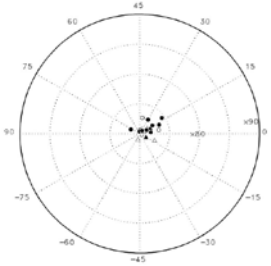
A Localization Technique For Multi-Agent Robot Formations

bots

Prateek Humane and Neelay Trivedi

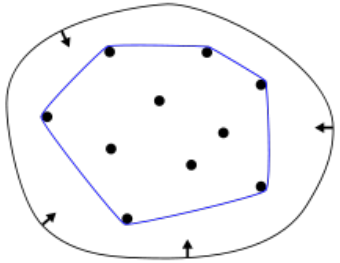
What Did We Do?

Indoor Localization System



Arduino-Based Sensor Module

Polygonal Formation Algorithm




(0,87)
(-20,73)
(10,73)
(23,54)
(-58,47)
(43,41)
(-20,43)
(10,43)
(0,0)

HARDWARE

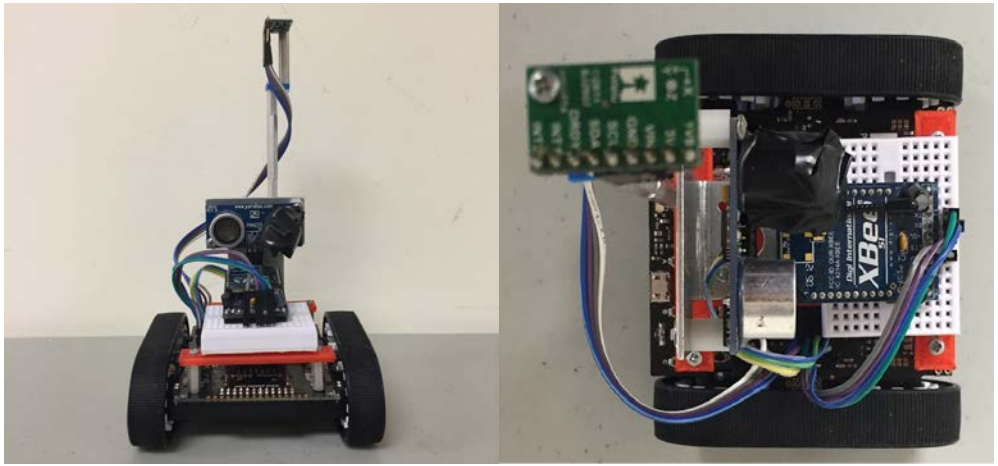
Sensor Module Overview

Compass Sensor

Pololu LSM303 compass sensor for absolute robot heading calculation (includes accelerometer for data filtering)

Ping Sensor

Ultrasonic sensor with range of 2cm to 3m. Every robot uses the ultrasonic receiver except for the beacon robot that only uses the transmitters



Xbee Module

Transmits a radio signal for peer to peer and broadcast communication with the other robots

Magnetic Encoders

Used in conjunction with the compass sensor for increased precision while turning

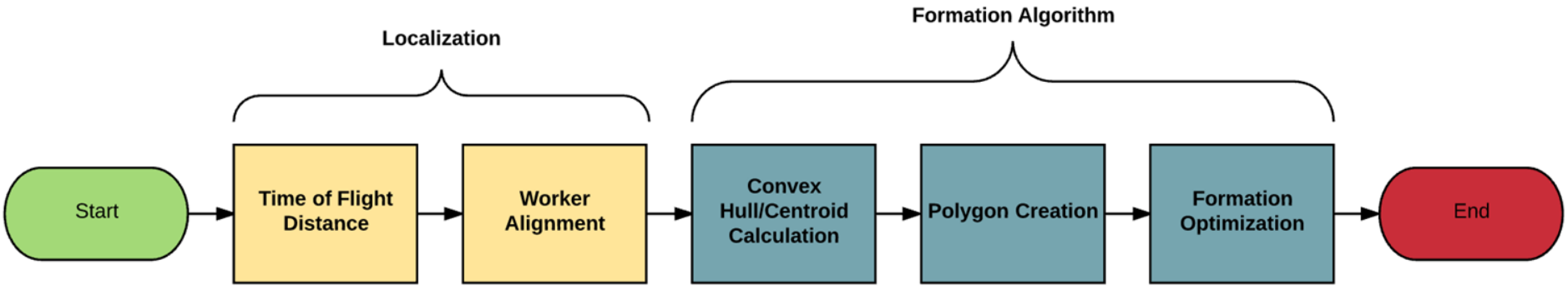
Low-Cost	Model System	Flexible
sensor module under $50	*new sensors = easy to add*	*cross-environment capable*

