A Position Estimation System Making Use of Signal Strength of Wireless LAN in a Shipyard

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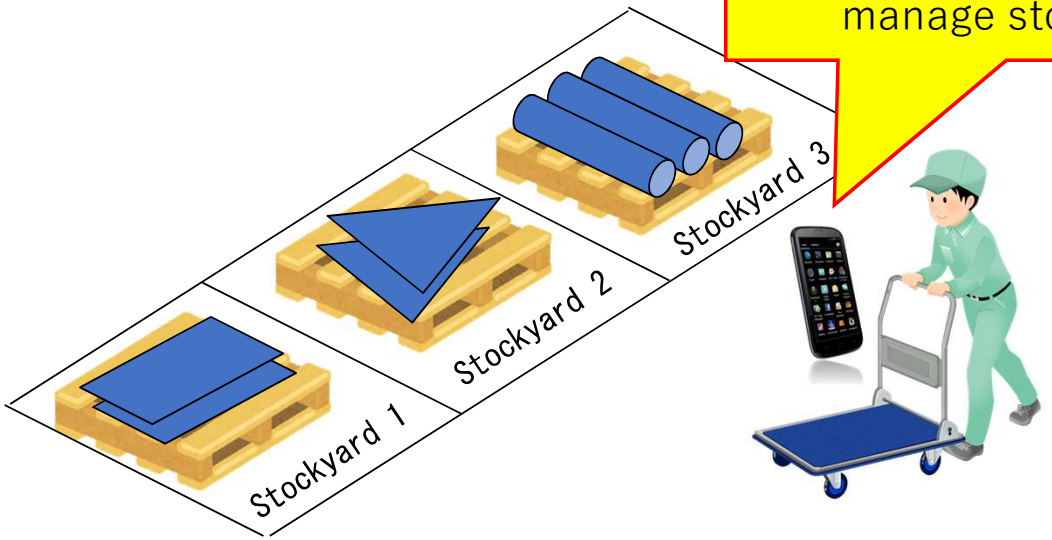
Background

It is required to obtain **Information of the position** of **workers** or **parts of products**

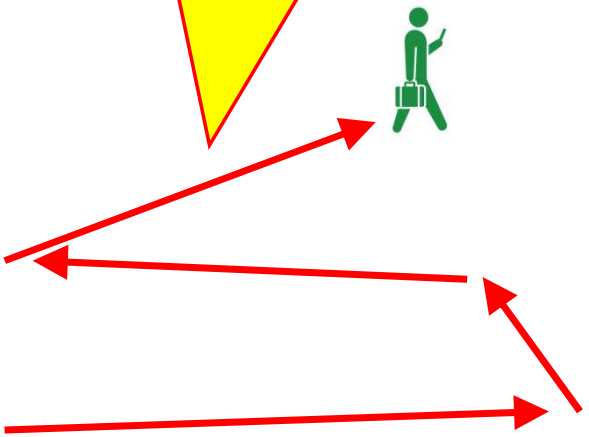
to manage **production schedules**, **stock of parts**, or **safety of workers**

We want to…

Record the position by touching button of the mobile terminal to manage stock of parts.

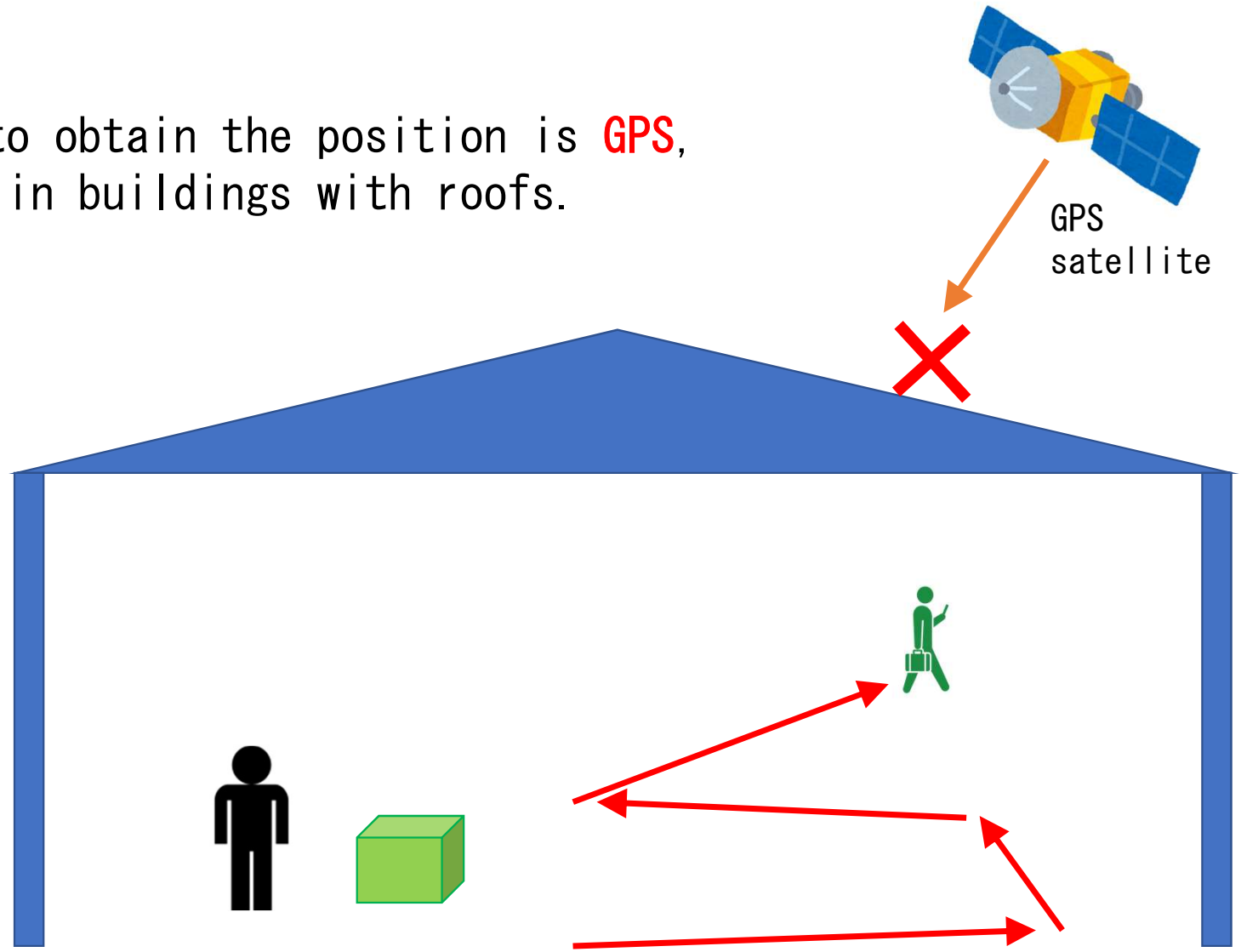


Get trajectory of workers to improve production efficiency.



Background

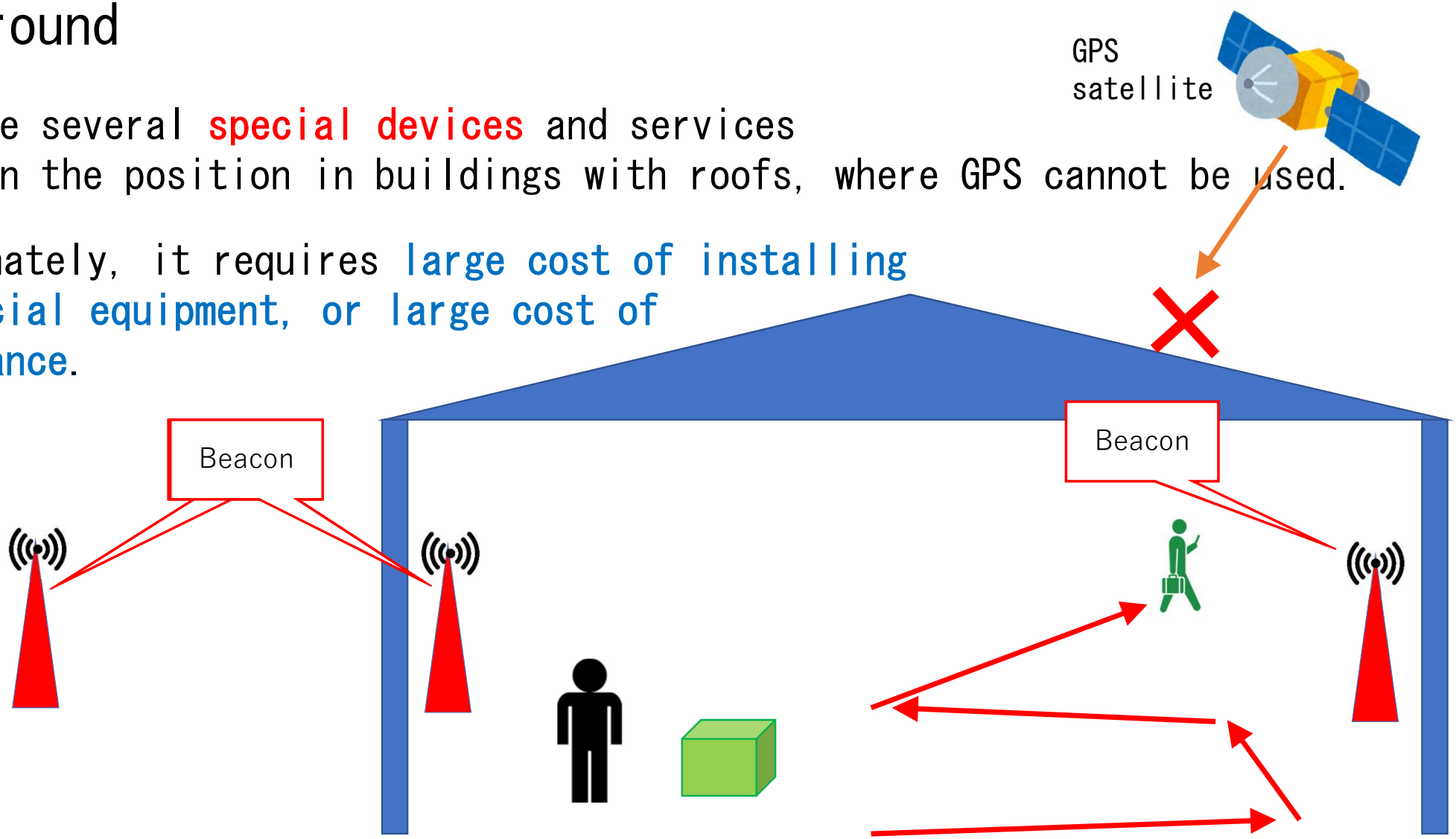
The most standard method to obtain the position is GPS,
however it cannot be used in buildings with roofs.



