Printed Miniature Nutrient Sensors

Senior Design
Group #19

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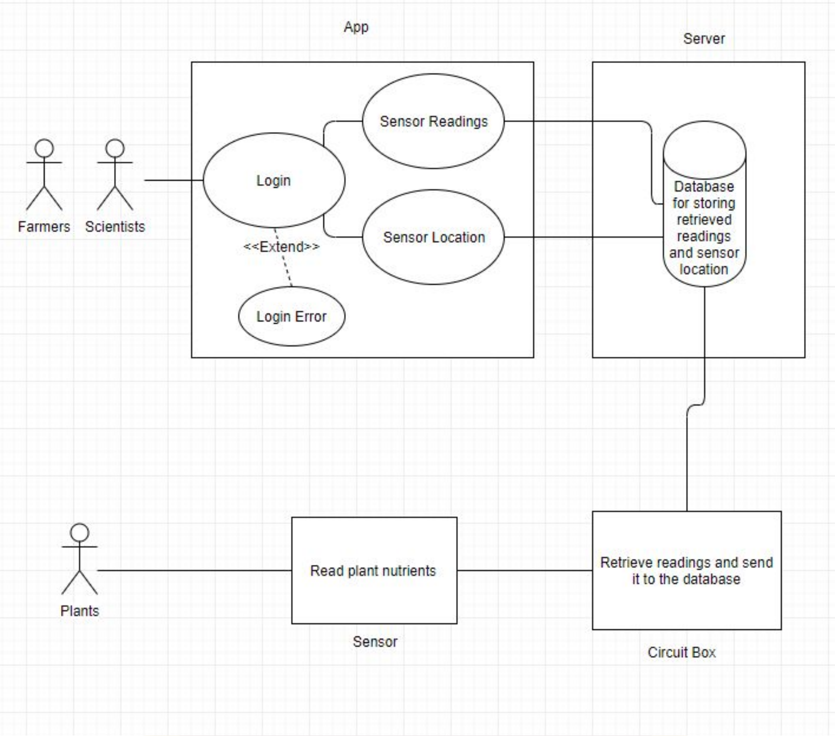
Samuel Keely	-Software/App Development
Clayton Flynn	-Manufacturing and Testing
Jonathan Hugen	-Manufacturing and Testing

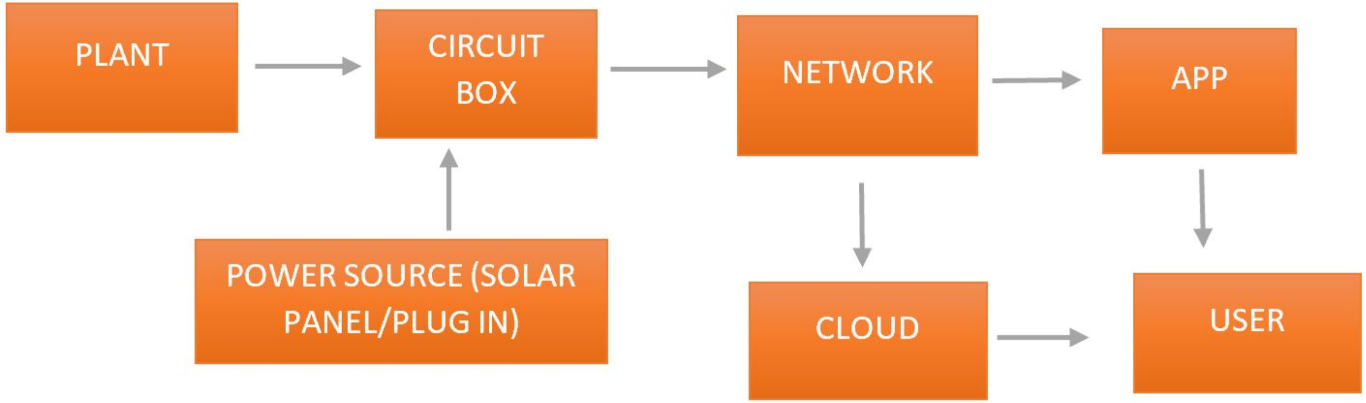
Problem Statement

Soil conditions are never the same of two patches of land adjacent to each other. One patch could be dense in NO_3 (Nitrates), while the other could be dense in P (Phosphorus). For the best yield per acre, farmers need accurate data about the current nutrient levels in soil, in order to determine the right type and amount of fertilizer required for that acre of land. However, inaccurate data and the long waiting time on soil analysis results, often leaves farmers with incomplete information about current soil conditions, which has detrimental effects on the harvest of a crop.