SOFTWARE

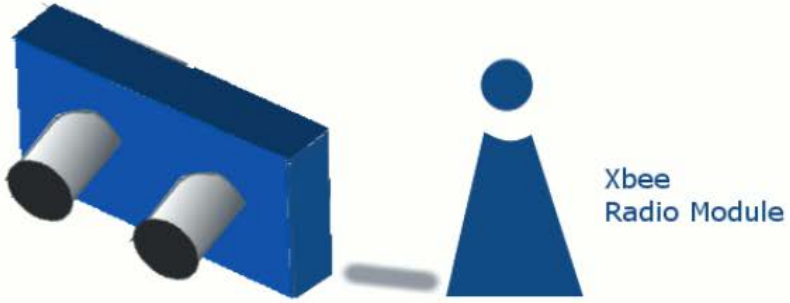
System Overview

Localization

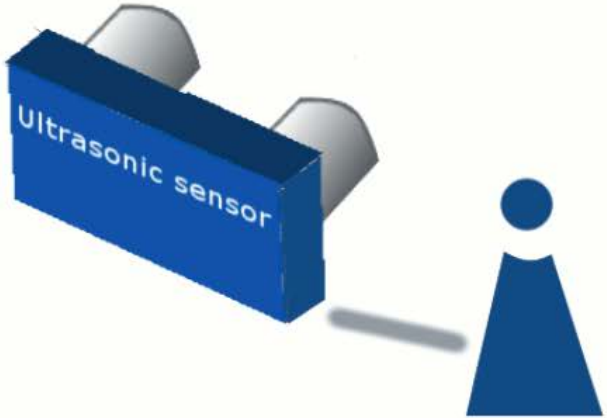
Formation Algorithm



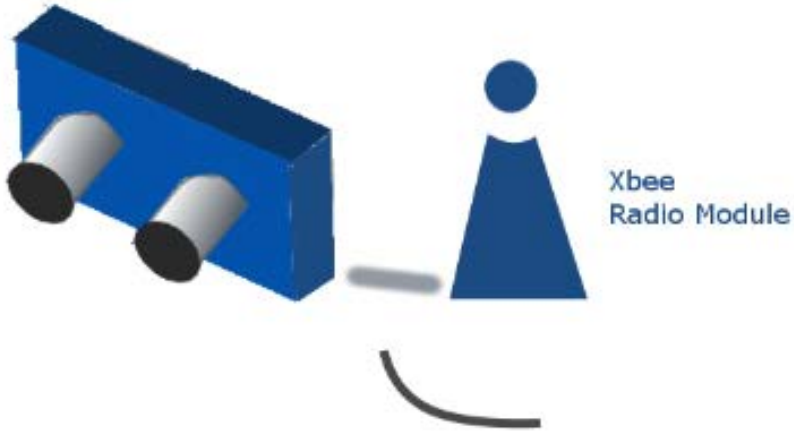
Distance Calculation



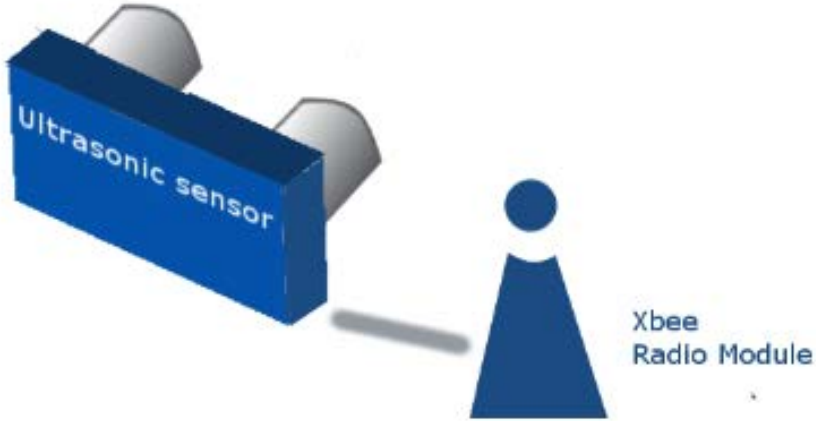
Xbee
Radio Module

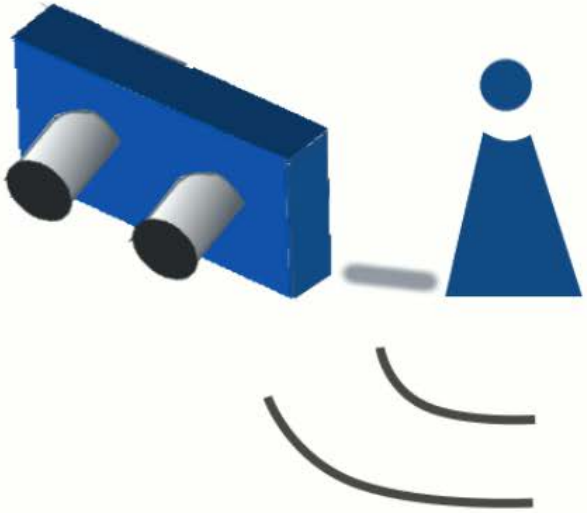


Xbee
Radio Module

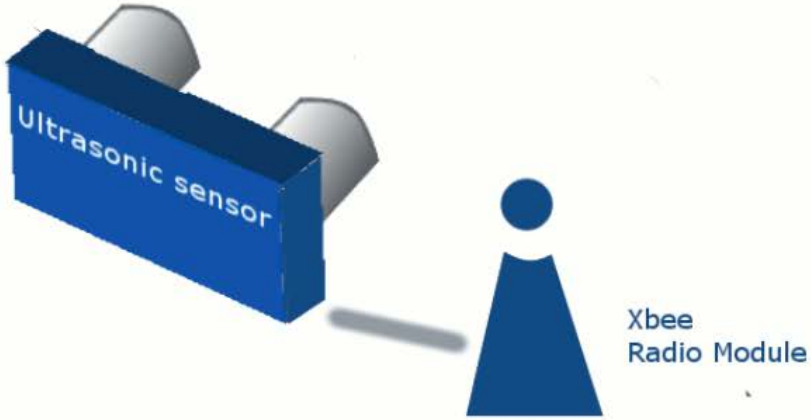


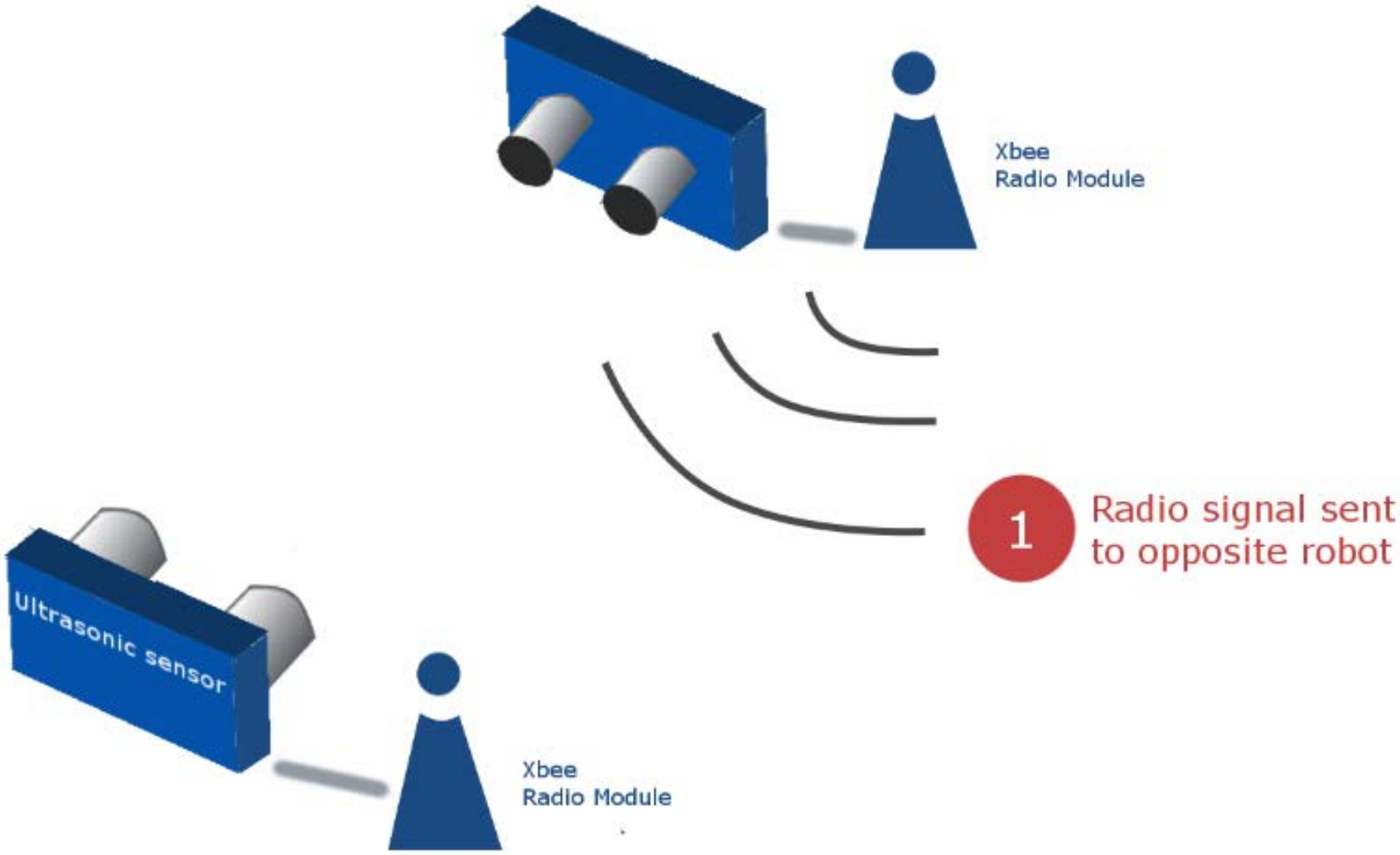
1 Radio signal sent to opposite robot

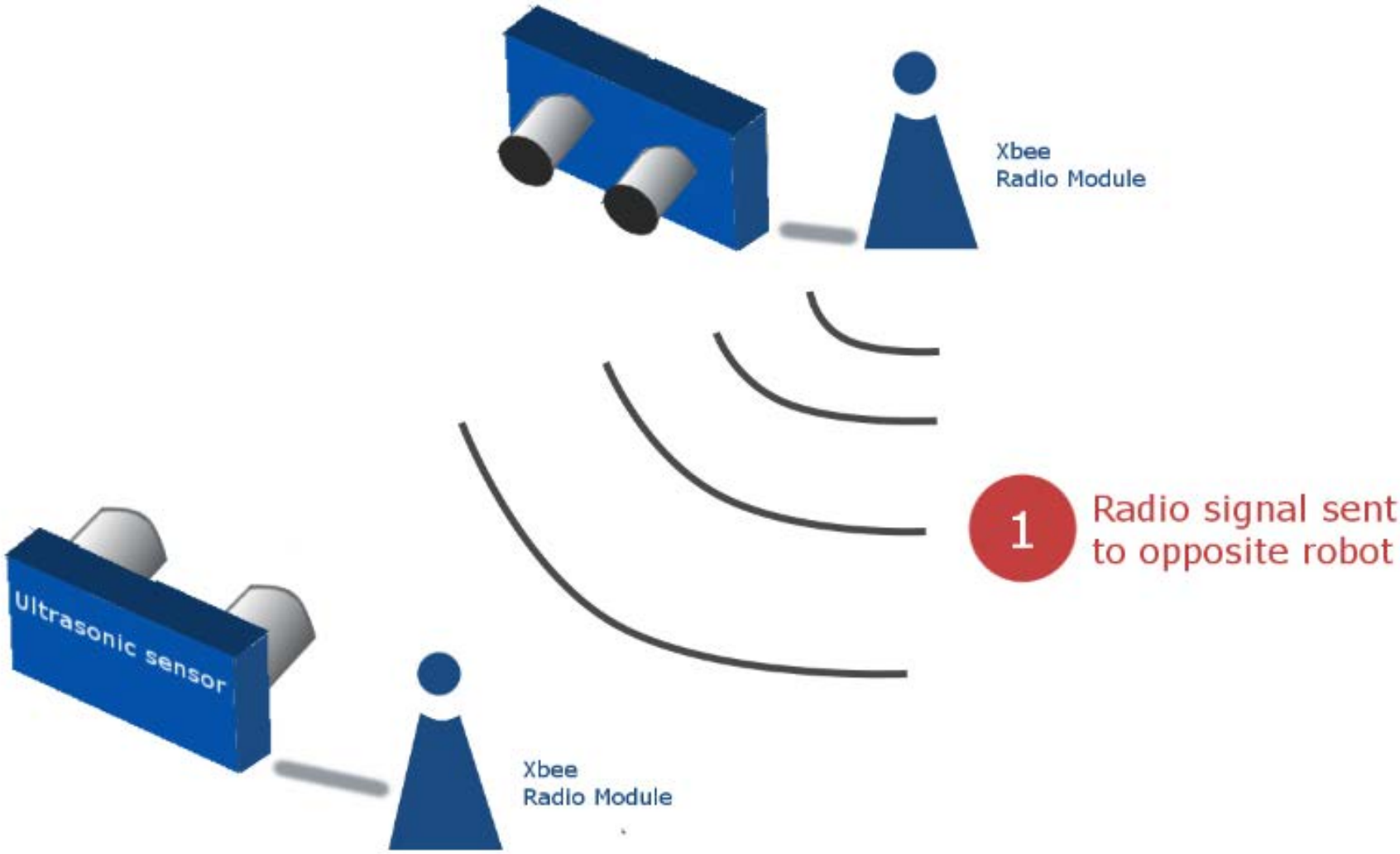




1 Radio signal sent to opposite robot




Xbee
Radio Module
1
Radio signal sent
to opposite robot
Ultrasonic sensor
Xbee
Radio Module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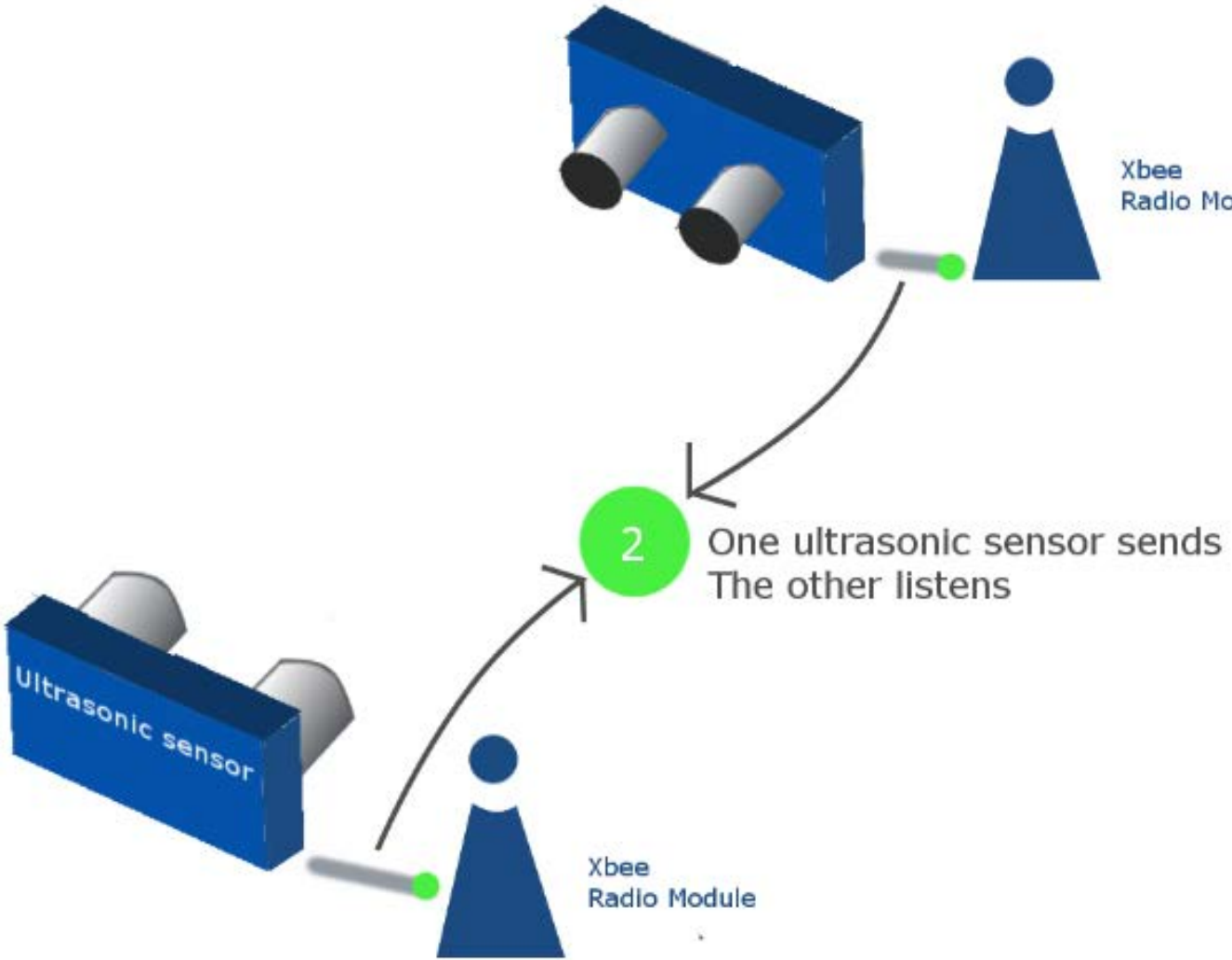
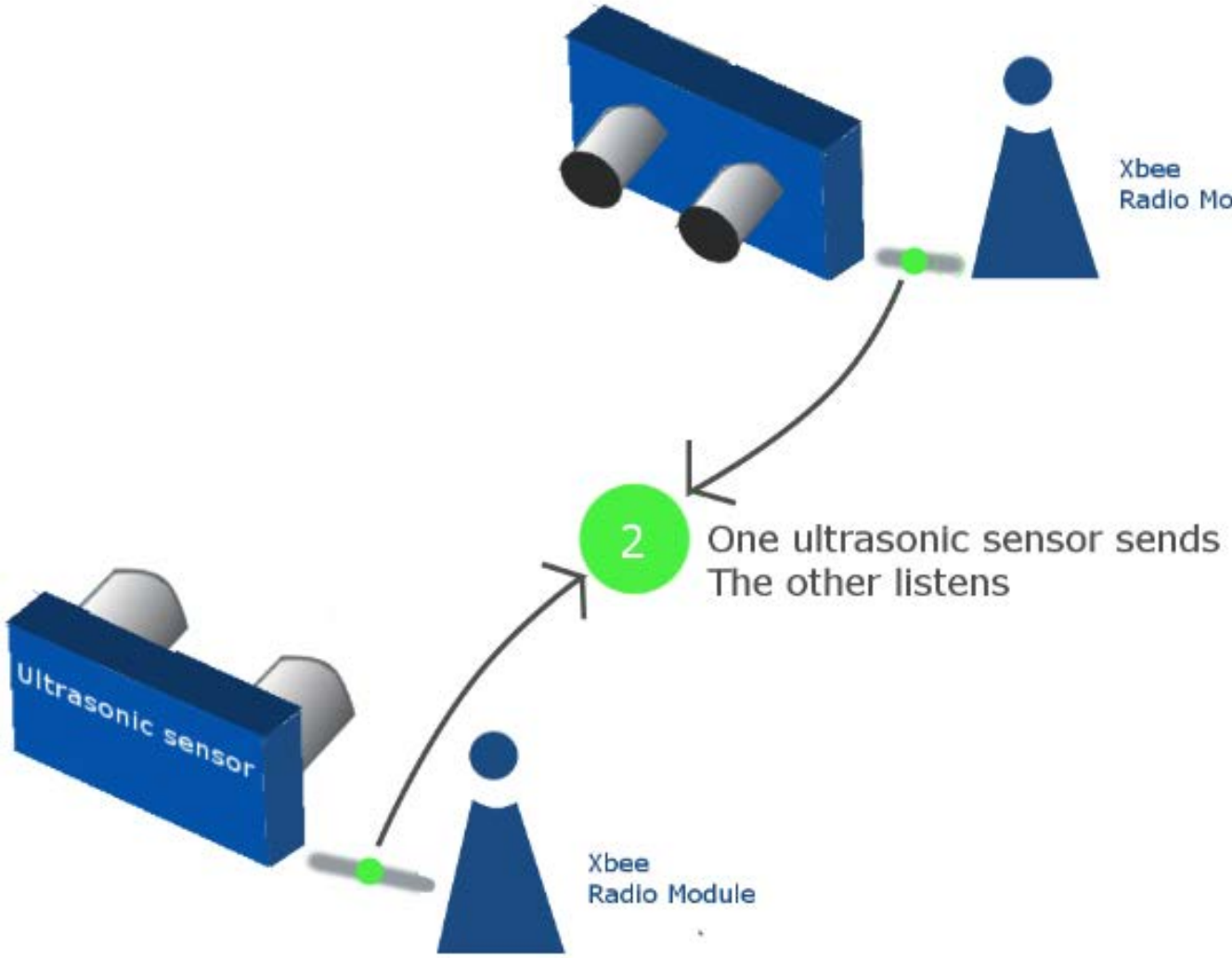