Background

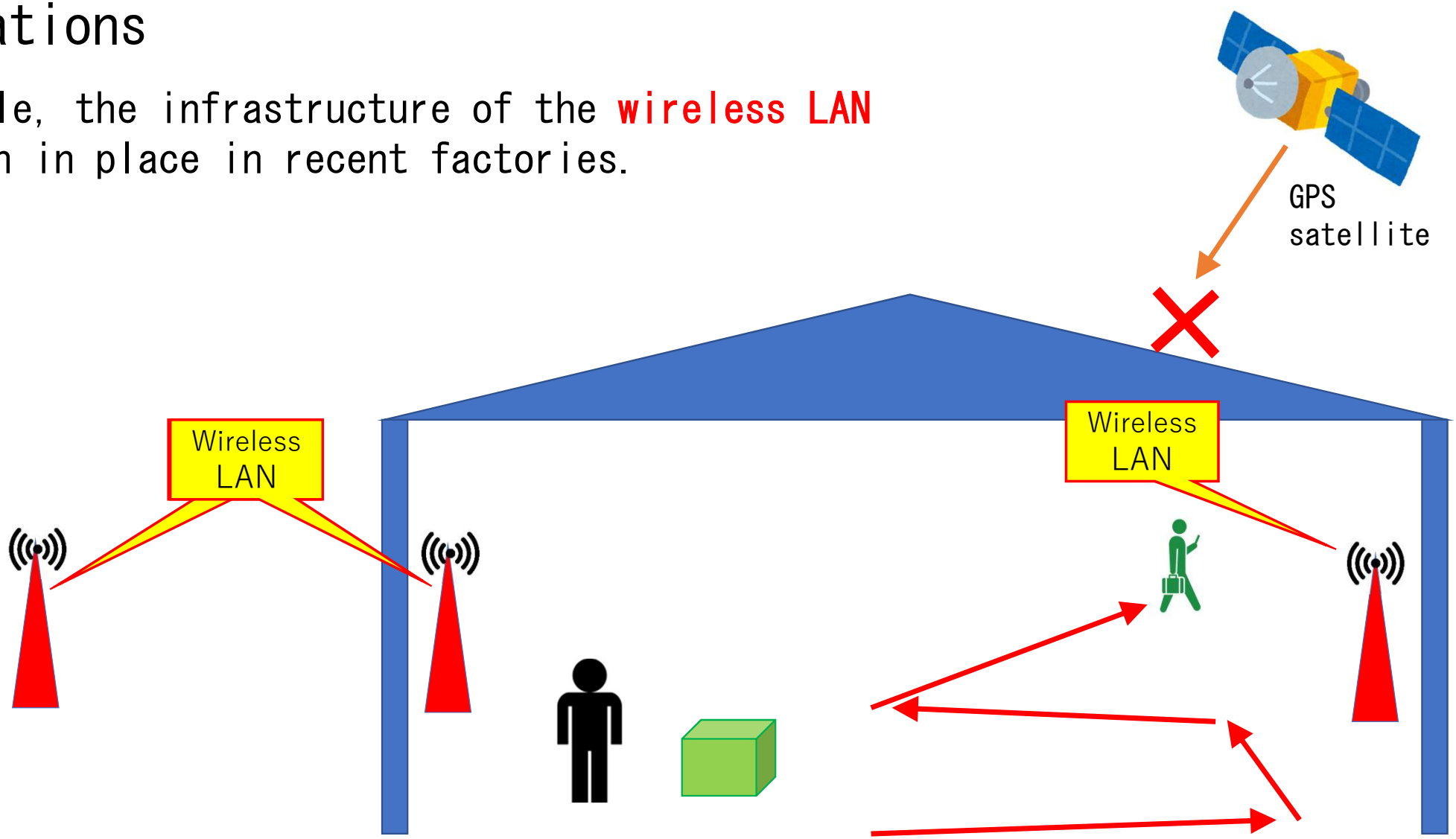
There are several special devices and services to obtain the position in buildings with roofs, where GPS cannot be used.

Unfortunately, it requires large cost of installing the special equipment, or large cost of maintenance.



Motivations

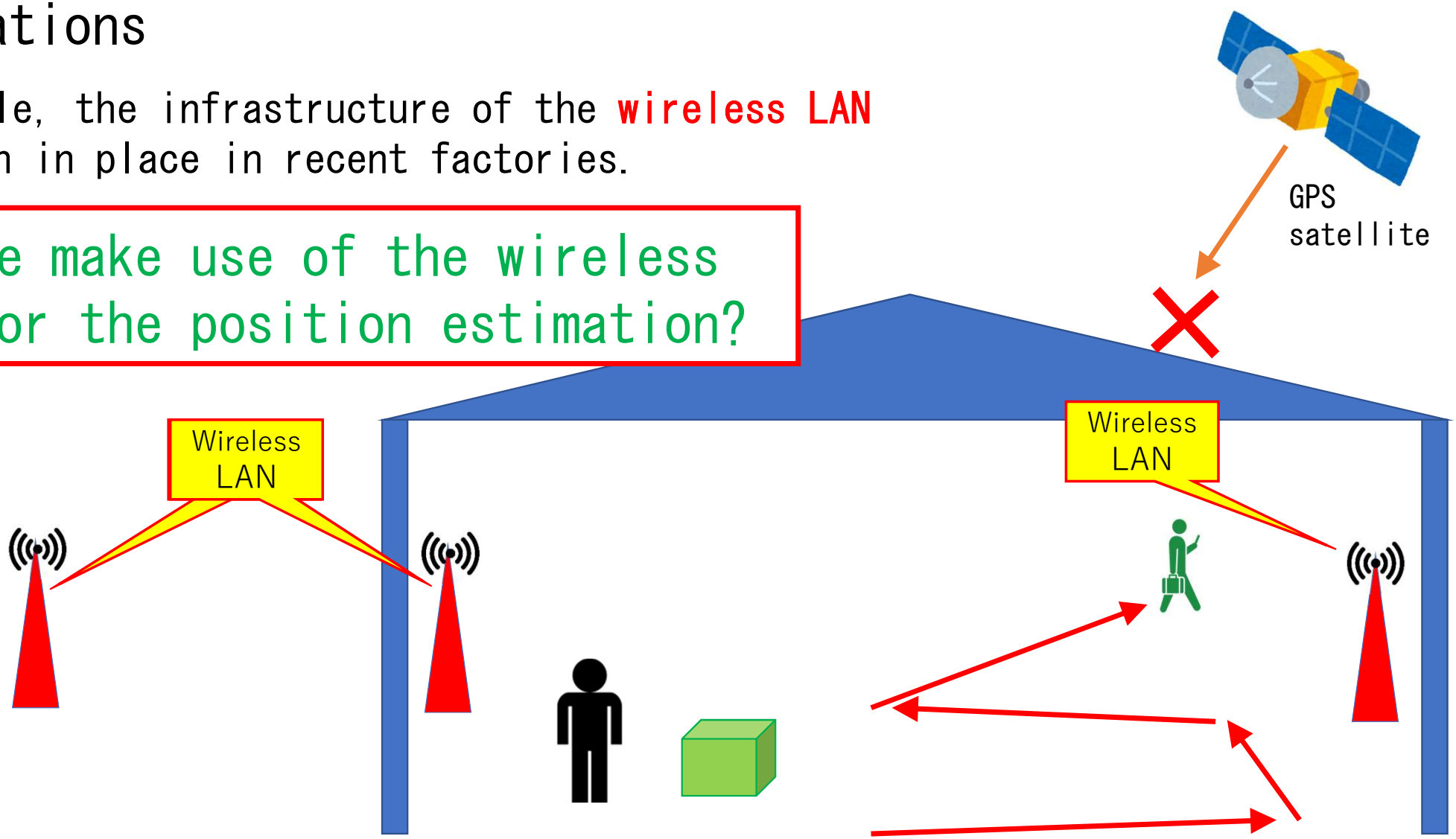
Meanwhile, the infrastructure of the **wireless LAN** has been in place in recent factories.



Motivations

Meanwhile, the infrastructure of the **wireless LAN** has been in place in recent factories.

Can we make use of the wireless LAN for the position estimation?



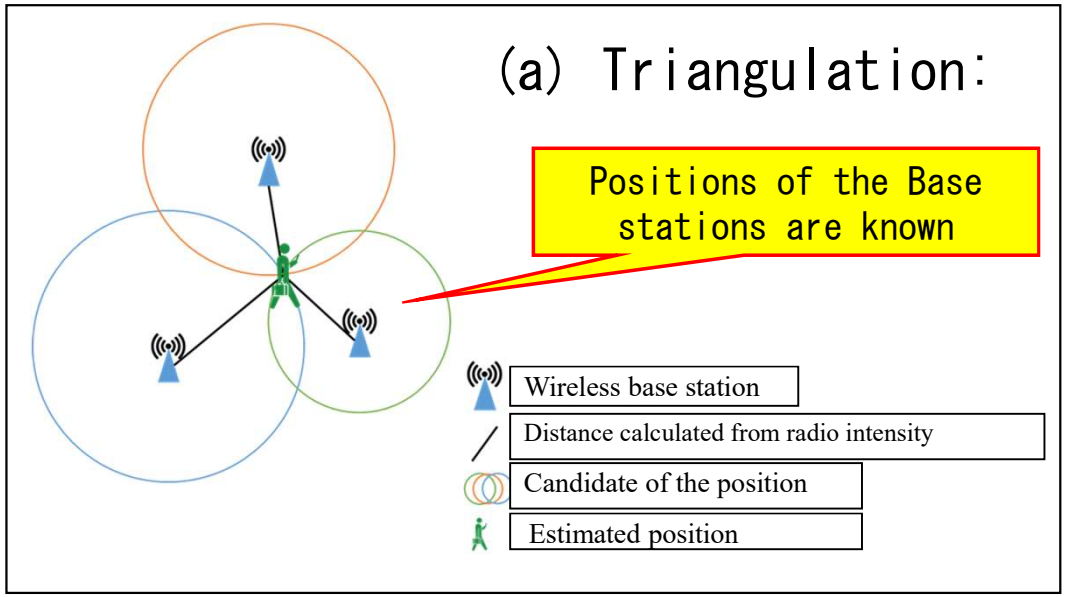
Existing Wireless LAN location detection methods

(a) Triangulation:

(b) Proximity：

(c) Scene Analysis：

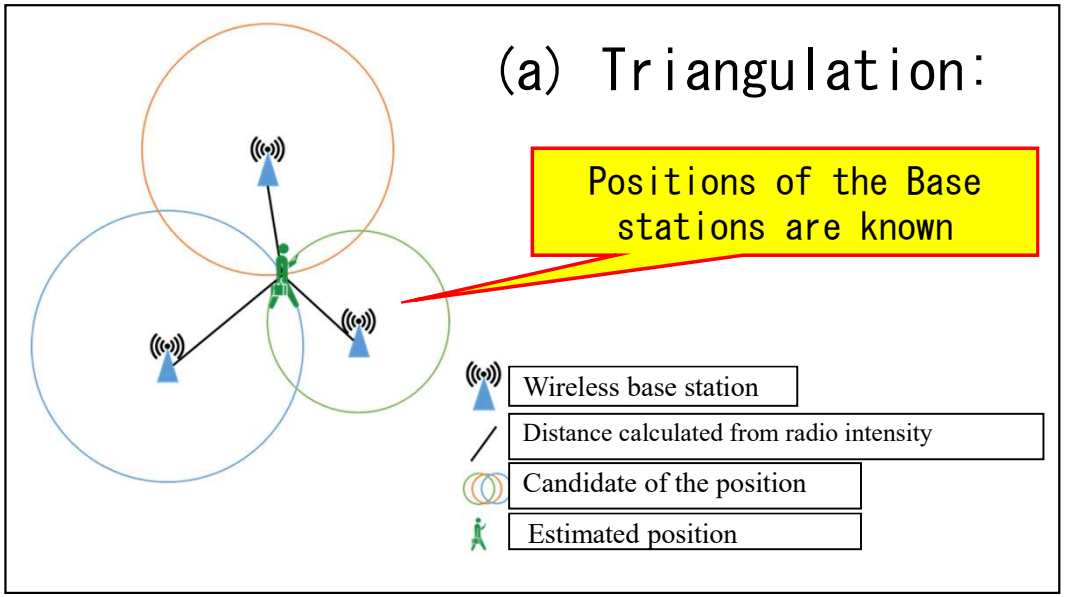
Existing Wireless LAN location detection methods

