competitors is battery life. To create a long-lasting and reliable deployment of our technology, the power supply that makes the Beacons operate must be extended. These Beacons are supplied by 2xAA LR6 alkaline (2800 mAh capacity @ 25°C) batteries. On these bases, a dedicated fine tuning of parameters setting (e.g., advertising interval, TX Power) can prologue **lifetime from 9-10 months up to 3 years**.

As anticipated, Nextome technology relies on smartphones for position calculation. It is, hence, mandatory to use a BLE-compliant smartphone that must be enhanced with a dedicated app, currently available for both Android and iOS.

The elaborating platform

The architecture of the elaborating platform is depicted in the scheme presented in ***Figure 3***. In what follows, the characteristics and roles of the various components are explored. All the parts and functionalities herein described concern the scope of the 'smartphone localization' document. All other features that belong to the asset tracking technology are omitted and will be detailed in a specific document.

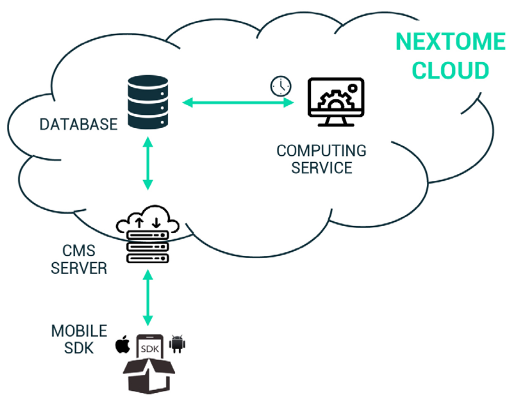


Figure 3*: Elaborating platform.*

The mobile SDK consists of a software library that can be integrated into third-party applications. It is used to detect the Bluetooth® signals coming from the anchor Beacons and uses them to calculate the position of the smartphone. The calculated position can be shown on the screen of the smartphone or, if specifically required, it can be stored in the database. In the latter specific case, the SDK sends the following information to the CMS Server: localized Smartphone ID, calculated position, timestamp.

Inside the SDK: a focus on algorithms

Nextome is the fusion of different patented and patent pending technologies created by Nextome research.

Novel localization methodology called MLV3 includes the following proprietary keys of innovation:

- **The innovative non-linear filtering technique of the Receive Signal Strength Indicator (RSSI)** limits the “multipath fading effect” by removing the non-linear noise caused by Bluetooth® signals bouncing on the walls, floor, furniture, and people moving around. In this way, it is possible to calculate the right location by using an advanced machine learning approach relying only on the true signals. This algorithm solves the theoretical problem in Non-Line of Sight (NLoS) condition. In the following pictures, the effect of our nonlinear filter for multipath mitigation in action is shown.

  The true signal is extracted by exploding the noisy signal in (theoretically) infinite dimensions and capturing only those dimensions that behave better in capturing the true signal, lowering noise.

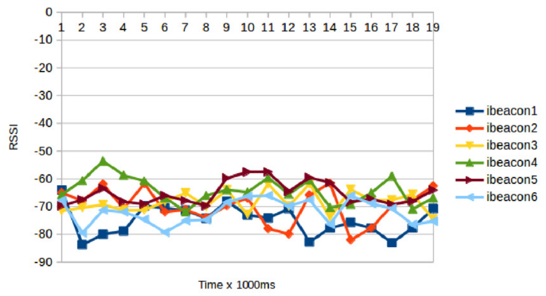


__Figure 4__: Unfiltered Signal coming from 6 iBeacons

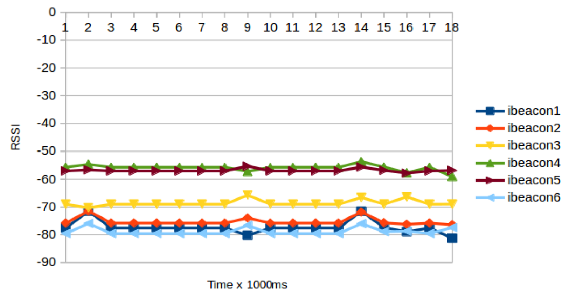


__Figure 5__: Filtered Signal coming from 6 iBeacons using MLV3

- The calculation of the coordinates of the target point is, hence, reduced to the resolution of a **weighted problem of non-linear least-squares optimization**, which derives from multilateration techniques in place of fingerprinting.

