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# Evaluating the Impact of the Number of Access Points in Mobile Robots Localization Using Artificial Neural Networks

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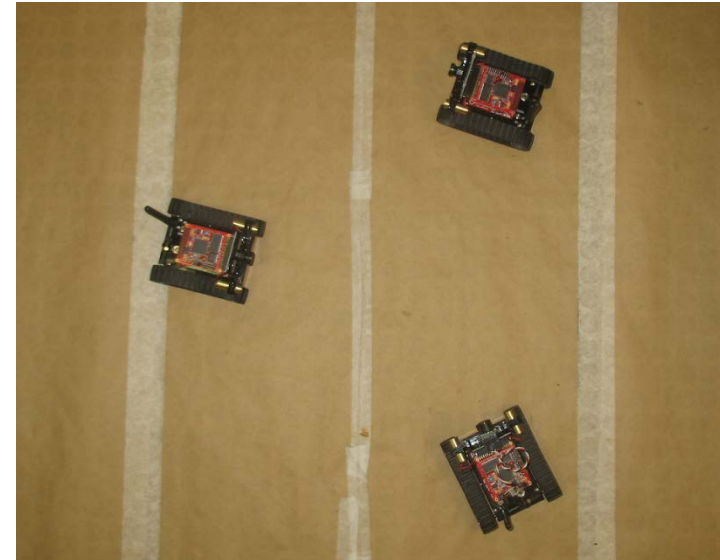
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# Summary

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- ▶ Motivation
- ▶ Objectives
- ▶ Methodology
- ▶ Results
- ▶ Future Work



# Motivation

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- ▶ Accurate position information of an agent (i.e. **robot, animal, or people**) is a requirement to accomplish several tasks.
- ▶ Some sensors like **GPS** provide global position estimation **but** it is **restricted to outdoor environments**.
- ▶ In **indoor** spaces, other sensors like **lasers** and **cameras** can be used for position estimation, **but** they require landmarks (or maps) in the environment and a fair amount of computation to process complex algorithms.

# Motivation

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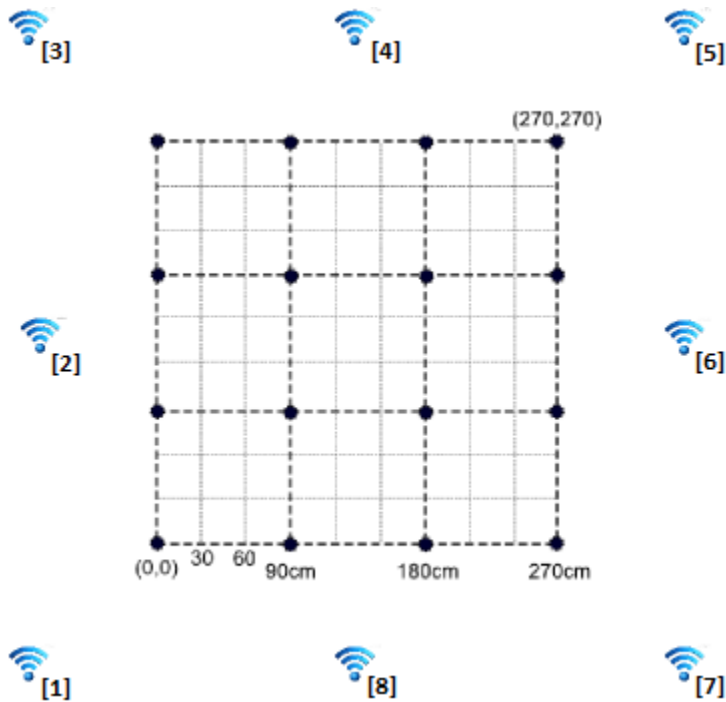
- ▶ Nowadays Wireless Networks (WN) are **widely available** in indoor environments and may allow global localization demanding relatively low computing resources.
- ▶ Other advantage of this approach is the **independence of specific features** of the environment.
- ▶ However, the **inherent instability** in the wireless signal **does not allow** its direct use for **very accurate position** estimation.

