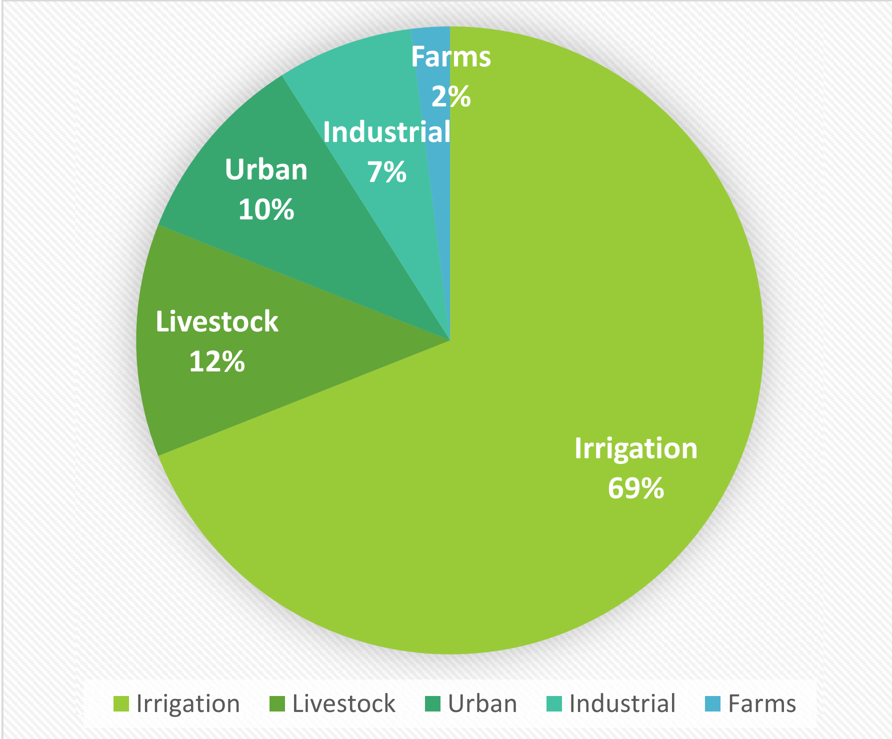
Modular sensor architecture for automated agricultural data collection on the field

ANDRÉ C. HERNANDES, RAFAEL V. AROCA, DANIEL V. MAGALHÃES, MARCELO BECKER

Introduction

- Soil water monitoring can be a key aspect for precision agriculture
- Brazil has a fresh water consumption of 986.4 m^3/s and irrigation alone is responsible for 680 m^3/s
- Real time information of crop parameters can increase water management, allowing Engineers, operators or automated systems to make informed decisions.