Xbee
Radio Module
2
One ultrasonic sensor sends
The other listens
Ultrasonic sensor
Xbee
Radio Module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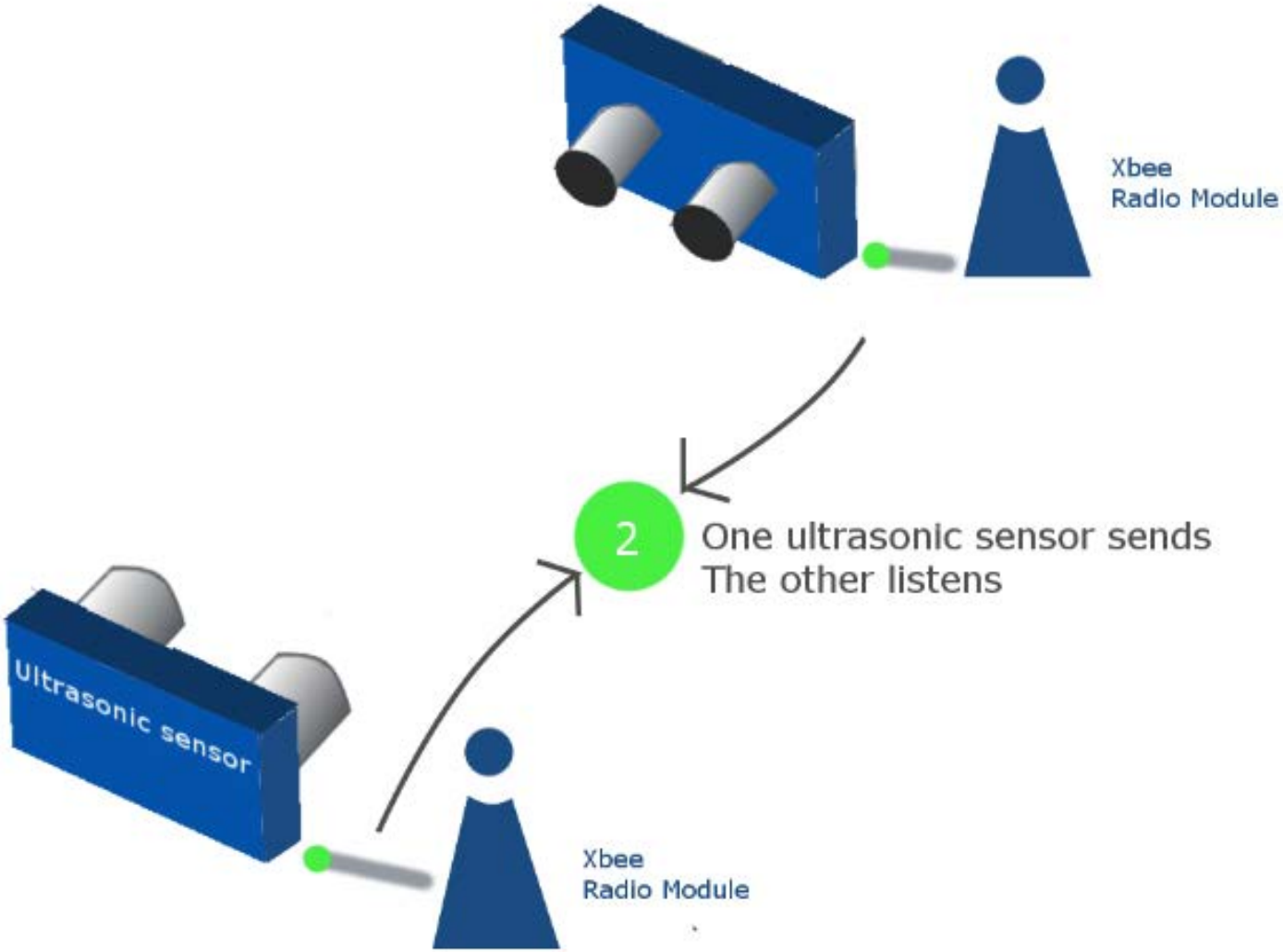
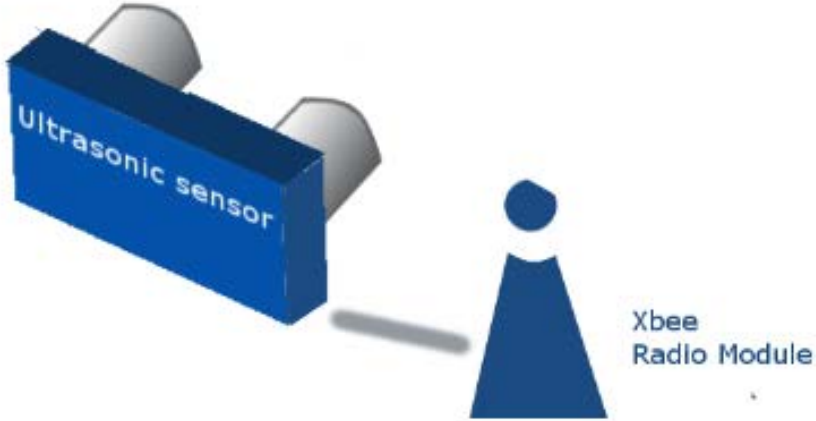
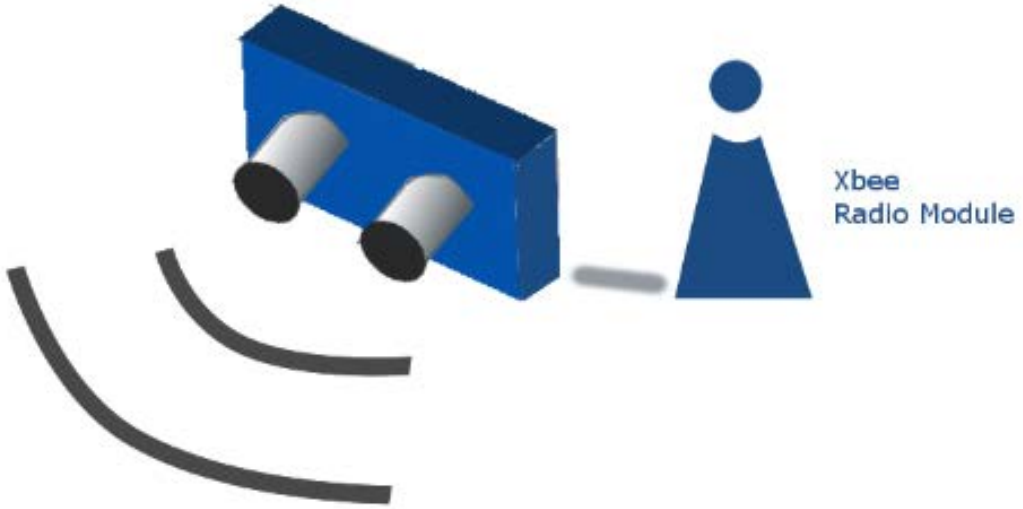

Xbee
Radio Module
2
One ultrasonic sensor sends
The other listens
Ultrasonic sensor
Xbee
Radio Module

0.15 milliseconds passed

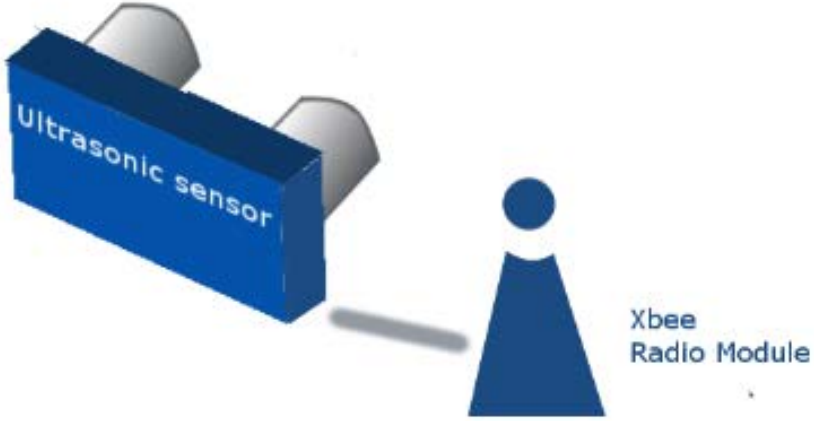
Receiving.