# Objective

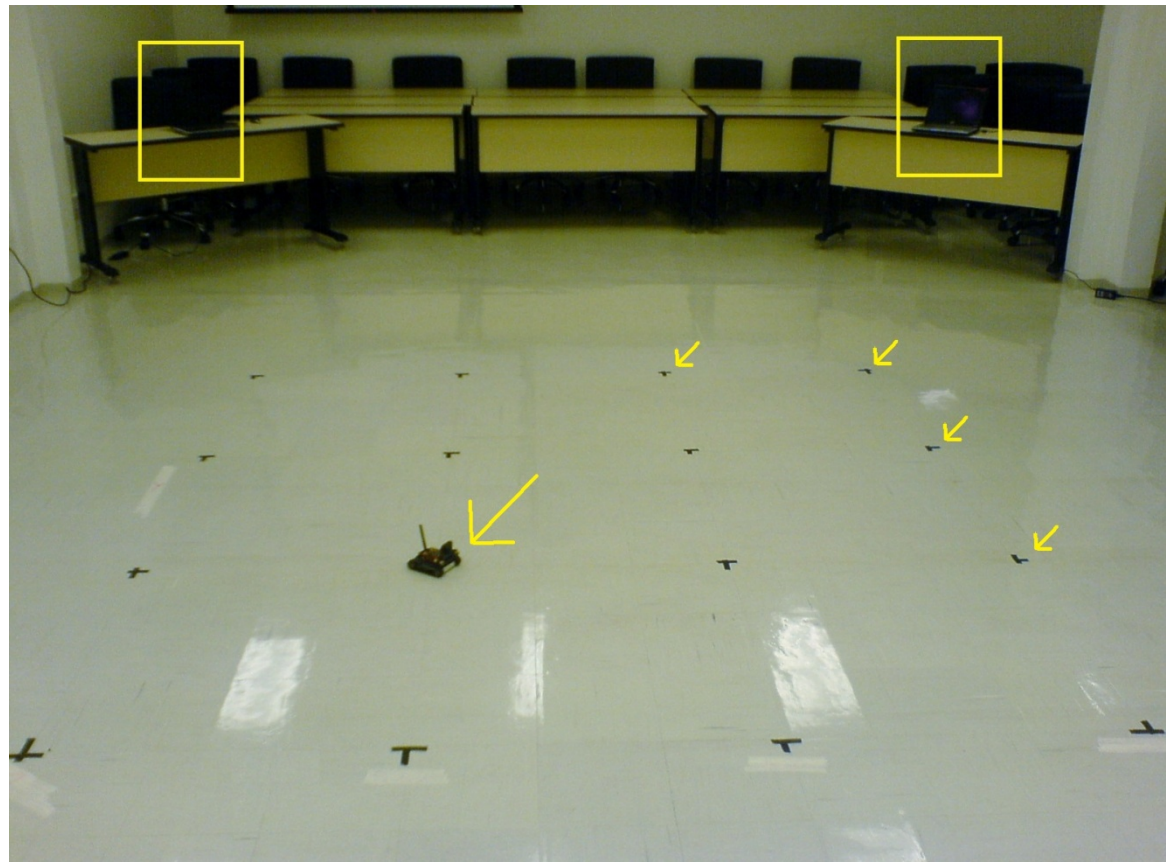
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- ▶ ***Evaluate the use of an Artificial Neural Network (ANN) to improve the estimation of the position (x,y) of a mobile node in indoor environment using data provided by wireless networks (802.11b/g).***
  - *The growth in the number of Access Points (AP) increases the overlap signals areas. Could it be a useful mean of improving the precision of the localization?*
    - ▶ *We use three to eight APs as a source signal and show how the ANNs learn and generalize the data.*
    - ▶ *From WN we use: Received Signal Strength Indication (RSSI)*
  - *Added to this, we evaluate the robustness of the ANNs and evaluate a heuristic to try to decrease the error in the localization.*
  - *In order to validate our approach several ANNs topologies have been evaluated in experimental tests that were conducted with a mobile node in an indoor space.*

# Methodology



The **working area** of the mobile node is **inside a room** and is represented as a Cartesian plane. There are 8 access points (APs), one in each corner of the plane. The mobile node is located inside the plane with one wireless card used to scan the networks and signals provided by the APs. The data used to train the ANN was collected in 15 readings from each marked point – displacement of 90cm.



This Figure shows a little robot inside the plane but to scan the WNs and to obtain the data used as ANN input we used a mobile computer. The GNU/Linux command *iwlist* used to scan the networks is not yet implemented in the robot.



# Methodology

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- ▶ In order to validate our approach, several ANN topologies have been evaluated.
  - The inputs of the ANN are the signals received by the mobile node antenna from the {3,4,6,8} statically positioned APs.
  - The values obtained from the wireless networks are the Received Signal Strength Indication (RSSI), obtained with the GNU/Linux command iwlist.
    - ▶ As we use the iwlist command, there is no need to establish a connection (or login) with the different specific networks. The scan of the networks without a connection provides enough information to this evaluation. Without a connection, the system becomes easier to use, more lightweight and flexible.

RSSI is a metric of the signal strength or signal power present in a received radio signal. Technically any device with wireless communication functionality provides it to the upper layers of the network stacks. The main advantage of using RSSI is its low cost. Given that every wireless device implements the possibility to deliver that value in its circuitry, there is no need of additional hardware development or adaptation.

# Methodology

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- ▶ The experiments are conducted in four steps:
  - I. We evaluate several ANN topologies seeking to obtain the topology which can achieve the lowest error – the hidden layers evaluated are with {4, 4x4, 8, 8x8, 12, 16, 20, 24, 28, 32} neurons.
  - II. We use the best ANN (best hidden layer) obtained in the previous stage and analyze the behavior of the ANN when more than 3 inputs are used (we use 3, 4, 6 and 8 inputs – respectively 3, 4, 6 and 8 APs providing RSSI values).
  - III. We evaluate how the ANN deals with errors in the inputs – we simulate failures in the APs, by injecting null values in some of the inputs.
  - IV. We evaluate an idea to try to decrease the error in the localization by using averages and medians of multiple measurements from the wireless network, broadening the idea outlined in a previous work.