Brazil fresh water consumption



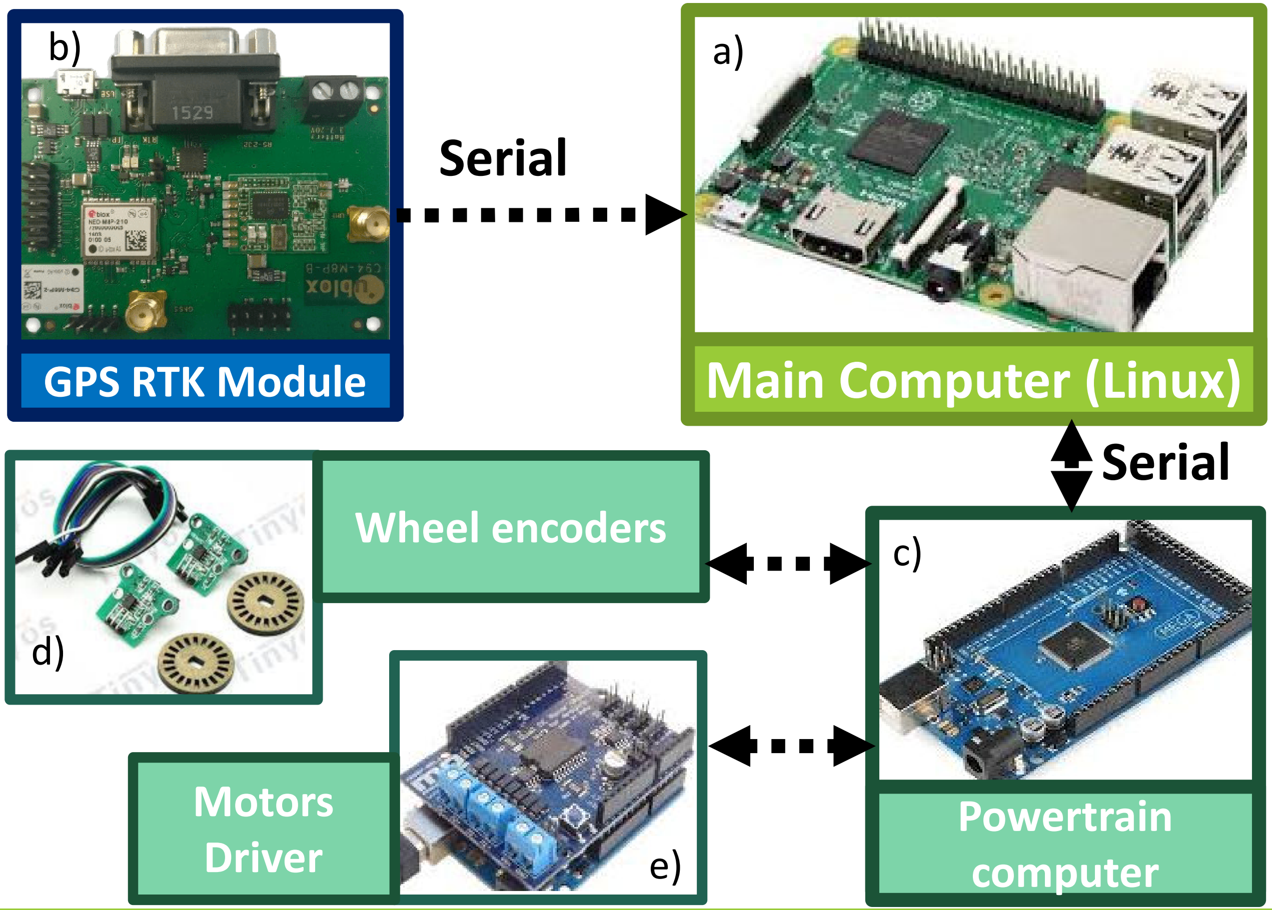
Introduction

- Precision agriculture faces a reality of large number of heterogeneous technologies to provide a sensor network.
- Permanently installed sensors and their communication infrastructure may be damaged by field’s harsh environment.
- Robotics in agriculture had a usage increase, however few of them collect data.

Motivation