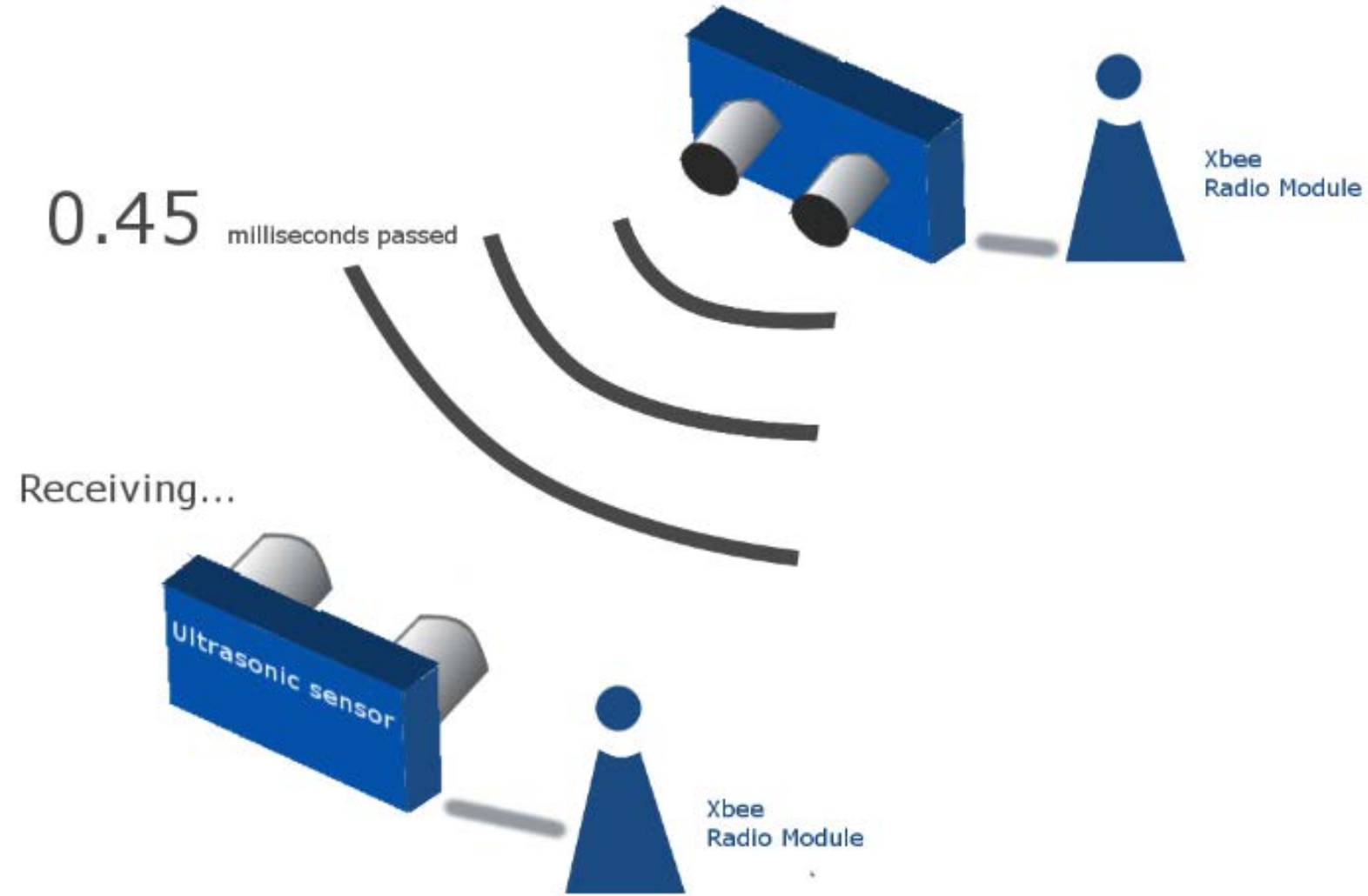


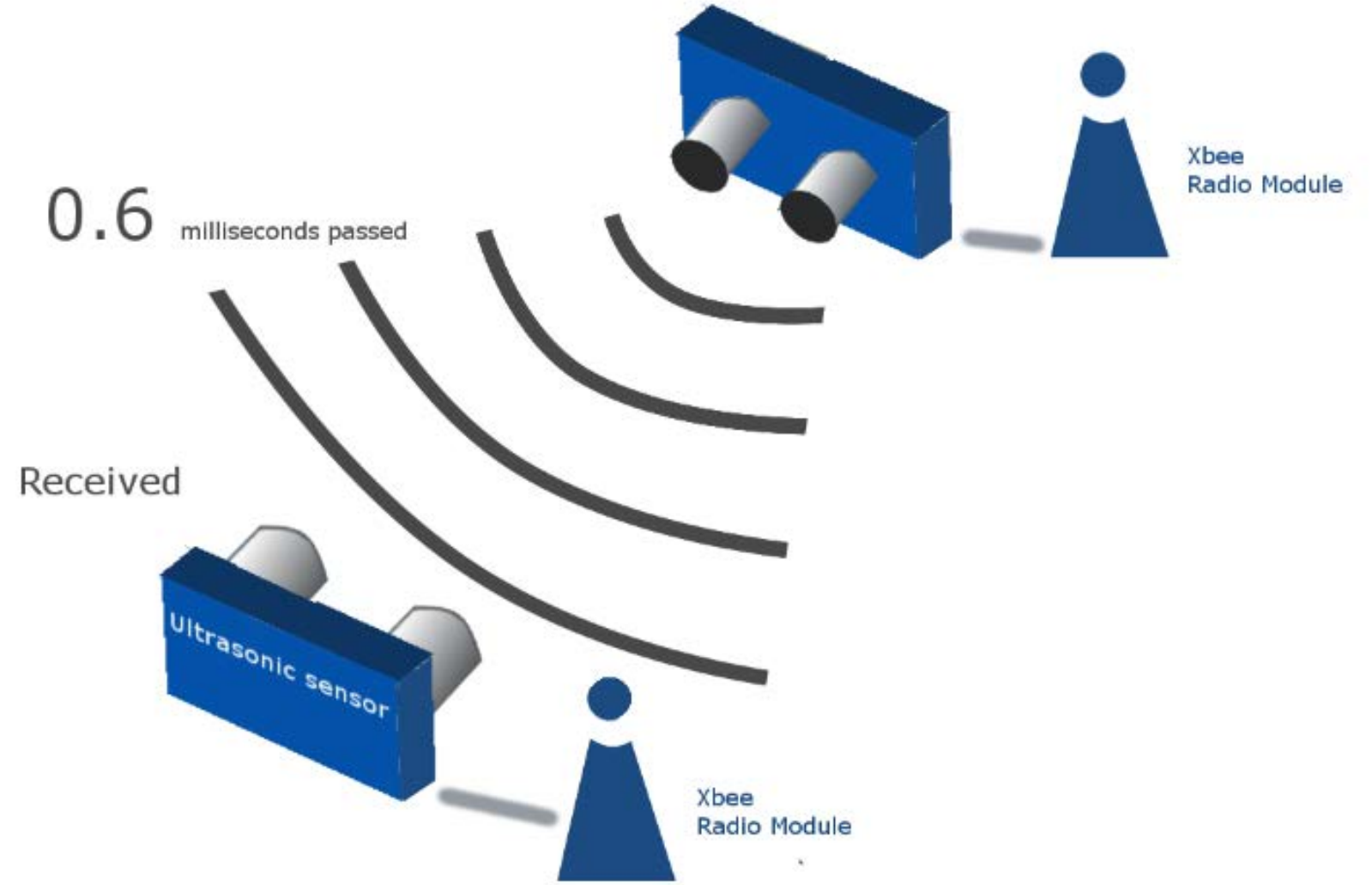
0.3 milliseconds passed



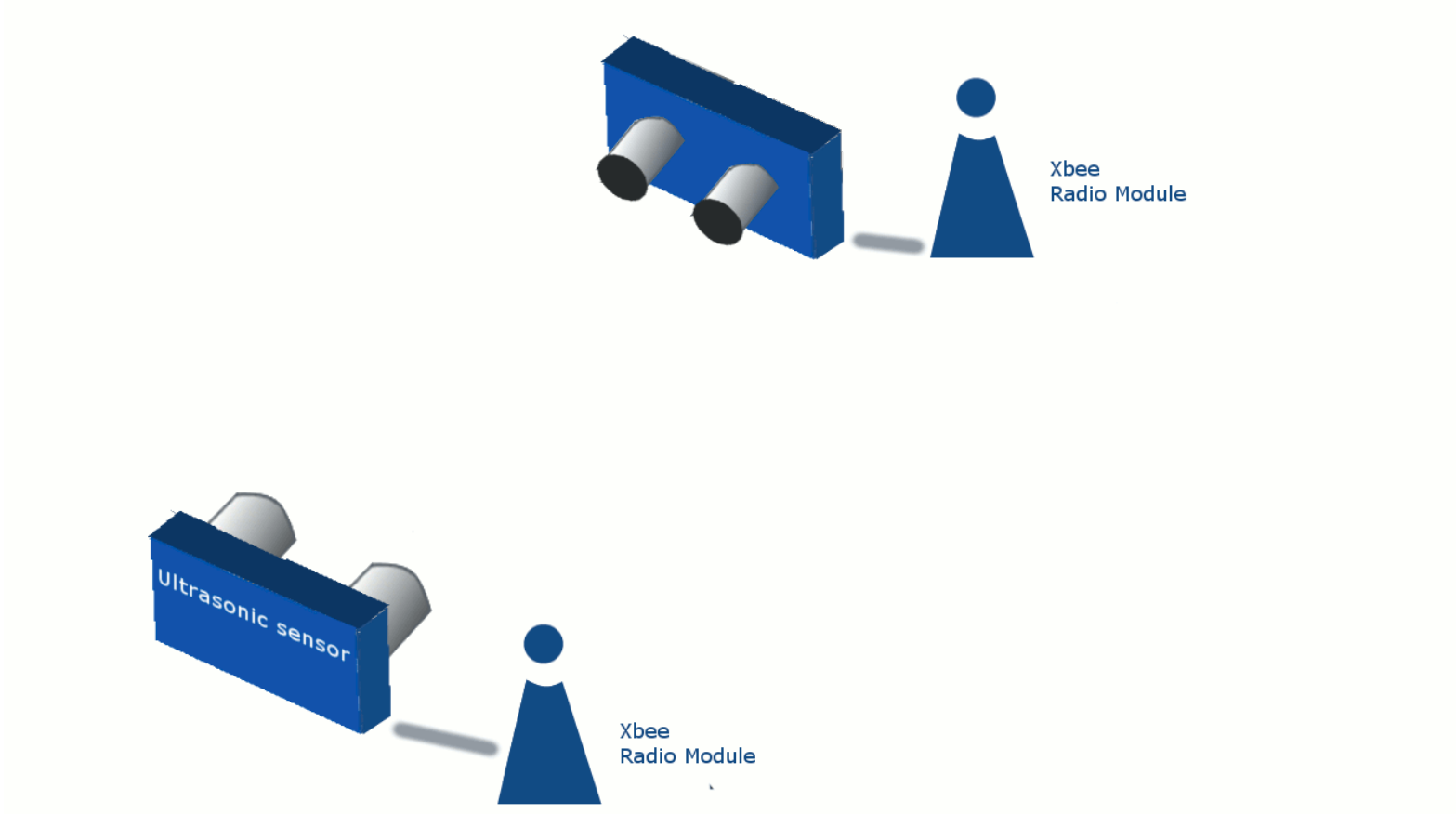
Receiving..




0.45
milliseconds passed
Xbee
Radio Module
Receiving...
Ultrasonic sensor
Xbee
Radio Module

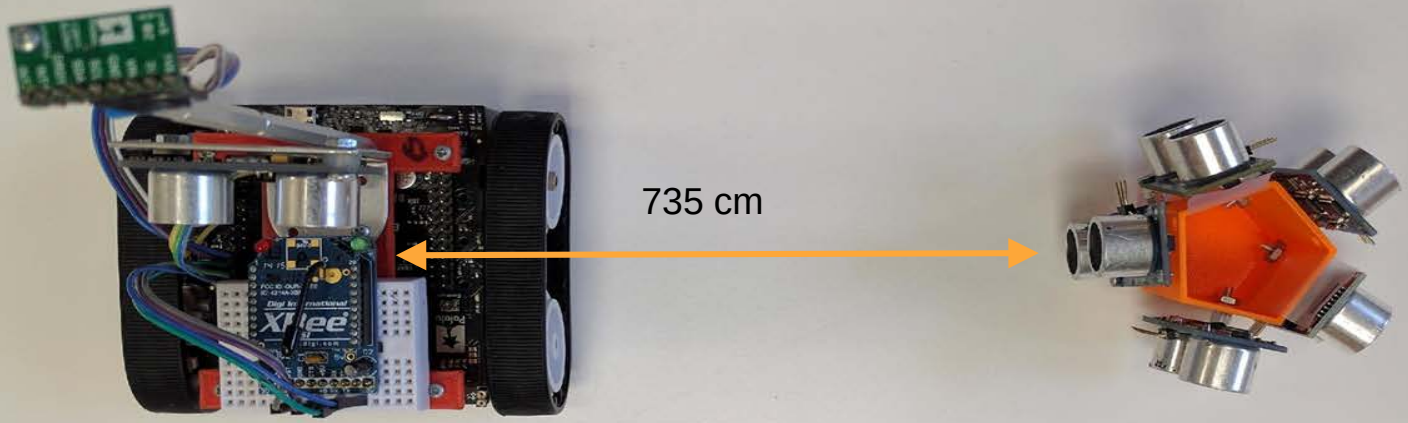

0.6
milliseconds passed
Xbee
Radio Module
Received
Ultrasonic sensor
Xbee
Radio Module