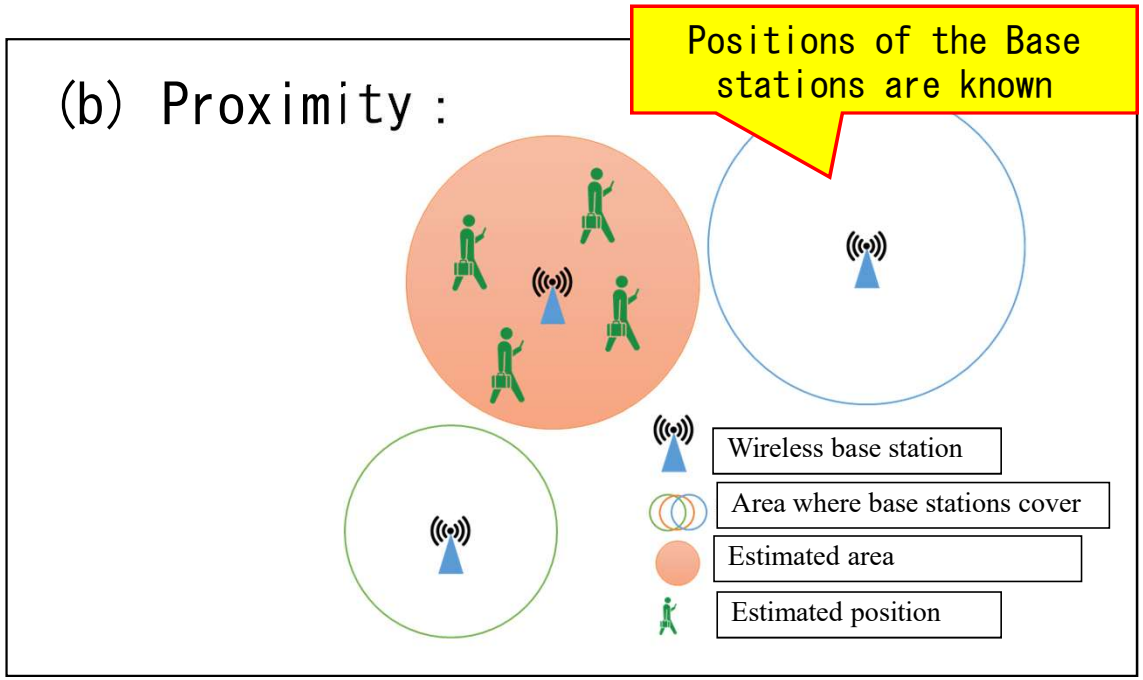


(b) Proximity：

(c) Scene Analysis：

Existing Wireless LAN location detection methods

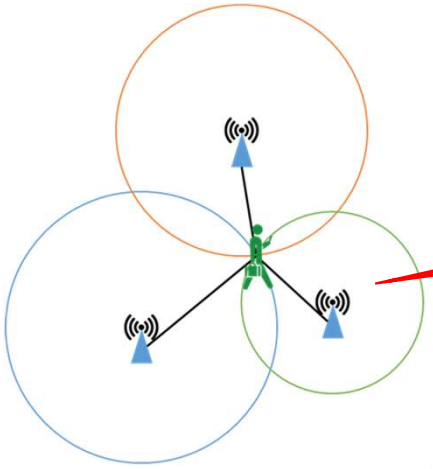




(c) Scene Analysis：

Existing Wireless LAN location detection methods

(a) Triangulation:

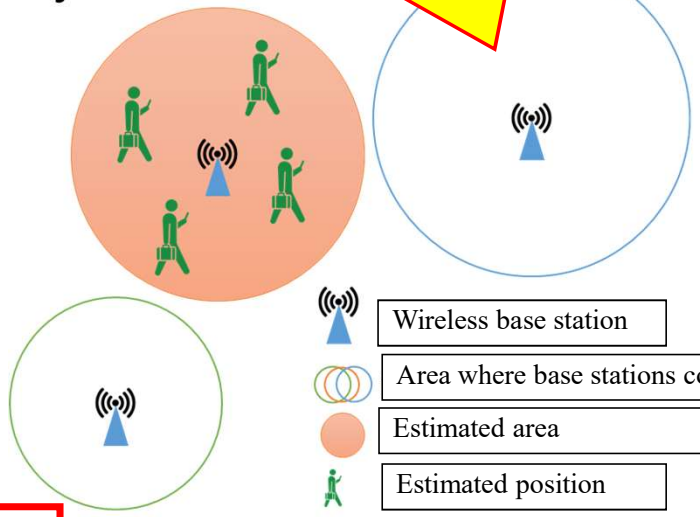


Positions of the Base stations are known

- Wireless base station
- Distance calculated from radio intensity
- Candidate of the position
- Estimated position

(b) Proximity :

Positions of the Base stations are known



- Wireless base station
- Area where base stations cover
- Estimated area
- Estimated position

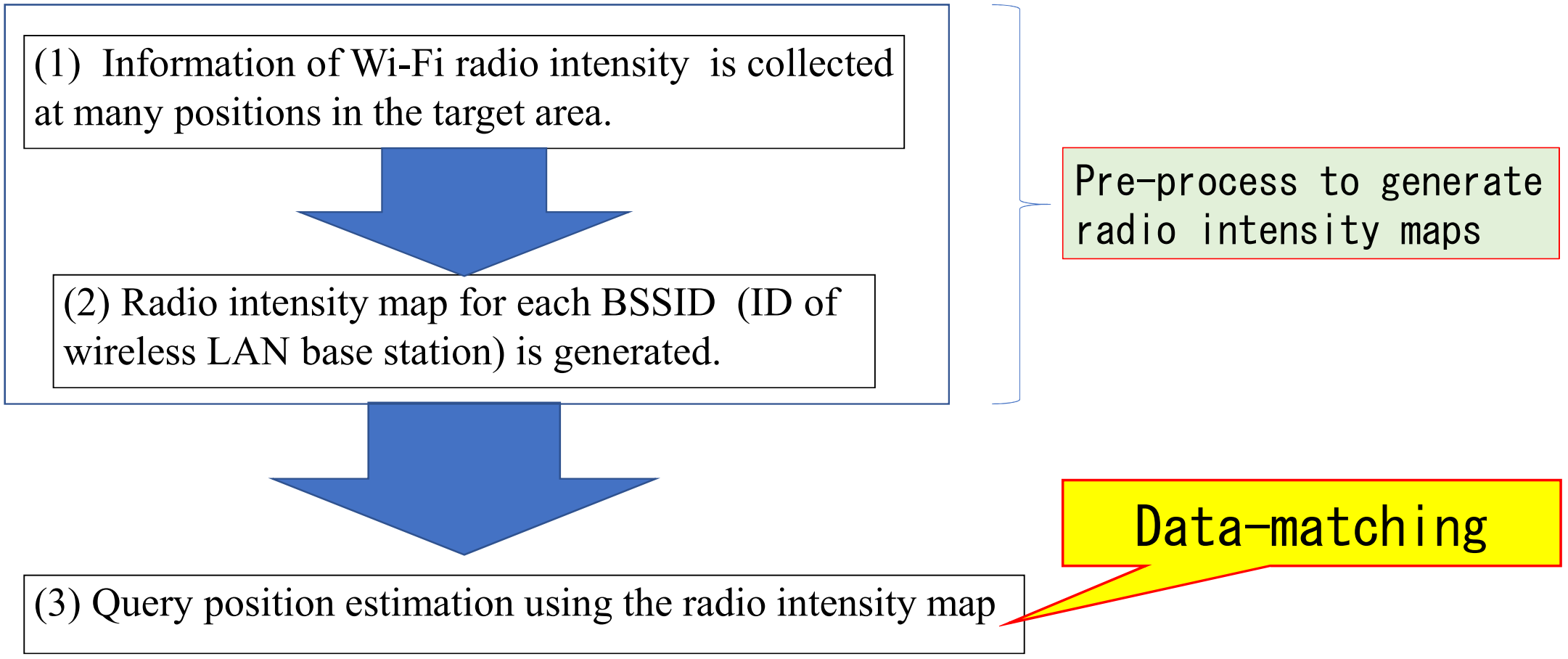
(c) Scene Analysis :

Observing scenes at many positions,
Constructing each database or machine learning

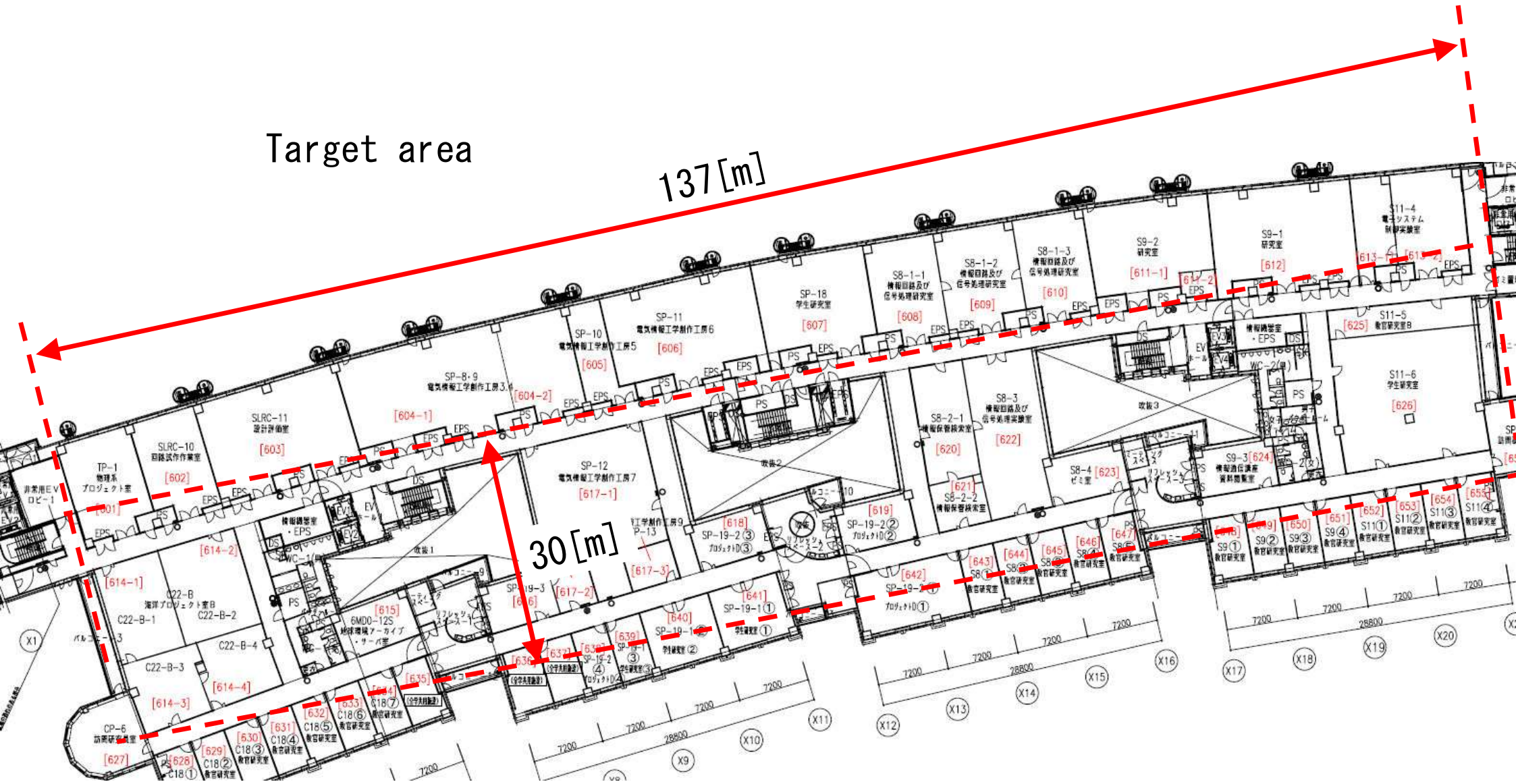
- Blue: Observed BSSID intensity and positions in advance
- Green: BSSID intensity of a query and its estimated position