- As a redundant factor, heterogeneous communications modules can be installed trying to overcome single sensor/infrastructure malfunction.
- An autonomous robotic platform can serve as a testbed for collecting data from field even with heterogeneous communication modules.

Robot Design – Proposed architecture



a) A Linux board as main processing unit. For instance, a raspberry PI 3.

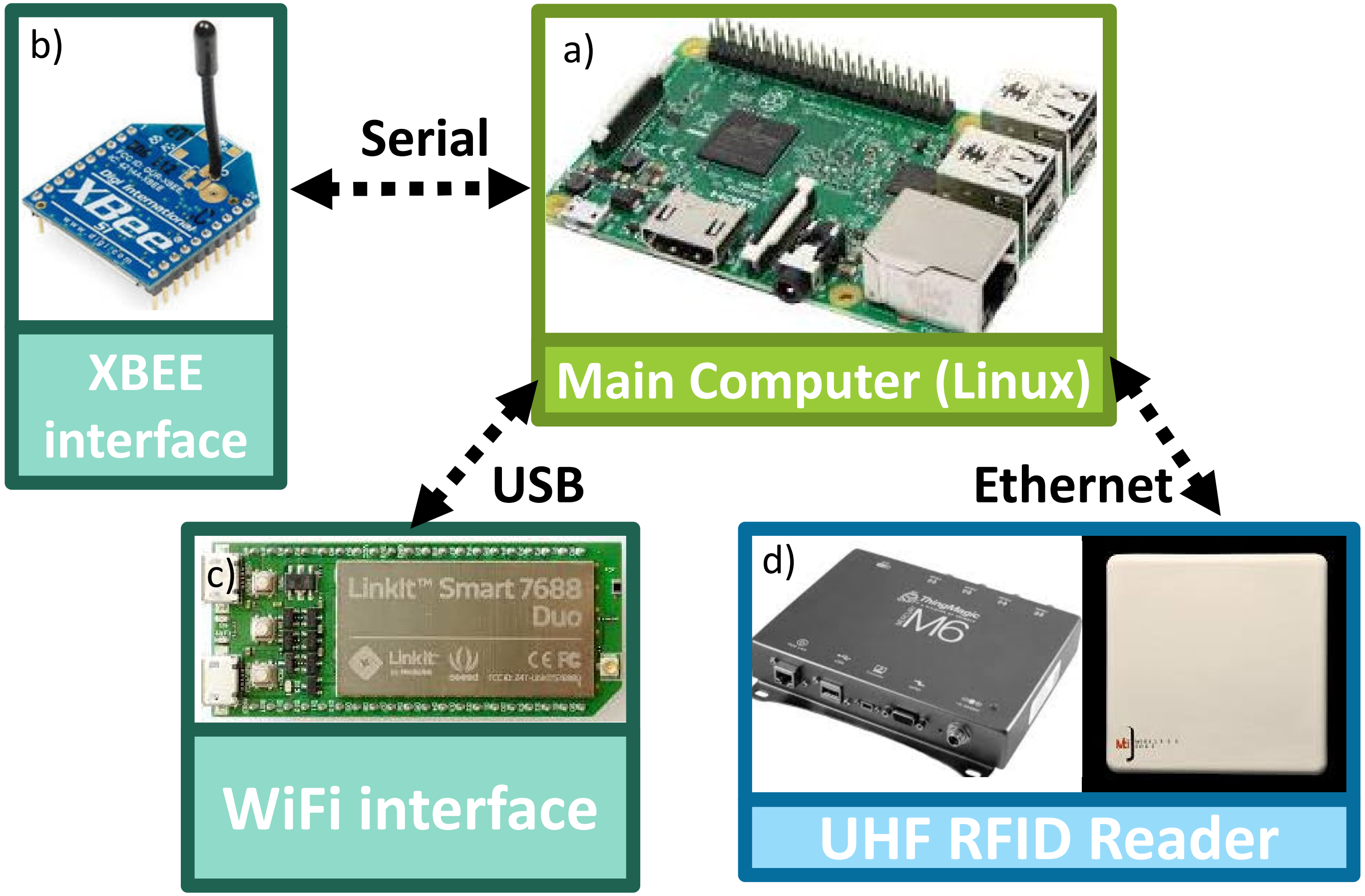
b) A GPS-RTK module for precise positioning.