Conceptual Sketch



Conceptual Sketch



Functional Requirements

1. Data can be transmitted effectively from the field to the app, within Ames.
2. The sensor must differentiate between Nitrogen and other particles in the soil precisely.
3. The sensors must be able to cope with a large range of temperatures, under which they work without any glitches.
4. A slight change in power should not have detrimental effects on the accuracy of data.
5. The units (needle sensor and circuit box) can run for 60 days without needing a change of batteries.
6. Batteries are recharged using solar panels.
7. Although, the current sensors provide good data, they cannot distinguish between NO_3 and other nutrients in soil within the 5% error margin. Another aspect we aim to optimize is increasing the range of the sensor from detecting 1 ppm of NO_3 to 5000 ppm of NO_3 with an error margin of 20%.

Non-Functional Requirements

1. Waterproofing
2. Increase transmission range
3. Increase operational lifetime
4. Reduce power consumption

Technical Considerations

1. High power consumption of the sensor. (1 W/ unit). Given the number of needle sensors on a sensing unit, it is difficult to significantly minimize the power consumption per unit.
2. The configuration/build of the sensor is based on the environments experienced in the Midwest. Given that the sensors are being manufactured here, the design requirements are adaptive of the weather and climate conditions here. If this sensor were to be used in more tropical climates or colder climates, the accuracy of the data will be largely affected due to the possibility of malfunctioning circuit components.
3. The app is only compatible with Android. Due to budget constraints, our app was only tested and installed on Android phones (bought in bulk). Anybody with an Apple OS, may not be able to access the benefits that the app has to offer.

Market Survey

1. The lab using tissue analysis are inconvenient for farmers looking for immediate results.
2. There are several optical sensors on the market including GreenSeeker and CropCircle.
3. There are also some handheld ISM sensors from companies like Horiba, but they require the plant sap to be made into a solution.
4. Our project should be the only field deployable sensor using ISM.

Potential Risks & Mitigation

1. Environmental hazards
2. Incomplete/inaccurate data in data retrieving process

Resource & Cost Estimate

1. All lab equipment including 3D printers and nano printers will be provided through Iowa State University through the Biosensor Lab. Information regarding technical specifications for biological sensors will be provided by chemistry and biology graduate students.
2. Cellular network subscriptions will be covered under the 2 million dollar project grant. This project has a budget of $500 budget but can be adjusted if needed. Printing materials will be minimal and they will be provided for this project by the grant and will not come from the $500 budget. The equipment such as the MCU's and cell-phones have already been purchased.

Project Milestones & Schedule

1. Decrease water damage to the sensor
2. Decrease power consumption
3. Switch data transmission network from Bluetooth to cellular data and eventually LoRaWAN.
4. Get current system working and test for issues and bugs
5. Rewrite code for cell based network
6. Find an epoxy resin that can withstand water penetration for 60 days
7. Finalize a pattern for depositing the ISM and resin onto the sensors
8. Begin greenhouse testing

Project Milestones & Schedule

Preparation and Information – Work on understanding how the sensors currently work.

