



# **Wireless ranging/localization and its applications in lighting IoT**

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# Outline

- **Lighting grid and IoT localization applications**
- **Automatic localization of lighting grids**
- **Phase measurements, ranging and distance data processing**
- **Graph matching and validations**
- **Conclusions and future work**

# Lighting grid and IoT localization applications

# Lighting grid is ideal for IoT localization



Wireless lighting infrastructure  
Lights are everywhere  
Lights are dense  
Lights are fixed and powered  
Commissioning already done  
for lighting control



No or low extra HW cost  
Ubiquitous coverage  
Better accuracy and reliability  
Less maintenance  
Easy to setup

# Use cases for hospitals

## Efficiency

Tracking of equipment

Tracking of patient and staff

## Cost

Optimize equipment stock level

Reduce unnecessary purchasing of new equipment





# Use cases for industry

## Efficiency

Tracking of tools

Tracking of parts

## Safety

Collision warning/prevention

Dangerous zone avoidance



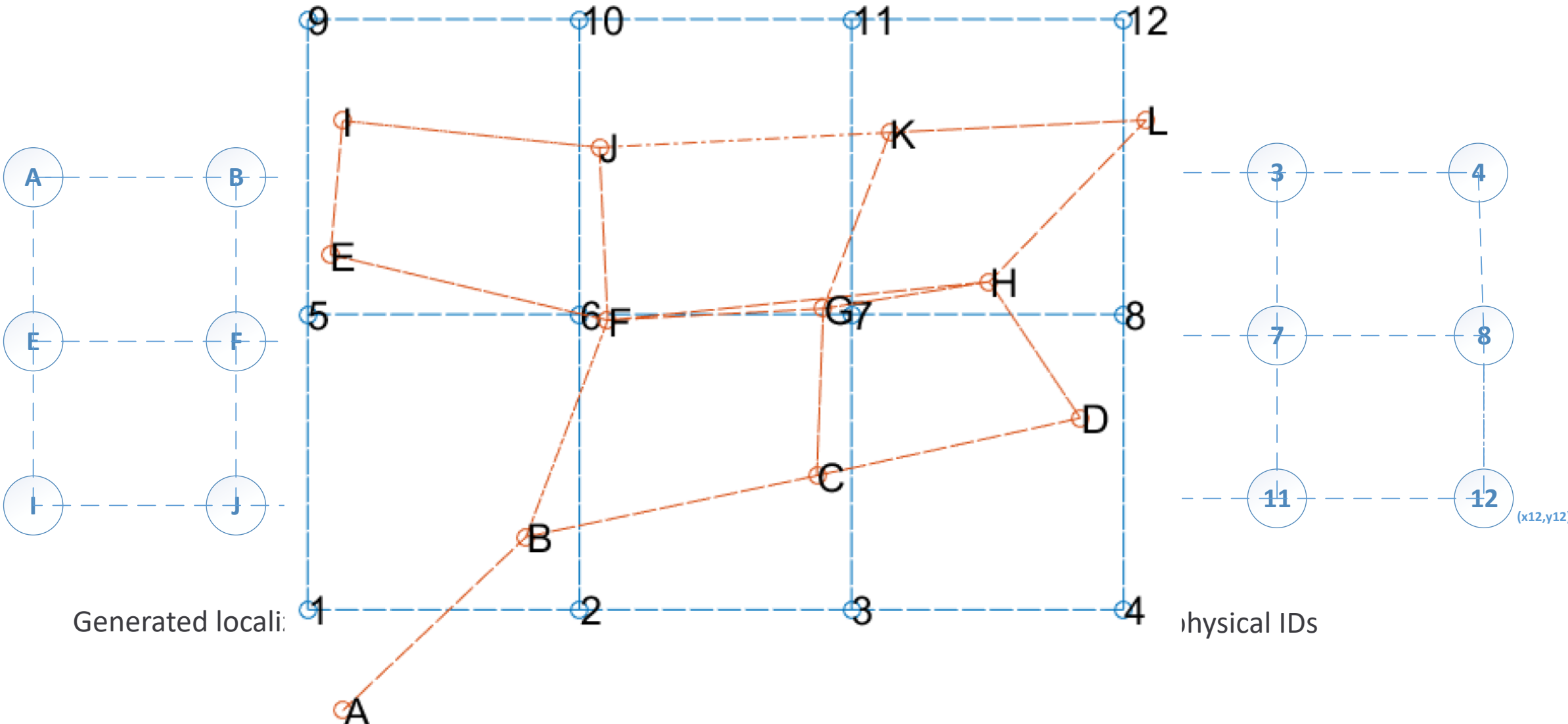
# Automatic localization of lighting grids