c) A microcontroller as powertrain computer, for instance, a Arduino ATMega.

d) Wheel encoders for feedback loop

e) Motor driver, such as Pololu Dual VNH5019 Motor Driver Shield

Robot Design – Proposed architecture



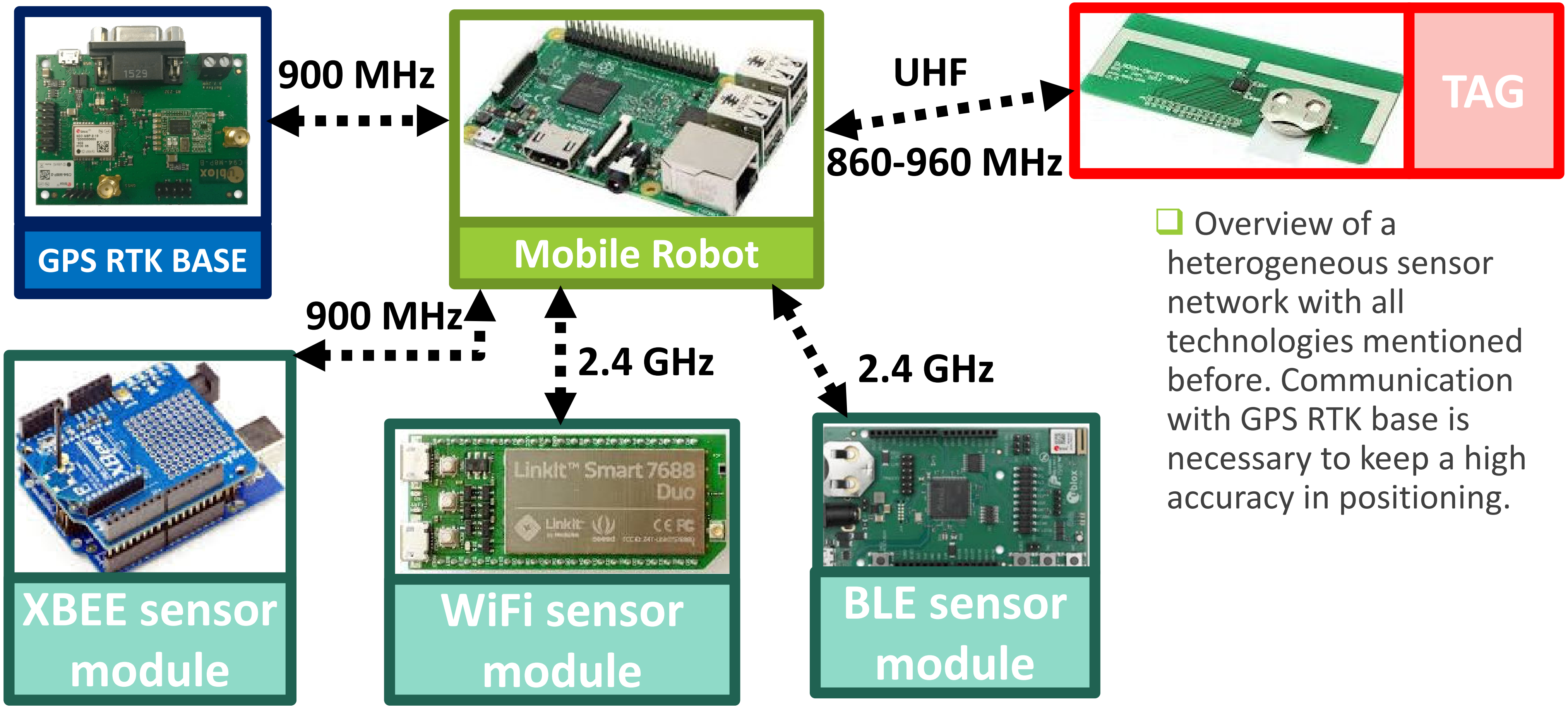
a) Using Raspberry PI 3, already have a Bluetooth Low Energy (BLE) hardware.