- An intelligent inertial step recognition algorithm, called **IntelliWalk**, is capable of understanding when and where the user is moving, the step size, the orientation, and the motion model of the user while walking, taking advantage of accelerometers, magnetometers, gyroscopes, and compass onboard the smartphone. The algorithm is continuously trained on the user’s steps.

- **Particle filtering approach (Sequential Montecarlo Filtering)** together with map constraints; in this way, the user will never be positioned in an unreachable zone and whatever error will be automatically corrected while the user is walking, also saving energy and battery on the Smartphone.

The **CMS Server** manages the system resources and exposes the APIs to operate on different data. Its presence is, therefore, necessary to allow the interaction between smartphones and the database. It takes care of storing data on the database every time the mobile SDK requests to save the calculated position of the smartphone. Data (e.g., localized Smartphone ID, calculated position, timestamp) are then stored in the relevant tables within the database. The CMS also allows the exchange of information, where necessary, between smartphone and database, such as in the case of the coordinates of the reference anchors mentioned above.

The **database hosts** the input tables and the output tables of the localization algorithms. An example of output consists of the positions of the Smartphones that auto-locate (if required). Also, the database houses all the information necessary for the calculations such as, for example, the map table, the reference anchor table, and the map subsection table (for example, single rooms).

The **computing service** consists of a server, which is essential for other features relating to the asset tracking technology that is not covered in this document.

Output

Real-time localization and navigation

Nextome technology can be used enabling the log of the positions on the database, or not, depending on the specific needs and peculiarities of the application. In the second case, the following features are allowed:

- **Display of the position on the map** (*Figure 6*) **of the floor of the structure**; the floor and the structure are automatically detected by the application.
- **Coordinates (x, y)** of the position.
- **Association of the calculated position to a specific section of the map**. The sections must be defined in advance and registered in the system. The sections can correspond to physical rooms within the structure or to fictitious areas, functionally defined by the user.
- **Notification** when a person enters/exits in/from certain areas. The areas must be defined in advance. The entry and exit from controlled areas are called 'event'.
- **Dynamic navigation to points of interest**, the suggestion of the route that is automatically updated as you get closer to the destination.

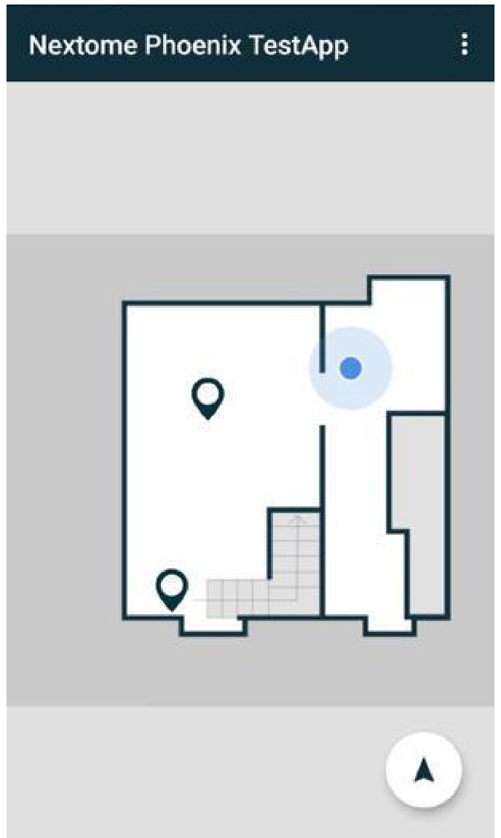


Figure 6*: Visualization of the position on the map.*

Business Intelligence

In case positions are logged, and hence stored on the database, it will be possible to take advantage of intelligent business services to obtain useful information, starting from raw data and supported by **Decision Support System (DSS) services.** The platform can be used in the analysis of phenomena that relate to the tracking of objects (asset tracking) and the tracking of people. This document focuses on the second one, in which the object of the survey are smartphone devices moving within the scenario.