Information of positions of the Base stations are not used

Position Estimation Process in Scene Analysis

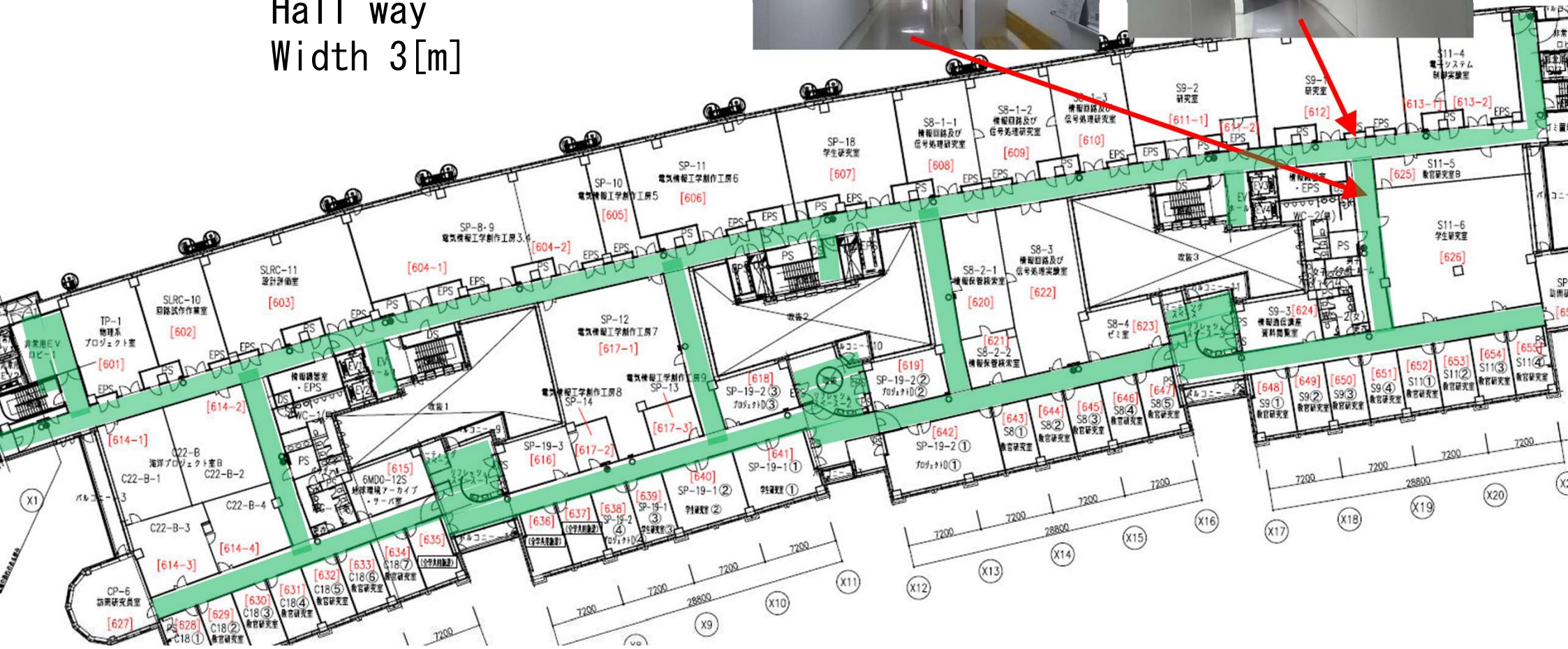


Example 1: A Research Building in Kyushu University



Example 1: A Research Building in Kyushu University

Hall way
Width 3[m]

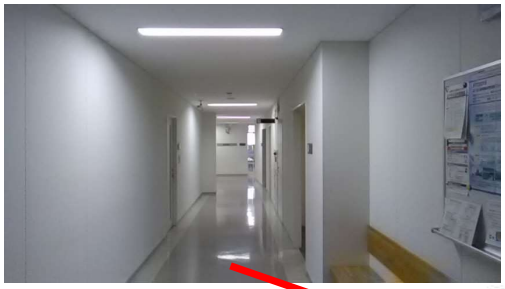


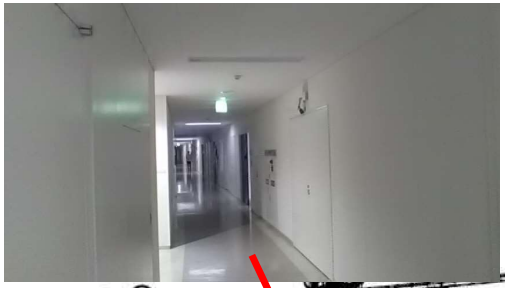
Example 1: A Research Building in Kyushu University

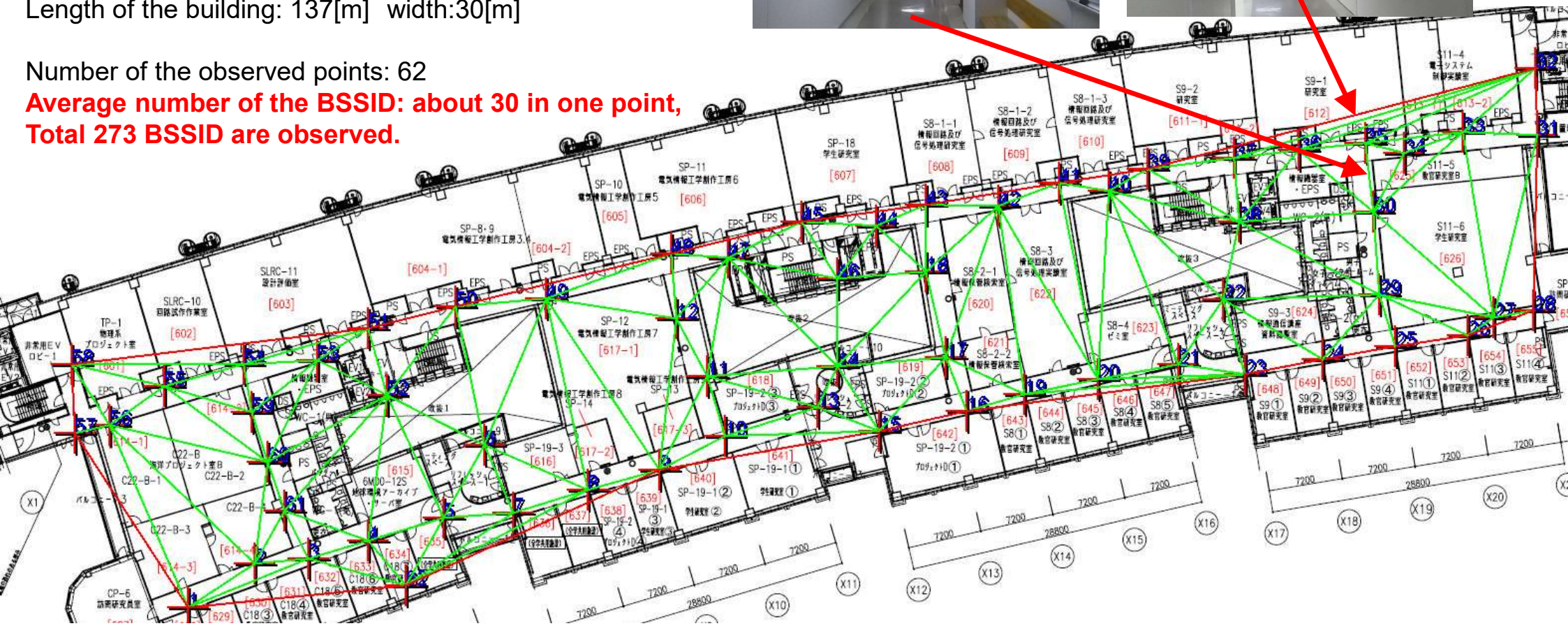
Observed points on the floor map, and
Delaunay triangulations

Average length of the Delaunay edges: 10.64[m]
Length of the building: 137[m] width:30[m]

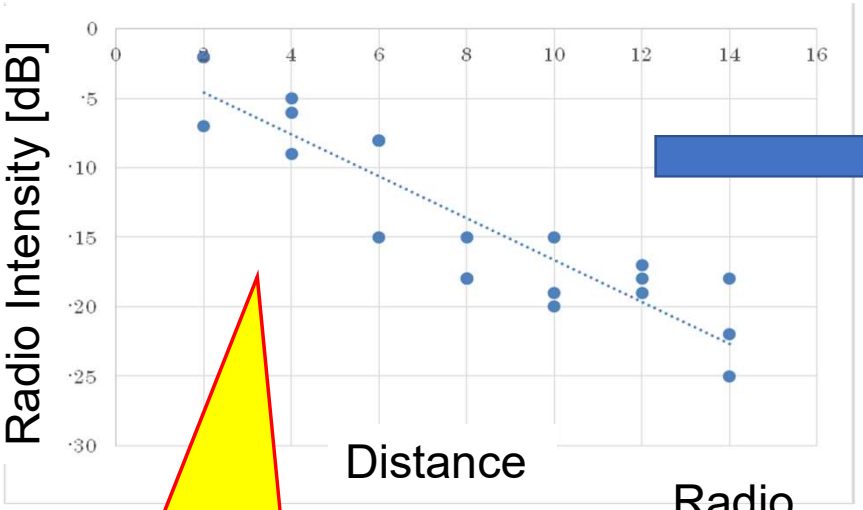
Number of the observed points: 62
Average number of the BSSID: about 30 in one point,
Total 273 BSSID are observed.





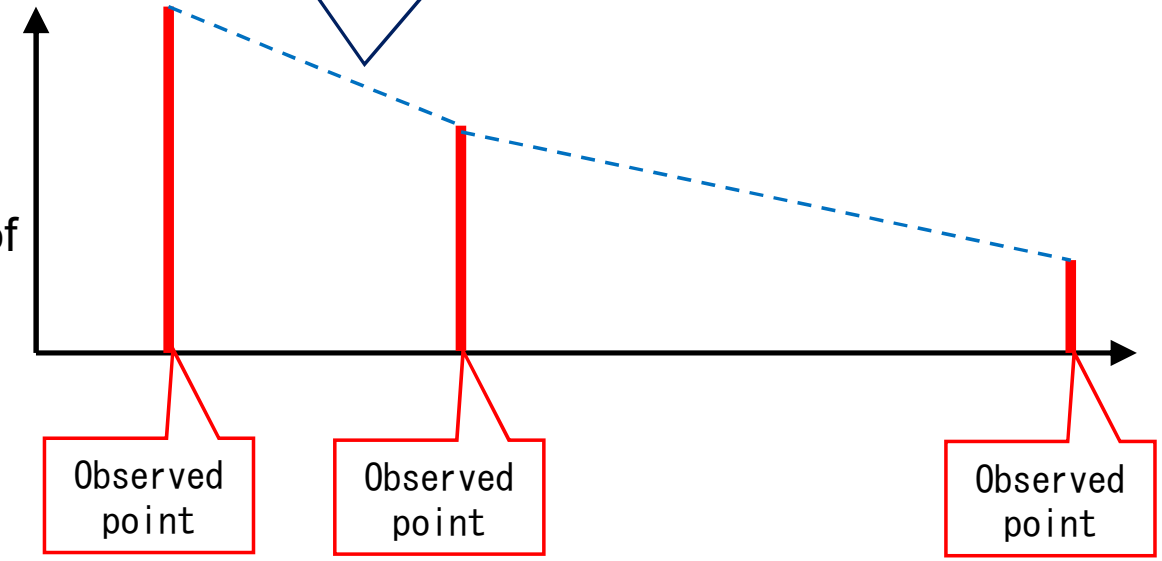


Generating Radio Intensity Maps from Observed Data



Radio wave intensity [dB] and distance can be approximated linearly

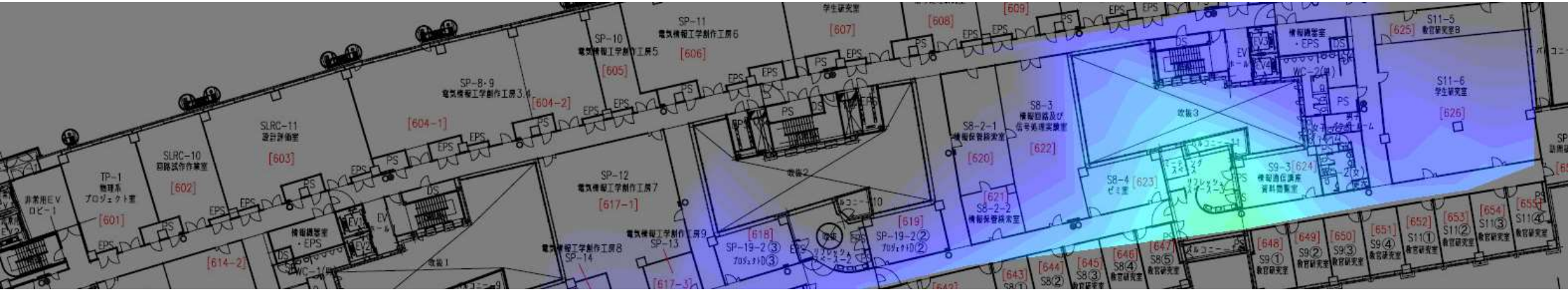
Radio intensity maps are generated by Delaunay triangulation and linear interpolation



Linear interpolation is practical because the positions of antennas are unknown in general.