# Automatic localization of lighting grid

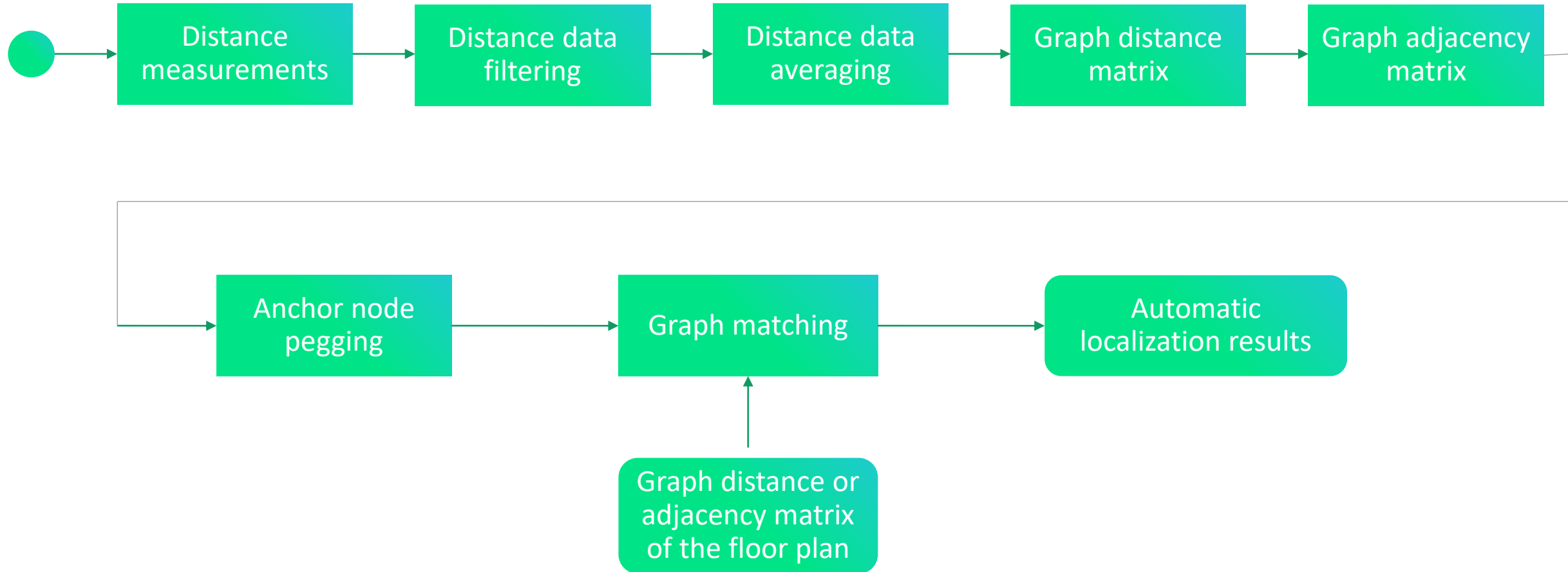




# Automatic localization of lighting grid

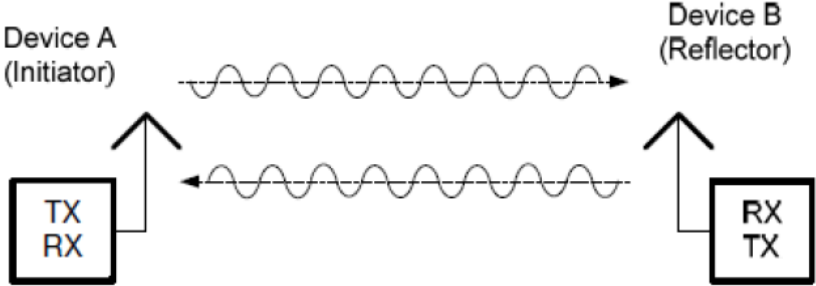


# Solution workflow



# Phase measurement, ranging and distance data processing

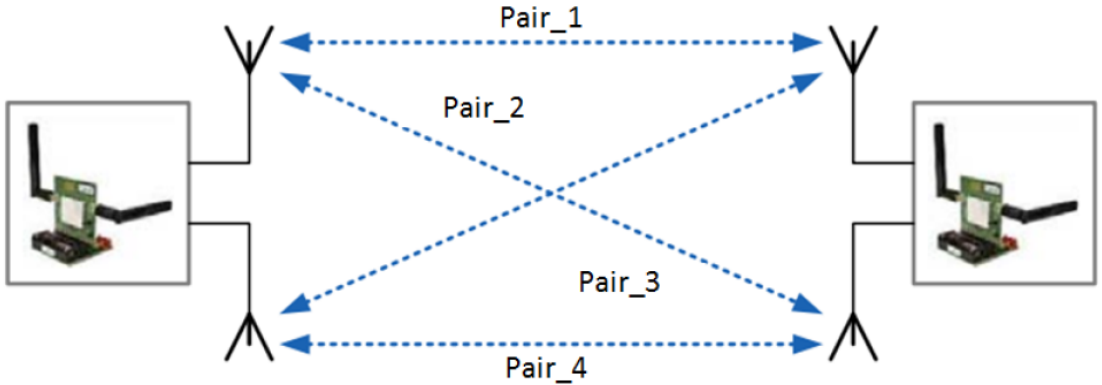
# Ranging / Distance measurement principle



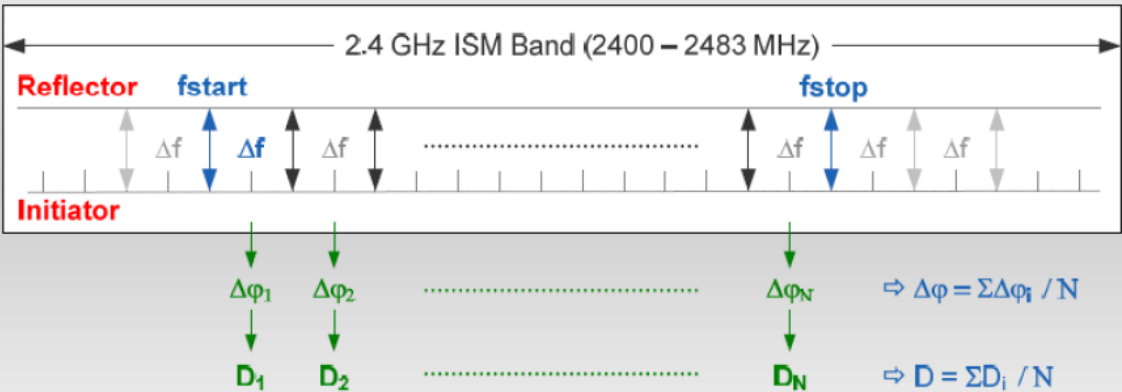
(a) Phase measurement devices

Iteration	Initiator	Reflector	Pair_-1 #	Pair_1	Pair_2	Pair_3	Pair_4
0	A B	144 73 #	161 100 228 97	143 100 287 92			
1	A B	86 80 #	126 100 146 92	85 100 228 97			
2	A B	138 78 #	159 100 206 100	136 100 254 97			
3	A B	127 78 #	132 97 184 85	126 95 281 90			
4	A B	156 65 #	154 95 266 82	94 93 243 66			
5	A B	87 78 #	124 100 135 81	86 95 214 95			
6	A B	118 81 #	161 100 174 97	115 100 215 87			
7	A B	222 74 #	219 90 293 85	105 95 303 78			