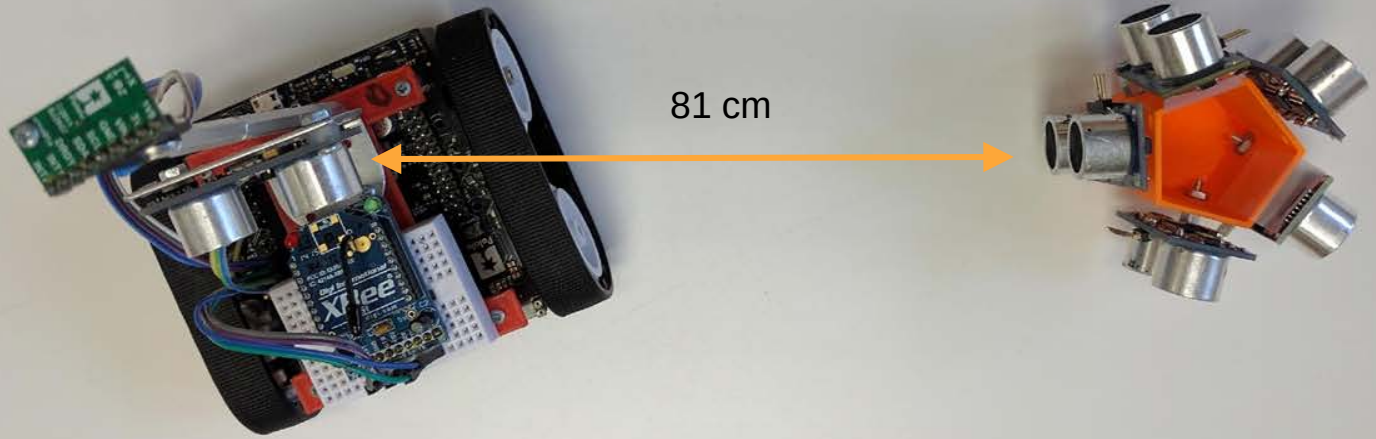
Putting it all together

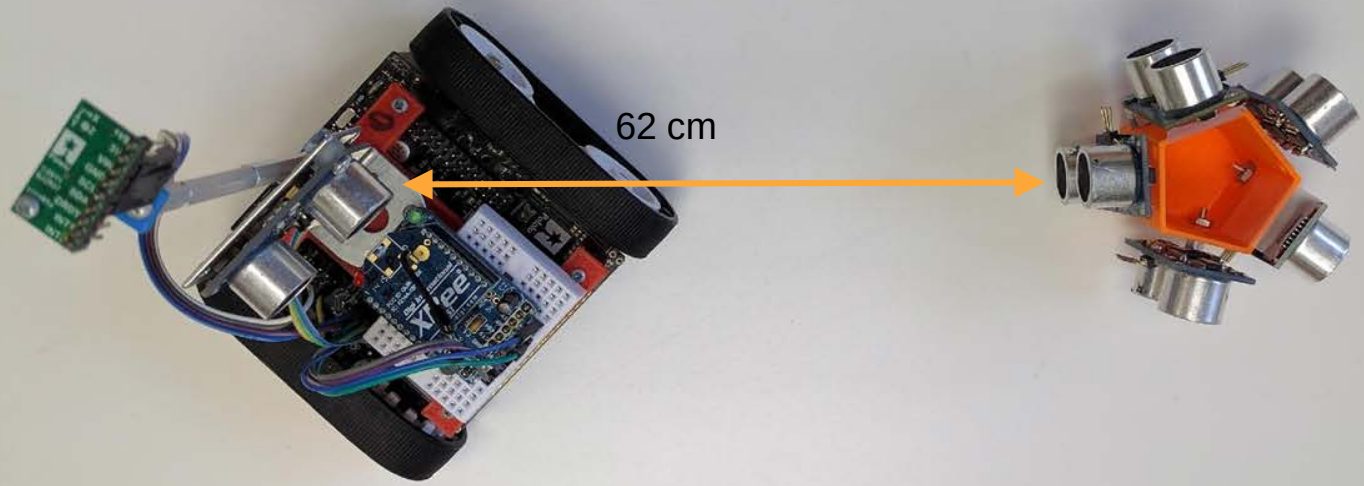


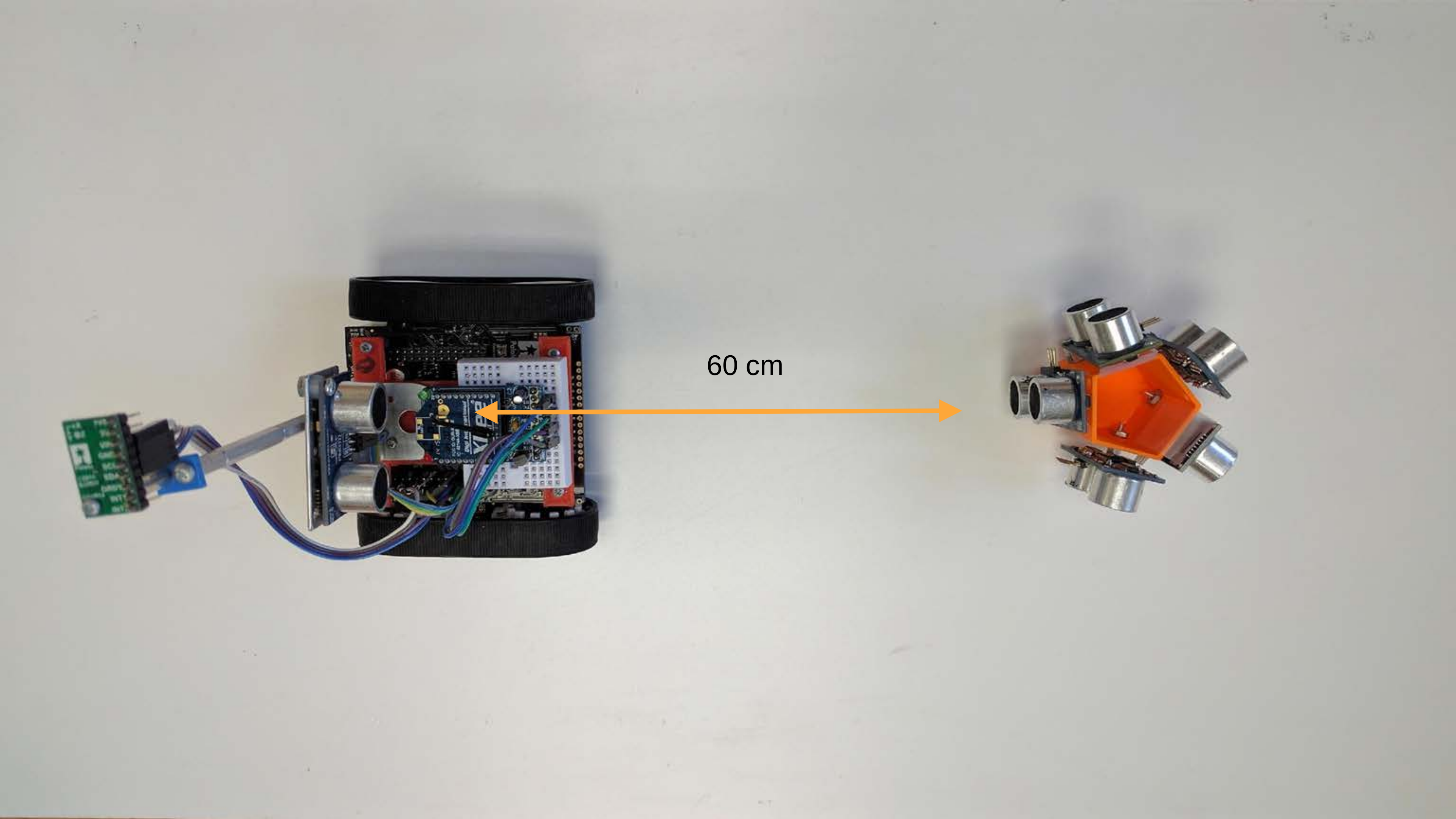
$$(20.4147\ cm) = (34.029\ \frac{cm}{ms}) * (0.6\ ms)$$

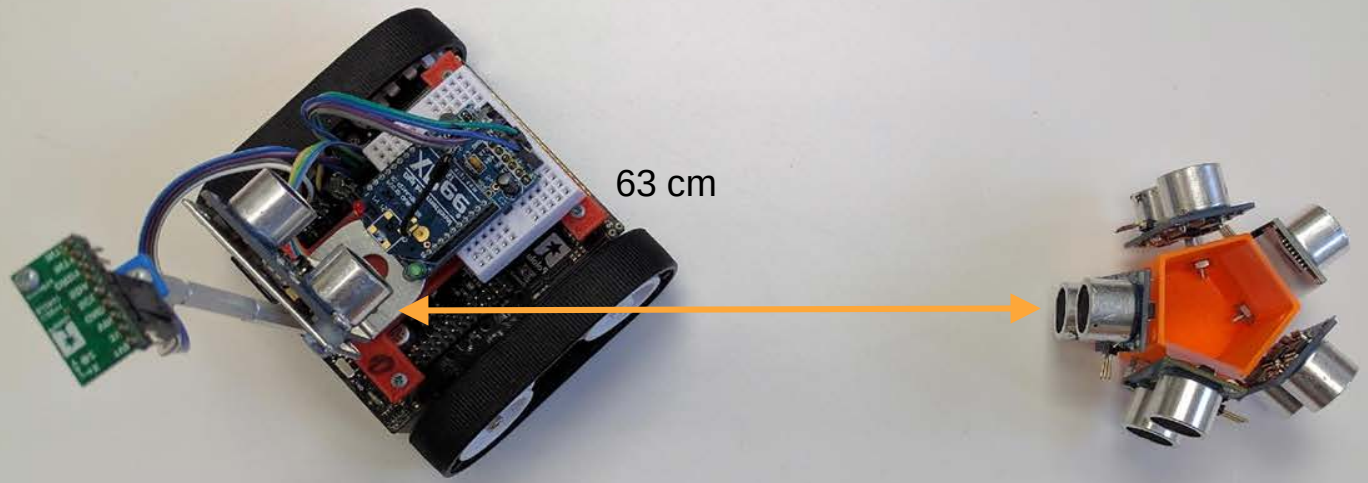
Distance between robots (speed of sound) (time of flight)