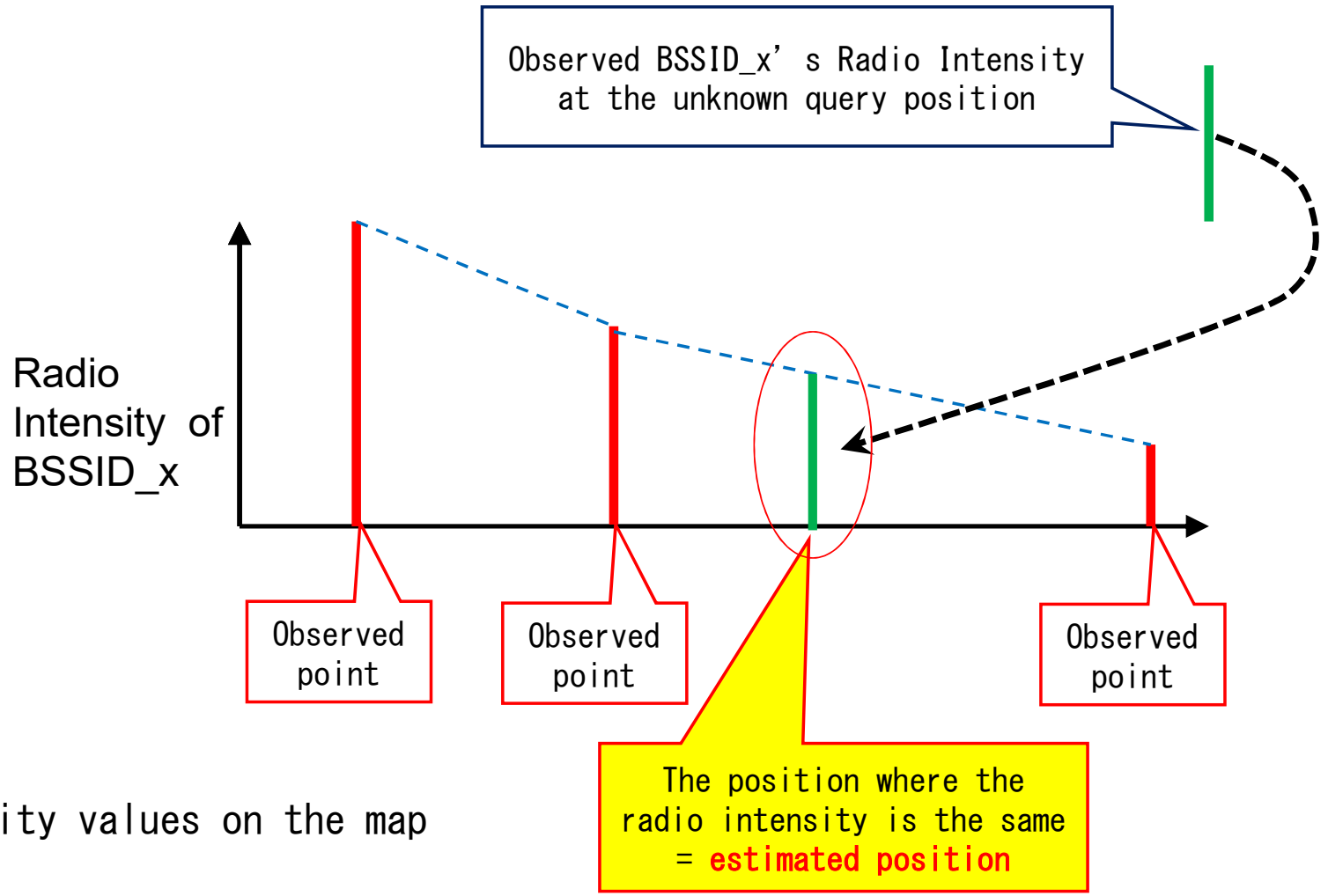
Generated Wi-Fi Radio Intensity Maps (Total 273 maps）

Radio intensity map of BSSID15

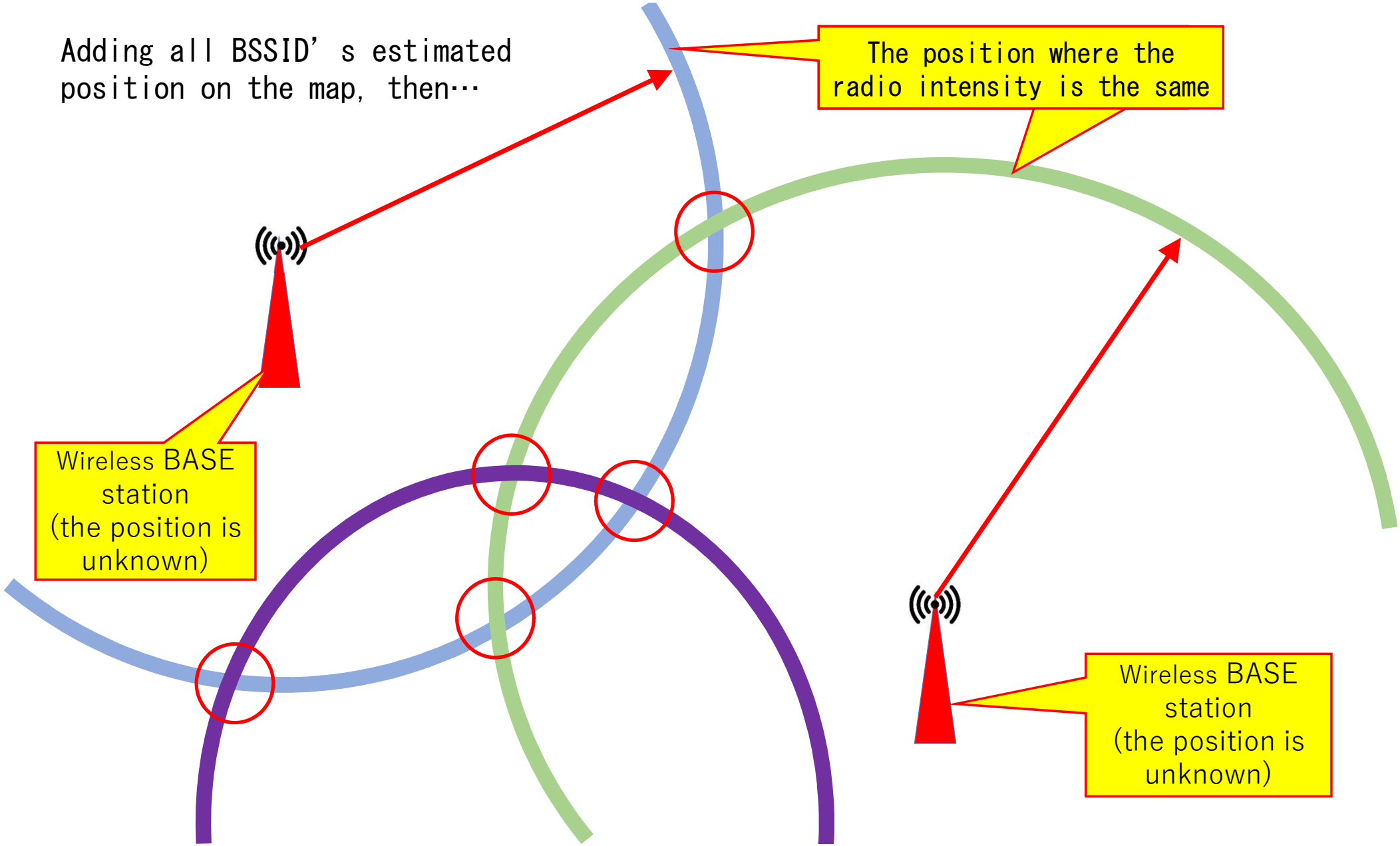


Radio intensity map of BSSID67

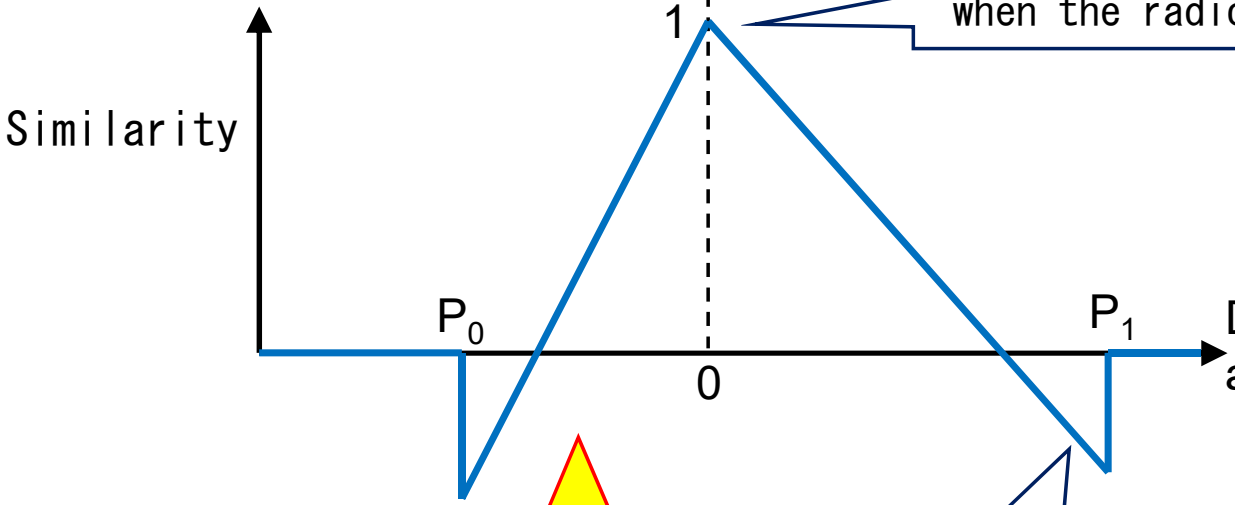
Query Position Estimation using the Radio Intensity Maps (1)



Adding all BSSID' s similarity values on the map


Adding all BSSID’s estimated position on the map, then…
The position where the radio intensity is the same
Wireless BASE station (the position is unknown)
Wireless BASE station (the position is unknown)

Query Position Estimation using the Radio Intensity Maps (2)



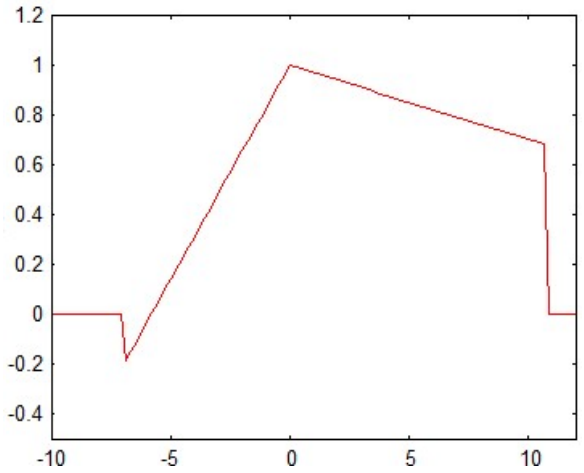
Maximum value of the similarity is 1 when the radio intensity is the same

Difference between query's radio intensity and radio intensity on the map of BSSID_x

Shape with negative value: Similar to **Edge Filter**

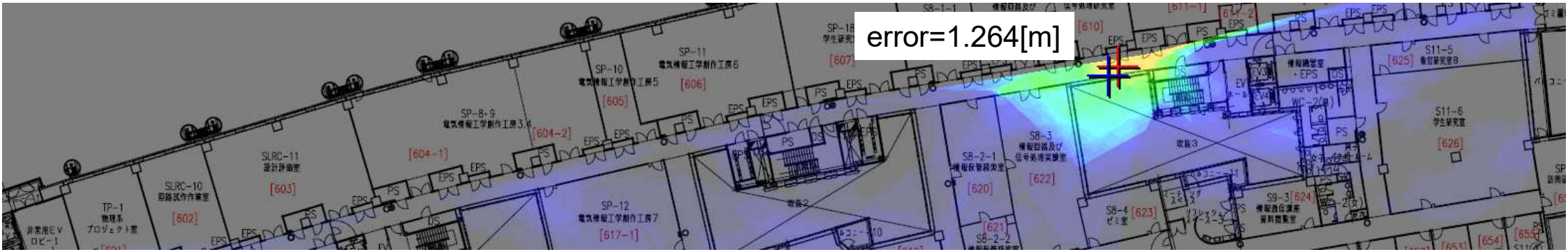
The shape of the similarity function is obtained automatically using nonlinear optimization using the value in the convex hull of the position of the observation data