b) Xbee interface can be connected via serial

c) WiFi connection can be made via miniUSB-USB

d) UHF RFID reader can communicate via Ethernet.

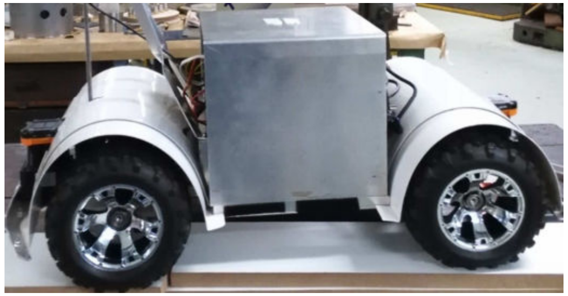
Robot Design – Proposed architecture



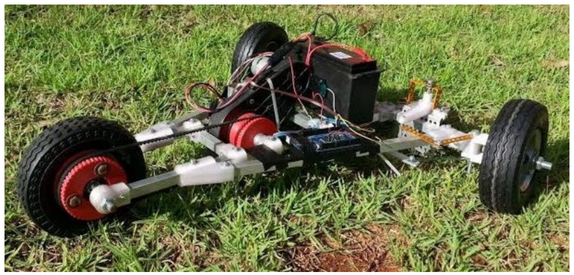
- Overview of a heterogeneous sensor network with all technologies mentioned before. Communication with GPS RTK base is necessary to keep a high accuracy in positioning.