As previously clarified, in addition to the position in coordinates (x, y) it is possible to know the room inside which people are. All sensors and devices present produce data that are collected by different systems depending on which variable is of interest. In the case of People Location applications, the data is collected via smartphone. The data collection and scanning phase is followed by their storage within a dedicated server that communicates with a database to store and historicize information.
The following step is called **ETL**, which stands for Extract, Transform, and Load.

These three distinct phases constitute the data processing process that will allow future analyses.

In particular, the first operation refers to the process of extracting data from the storage source. In this case, the data source is single and is represented by the database, as shown in ***Figure 7***.

In general, data sources are manifold, which means that multiple databases can be working at the same time. Moreover, data are stored within heterogeneous systems, with different representations, such as files in CSV (Comma Separated Values) format, or even unstructured data.
As for the data collection phase, handling unstructured data represents the worst case, even more when data sources are heterogeneous, as well as their organization. In such cases, data are not all structured in the same way, and therefore do not meet the same storage policy. Since in the specific case of interest data belong to a single data source and are stored on a single database, aggregation is not needed. However, the system could manage an increasing amount of heterogeneous data and/or data sources at scale.

The purpose of the transformation phase is to ensure that data have a homogeneous structure, but also to perform calculations on the starting data to **obtain new information**. As an example, the case in which it is not needed to carry out an analysis on the length of the path taken by a person. In this context, a list of positions may not be sufficient, as it could be useful to subdivide the path and create a list of lengths.