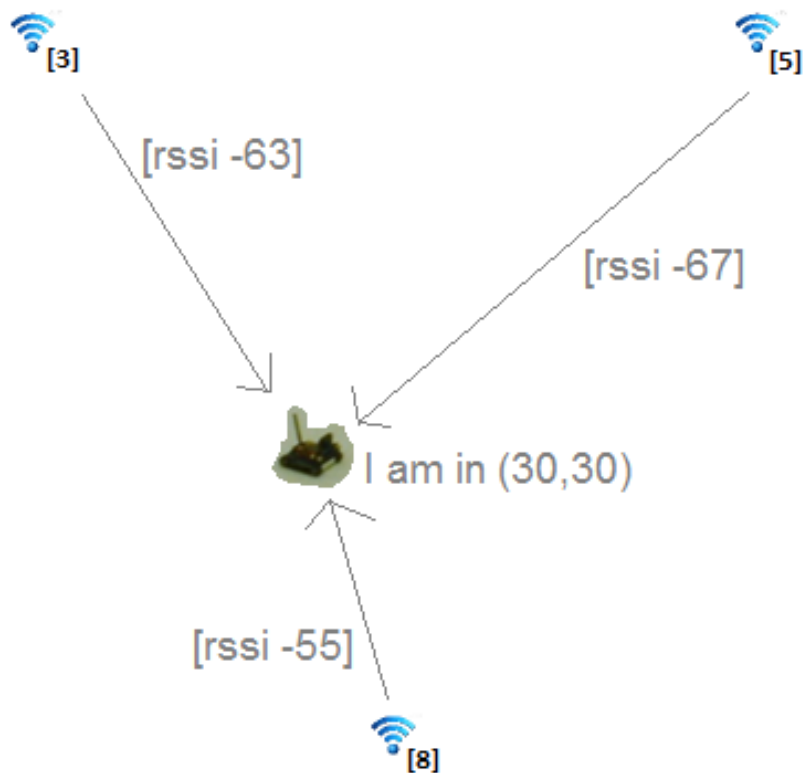
# Methodology

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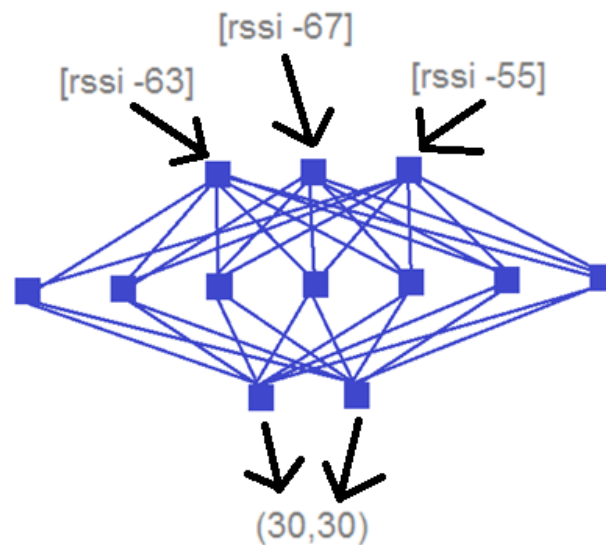
- ▶ As we use 3 to 8 APs, we use one neuron for each network signal.
- ▶ The order is important, and hence, the AP 1 was associated to neuron 1, AP 2 with neuron 2 and so on.
- ▶ **The outputs** of the network are two values, the coordinates (x,y) - the mobile node position.
- ▶ The error is measured in centimeters, using the distance formula (distance between two points):