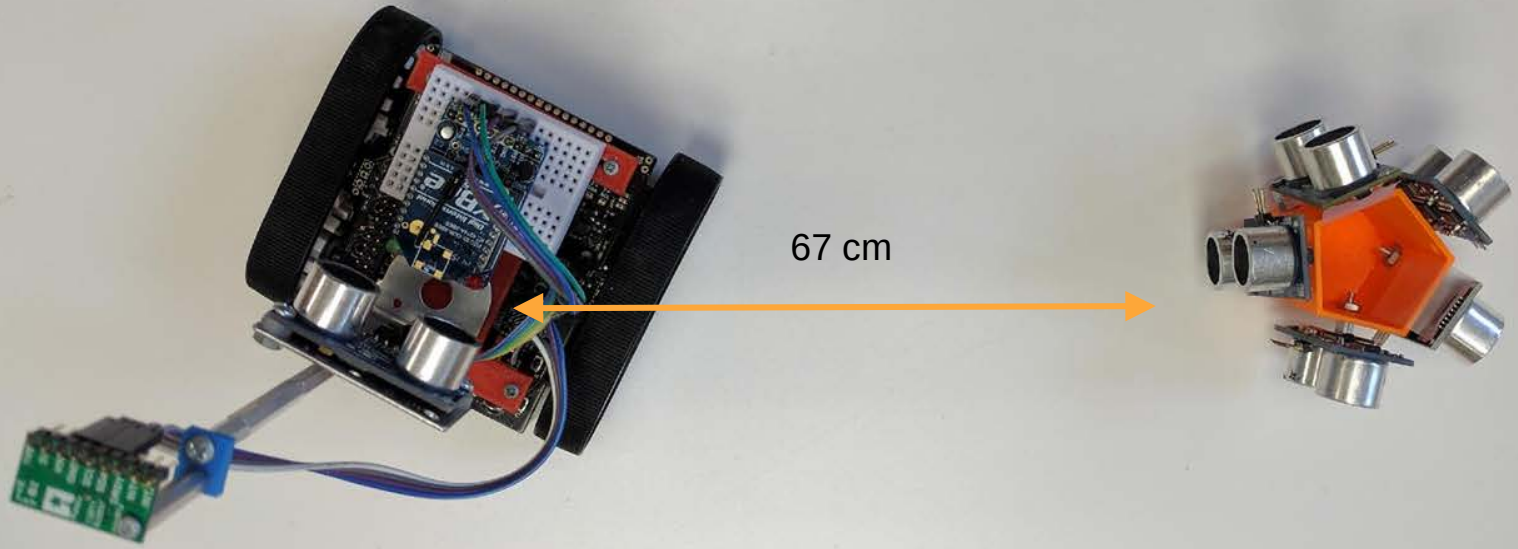

735 cm

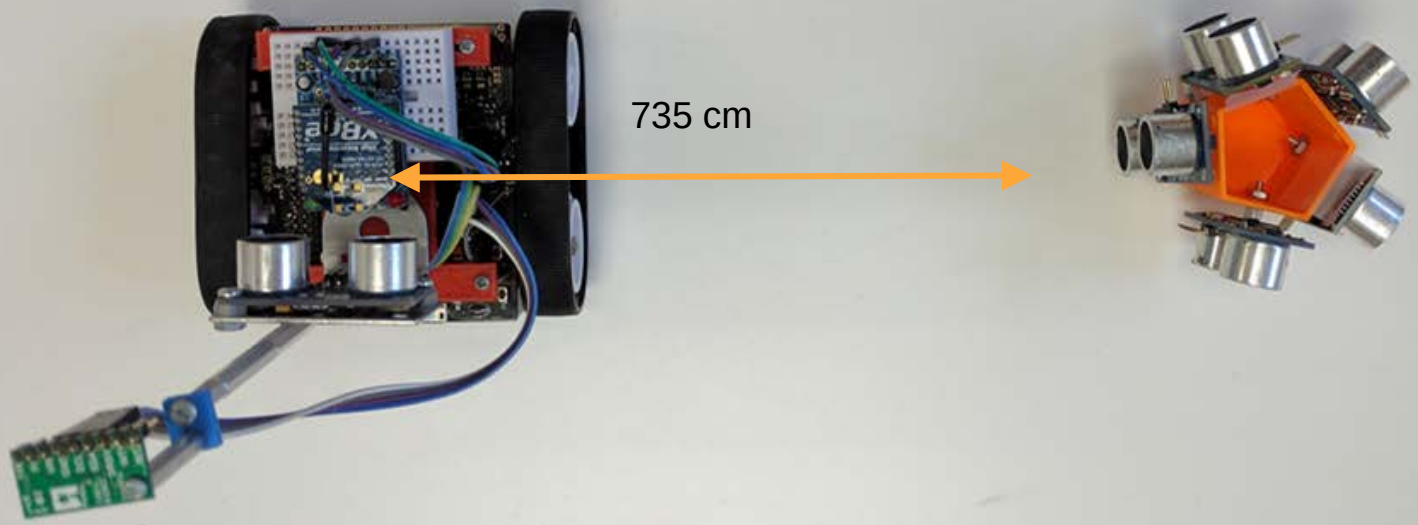

81 cm


62 cm


60 cm


63 cm

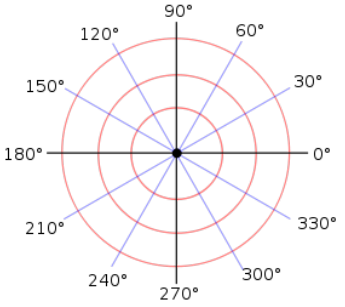

67 cm

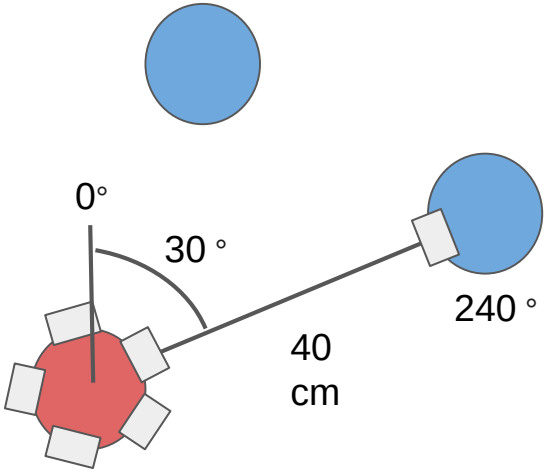

735 cm

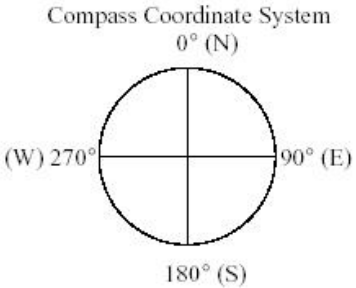
The Coordinate System

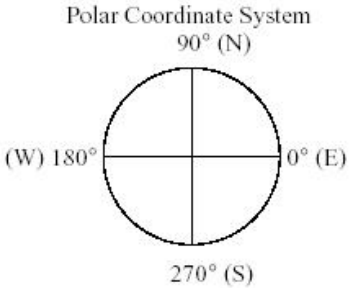
Master

Workers

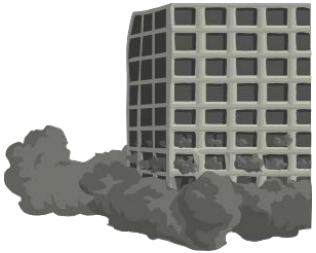






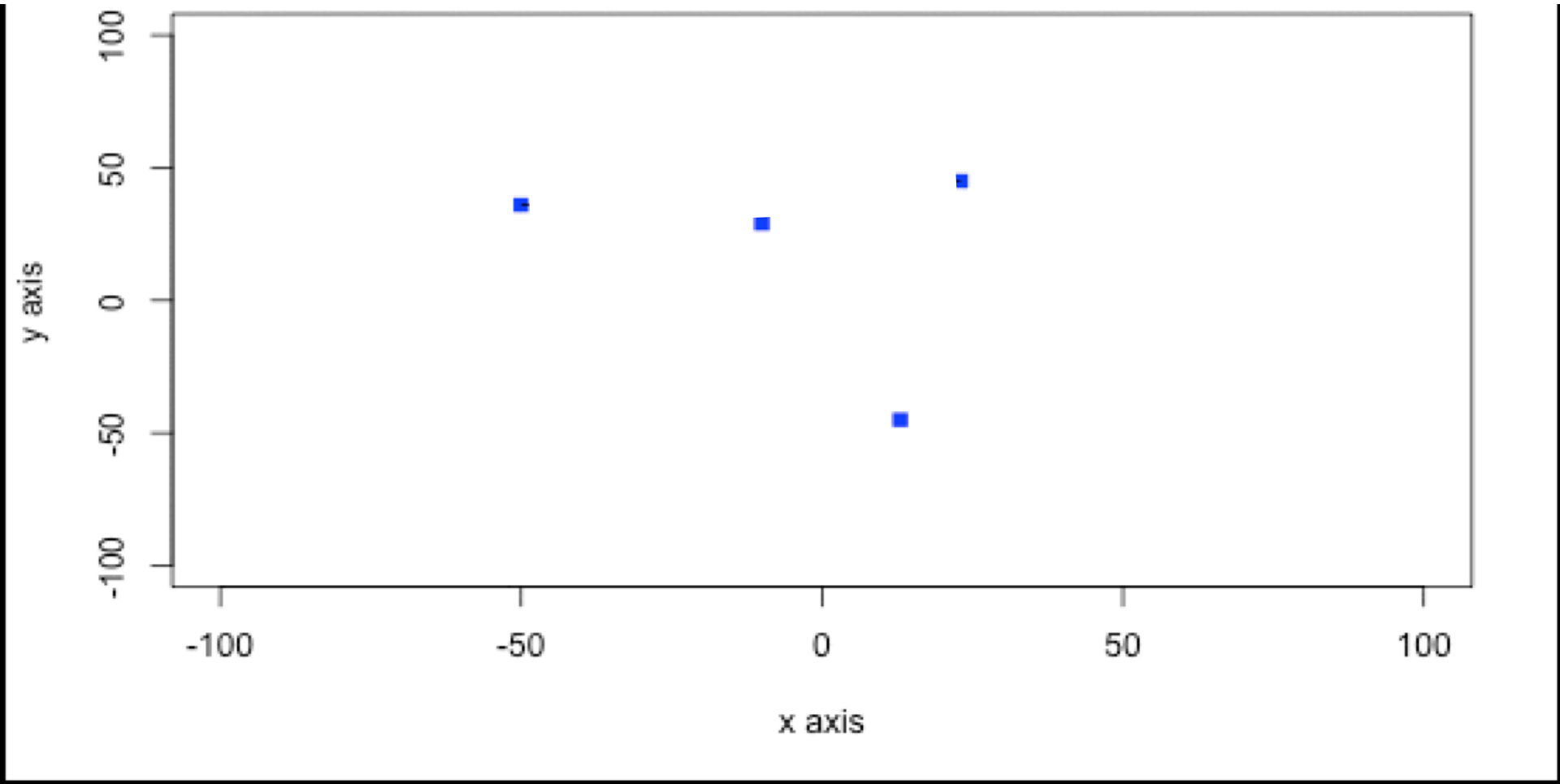


What's the Point of the Localization?

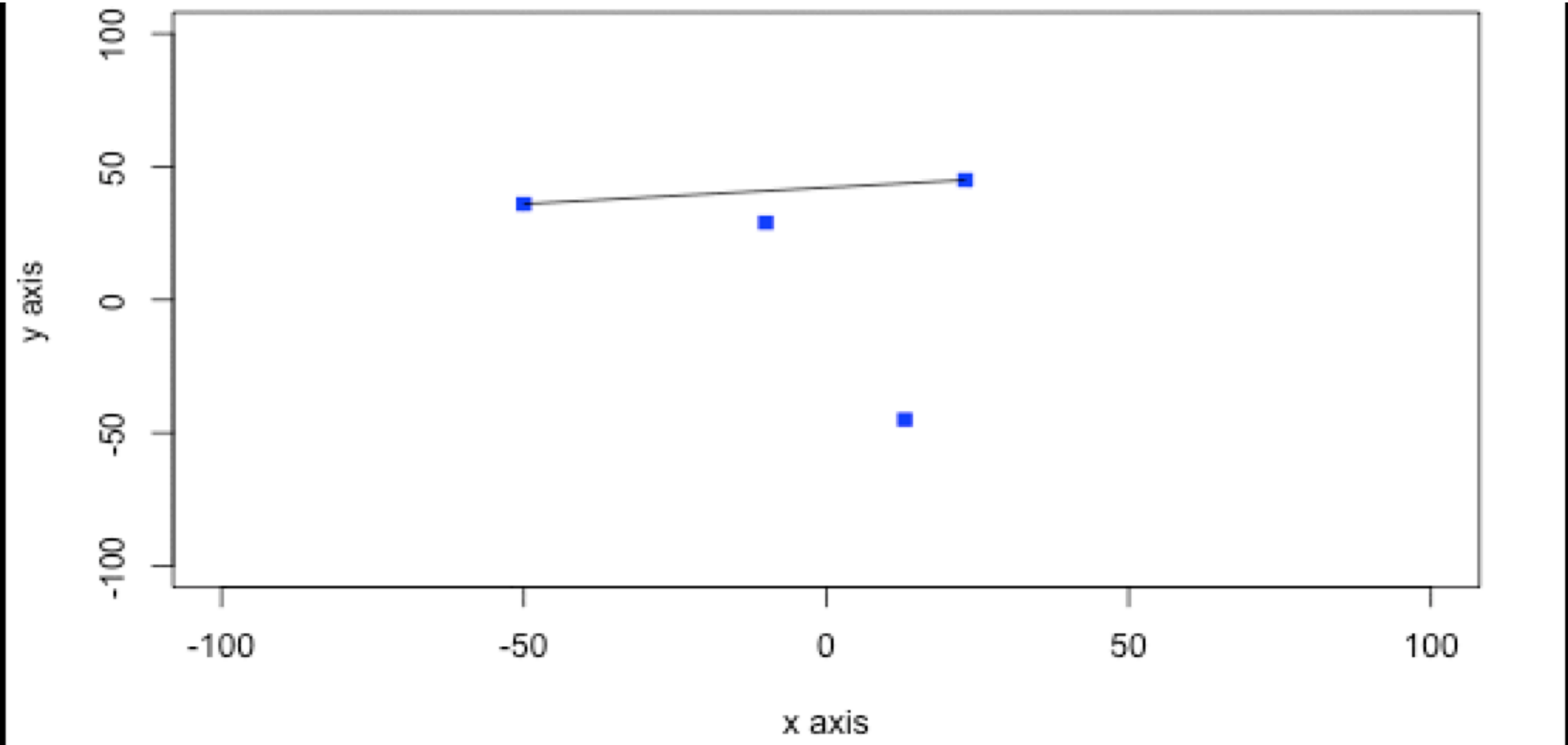
Accurate	Works Indoors	Closed System
2 cm margin of error	useful for close-range tasks	Works in anv environment
		


SAMSUNG
80% 12:41 PM
GPS signal not found.
androidcentral

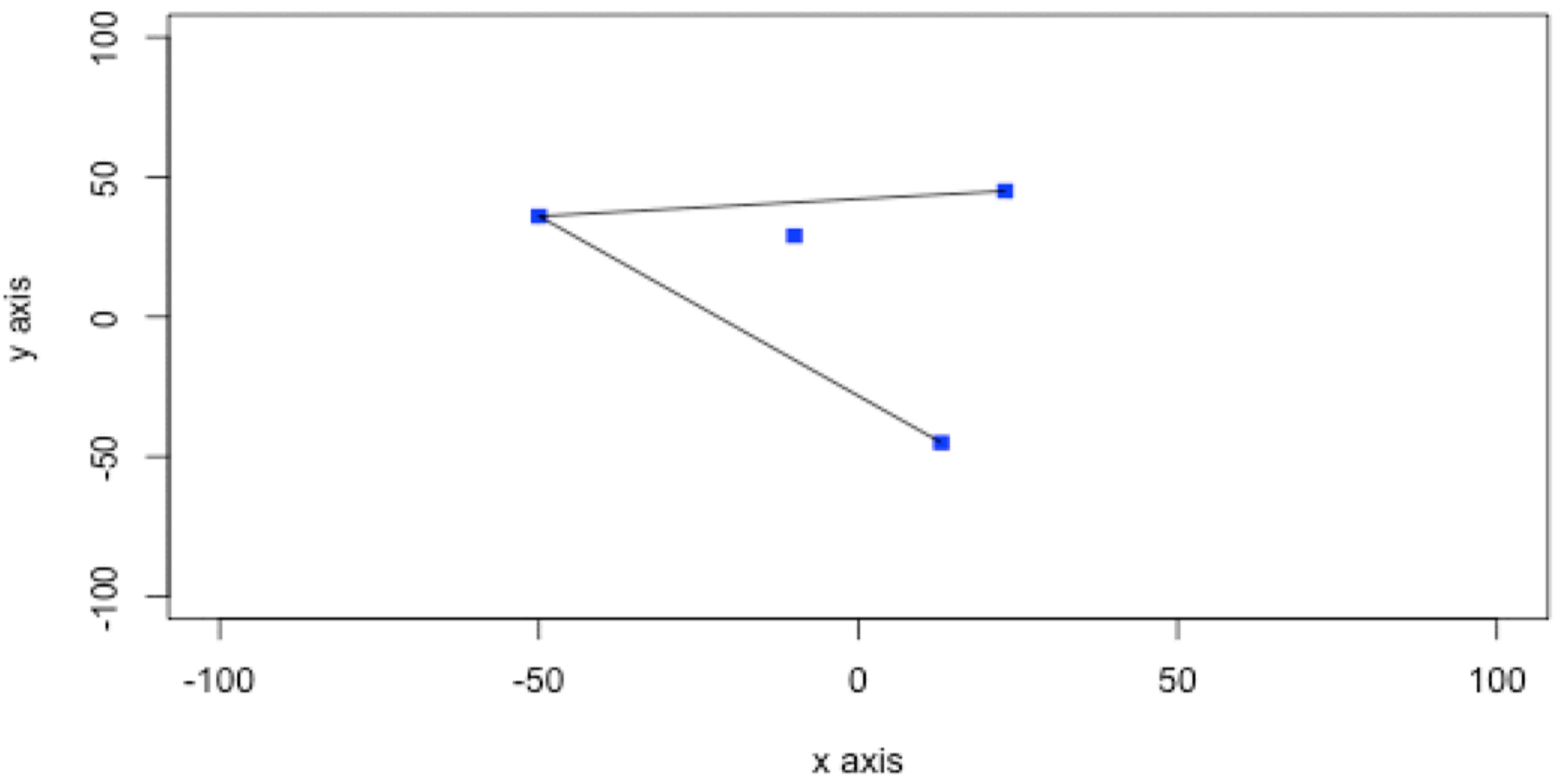
How Does It Work?