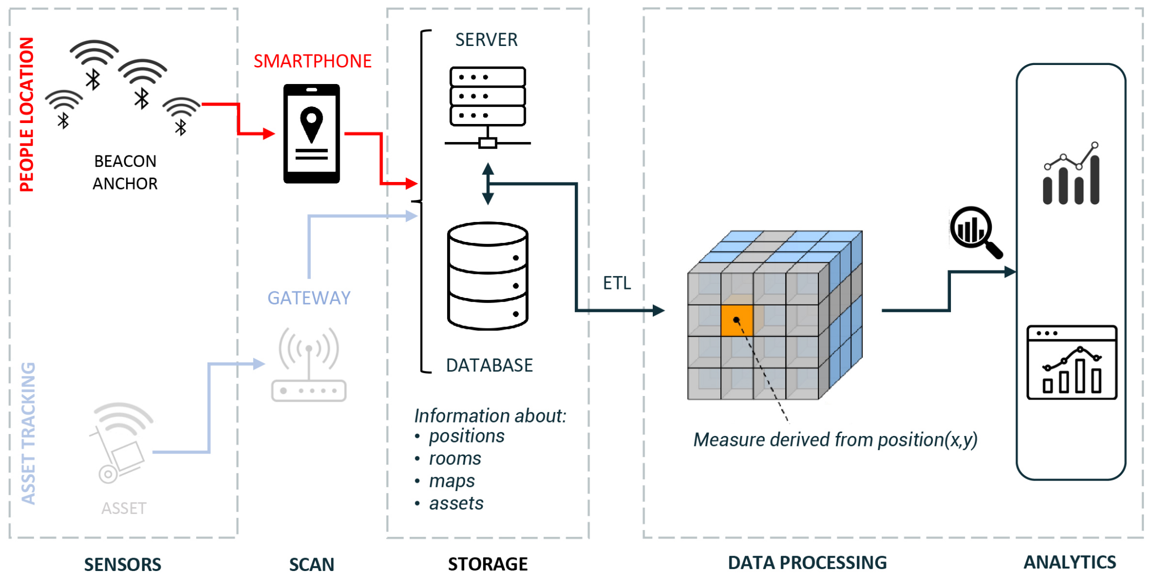


Figure 7*: Business intelligence flow.*

After transforming the data and obtaining all the information necessary for future analyses, the following phase of loading the data within structured objects, such as a star diagram or, in more complex cases, a multidimensional cube.
Once data are structured, complex analysis can be conducted by adopting analytics tools that make it possible to visualize data in various forms, such as, for example, analysis of KPIs (Key Performance Indicators), historicizations, and trends.

A compact representation of the structure of the data, the multidimensional model is reported in Figure 7, where the main **analysis dimensions** are:

- **Time.**
- **The device.**
- **The subdivision of space (maps, plans, rooms).**

The measures are derivatives of the position such as:

- **Number of minutes spent in a given area.**
- **Meters travelled.**
- **Number of devices present.**
- **Average residence time.**

The measures are already available but **can be customized according to specific needs and/or application peculiarities**.

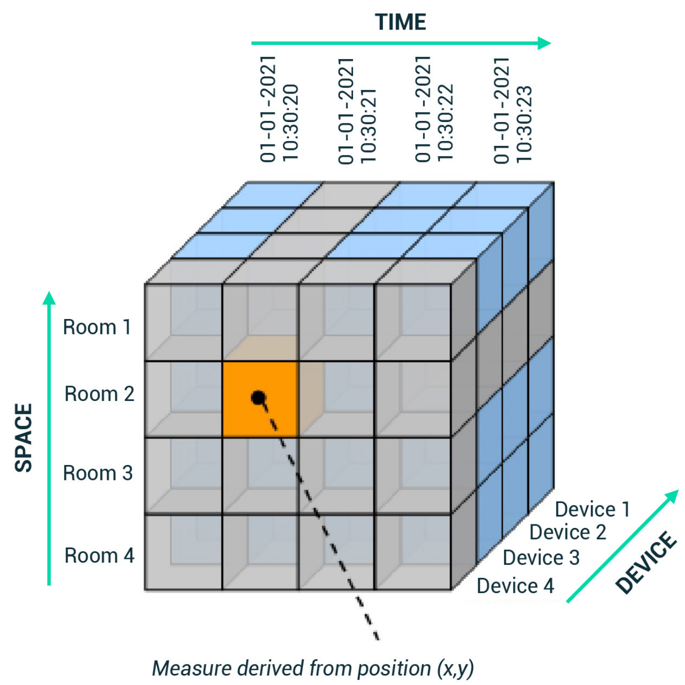


***Figure 8**: Multidimensional cube.*

After choosing the measures of interest and the display methods, as well as the level of interactions with the end user, it is possible to take advantage of dashboards that supports the user in strategic decisions or in monitoring situations of interest.

The following figures show some examples of views present in the dashboards.