Robot Design – Mechanical Frame

Predecessors

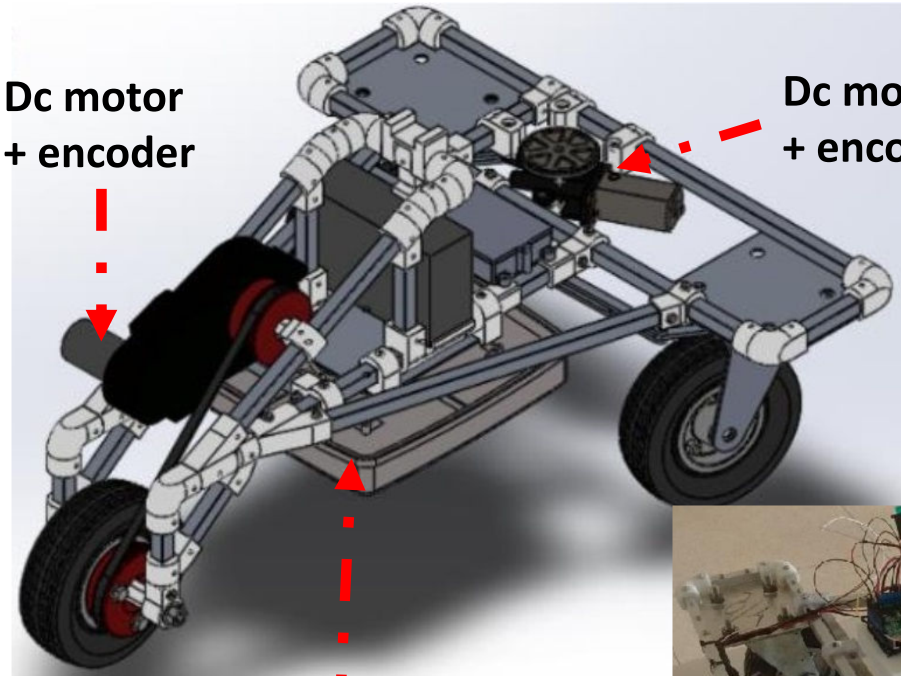


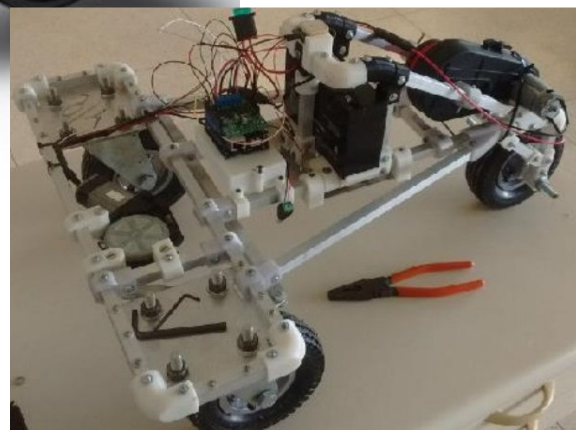
helvis 3



Frey 1

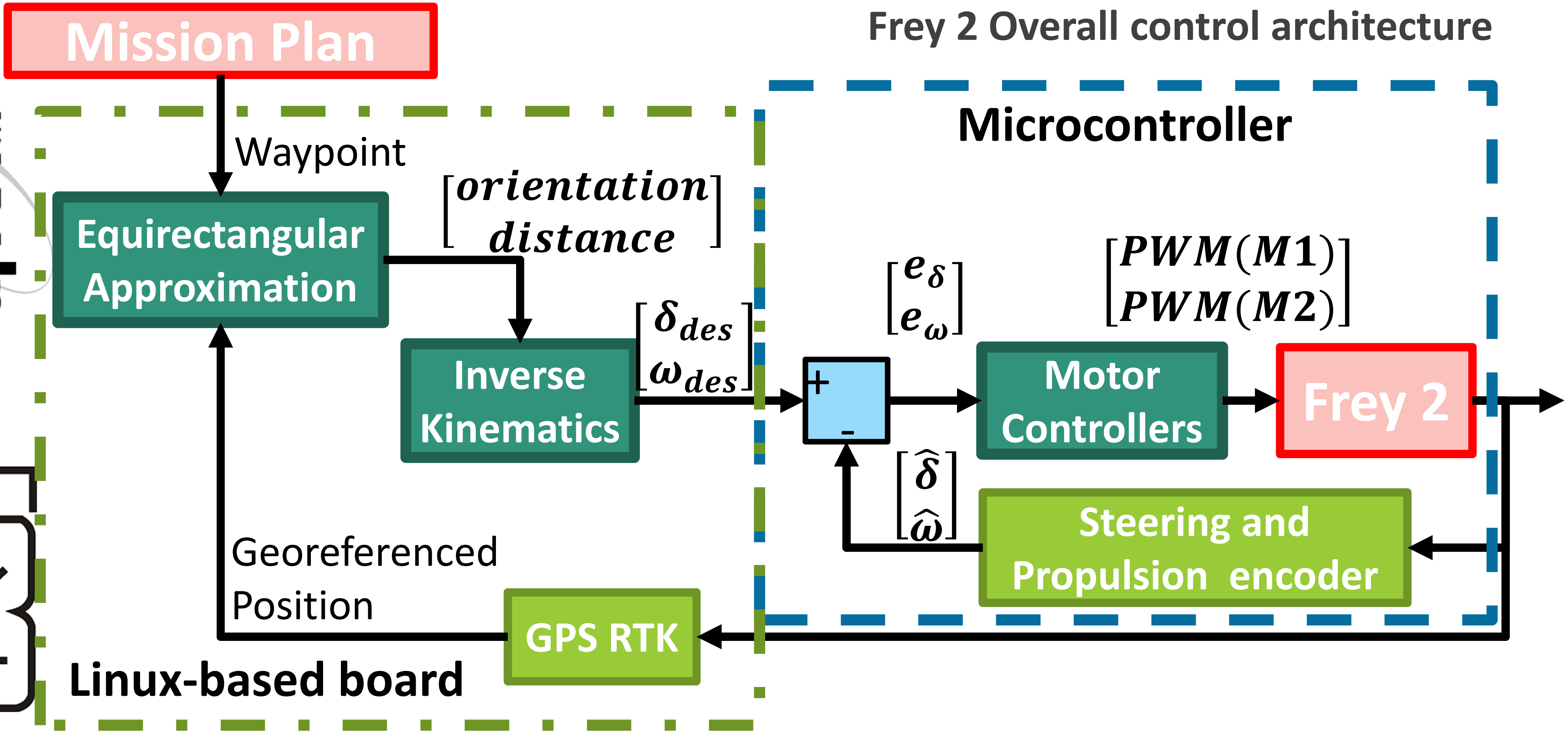
Both too close to the ground





Frey 2

Robot Design – Control Overview



Materials

- RTK GPS u-blox NEO-M8P, using 2 boards C94-M8P
- 1 Linkit 7688 Duo wifi module
- 2 Xbee series 1 from Digi International
- 1 Evaluation board EVK-NINA-B1 for Bluetooth Low Energy module
- 1 ThingMagic M6 RFID reader
- 1 Tag board without battery SL900A from AMS
- 1 Dell Laptop with a Network controller Qualcomm Atheros QCA9565/AR9565 Wireless Network Adapter
- 1 xbee shield for arduino.
- 1 arduino ATMega
- 1 Raspberry PI 3