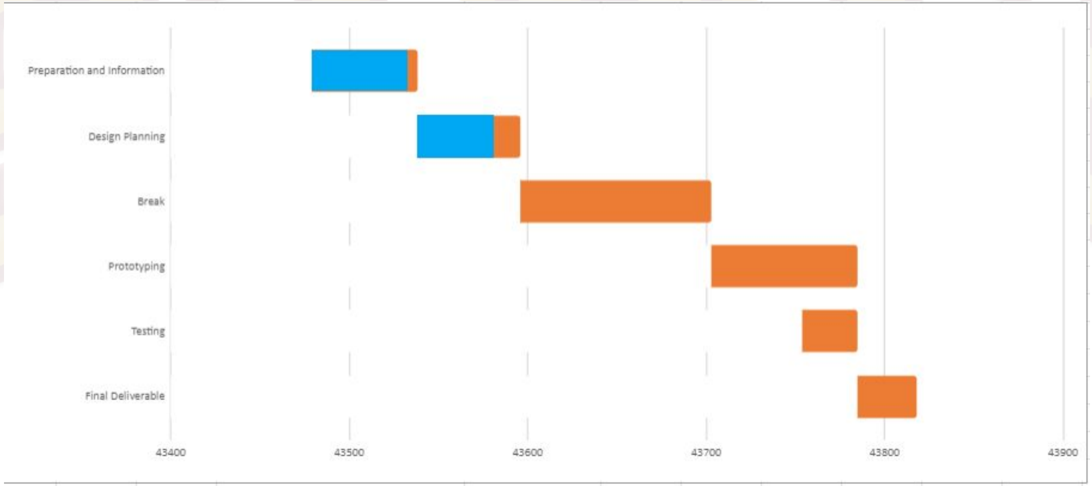
Design Planning – Design a plan for improving each part of the project; needle sensor, circuit box, app.

Break – No work will be completed over the summer break.

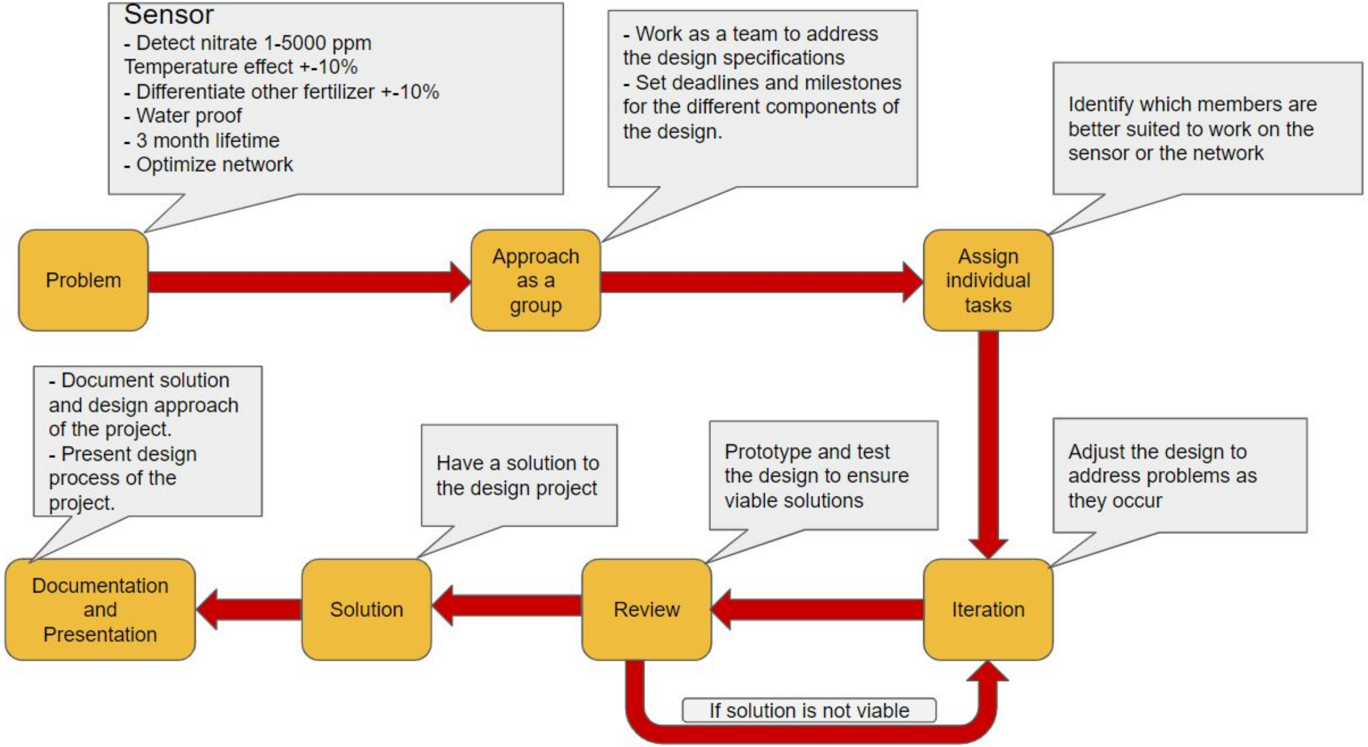
Prototyping – Implement the design changes into the project.