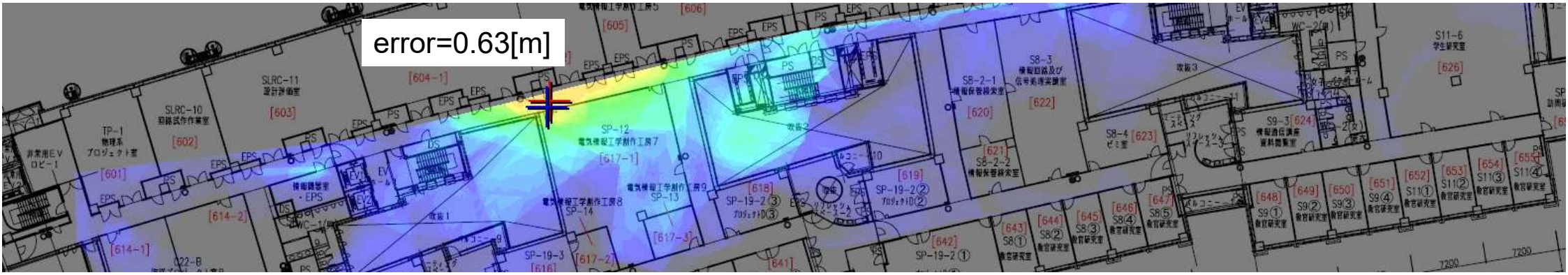
The shape of optimized similarity function for the building of Kyushu Univ.



Estimation Results（Example 1: Kyushu University 6F）

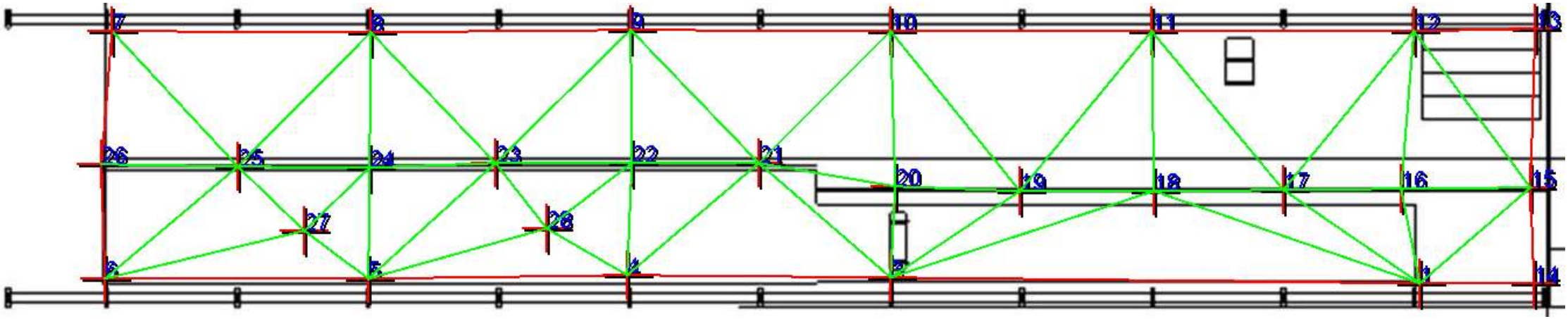
Estimated position
True position
The contour shows similarity,





For all measurement points inside the convex hull, if the point is excluded from the database and the position is estimated from other measurement points, the average error from the true position is **2.46 [m]**

Example 2：Assembly Line for Small Blocks in a Shipyard

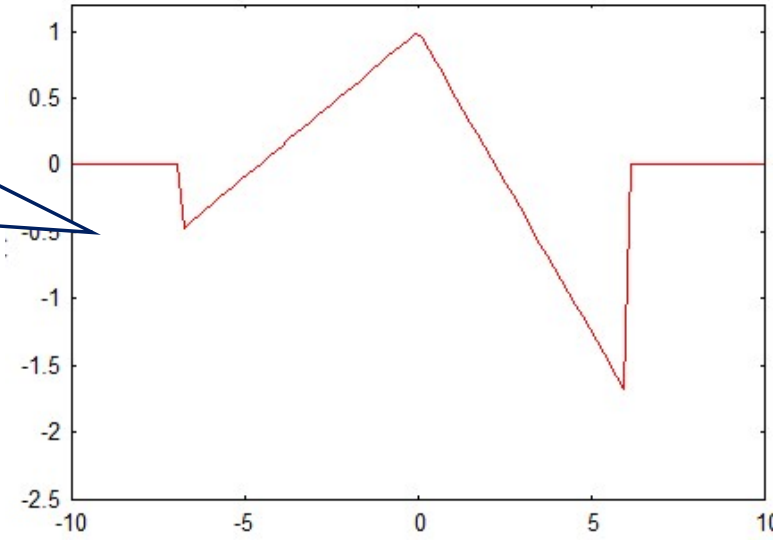


Observed points on the floor map, and Delaunay triangulations

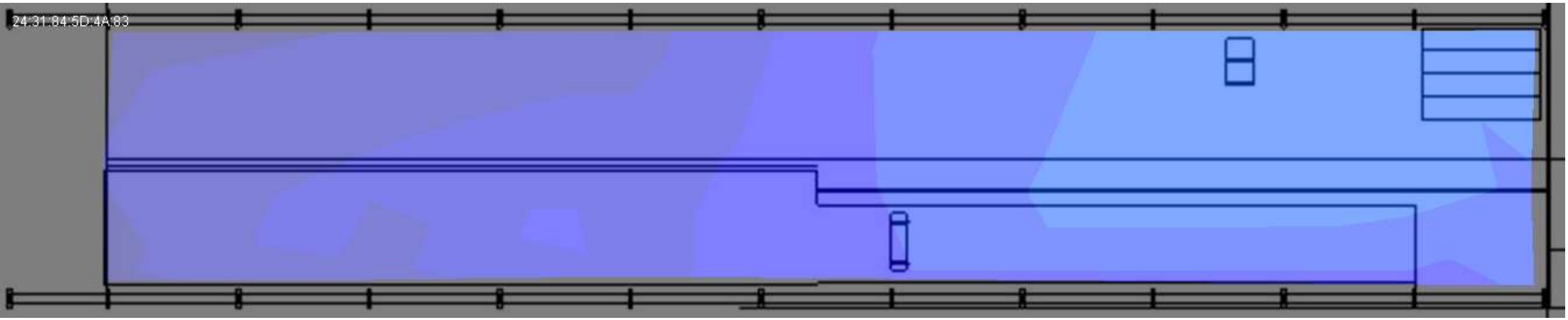
Average length of the Delaunay edges: 26.9[m]
Length of the building: 248[m] width:43[m]

Number of the observed points: 28
Average number of the BSSID: about 20 in one point,
Total 29 BSSID are observed.

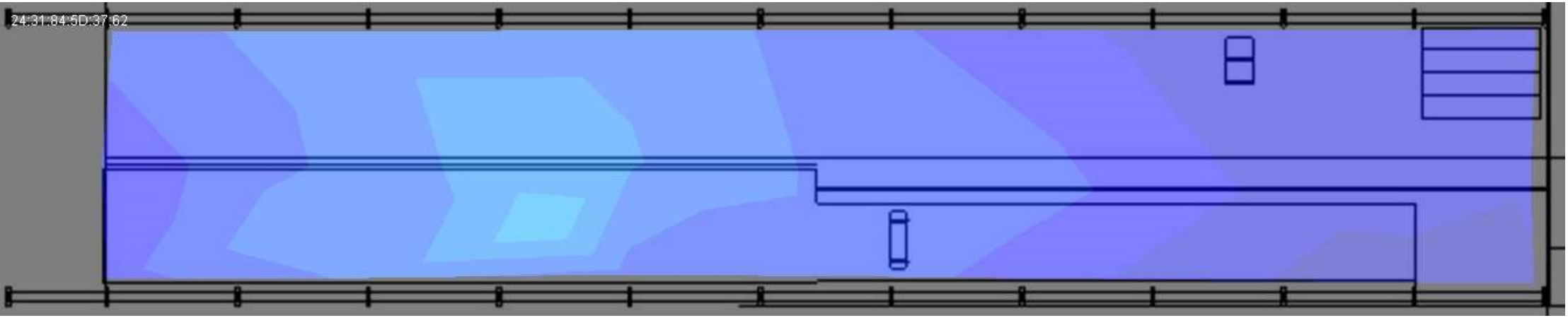
Optimized shape of the similarity function



