An SoC for IoT Applied to Smart Agriculture

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MPSoC 2019, Hakone, Kanagawa

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Background

- This work is part of my PhD thesis.
- This work is made in collaboration with the IMS Lab at University of Bordeaux.
- Thanks to
  - Christophe Jego: Thesis Director, IMS (France)
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  - Nicolas Vergara: U Santo Tomas (Chile).

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Plants need more than water

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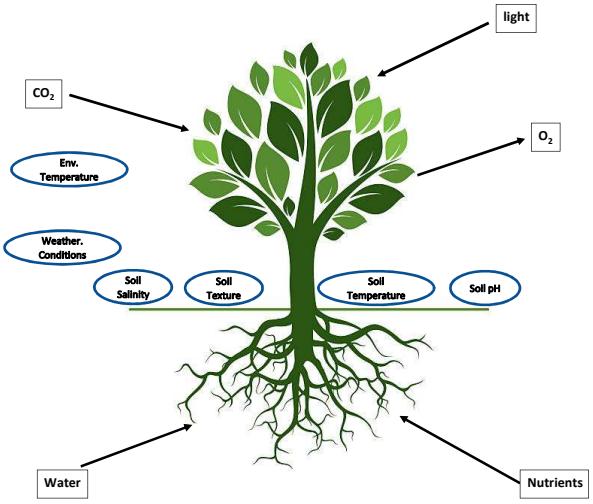

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Why it's so important?

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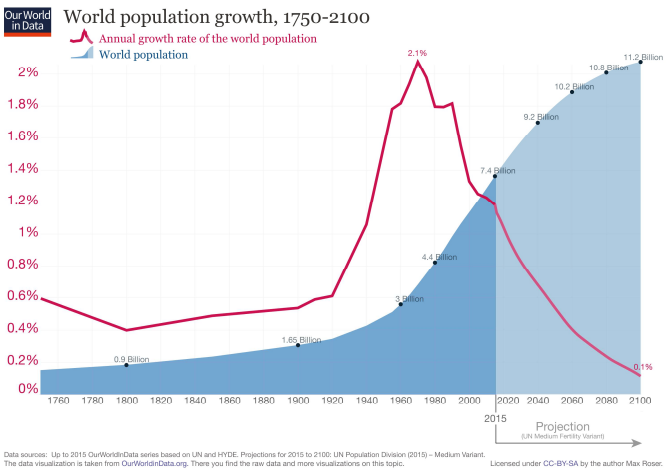

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PROJECTED CLIMATE CHANGE IMPACTS ON CROP AND LIVESTOCK YIELDS

Expected changes in crop and livestock yields by 2050 given mid-range emissions. Note that tropical regions suffer more losses than temperate regions due to climate change.

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For 2050 it is needed to increase 70% of current agricultural production.

almost double current production

Source: FAO

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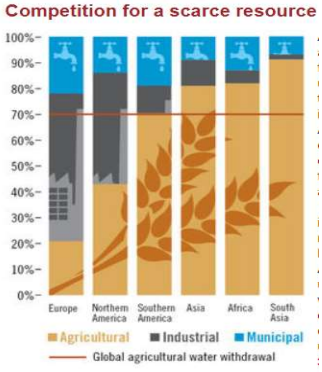
Additional Relevant Data

- Agriculture is the heaviest consumer of our planet's available freshwater.
- 70% of "blue water" withdrawals from watercourses and groundwater are destined to agricultural usage.
- Water is very important for agriculture in South American countries.
- Agriculture's global water demand is estimated to increase by 19% by 2050.