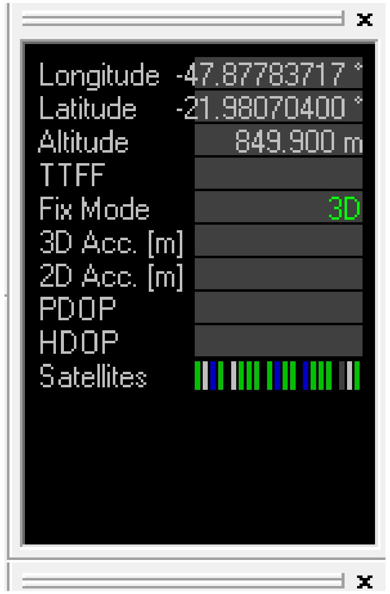
Results and Discussion

GPS considerations – images from Google Maps

50 m scale

UFSCar Eletric and Mechanic Departments – São Carlos, Brazil

GPS RTK BASE

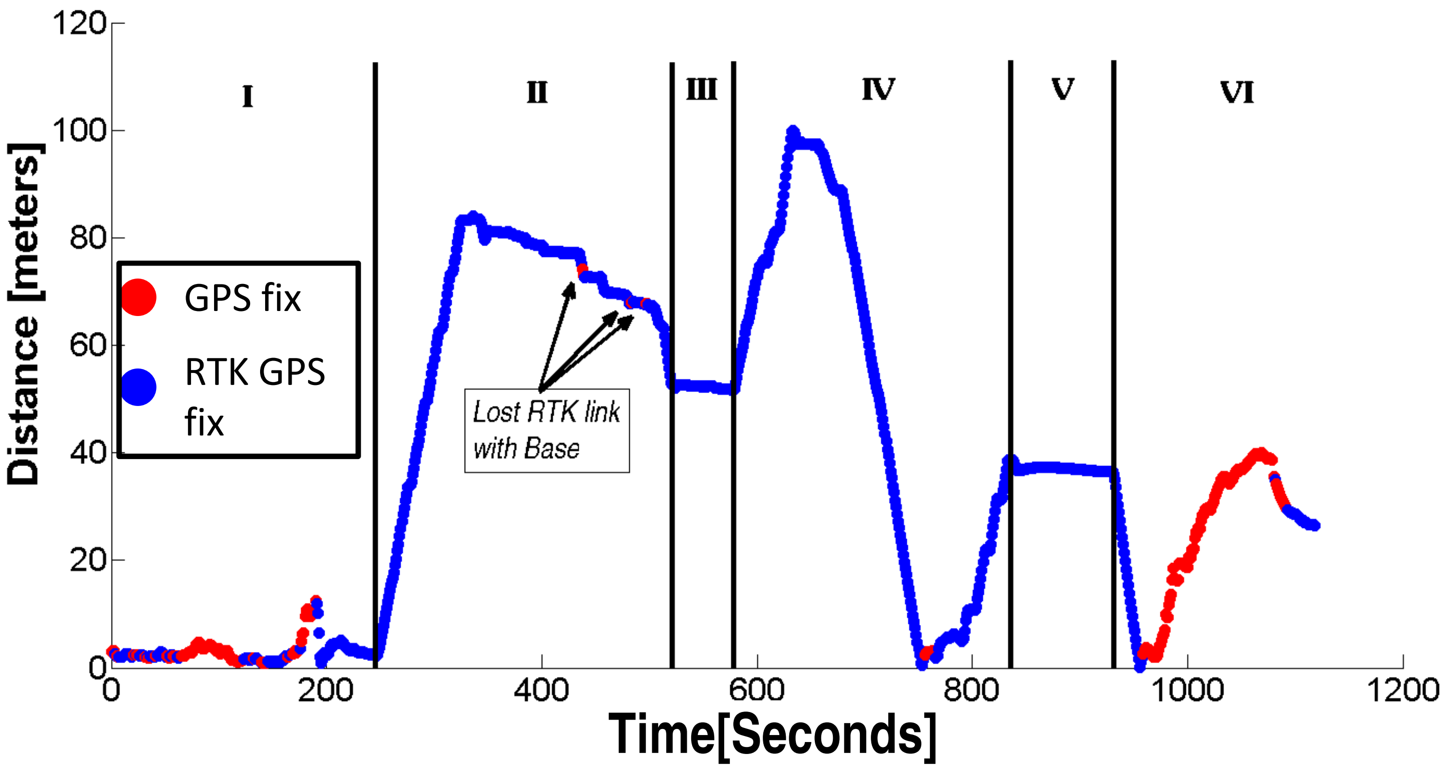


U-blox software on base.
Fixed Position

Base position located Brazil's map

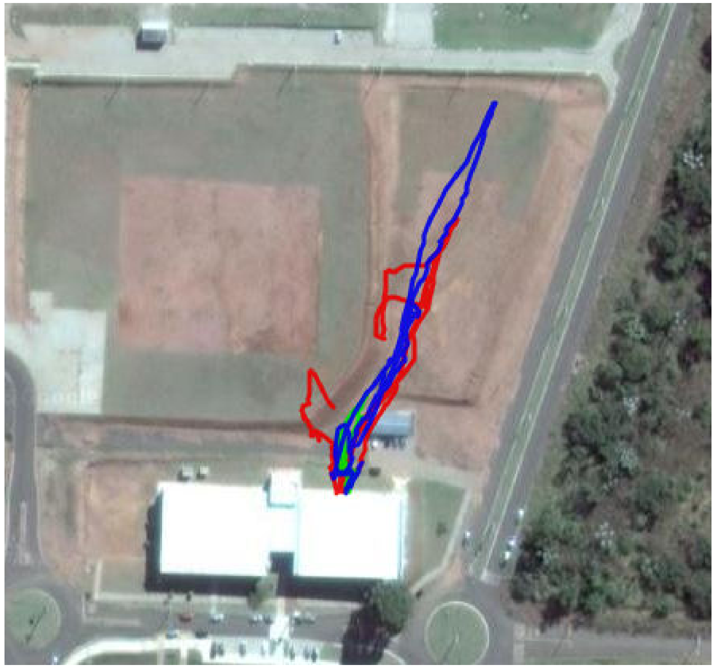
Results and Discussion

GPS considerations – Stages for measurement



I. **Warm-up:** time necessary to ensure RTK link connection and sensor communication
II. **Distance trial:** First path to check maximum distance.
III. **Convergence test:** Wait period to check methodology reliability
IV. **Distance trial:** Second path trial.
V. **Convergence test:** Wait period to check methodology reliability
VI. **Cool Down:** time necessary to end experiment

Results and Discussion



Map (from google maps) overview of distance trials for Bluetooth Low Energy (Green), Xbee (red) and Wifi (blue) modules

Zoomed view from map of google maps. Bluetooth Low Energy module (Green), Xbee module (red) Wifi (blue) module.

Results and Discussion

Technology	Distance [m]	Read Rate [Hz]	Power Consumption [mW]	Power/Distance [mW/m]
Bluetooth Low Energy (BLE)	26.90	10	21	0.78
Xbee	100.03	10	150	1.5
WiFi	139.19	10	1000	7.18
RFID	1.37	1	0.27	0.2

From Convergence tests, GPS RTK shown a standard deviation from 5 cm to 20 cm!

Despite BLE had a maximum of a little less than 27 meters, it is power efficient, with less than 1mW per meter

In absolute number, the WiFi module had the maximum distance, close to 140 meters