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

# Methodology (simple example)

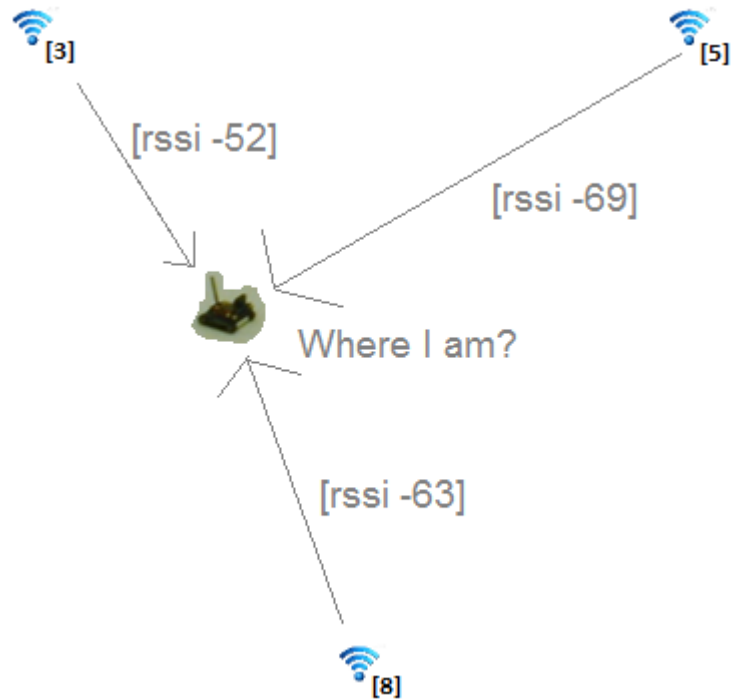


## [ann learning]

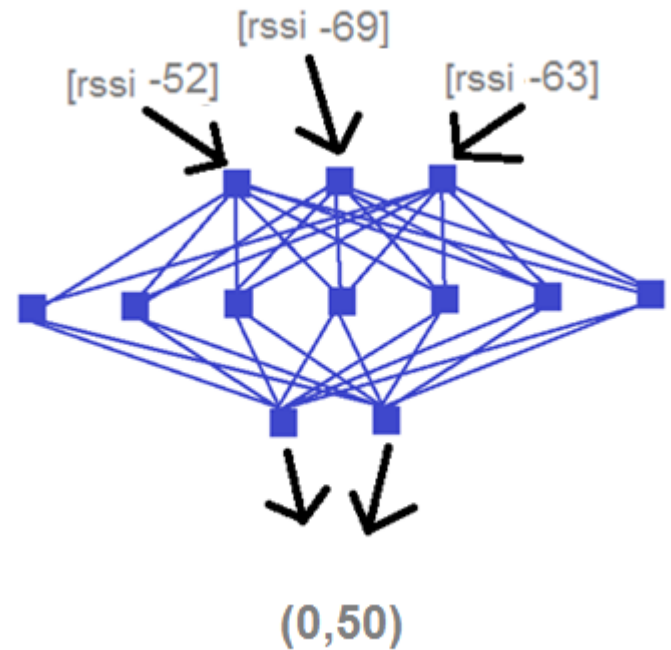


We use 240 tuples in the ANN learning phase.

# Methodology (simple example)



## Where I am?



## Experiments and results [i/iv]

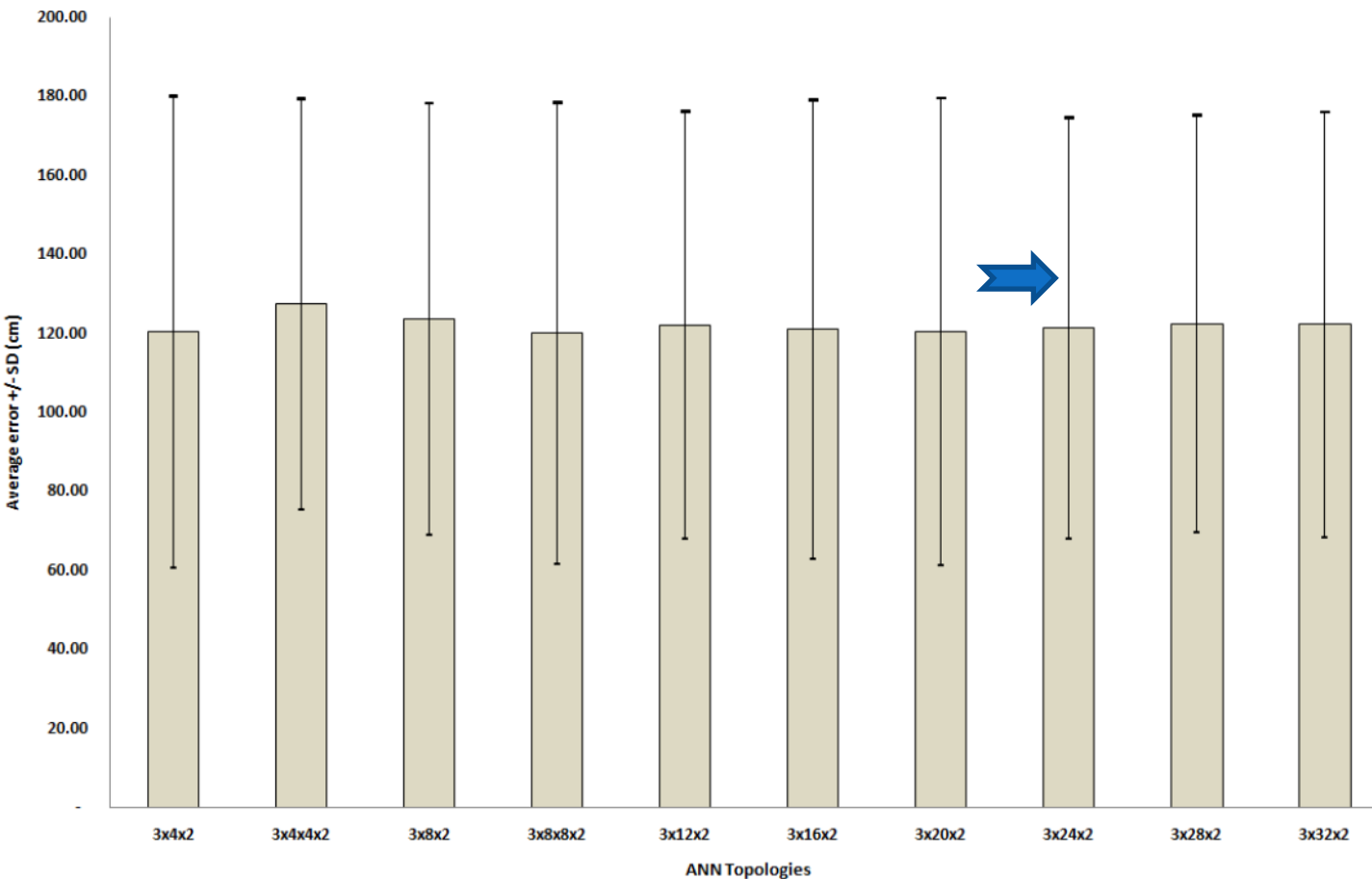
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- ▶ **In the first step**, we evaluate several ANN topologies seeking to obtain the topology which can achieve the lowest error – the hidden layers evaluated are with {4, 4x4, 8, 8x8, 12, 16, 20, 24, 28, 32} neurons.
- ▶ ANNs are susceptible to random values used in the initialization of the weights, so, we show in all tables the result of 5 different initializations and ANN training and validation.
- ▶ We run the ANN training for 200.000 cycles, doing validation each 1.000 cycles. After 200.000 training cycles we use a script to find the cycle where the lower error occurred in the validation set (Optimum Generalization Point - OGP).