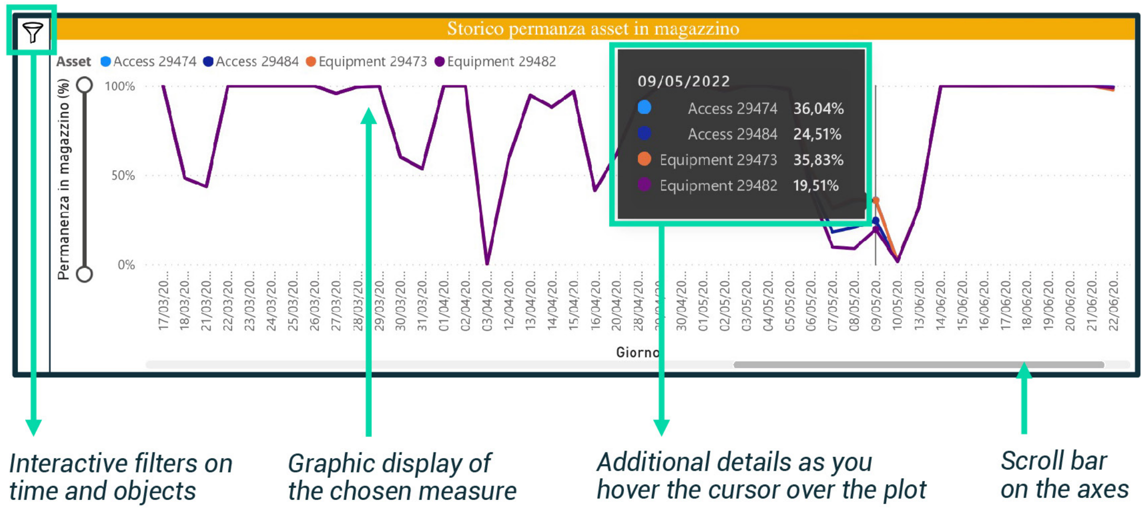


***Figure 9**: Graph representing the percentage of time spent in the warehouse by the different assets.