distance DQF



Atmel AT86RF233 evaluation kit



(b) Repeating individual frequency measurement

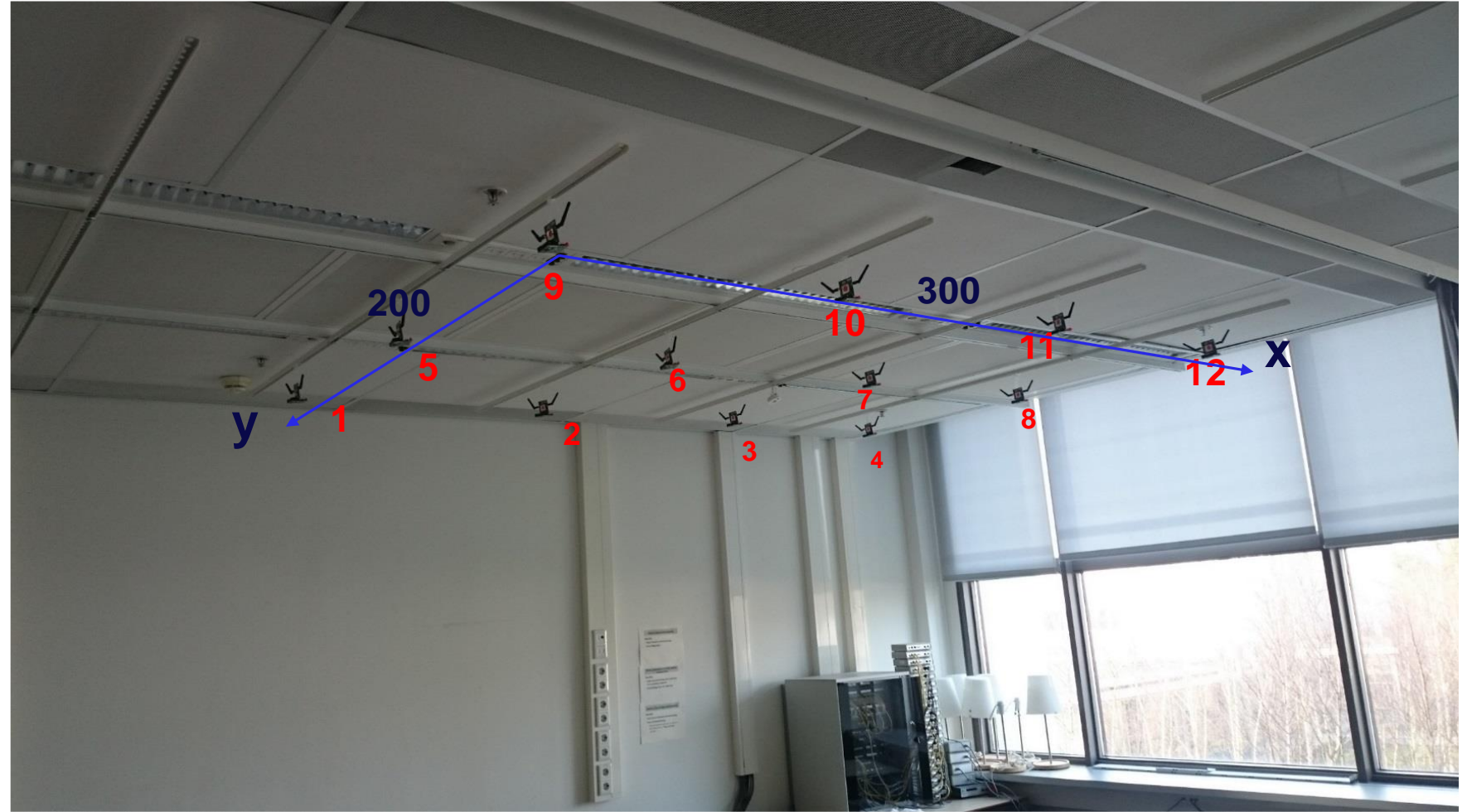
Source: Atmel / Metirionic