# Experiments and results [i/iv]

Table 1: Results of the best ANN for each topology (in cms).

	ANN Topology									
	3x4x2	3x4x4x2	3x8x2	3x8x8x2	3x12x2	3x16x2	3x20x2	3x24x2	3x28x2	3x32x2
Average error	120.37	127.49	123.78	120.04	122.10	120.94	120.44	121.31	122.36	122.25
Std. dev.	59.63	51.89	54.59	58.38	54.07	58.12	59.08	53.28	52.84	53.80
Larger error	220.30	221.66	204.67	213.06	238.31	246.33	220.76	208.89	194.53	203.86
Smaller error	2.77	28.30	12.22	0.76	18.46	0.98	6.32	4.39	18.21	22.71



-As can be seen, results for all the evaluated ANN topologies are fairly similar.

-Although quite similar, the ANN which had the lowest error (taking into account the sum of the average errors and standard deviation) was the ANN with 24 neurons in the hidden layers. Because of this, we will use this ANN topology in the next stage.

Graphical representation of values from Table 1 – results of the best ANN for each topology.

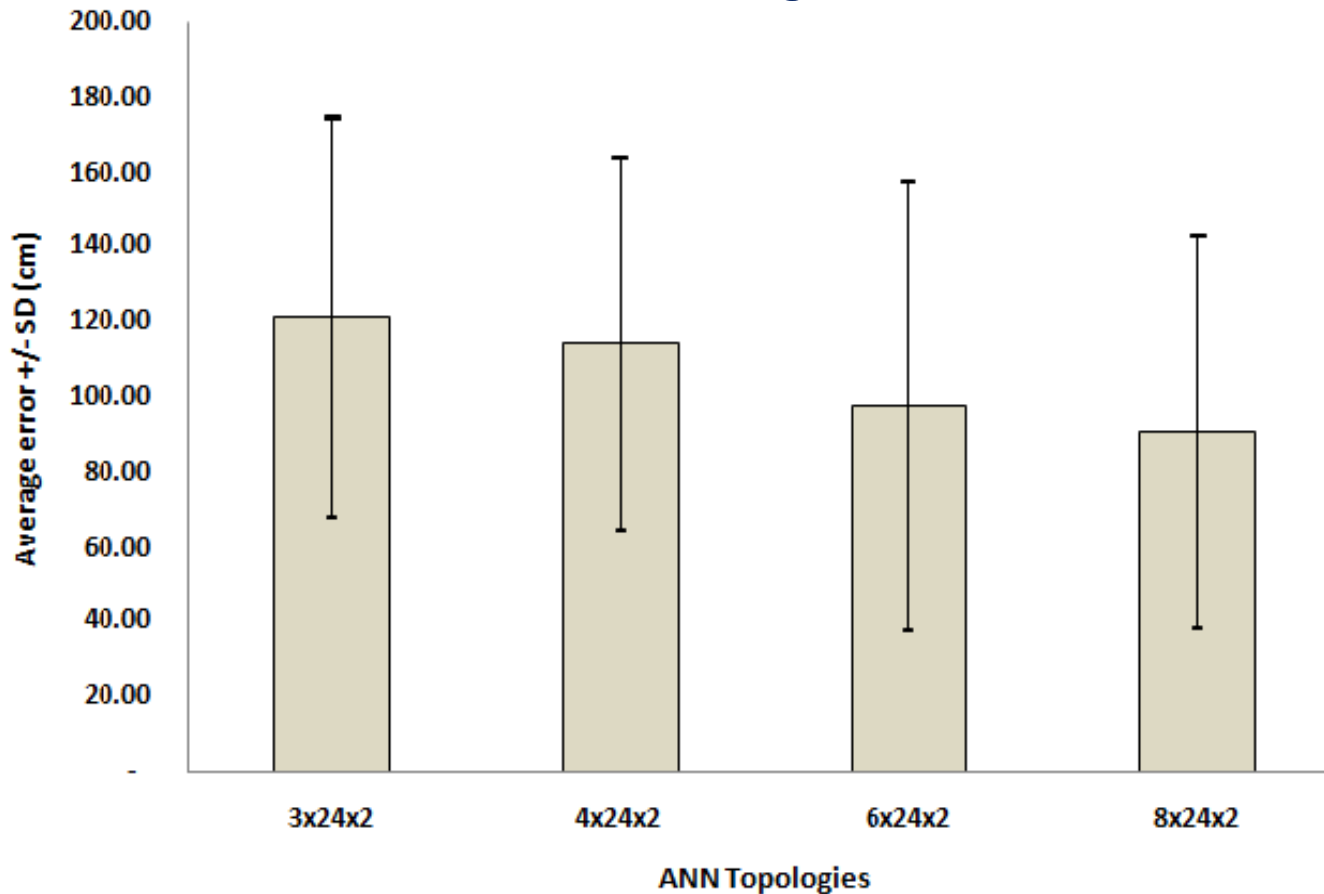
## Experiments and results [ii/iv]