Source: World bank (http://www.worldbank.org/en/topic/water-in-agriculture/)

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Important Parameters for Plants' Growth

- Soil parameters
  - Moisture
  - Nutrients
  - Ph
  - Salinity
  - Temperature
  - Texture
  - Salinity
- Environment parameters
  - Light
  - Temperature
  - Weather

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Proposed Solution

- An SoC (single chip) able to
  - Capture data through sensors
  - Acquire external data through a communication channel (LPWAN)
  - Process data
  - Act based on received data to improve soil parameters
  - Use machine learning techniques to improve soil yield
  - Generate alarms to the farmer
  - Transmit data to the cloud for further analysis
- Work on real time.
- Work on rechargeable batteries.
- Harvest energy to recharge batteries.
- Low cost so it can be used by small – medium farmers.
- Why Edge Computing
  - Real time capture, analysis, and action.
  - Communication availability in rural areas.
  - Too many data to send, so bandwidth and speed issues
  - Low cost.

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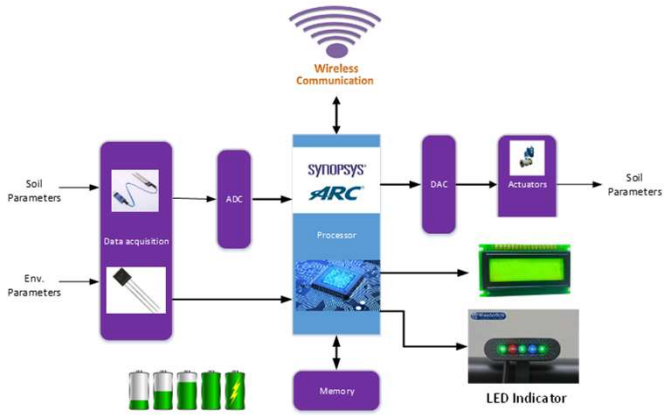
Proposed Edge



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Soil Moisture

- Soil is composed by 50% of minerals and organic particles and 50% of porous space.
- Water in the soil is classified in three categories
  - Gravitational
  - Non available for plants
  - Available for plants – between the gravitational and the non available
- Two kind of sensors: resistive and capacitive.
- Capacitive is more stable but expensive
- Moisture sensors are found in the market.
- Need to act is below the irrigation threshold.
- Plant dependent.

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Soil Nutrients

- 16 chemical elements (mineral and non minerals) are important to plants growth and survival
- The most important non minerals are Hydrogen (H), Oxygen (O) and Carbon (C).
- Main minerals are Nitrogen (N), Phosphorous (P) and Potassium (K), known as NPK.
- Based on NPK optical reflection characteristics
- Sensor to be built (has a first prototype).
- Need to act if not convenient for the plant.
- Add fertilizers through irrigation (automatic).
- Plant dependent.

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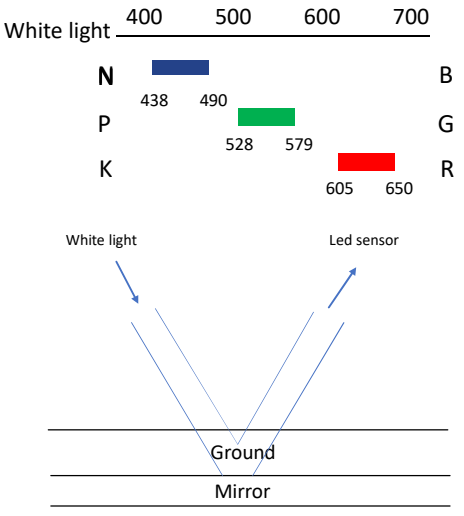
NPK Sensor



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Soil Ph

- Affects the availability of nutrients in relation with plant roots and microbial activity.
- NPK less available in soil with low pH.
- In-situ sensor low cost not found so far.
- Should not change very often (assumption).
- Need to act if not on the accepted range.
- Should generate an alarm.
- Plant dependent.

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Soil Temperature

- Soil is a major storage for heat.
- It governs physical processes, chemical processes and biological processes.
- Measured through a temperature sensor.
- Cannot act if out of range.
- Prediction would help.
- Should generate an alarm.