Generated Wi-Fi Radio Intensity Maps (Total 29 maps）



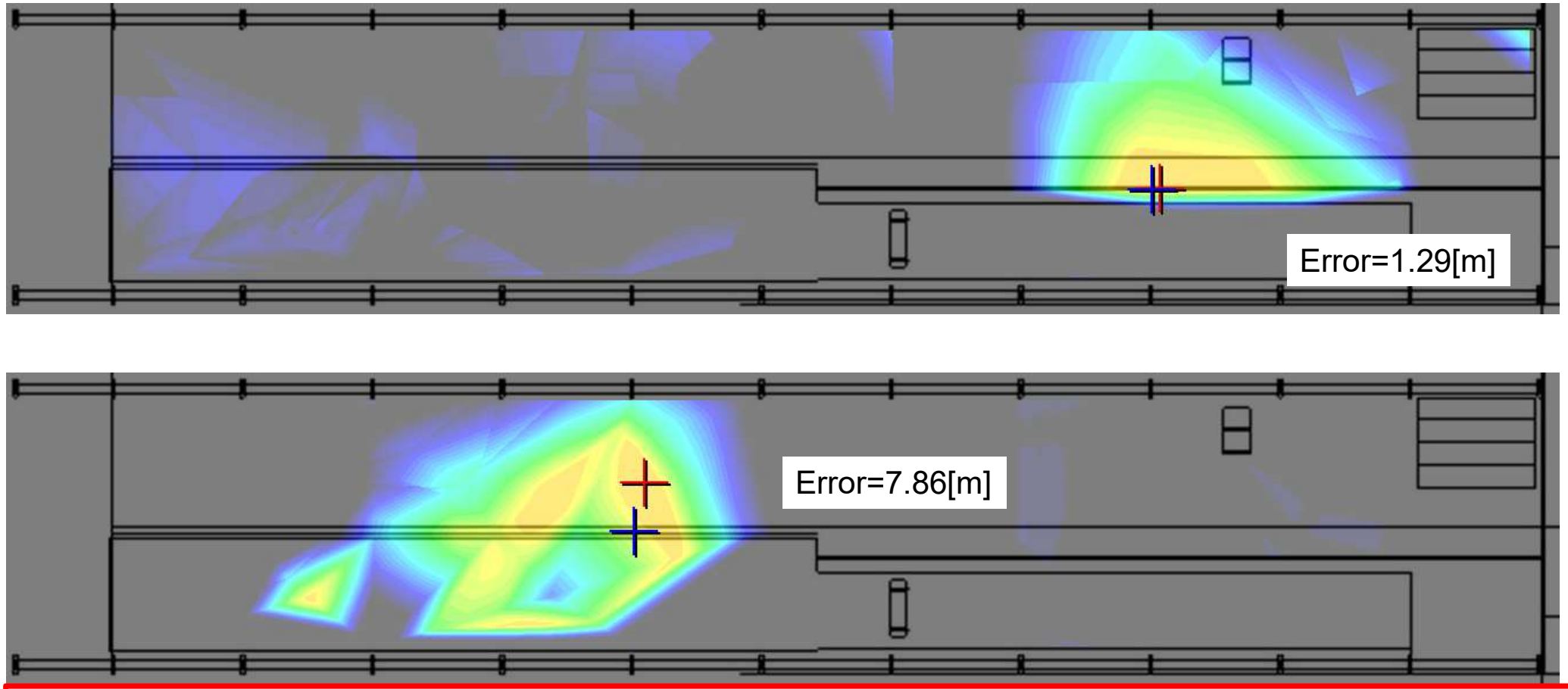
Radio intensity map of BSSID4



Radio intensity map of BSSID14

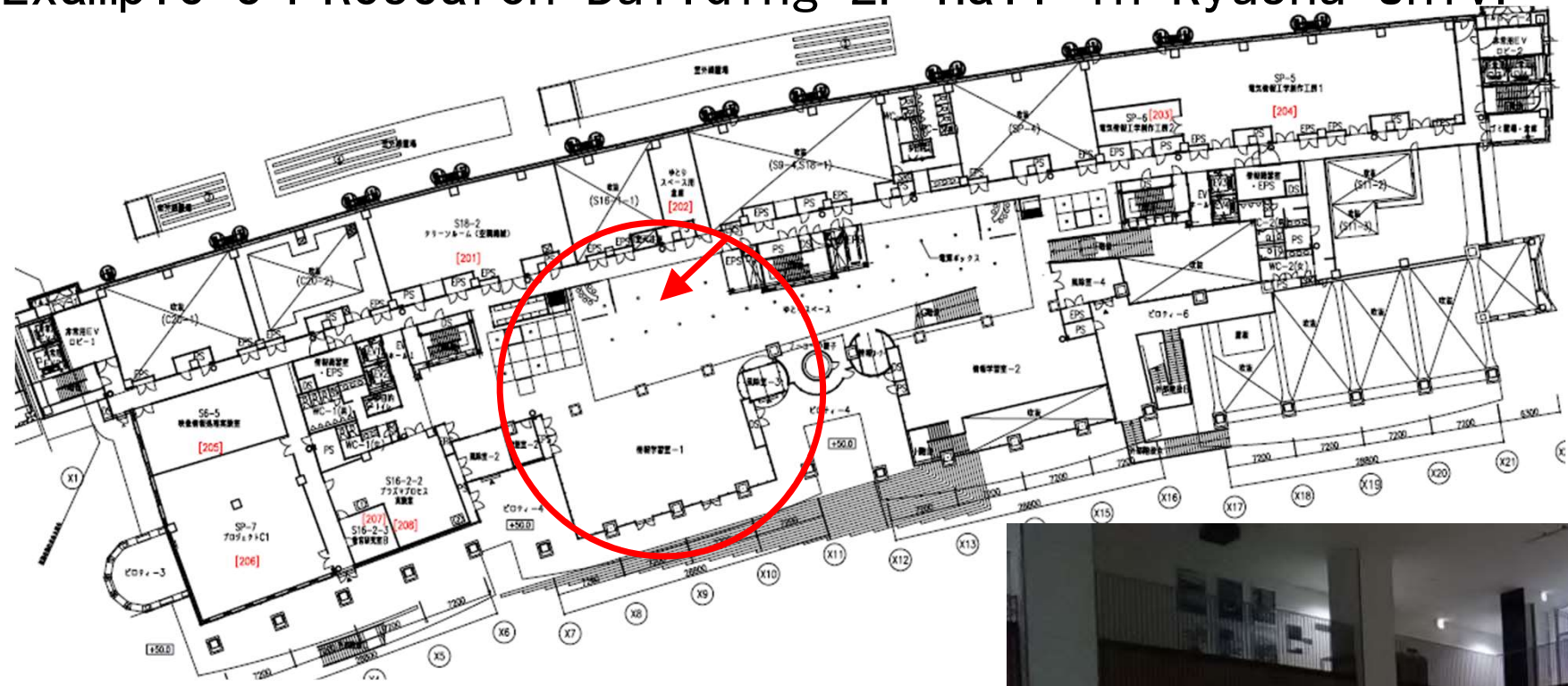
Estimation Results（Example 2: Assembly line in a shipyard）

Estimated position　True position　The contour shows similarity

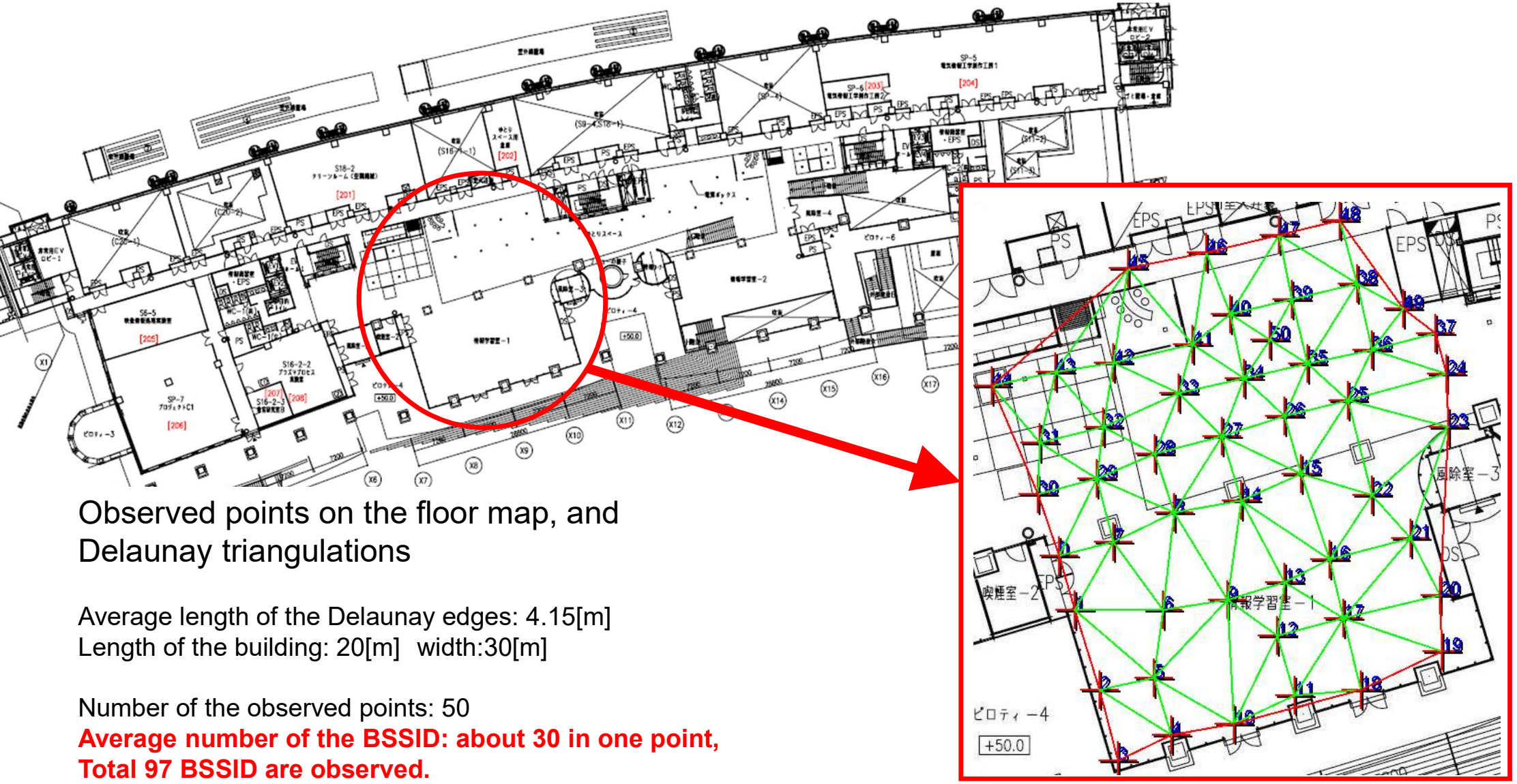


For all measurement points inside the convex hull, if the point is excluded from the database and the position is estimated from other measurement points, the average error from the true position is **12.3 [m]**

Example 3：Research Building 2F Hall in Kyushu Univ.



Example 3：Research Building 2F Hall in Kyushu Univ.

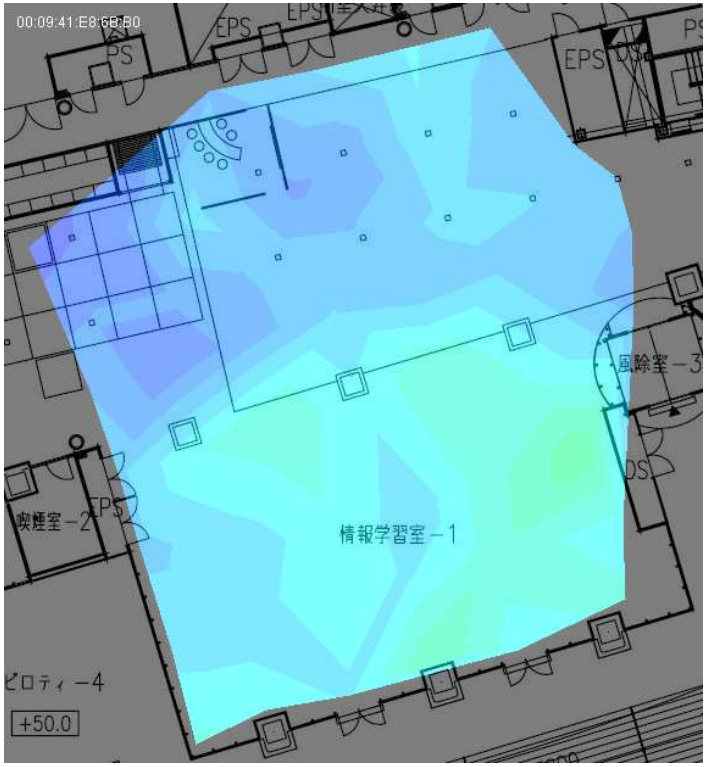


Observed points on the floor map, and
Delaunay triangulations

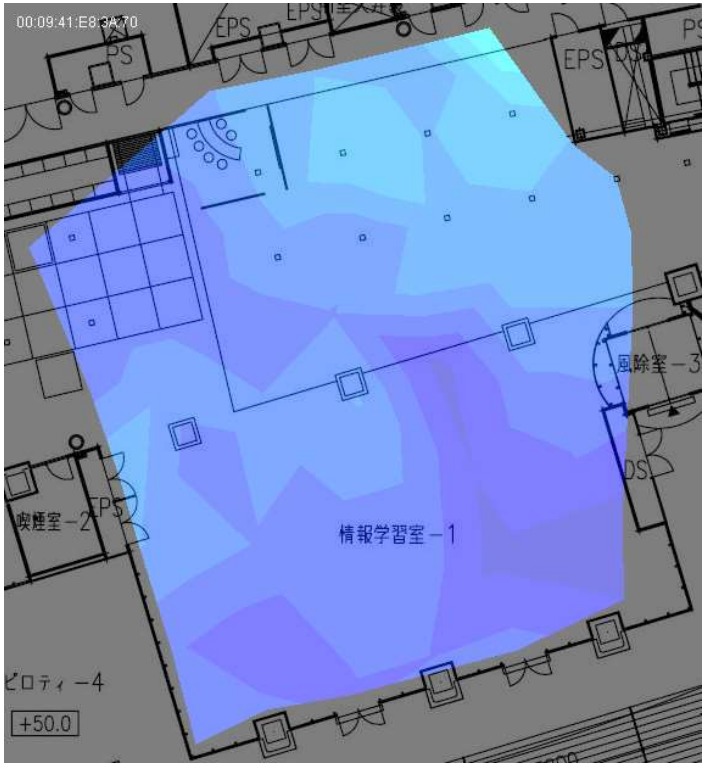
Average length of the Delaunay edges: 4.15[m]
Length of the building: 20[m] width:30[m]

Number of the observed points: 50
Average number of the BSSID: about 30 in one point,
Total 97 BSSID are observed.