*

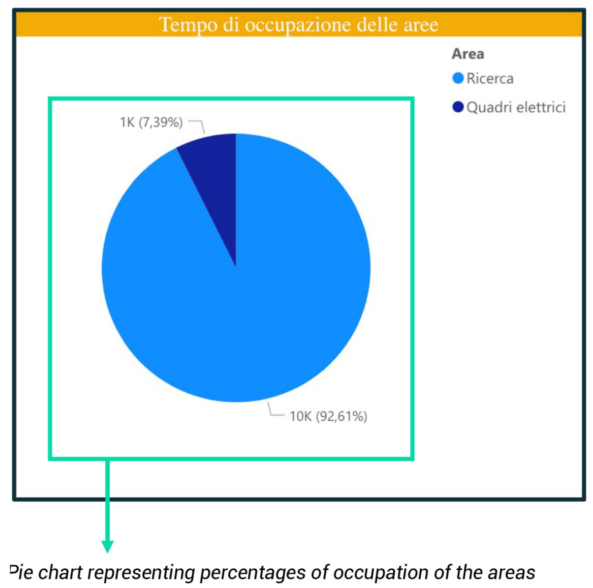
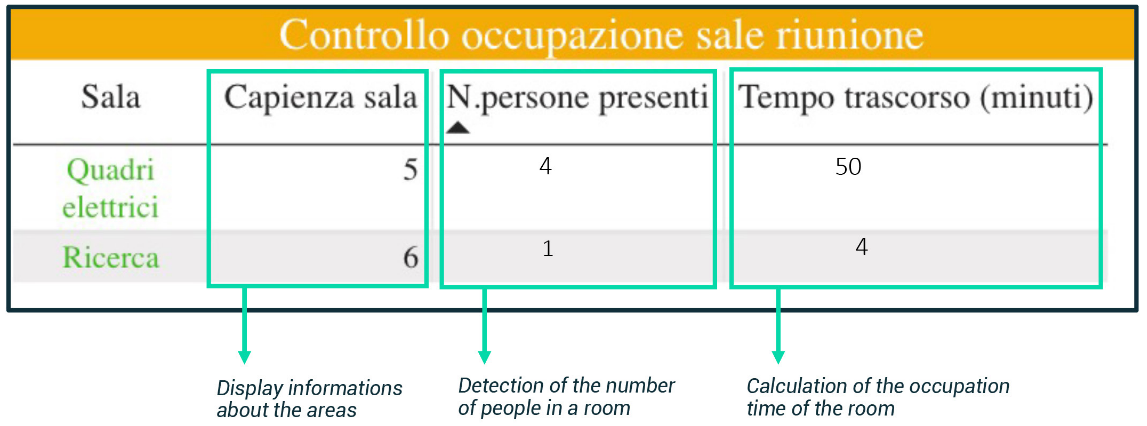
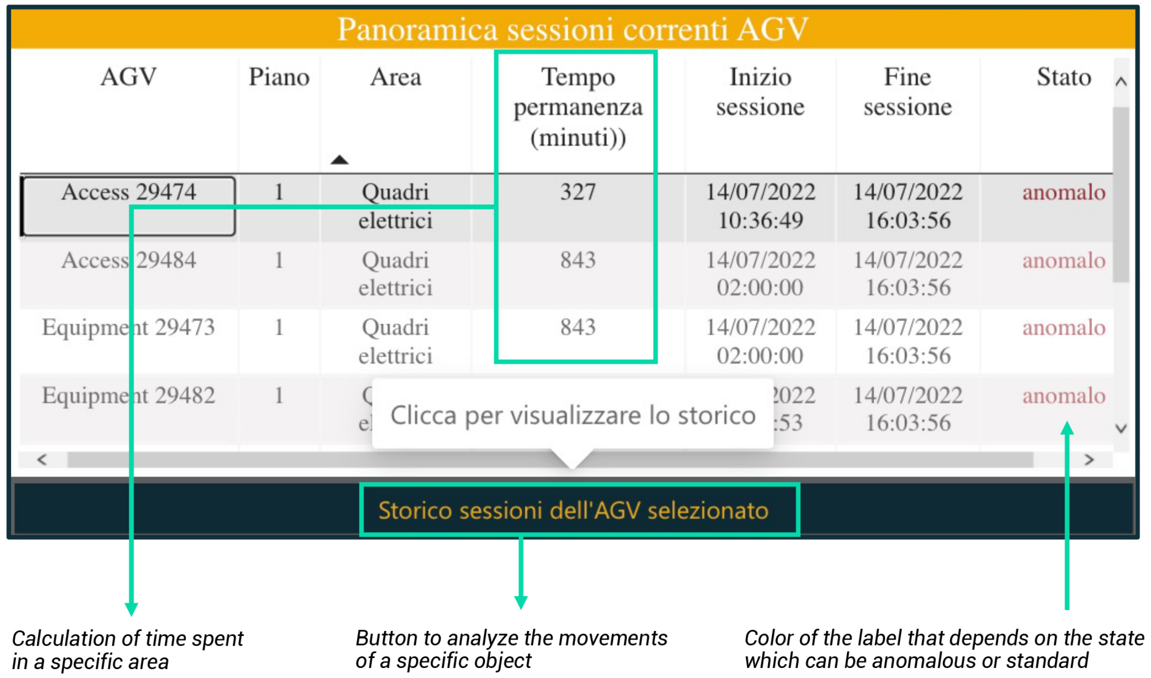