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Soil Salinity

- High salts concentration results in high osmotic potential of the soil solution
- plants use more energy to absorb water.
- Under extreme salinity conditions, plants may be unable to absorb water and will wilt, even when the surrounding soil is saturated.
- Measured by passing an electric current between the two electrodes of a salinity meter.
- Not yet implemented

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Soil Texture

- Correspond to the amount of sand, silt, clay and organic matter.
- Affects how good nutrients and water are retained in the soil.
- Ideal soil contains equivalent portion of sand, silt, clay, and organic matter
- Doesn't need to be measured on real time
- Data will be used as an input of the system

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Data Acquisition – Environment Parameters

- Environment temperature
  - Measured through a temperature sensor.
  - Cannot act if out of range.
  - Should generate an alarm.
- Weather
  - Data acquired from an external weather station.
  - Data to be taken in account.
  - Should generate an alarm.
- Light
  - Need to know the light components intensity.
  - Can be modified only on a greenhouse environment.

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Communication

- The node has a LoRa interface.
- Data is transmitted to a LoRa gateway
- Lora gateway transmit data to the cloud.

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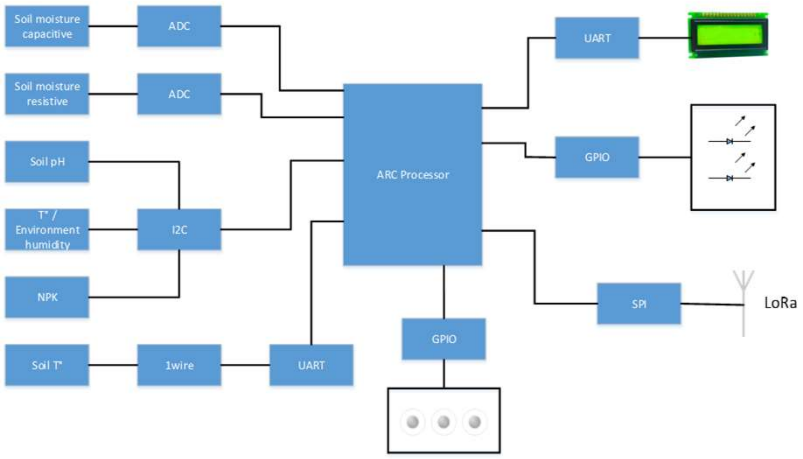
Prototype Block Diagram



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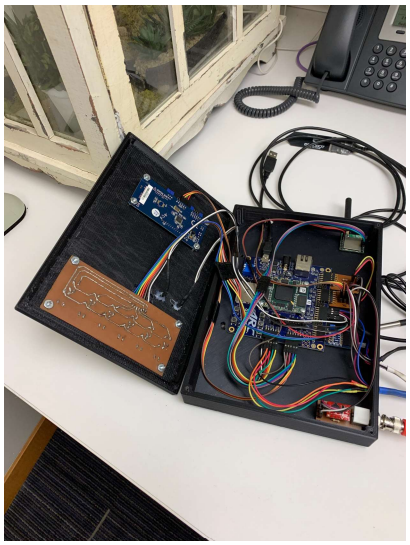
Current Prototype



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Current and Future Work

- Current work
  - Investigating/Build sensors for
    - Soil NPK
    - Soil Ph
    - Soil salinity
  - Investigating the frequency of change of each relevant parameter, change origin, and change consequences.
  - Calibrating the sensors of the prototype
  - Using the prototype in the field
- Future work
  - Implement an app to review data through the internet.
  - Define how to act when parameters are not in the valid range and define corresponding actuators.
  - Define the SoC architecture and IP to be used.
  - Build the SoC.

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Conclusions

- Agriculture provides our food.
- Population is growing, so more food is needed.
- Arable land is decreasing.
- Need to improve soil's yield.
- Precision agriculture and IoT is the key.
- Have implemented a prototype of the edge of the system.
- Machine learning will allow the IoT system to work independently
- Artificial intelligence will provide algorithms to improve the yield
- Need to work close to agronomist.

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