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- ▶ **In the second step**, we analyze the ANN behavior when more than three access points are included, we use 4, 6 and 8 RSSI values from different access points.
- ▶ Using three inputs => APs {3,5,8}
- ▶ Using four inputs => APs {1,3,5,7}
- ▶ Using six inputs => APs {1,2,3,5,6,7}
- ▶ Using eight inputs => all APs
  
- ▶ **These choices were made in an attempt to maintain a balance on all sides of the working area.**

# Experiments and results [ii/iv]

## Using 3,4,6 and 8 RSSI values



As can be seen, when the number of access points is increased, the average error decreases considerably. The average error falls from 121.31cm (using 3 inputs) to 90.46cm (using 8 inputs). But the standard deviation remains very similar in all cases.

**Results of the best ANN for each different input layer (in cms).**

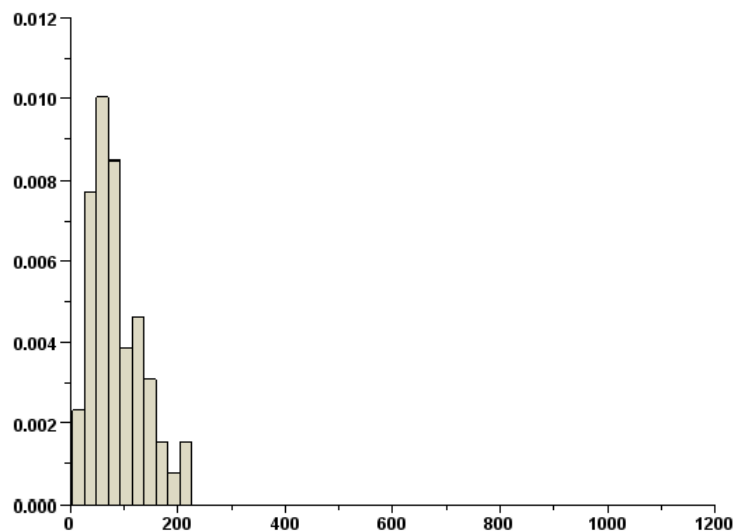
## Experiments and results [iii/iv]

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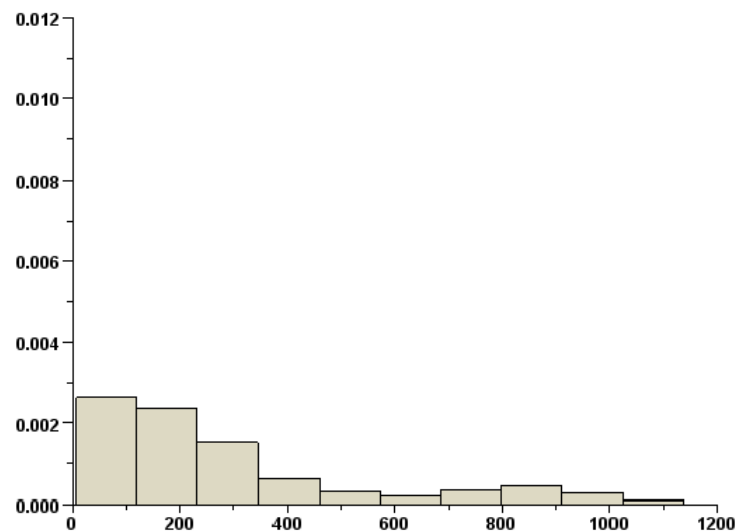
- ▶ **In the third step**, we sought to evaluate how the ANN deals with the problem of errors in the inputs – we simulated failures in the APs, by injecting null values in some of the inputs.
- ▶ In this way, we pick the best ANN from the previous stages (ANN with 8 inputs and 24 neurons in the hidden layer). We used the trained ANN to read the original validation set and obtain the output values for all of the sets. For each complete reading in the validation set, we put a null value in one input neuron (keeping the true values of the other seven). This meant that we ran the ANN eight times, one for each AP, and in this way obtained the difference between the expected and obtained values.

# Experiments and results [iii/iv]

The ANN with simulated input error really produces worse results. Figure 6 shows the histogram of the error taking account of the ANN with original 8 inputs and with simulated input error. It can be seen in Figure 6(b) that it has a big tail, and obtains really worse errors than Figure 6(a).