***Figure 10**: Pie chart representing percentages of occupation of the areas.*



Sala	Capienza sala	N.persone presenti	Tempo trascorso (minuti)
Quadri elettrici	5	4	50
Ricerca	6	1	4

__Figure 11__: Table used to control the occupancy of the meeting rooms.

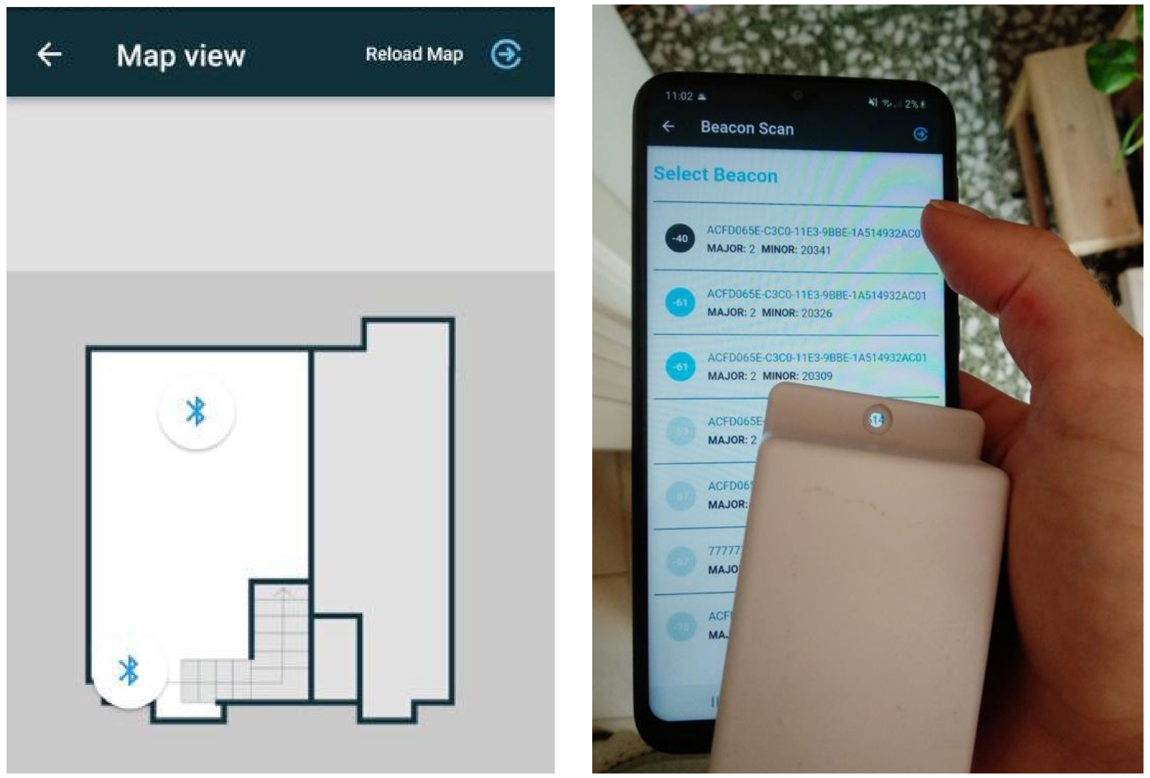


AGV	Piano	Area	Tempo permanenza (minuti))	Inizio sessione	Fine sessione	Stato
Access 29474	1	Quadri elettrici	327	14/07/2022 10:36:49	14/07/2022 16:03:56	anomalo
Access 29484	1	Quadri elettrici	843	14/07/2022 02:00:00	14/07/2022 16:03:56	anomalo
Equipment 29473	1	Quadri elettrici	843	14/07/2022 02:00:00	14/07/2022 16:03:56	anomalo
Equipment 29482	1	[illegible]	[illegible]	...2022 ...:53	14/07/2022 16:03:56	anomalo

__Figure 12__: Table used to check the status of Automated Guided Vehicle in motion.

Considerations on installation

As previously stated, the localization algorithm is based on the positions of anchor Beacons. Therefore, a preliminary step for the deployment is the **coverage analysis of the reference area**. This includes the evaluation of the number of anchors to be deployed in the area, together with the decision on the suitable positions.
Nextome covers this phase paying attention to the peculiarities of the venue, evaluating radiofrequency signals propagation to grant an effective multilateration, according to the involved algorithms.
At the same time, it is of upmost importance to register Beacons in the right positions, thus reducing errors, installation time, and making the registration phase as easy as possible.
To this aim, **Nextome has developed a dedicated app, namely Venue Configurator. This app is a useful aid for placing the Beacons inside the map**. An intermediate result of this procedure is shown in the ***following Figure***.



The Venue Configurator app integrates a BLE scanner that is used to detect the Beacons to be installed.
After registering the Beacon, it will be possible to place the sensor on the ceiling or on the walls in the corresponding point of the venue. For better results, the Beacons should be installed at about **3 m height** and with an average density of **one beacon every 50 square meters**. These parameters vary according to the geometry of the structure, the division into rooms, the type of walls and the desired accuracy.

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