Results and Discussion

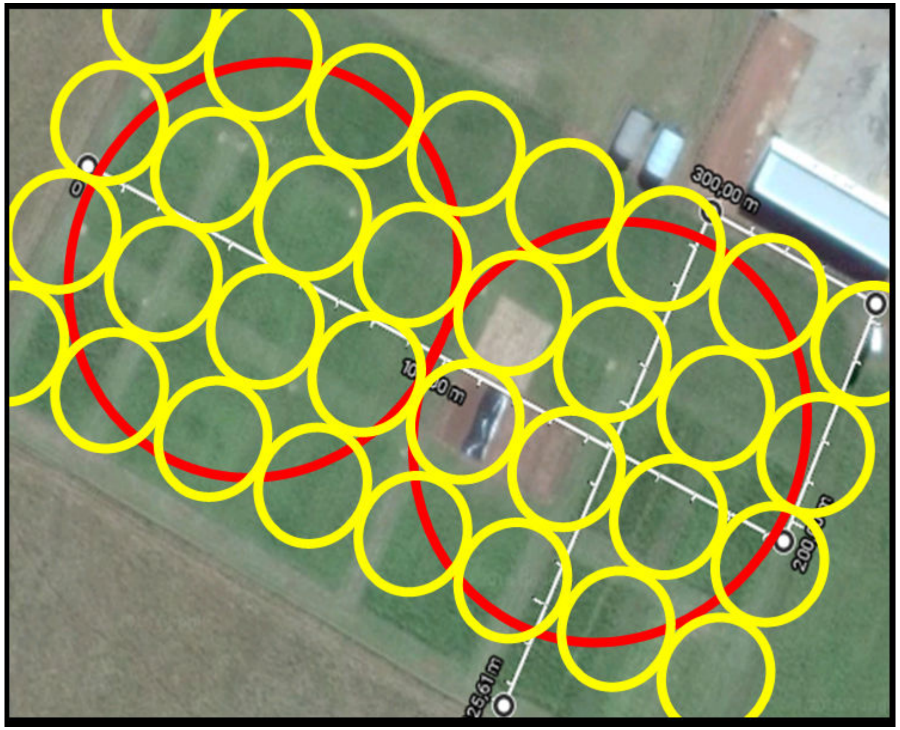
Technology	Distance [m]	Read Rate [Hz]	Power Consumption [mW]	Power/Distance [mW/m]
Bluetooth Low Energy (BLE)	26.90	10	21	0.78
Xbee	100.03	10	150	1.5
WiFi	139.19	10	1000	7.18
RFID	1.37	1	0.27	0.2

For RFID, antenna and tag were fixed, and tag distance were increased. Distance error around 1 cm.

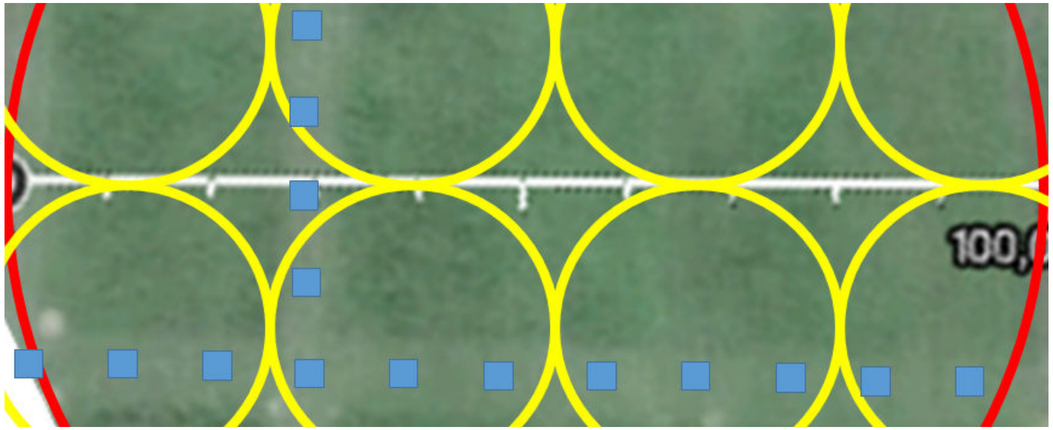
In this test, Xbee presented a good trade-off between distance and energy consumption.

The tag RFID was able to be powered by the antenna and had a power consumption of 0.27 mW. Also the antenna could read until a little more of 1 meter

Results and Discussion



With an heterogeneous sensor technology, is possible to build a mix map, for instance, it is possible to have Xbee nodes (red) and BLE nodes (yellow)



Also, tags without battery (blue squares) can be placed and a autonomous robot may collect such data.

Conclusions and Future Works

- Proposed architecture enables robotic systems (Ground, aerial or other kind) to navigate and collect data from heterogeneous sensor communication technologies. Leading to a integration, due to sensors manufacturers for precision agriculture do not follow specific standard.

- Tested interfaces:
  - ZigBee: Interesting trade-off between distance and power consumption.
  - Bluetooth Low Energy: Good energy performance, having less than 1mW/m. Also, BLE is small (about 10mm X 10mm).
  - Wifi: Maximum range for the device tested. Is a common interface for wireless communication.
  - RFID: RFID reader can power tags and read them until a bit more than 1 meter. This enables placement of sensors in different depths in soil to assert more properties.

- All communication technologies can be embedded and used on a ground robot.

- Although RFID, RTK-GPS and ZigBee work on 900 MHz, harmful interference was not perceived.

- Future works: Finish Frey 2 construction and controllers programming to enable it to locate previously buried tags, marked with RTK-GPS coordinates.