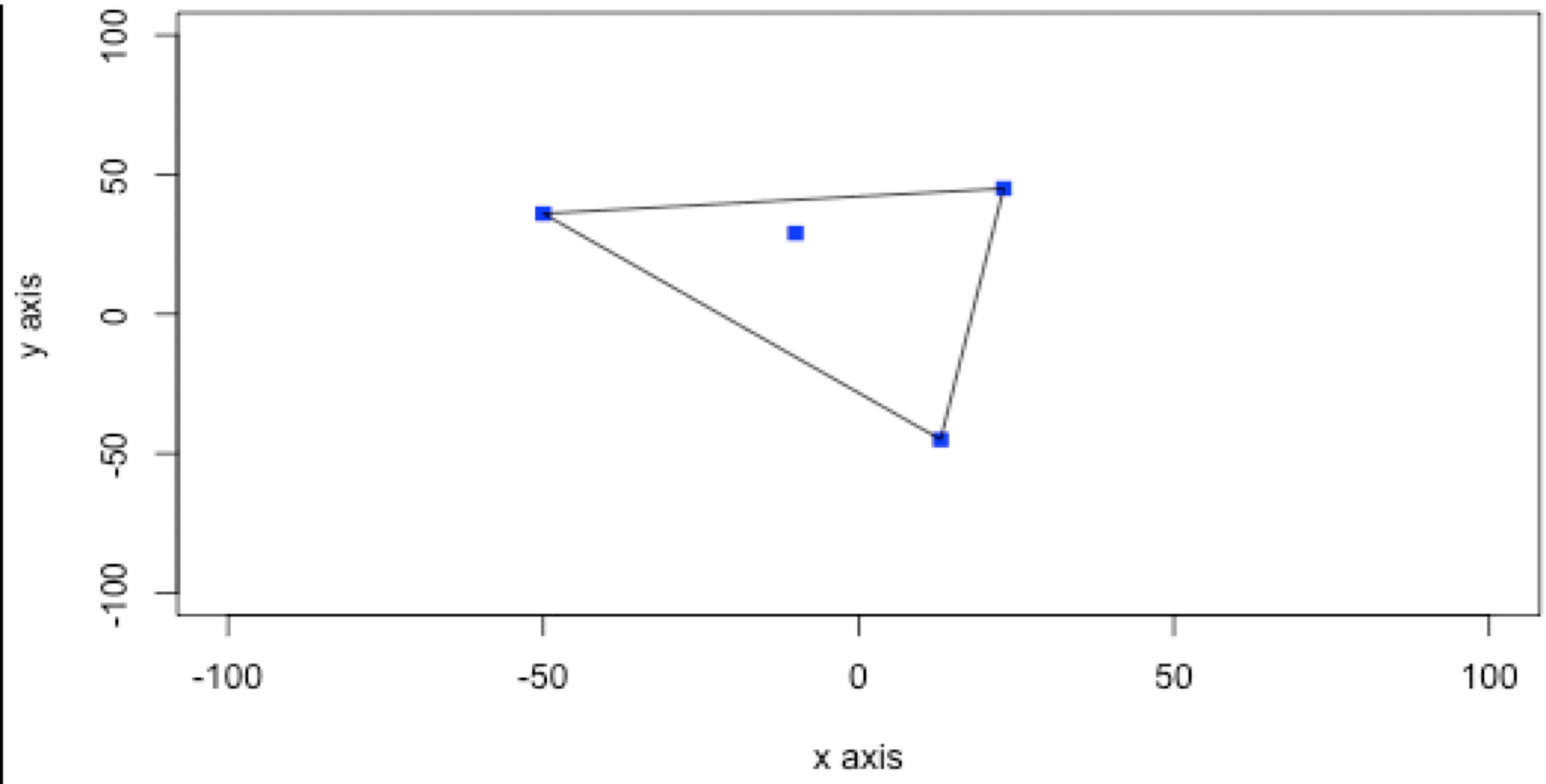
How Does It Work?



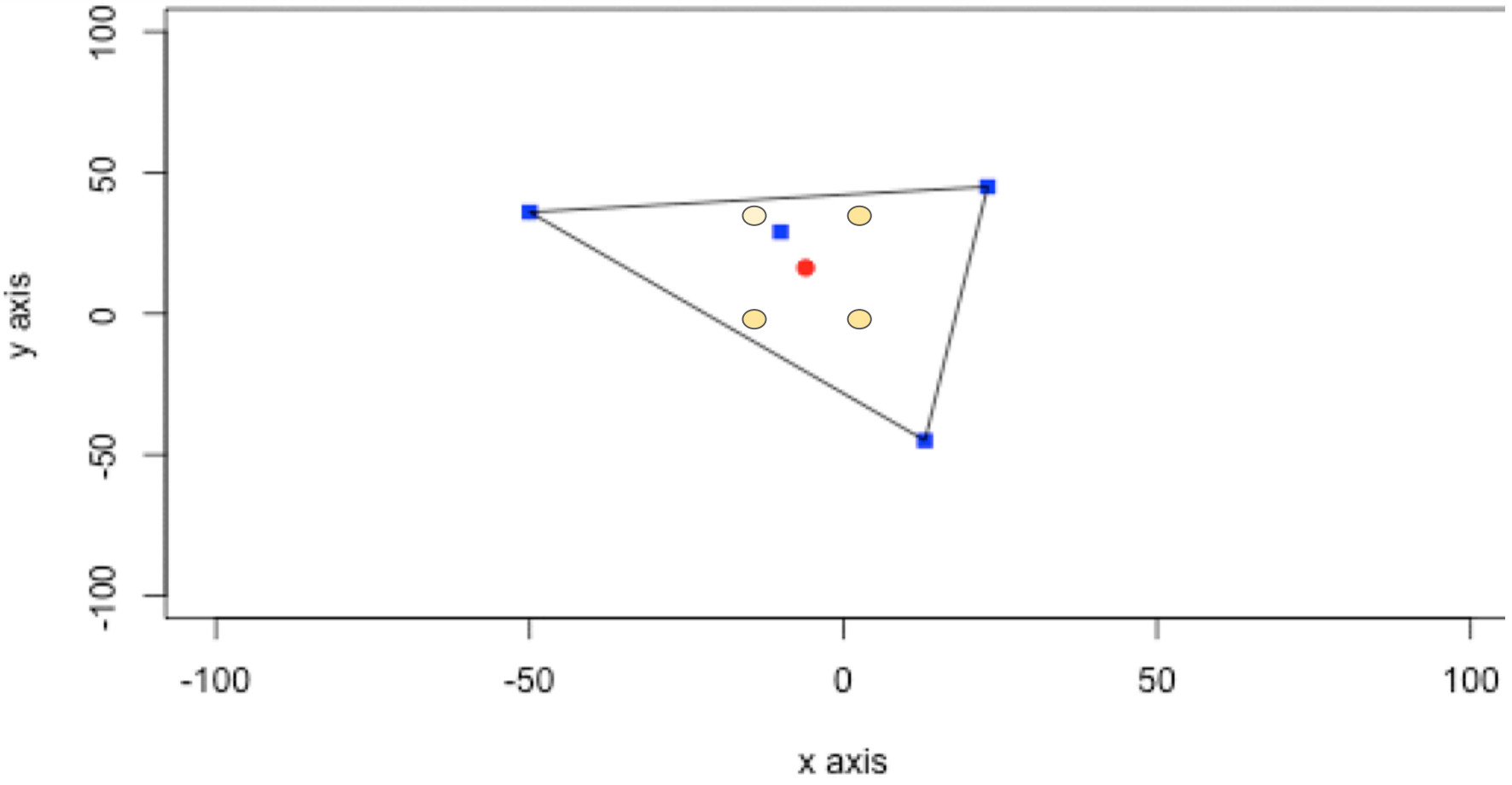
How Does It Work?



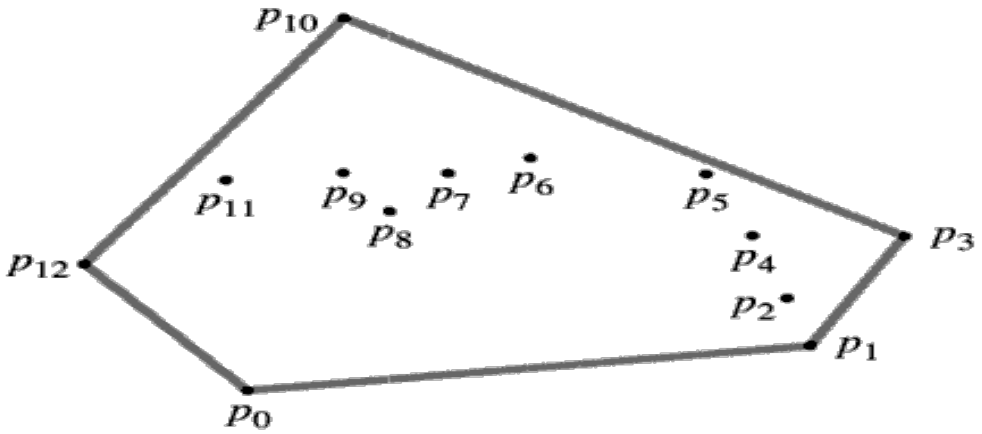
How Does It Work?



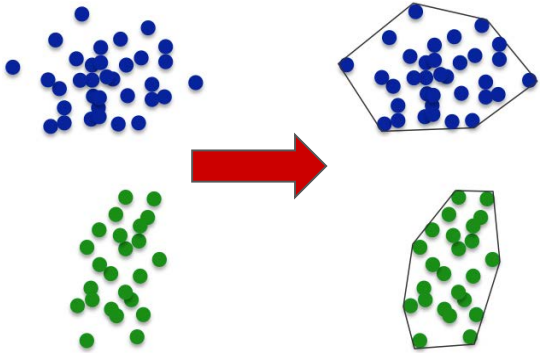
How Does It Work?



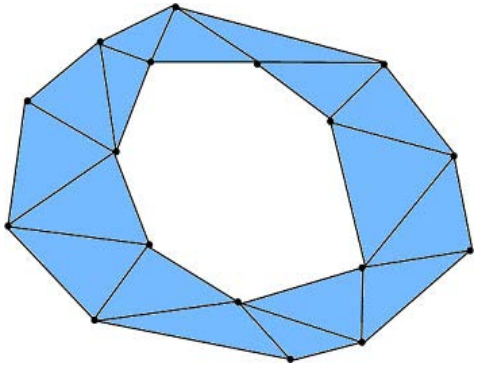
What is a Convex Hull? (and why it matters)



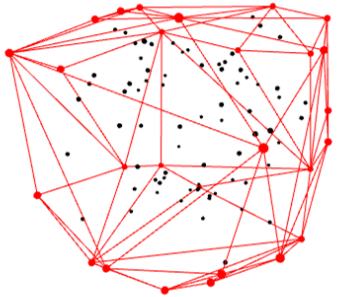
Reduces Complexity



Motion Planning



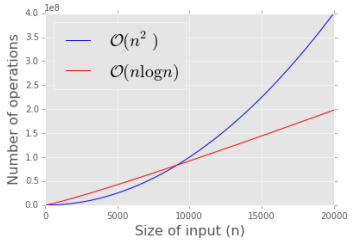
3D Formations



What's the Point of the Formation Algorithm?