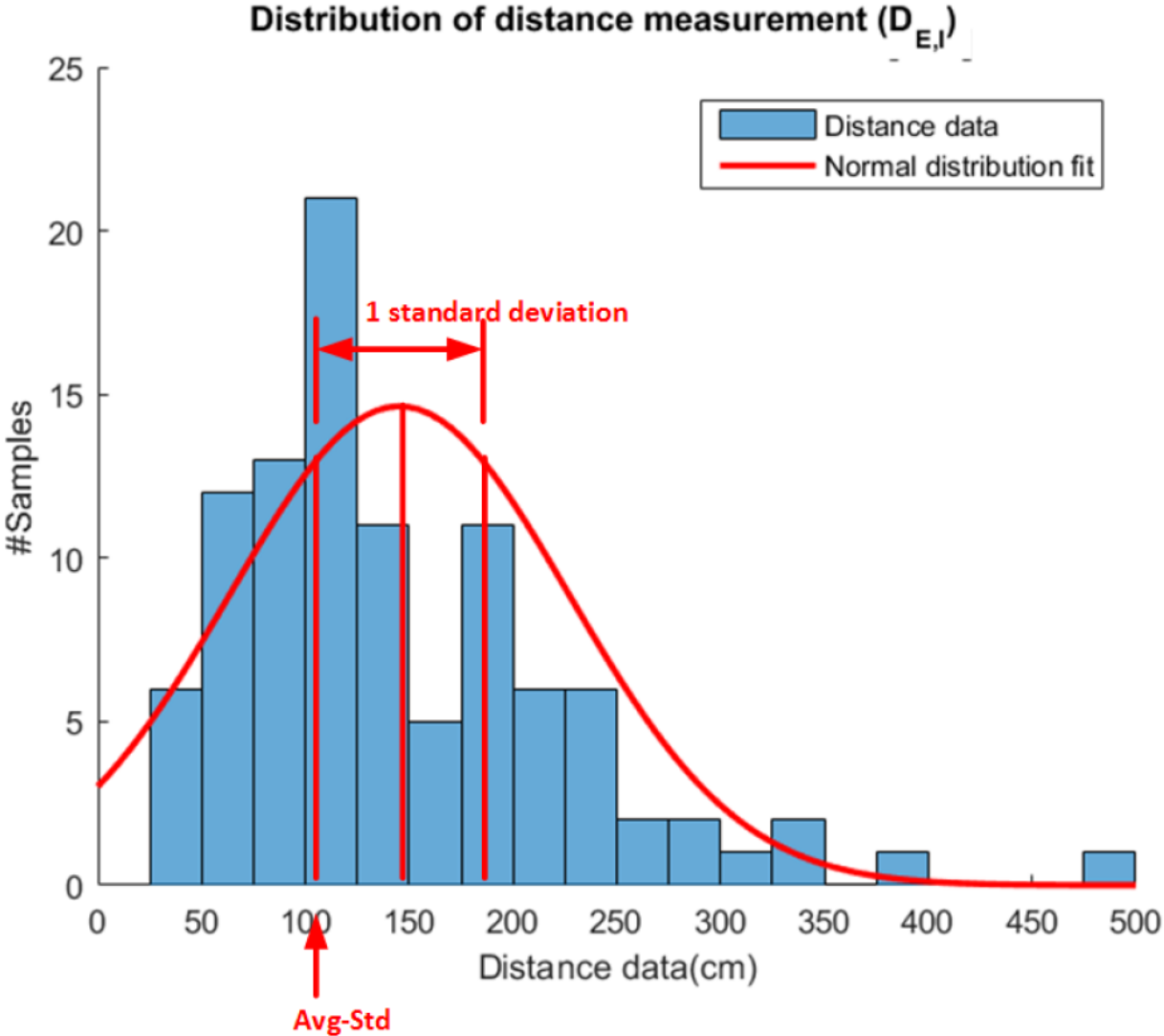


# Experimental setup

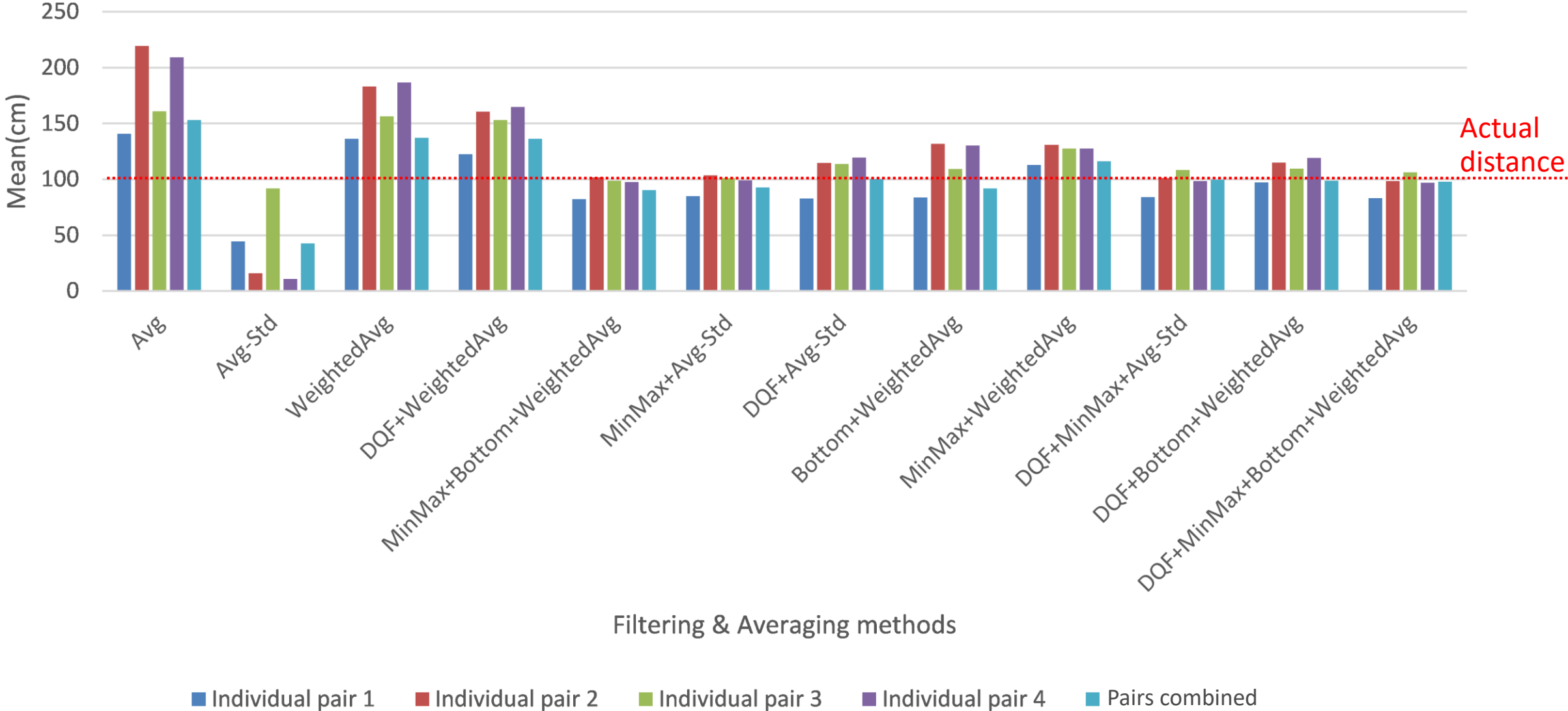
Inter-node distance:  
1m in both X and Y  
directions