(a)



(b)

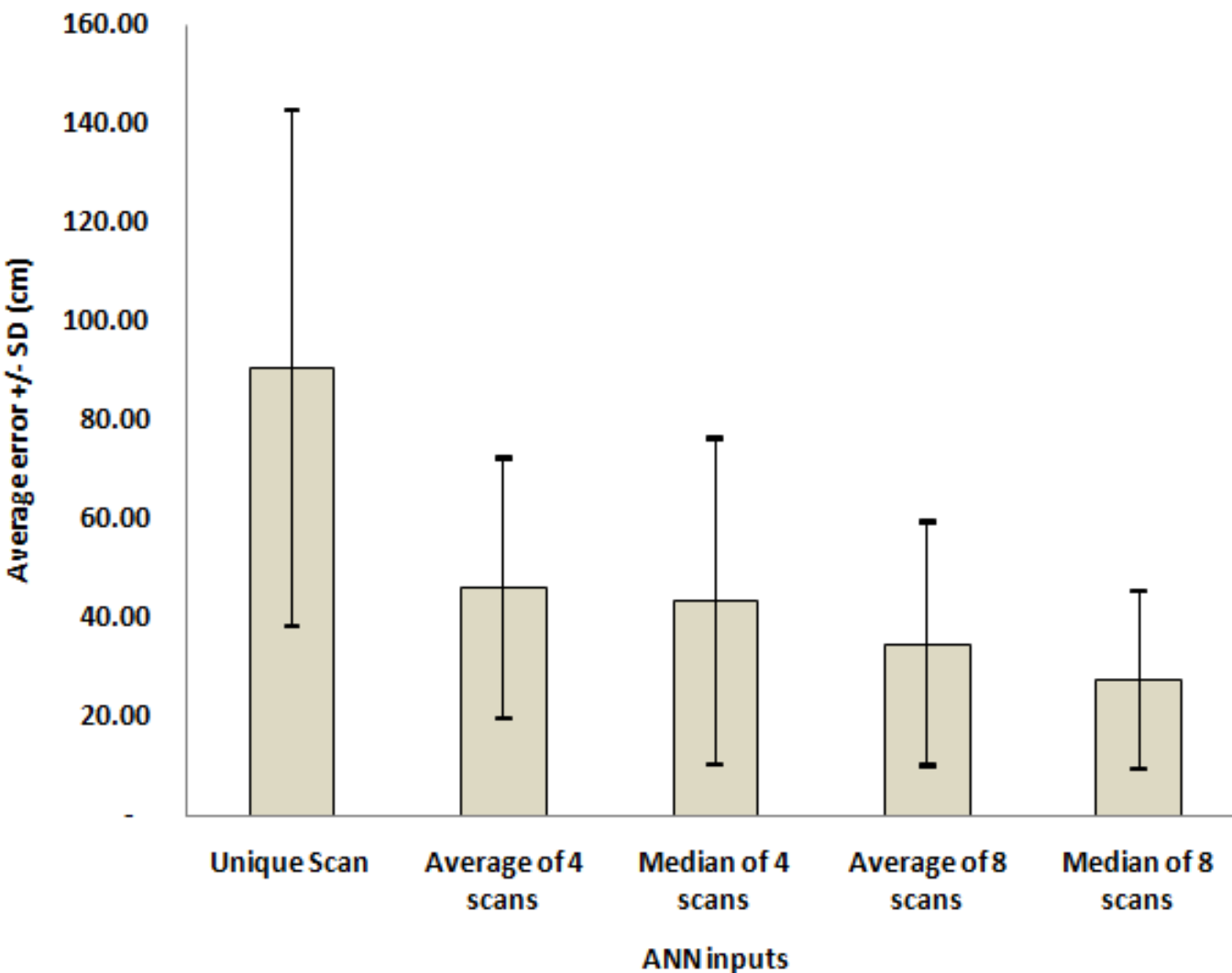
Figure 6: Histogram of the error. (a) Using original 8 inputs. (b) Injecting error (null value) in one neuron in the ANN input. The  $x$  axis represents the error in centimeters.