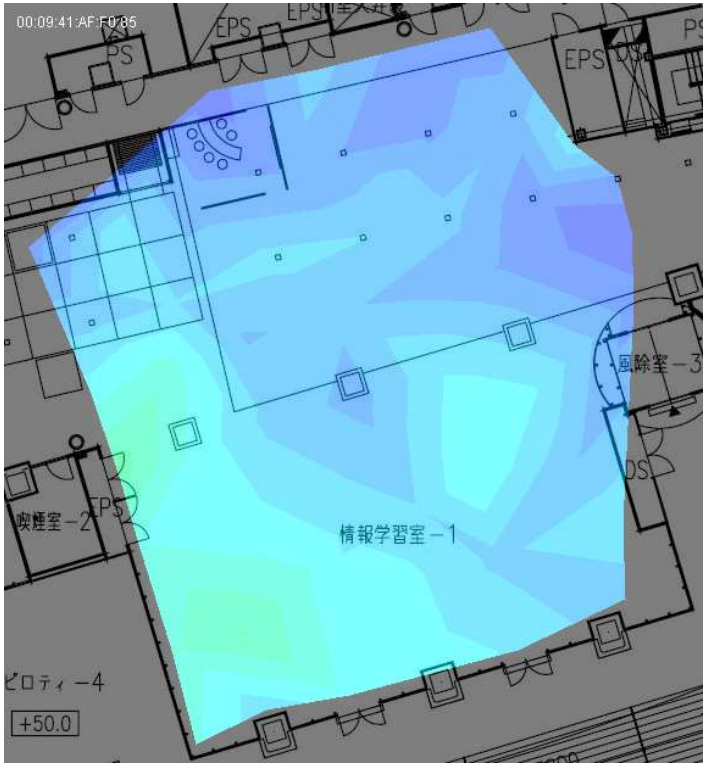
Generated Wi-Fi Radio Intensity Maps (Total 97 maps)



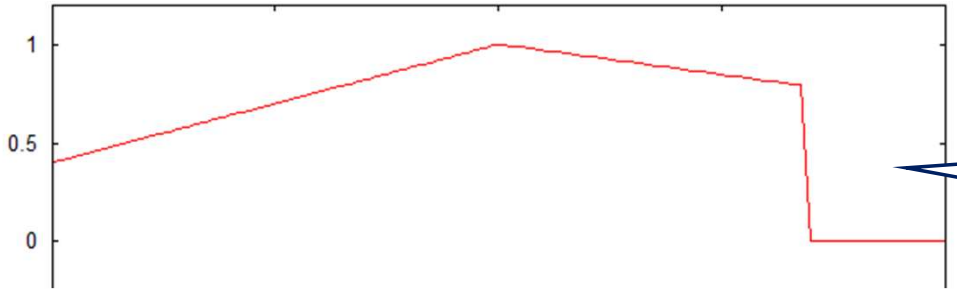
Radio intensity map of BSSID0



Radio intensity map of BSSID3



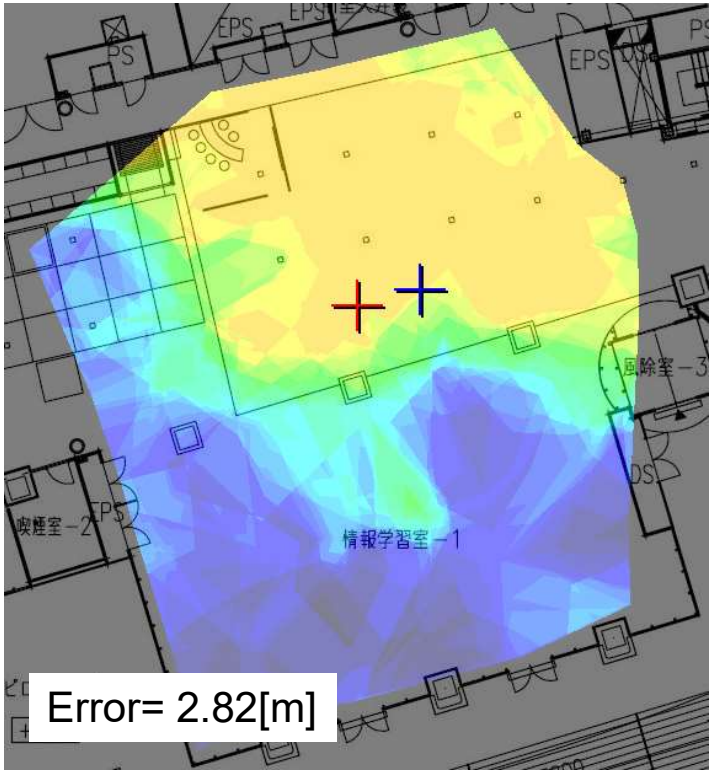
Radio intensity map of BSSID5



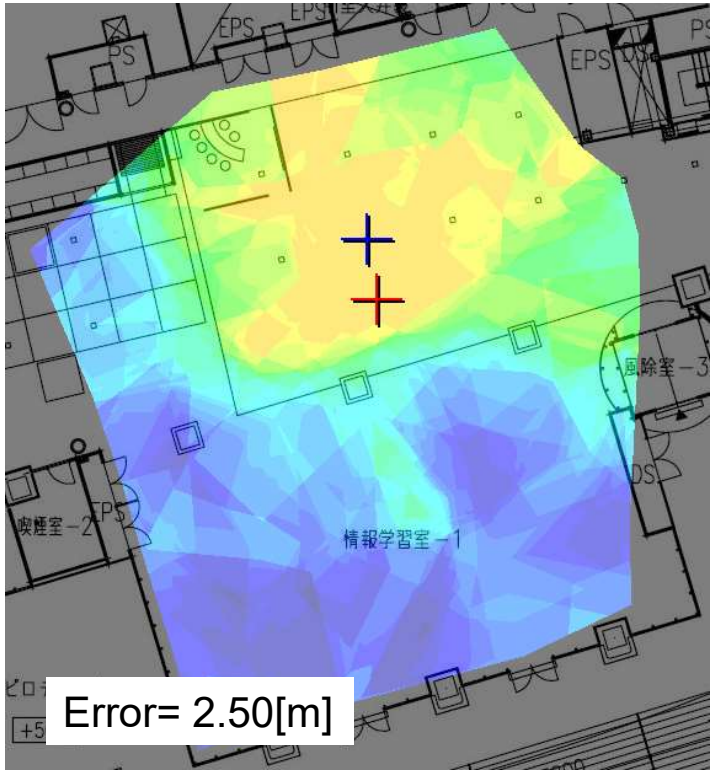
Optimized shape of the similarity function.
Notice that there is no negative part.

Estimation Results（Example 3: Kyushu University 2F Hall）

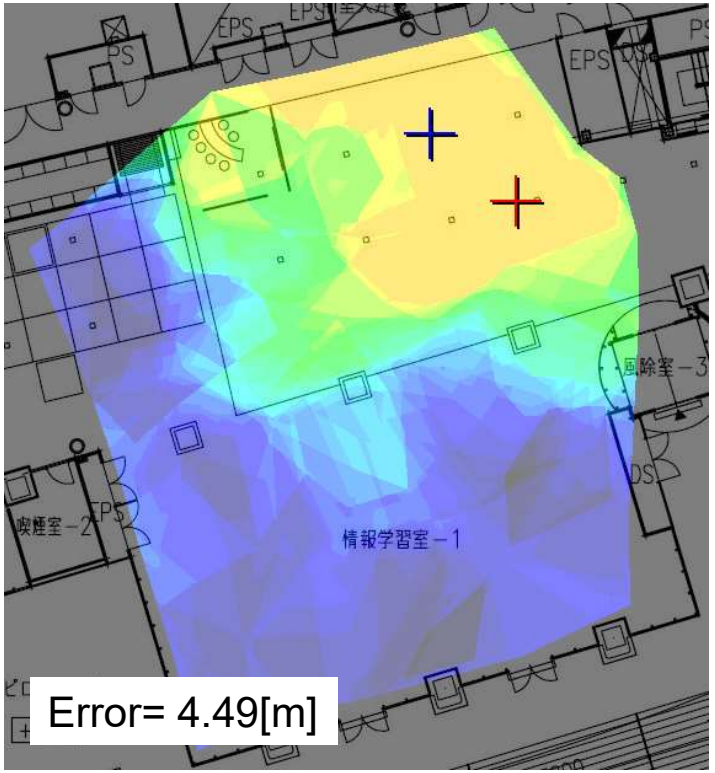
Estimated position
True position
The contour shows similarity,



Error= 2.82[m]



Error= 2.50[m]



Error= 4.49[m]

For all measurement points inside the convex hull, if the point is excluded from the database and the position is estimated from other measurement points, the average error from the true position is **4.18 [m]**

Discussion

1) Estimation accuracy is largely depend on the number and arrangement of the Wi-Fi antennas. Target area should be surrounded by Wi-Fi ant.

- Research Building 6F Average length between observed points: 10[m]
  Average number of BSSIDs: about 30 in one point, Error= 2.5[m]
- Research Building 2F Average length between observed points: 4.1[m]
  Average number of BSSIDs: about 30 in one point, Error= 4.18[m]
- Assembly Line Average length between observed points: 26.9[m]
  Average number of BSSIDs: about 20 in one point, Error= 12.3[m]

There is no Wi-Fi antenna in the inside of the target area.

2) Estimation accuracy can be improved by optimization of the shape of the similarity function.

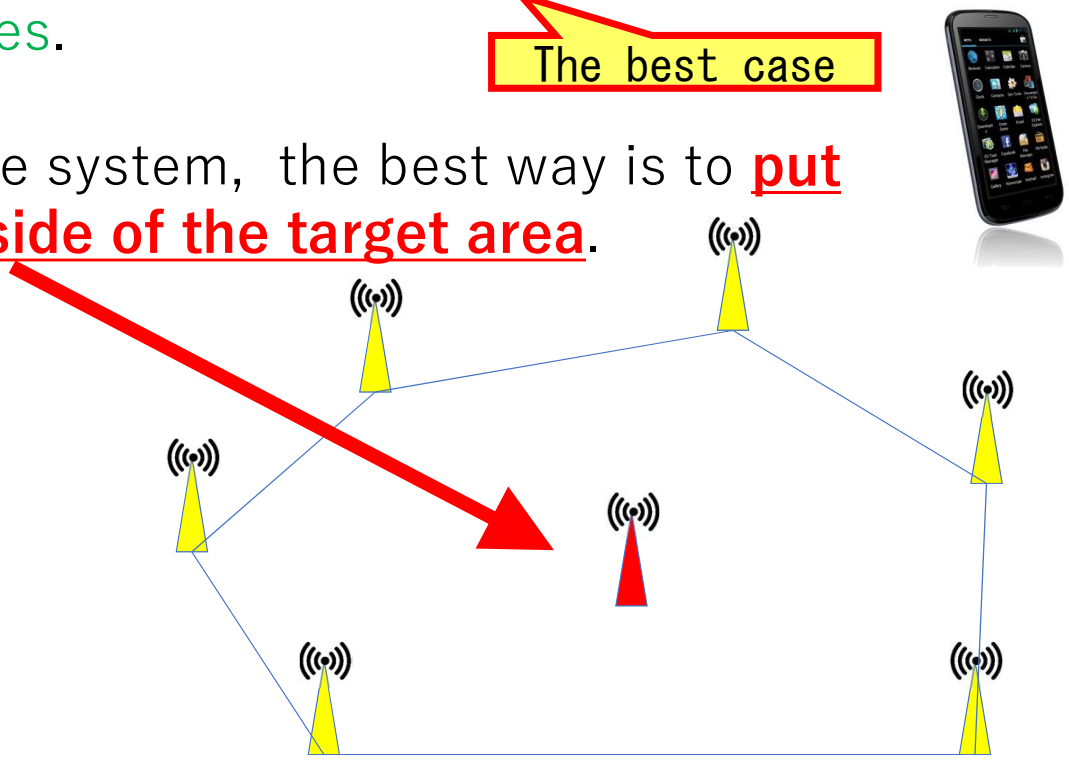
Ex.) Initial error 6.28[m] is improved to 4.18[m] in Research Building 2F

Conclusion

- we investigate the possibility to **make use of existing Wi-Fi infrastructure** to estimate positions of workers or parts of the products in buildings where GPS cannot be used.

- In our experiments, the accuracy of the system is **2.46 [m]** in some special conditions without any specific devices.

- If you want to improve accuracy of the system, the best way is to **put additional Wi-Fi antennas in the inside of the target area**.



Acknowledgements

We thank Oshima Shipbuilding Co., Ltd for the experiments in the factory building.

Remarks

This technology is Patent pending by Kyushu University.
(Japanese Patent Application No. 2018-095290)

If you want to get the source code of the programs,
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