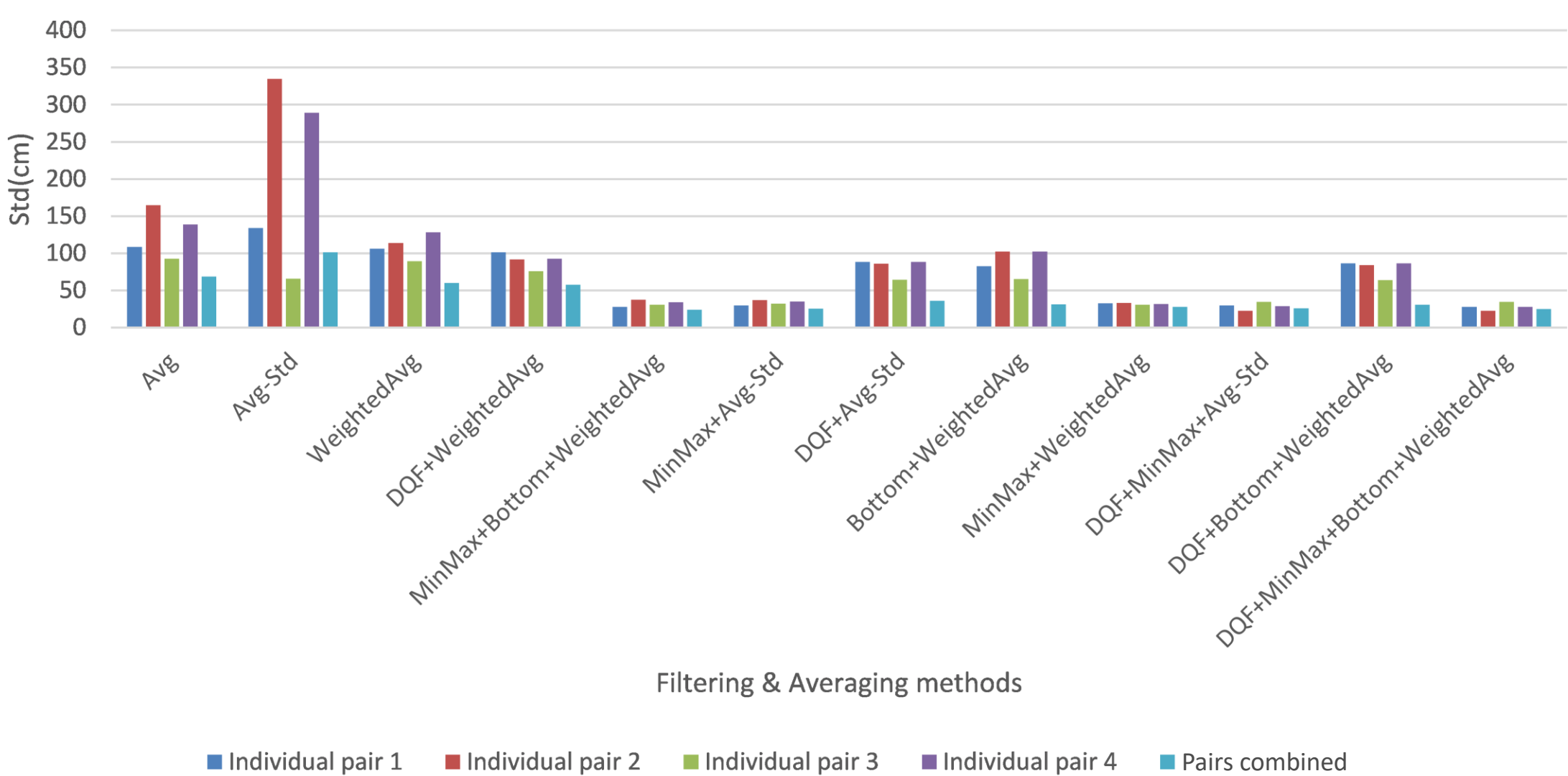
# Illustration of distance data processing