## Experiments and results [iv/iv]

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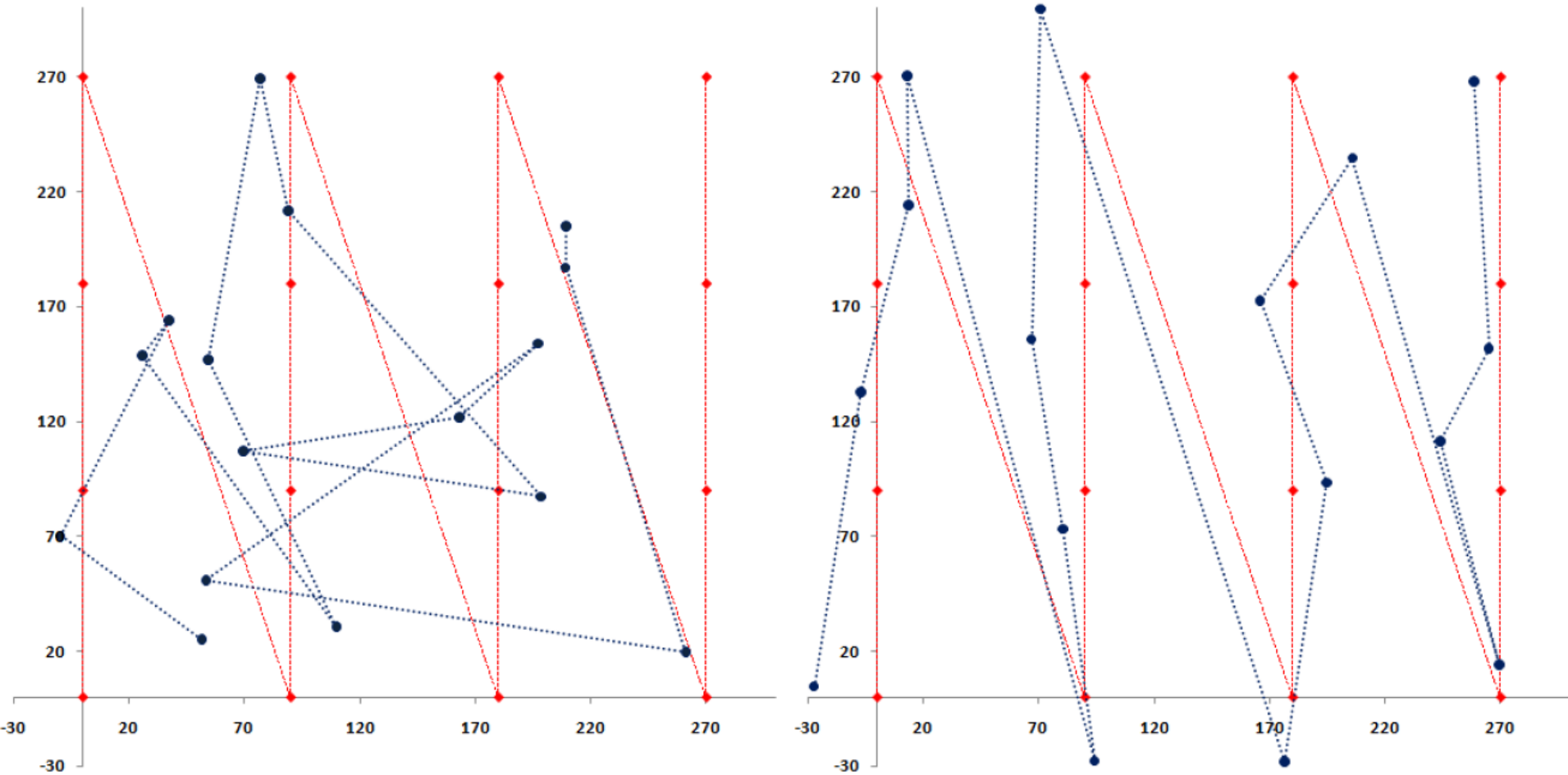
- ▶ **In the forth step**, we sought to evaluate a simple idea to reduce the error; so we made a comparison between the use of average and the use of medians of multiple readings of the wireless network signals as ANN input.
- ▶ Hence, the average and medians of multiples readings of wireless networks were used as input of the ANN. We evaluated the average and medians of 4 and 8 readings of the wireless network signals (scans of wireless signals).
- ▶ In this evaluation, we used the best ANN topology chosen from the second stage (ANN with 24 hidden neurons where all eight APs were used).

# Experiments and results [iv/iv]



-By using the average and the median of the multiple readings from the wireless network as the input in the ANN, we could reduce the average error in the ANN learning from 90.46cm (without using the average of the scan) to 34.69cm (using an average of 8 scans) and to 27.40cm (using a median of 8 scans).

# Experiments and results



Paths using the best trained ANNs (Red line: original path; Blue line: ANN tracking):  
(a) Just one scan used as ANN input.  
(b) Mdn of 8 scans used as ANN input.

-We use the mobile node to traverse a path (get the track) in the environment, considering wireless scanning each point.  
- The results are not quite good yet, but Fig. (b) present results significantly better than Fig. (a). We can see from Fig. that the tracked path improves with the use of averages.

## Conclusions and Future Work

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- ▶ We have evaluated the use of an ANN to obtain the position of a mobile node in indoor environment using data provided by wireless network.
- ▶ We could reduce the error from 121.31 cm (using 3 APs) to 90.46 cm (using 8 APs).
- ▶ In addition, when an error was injected in the ANN, the results became really worse. This fact might discourage the use of the ANN since a failure in some AP might be identified.
- ▶ To further reduce the error, it has been shown that the use of multiple readings and the use of median could reduce the error from 90.46 cm to 27.40 cm.

# Future Work

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- ▶ Future work planned is to seek improvements in the system to obtain, beyond the position  $(x,y)$ , the orientation of the mobile node – complete pose  $(x,y,\theta)$ .
- ▶ In this way we plan use another wireless technologies, like Bluetooth and ZigBee and make evaluations with more than 4 Access Points.
  - There are two grad students working on it.
- ▶ Evaluations to reduce the WN instability.
  - There are one grad student working on it.

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# Thank You

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► Questions?

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