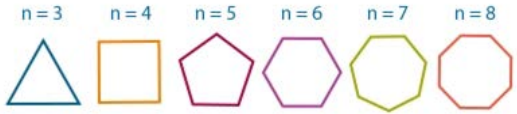
Scalable

works for n robots



Adaptable

works with any n-sided regular polygon



Extendable

stepping stone for more complex systems

Future Work

mesh networks

relaying data quickly

more robots!

more fun!

better algorithms

for cooler formations

robot mapping

for unknown environments

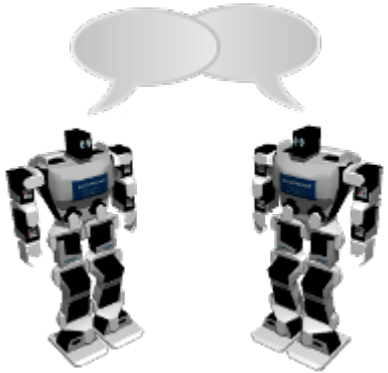
add drones

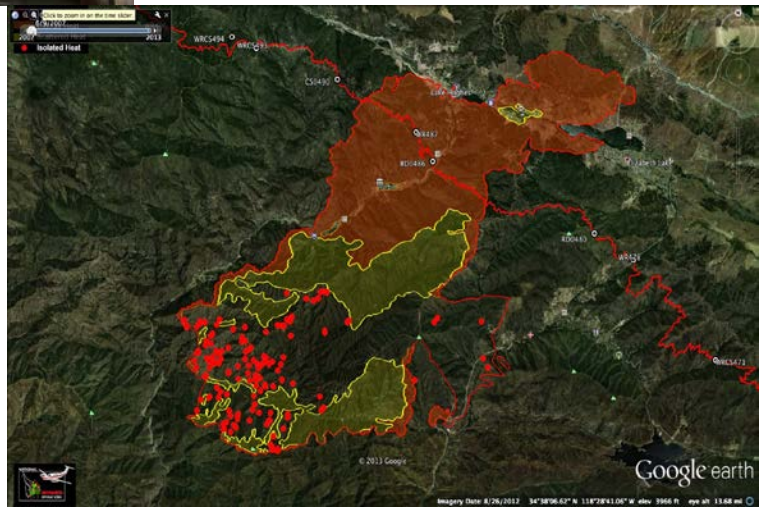
ground-air coordination

make it all faster

to improve response time

Why Does This Matter?





Questions

Appendix

Polar Coordinate Math

More on Convex Hulls

$$\mathcal{O}(n \log n)$$

XBee Radio Module

Networking Protocols

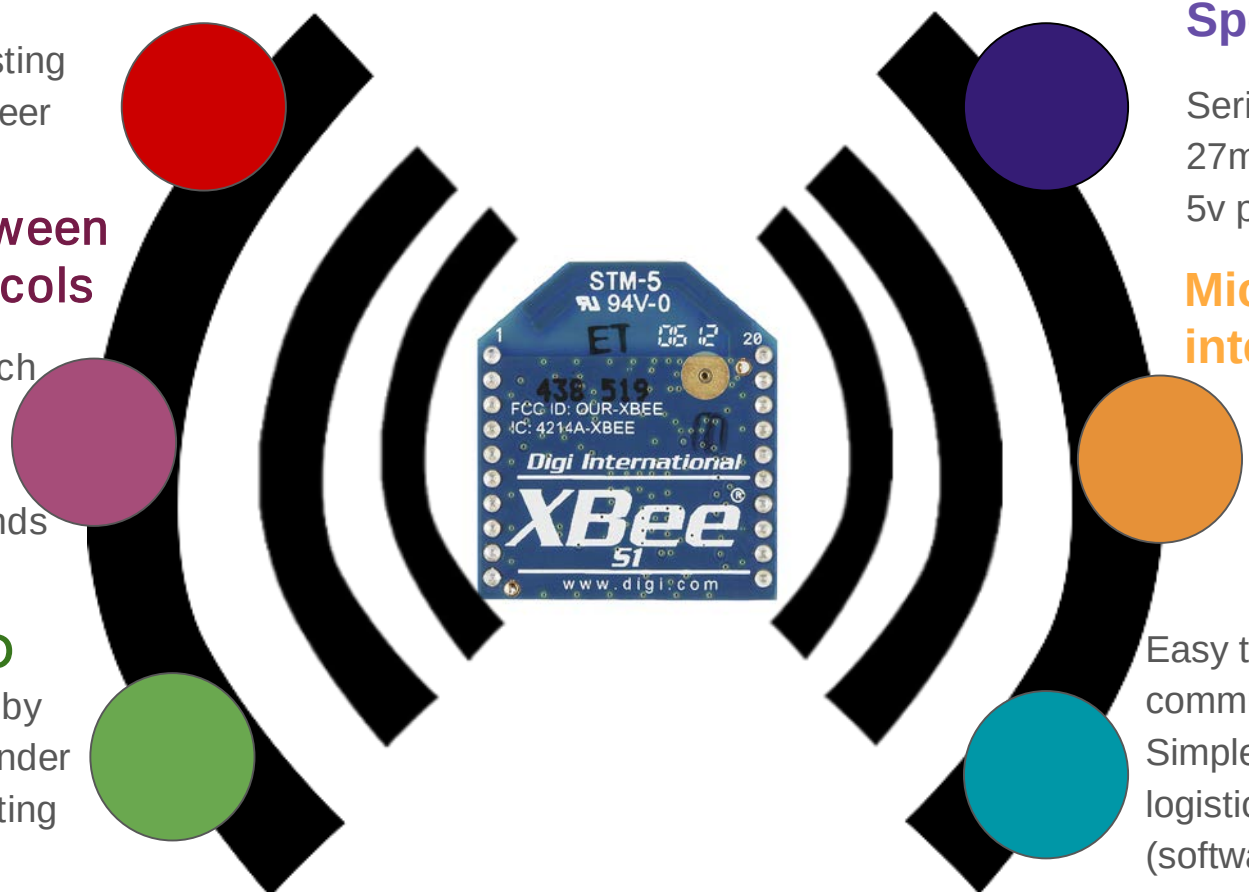
Broadcasting
Peer to Peer

Switching between network protocols

Allows you to switch between the protocols in code using AT commands

Network ID

Can be identified by unique address under a specified operating channel



Specifications

Series 1 model 1714
27mm x 24mm x 9mm
5v power module

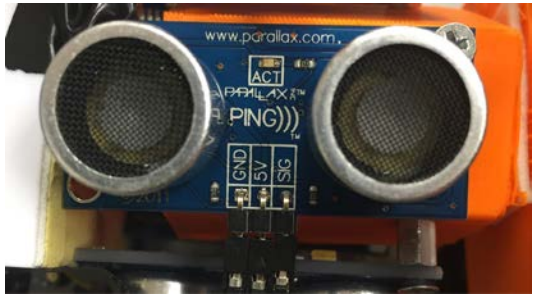
Microcontroller interface

Uses Serial to communicate with Arduino

Setup

Easy to wire due to Serial communications.
Simple to setup network logistics using XCTU (software provided by Digi)

Parallax Ping Sensor



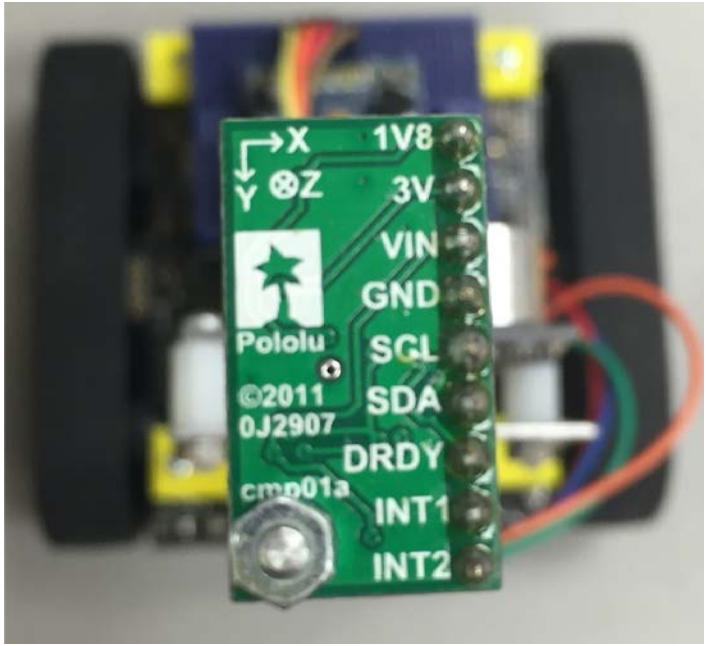
Receiver

Sender

- Uses ultrasonic transmitter(on the right) and a receiver (eye on the left) to measure distance
- 2 cm to 3 m range
- Led flickers to show when burst is sent
- 3 pins (data, power and ground)
    - Uses data line that can be set to high or low to measure distance or to send ultrasonic burst

Ultrasonic sensor sends a ping from the right and measures the time it takes until the left ping receives the ultrasonic burst.

LSM303 Compass Sensor



I2C device

Uses an accelerometer in addition to the magnetometer to compensate for sudden movements

Mounted higher up on standoffs so that the electromagnetic field from the motors doesn’t interfere with the compass magnetometer

Returns a heading in degrees relative to north

Sensor Module Overview

Cost-Efficient

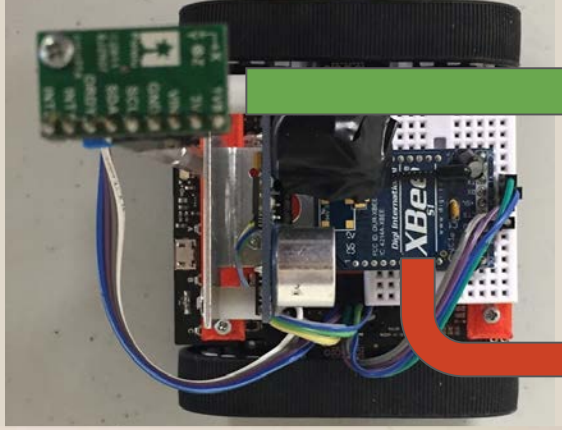
Our prototyped sensor model was under $70. However, since we used Parallax Ping Sensors that we already owned and not generic 4-pin sensors, our true cost is actually under $50.

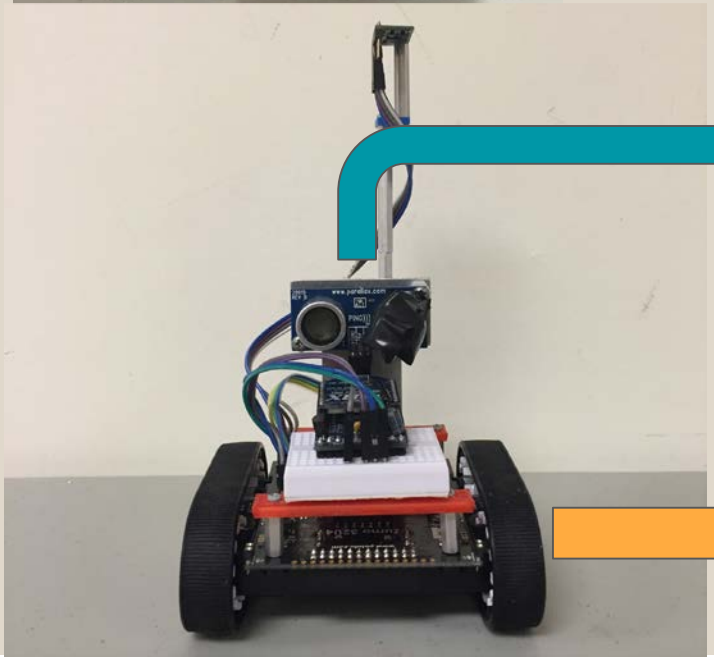
Closed System

Cross-environment functionality, no need to communicate with outside technologies like GPS, satellite, etc;

Indoor Accuracy

Margin of error under 2 cm indoors, unlike GPS and other methods





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Magnetic Encoders

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Formation Algorithm Overview/Flowchart

After each robot's relative polar coordinate has been calculated, each robot is assigned a new point in space to travel to and the robot formation is constructed.

- Finding the convex hull of the shape formed by the robots guarantees that the resulting shape will be non self-intersecting and that its centroid will lie inside the area bounded by its edges.
- The centroid of the shape is not necessarily the point assigned to the beacon robot: rather, point assignment is based upon ranking distances sequentially. Therefore, minimum distances to the target and maximized and maximum distances to the target are minimized, thus optimizing the distance each robot must travel to reach its target.