# Comparison of various filtering and averaging strategies

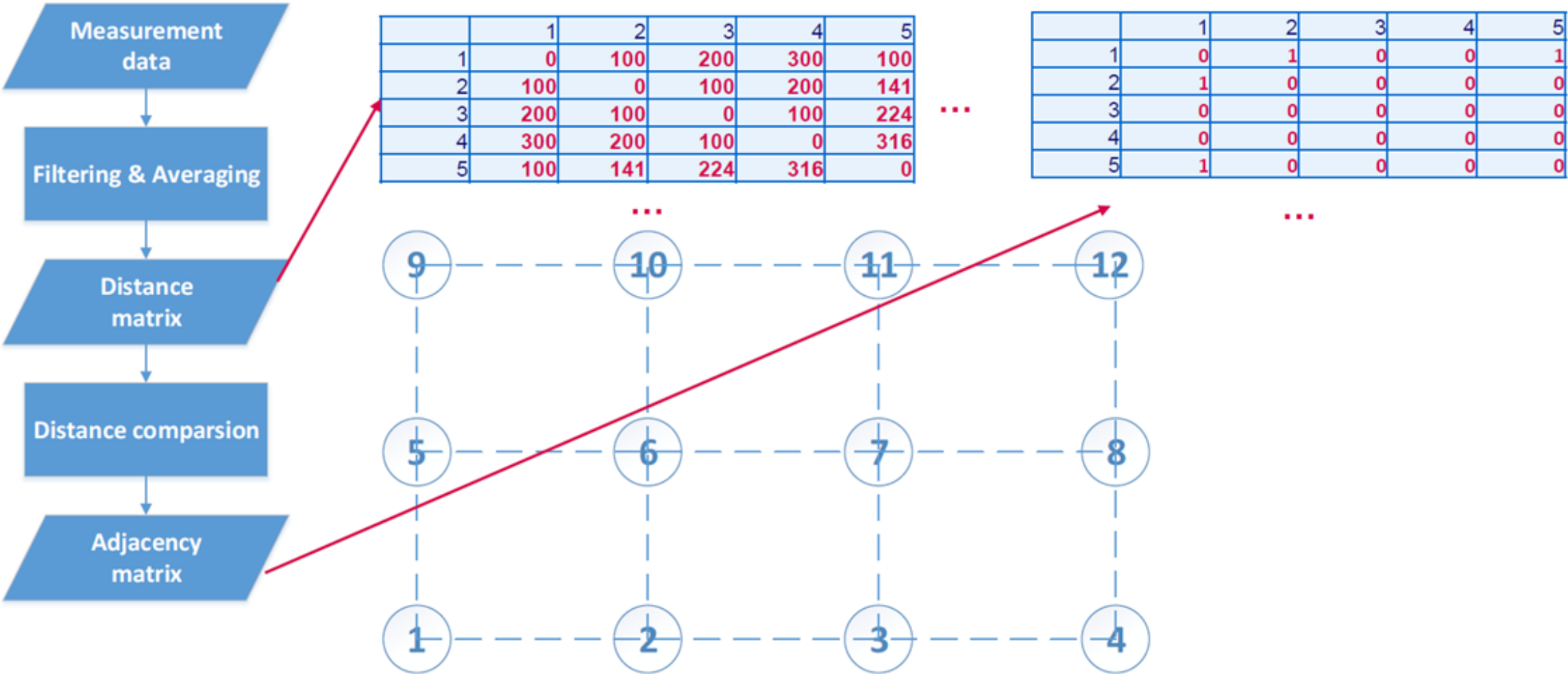


# Comparison of various filtering and averaging strategies

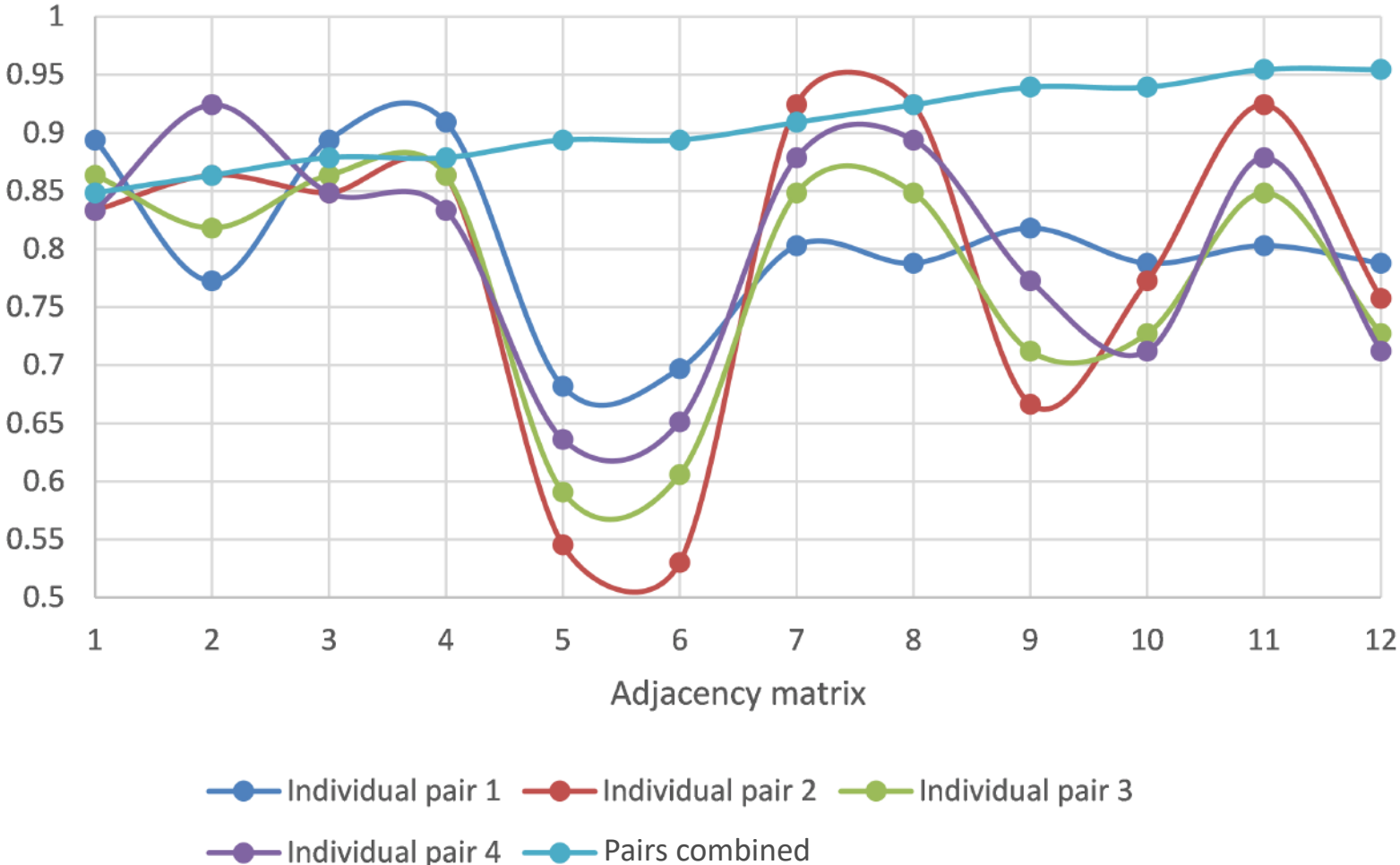




# Graph adjacency matrix



# Evaluation of adjacency matrix



# Graph matching and validations

# Graph matching overview

Method 1: Graph drawing and vertex matching

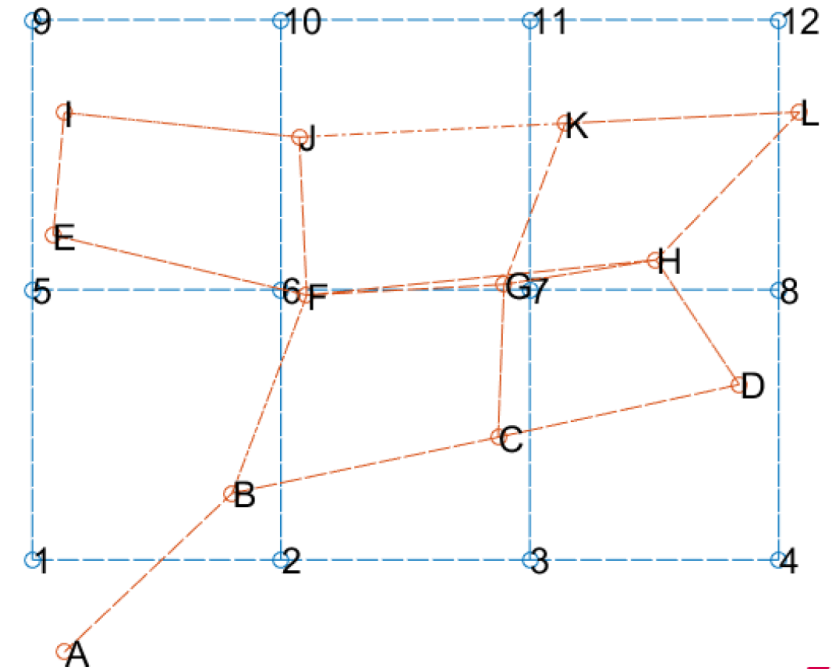
- objective function:  $\sum_{i,j \in N} d_{est(i),act(j)}$