Testing – Test the new models and makes changes as necessary.

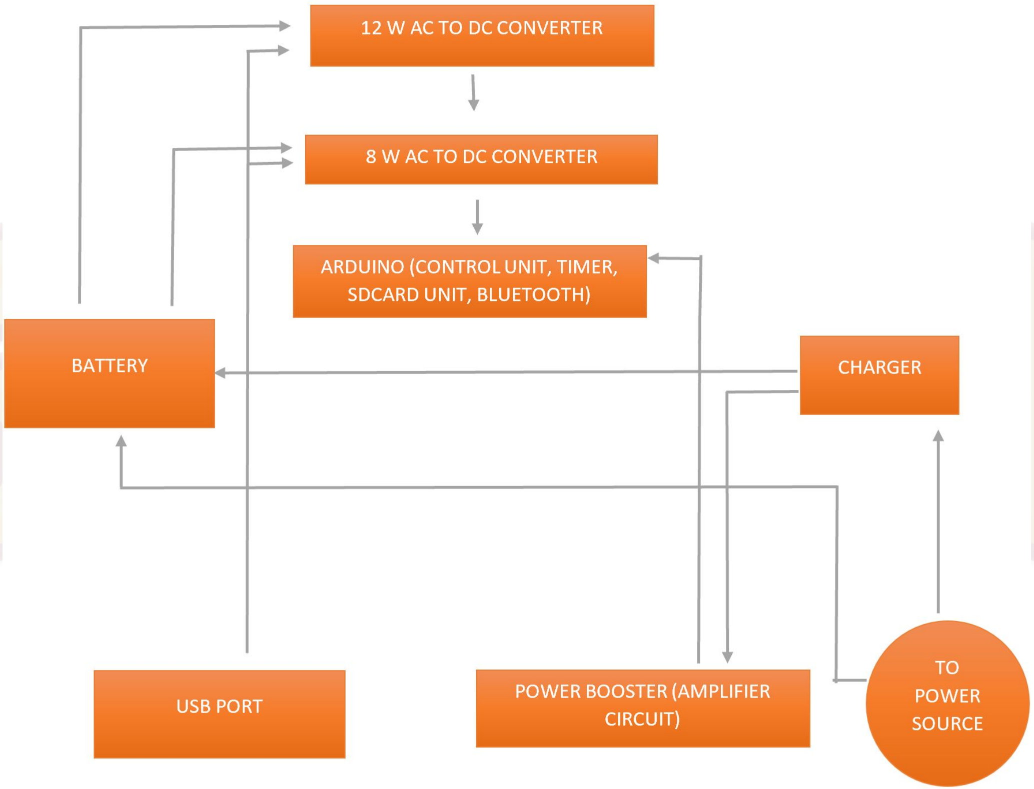
Final Deliverable – Finish the final product for the project.