Method 2: Iterative vertex matching based on distances

- objective function:  $\sum_{i,j \in N} (d_{est(i),est(j)} - d_{act(i),act(j)})^2$

Method 3: Heuristic edge matching

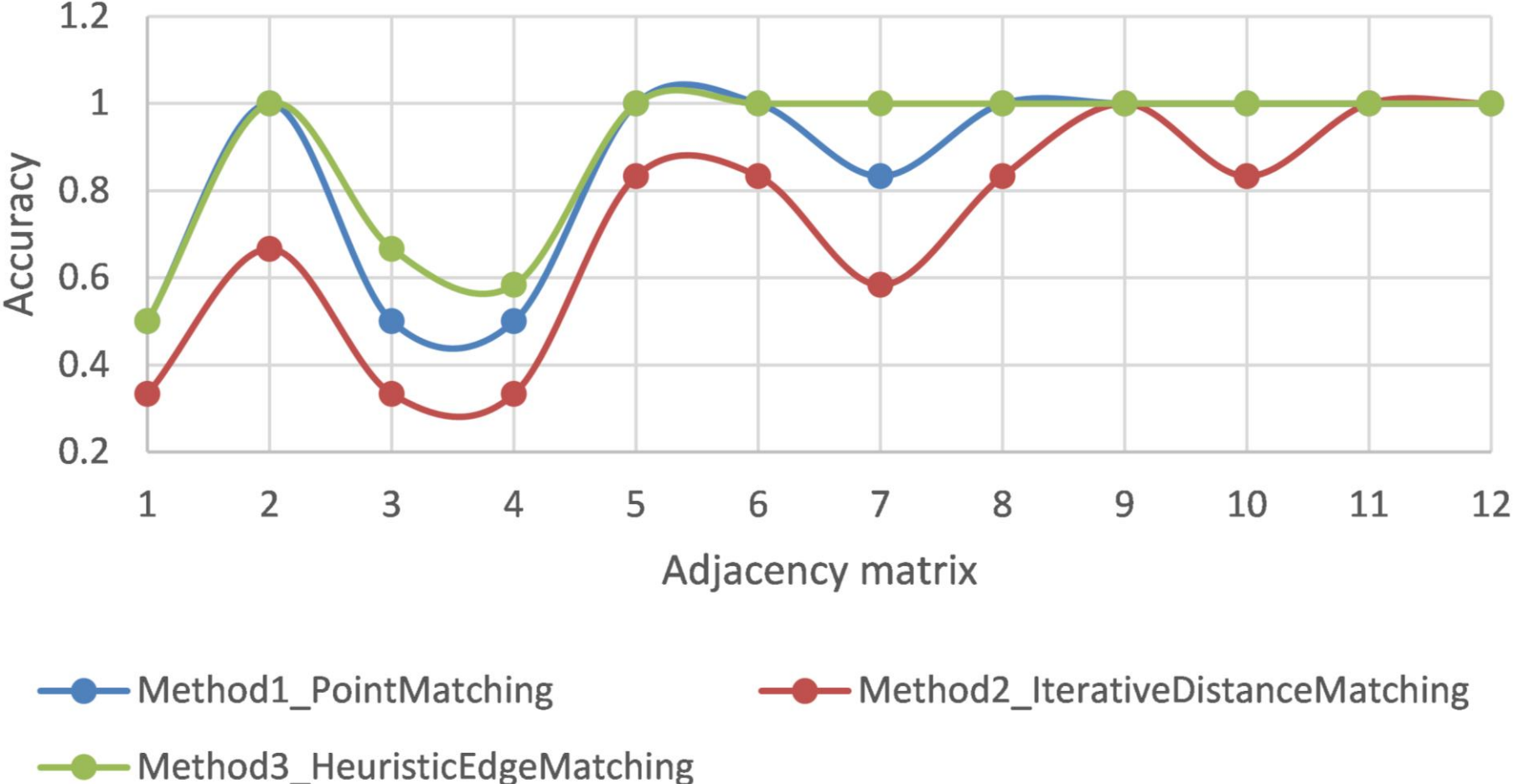
- Objective function:  $\sum_{i,j \in N} estAdjMatrix_{i,j} * actAdjMatrix_{i,j}$





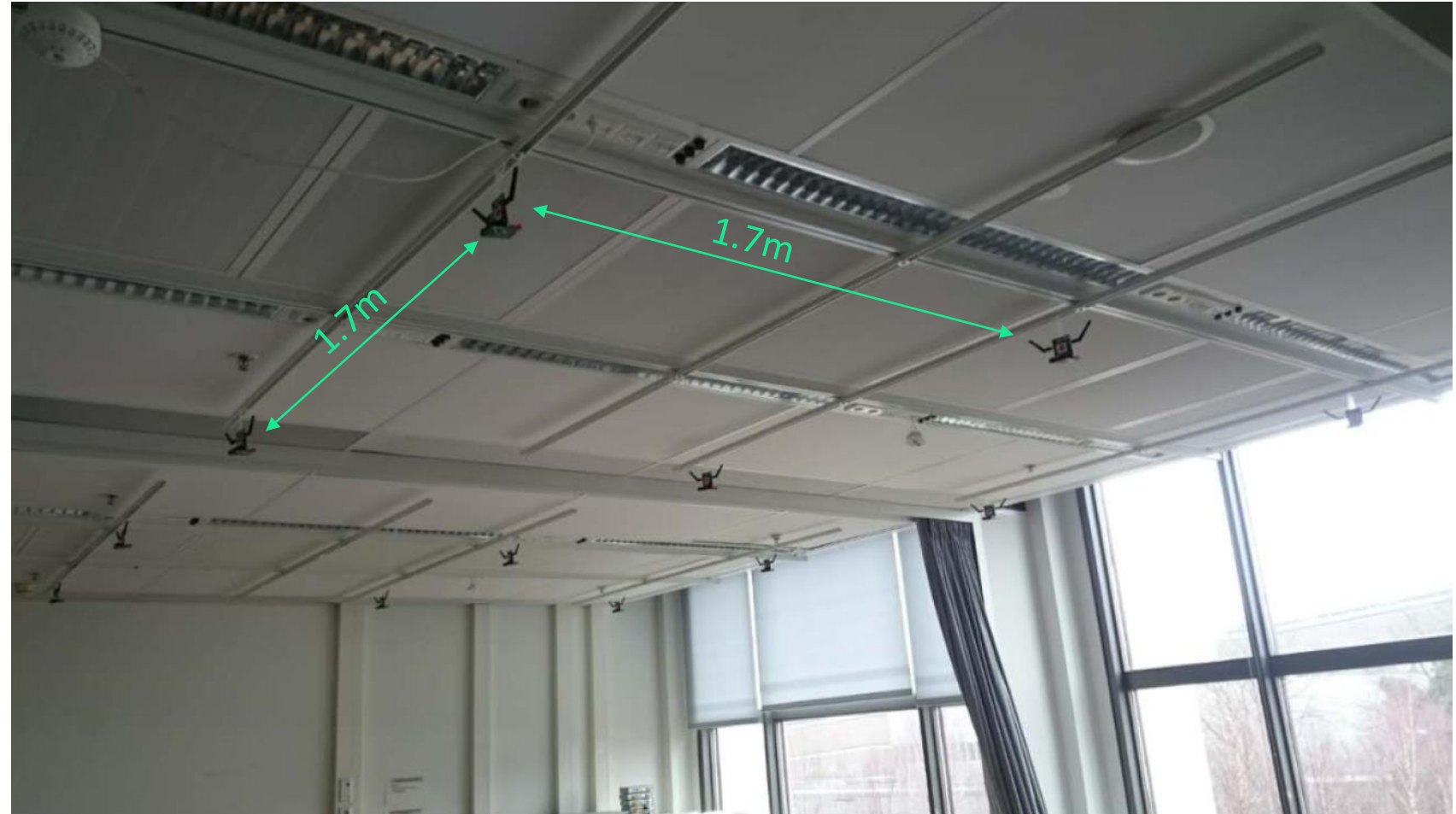
# Comparison of the three graph matching methods

## Accuracy of three methods



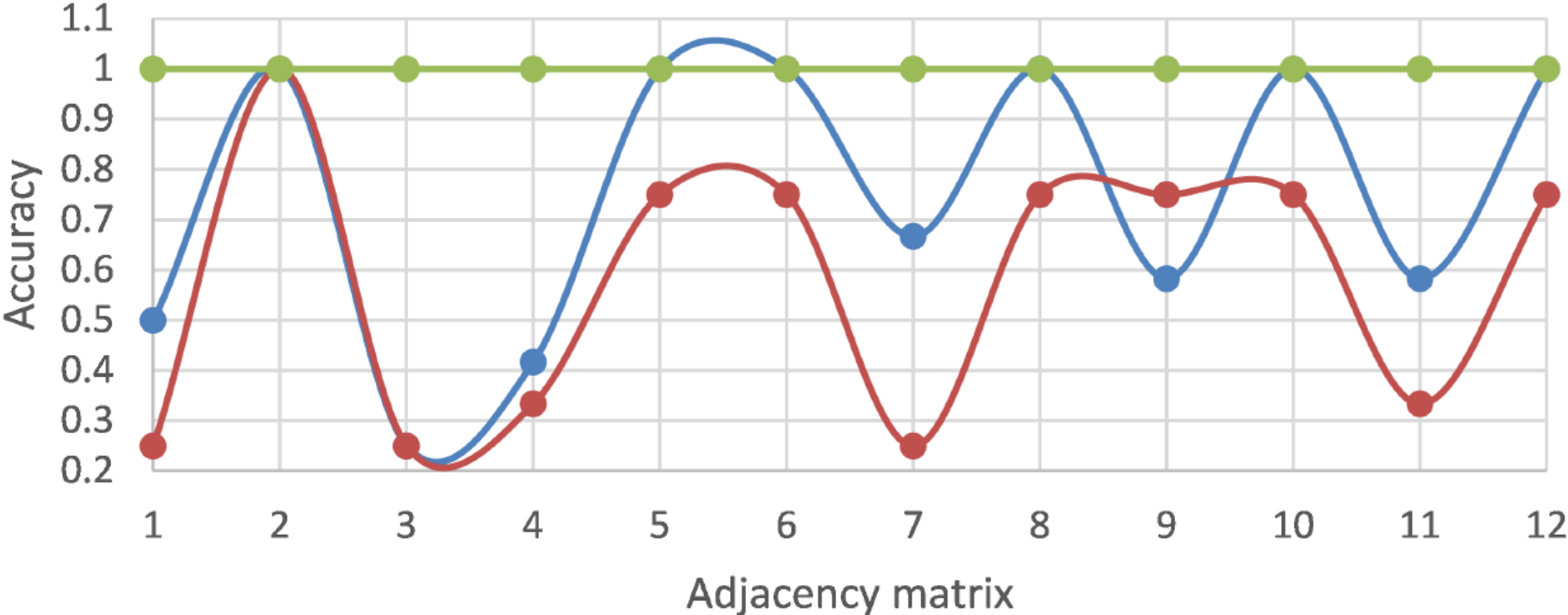
## Experimental setup 2

Inter-node distance:  
1.7m in both X and Y  
directions



# Comparison of the three graph matching methods

## Accuracy of three methods



Method1\_PointMatching

Method2\_IterativeDistanceMatching

Method3\_HeuristicEdgeMatching

# Conclusions and future work

# Conclusions and future work

- Phase measurement / ranging pioneered by Atmel/Metirionic is a low cost and accurate solution for IoT localization
- Lighting grid offers many advantages for deploying IoT localization applications
- For automatic localization of lighting grid, measurement data processing is one of the key aspects
- Graph matching method, particularly the heuristic edge matching method, appears to be promising
- The validations so far are for a small and regular lighting grid (3 by 4). Larger test setup and irregular lighting grids are to be studied.

# Acknowledgement

- Former Master's student, GONG Li, previously at Eindhoven University of Technology

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