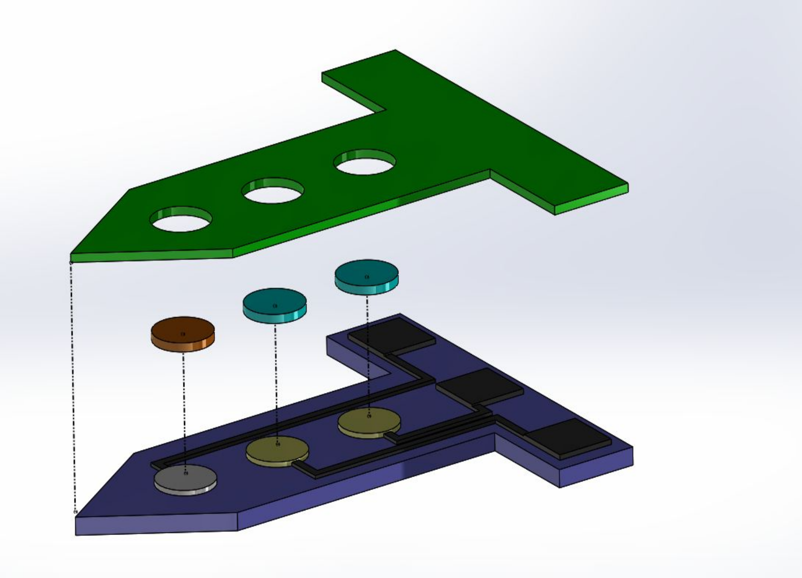
Functional Decomposition



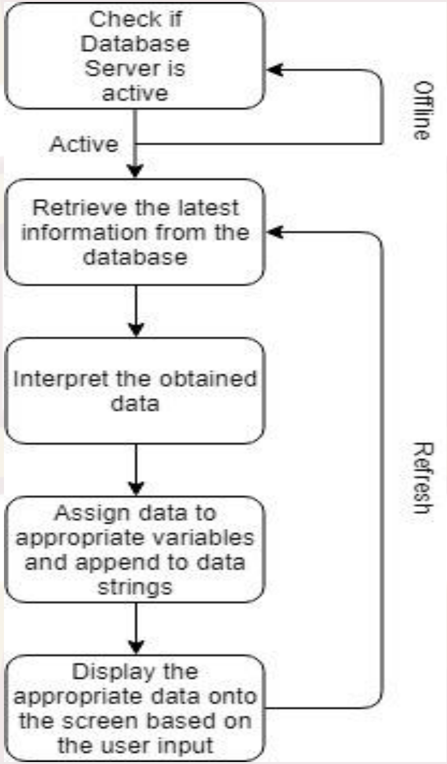
Detailed Design (Circuit box)



Detailed Design (Needle point sensor)



Detailed Design (App)



HW/SW/Technology Platform

1. 3D Printer
2. Nanomaterial Printer
3. User Interface for sensors' data
4. Cellular Network and bluetooth module
5. LoRa (digital wireless data communication technology)
6. Microcontroller Unit (MCU)
7. Cloud Storage

Test Plan

1. Measure Nitrate Between 1 to 5000 ppm
2. Temperature Invariance
3. Differentiate From Other Nutrients(e.g Phosphorus)

Prototype Implementations

1. Polymer sealer
2. ISM pattern
3. App algorithm

Contributions Of Each Project Member

1. Jonathan Hugen
   a. Learned programming methods for fluid dispensing robot (Intuitive G code)
   b. Learned to calibrate robot
   c. Learned how to scale and rotate programs
   d. Experimented with printing patterns to deposit materials
2. Samuel Keely
   a.
3. Jeremy-Min-Yih Chee
   a. Tested the app to understand how they worked.
   b. Designed the software layout of the project (Interaction of the server, app, and MCU).
   c. Designed the cellular module that will be used as a medium for data transmission

Contributions Of Each Project Member

1. Ritika Chakravarty
   a. Tested circuit boxes to understand how they worked.
   b. Designed circuit diagrams and block diagrams to understand the circuit box and the data collection/ transmission network better.
   c. Understood the mechanism of data collection by the circuit box, and how this data is calibrated into a input voltage and nitrate level curve.
2. Clayton Flynn
   a. Worked with the fluid dispenser for making the sensor
   b. Developed printing patterns to deposit materials

Plan For Next Semester

1. Test sensors in lab and field.
2. Use the collected data to calibrate other needle sensors to the voltage ppm curve.
3. Test the app’s updated data storage feature and user interface.