

MID-YEAR CEJS REPORT
REMOTE ENVIRONMENTAL MONITORING USING INTERNET OF THINGS
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The primary objective of this project was to build and deploy smart, connected sensors that provide remote and continuous monitoring of air, water, and soil quality. Acquired data would be displayed on a graphical user interface (GUI) that provides real-time information of the parameters being monitored, and thresholds would be established in order to trigger email alerts to monitoring personnel, when there is a deviation from normal.

Summer 2016:

This project got off to an early start in June 2016; prototypes of the smart soil and water quality sensors were developed, and initial results were recorded. Details of the soil moisture sensor are presented in this report. The experimental setup, as shown in Figure 1a., consists of a Raspberry Pi

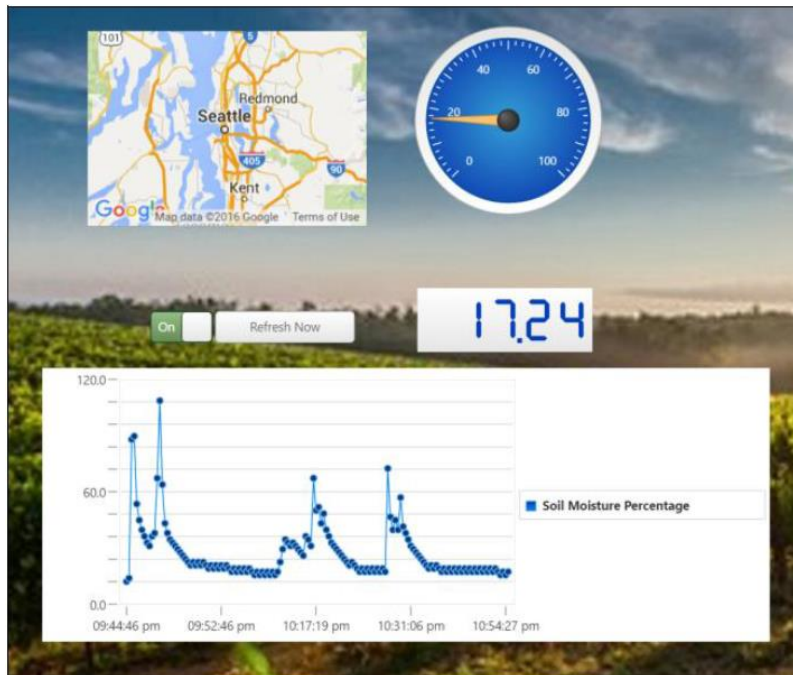
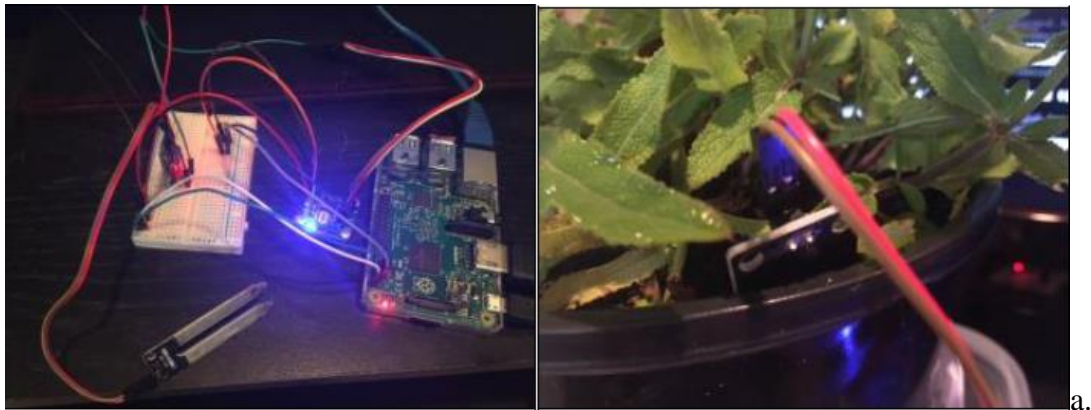


Figure 1: a. Experimental setup for the smart soil moisture sensor b. Mashup displaying soil moisture

percentage

B+, an Arella soil hygrometer, and a PCF8591 Analog to Digital Converter (ADC). The Arella soil hygrometer is a resistive soil moisture sensor that measures volumetric water content in soil by measuring the resistance between its two electrode probes. Low resistance corresponds to high moisture content, and vice versa. The sensor was calibrated using an in-built potentiometer to read 0% moisture in baked soil. The percentage of soil moisture of a container garden plant was monitored over a period of one-hour, during which the plant was watered five times, arbitrarily.

The Mashup shown in Figure 1.b illustrates the variation of soil moisture over the test duration, with spikes noticed at the time instants when the plant was watered, followed by a decline towards a steady state value of around 17.24 %. This observation can be explained by the fact that physical characteristics of soil such as its composition, texture, structure, and porosity, influences the amount of water retention. Once the soil has reached saturation, the excess soil water drains or percolates through the drainage holes in the container, and soil moisture decreases rapidly. The point at which drainage becomes negligible is when the soil reaches its Field Capacity [1]. Drainage is faster for sandy soils with a Field Capacity of about 15 to 25 %, when compared to clay soils with 45 to 55 %.

The web-application platform used for this project was Thingworx by PTC Inc., which is a leading developer of solutions for the IoT. The Thingworx email server was configured to send an email notification when the soil moisture percentage reached a lower threshold of 14 %. This experiment serves as a proof of concept to show that an IoT soil moisture sensor can be quickly developed and deployed for smart gardening or agricultural applications.

An abstract documenting results from the pilot implementation of this project was submitted to the IEEE Global Humanitarian Technology Conference, 2016. Although the abstract was accepted for submission, I was unable to submit the full paper due to time constraints resulting from another academic engagement. These results were also included in an undergraduate research proposal to the W.M. Keck Foundation; the proposal was funded for \$250,000 for three years.

Fall 2016 and Winter 2017:

With the prototype successfully implemented and tested in Summer 2016, most of Fall 2016 and Winter 2017 was spent exploring opportunities for remote deployment of the sensors. I was presented an opportunity to work with Seattle University's chapter of ESW (Engineers for a Sustainable World) on water quality projects. In March 2017, the ESW team travelled to the town of Manchay, Peru, and helped install a sensor system for an aquaponics facility. The system consisted of Raspberry Pi-controlled sensors for pH, temperature, and dissolved oxygen, and the corresponding time-variations of these parameters are shown in Figure 2. Real-time data from this system is uploaded to a web server, and can be accessed remotely through the URL: <https://thingspeak.com/channels/234902>.

Similar water quality sensors were installed for an aquaponics facility in Washington Middle School, Seattle in May 2017. Future projects include an installation at Zion Children's home near Chiang Mai, Thailand in July 2017, and at Rotary boys and girls club, Seattle in Summer 2017.

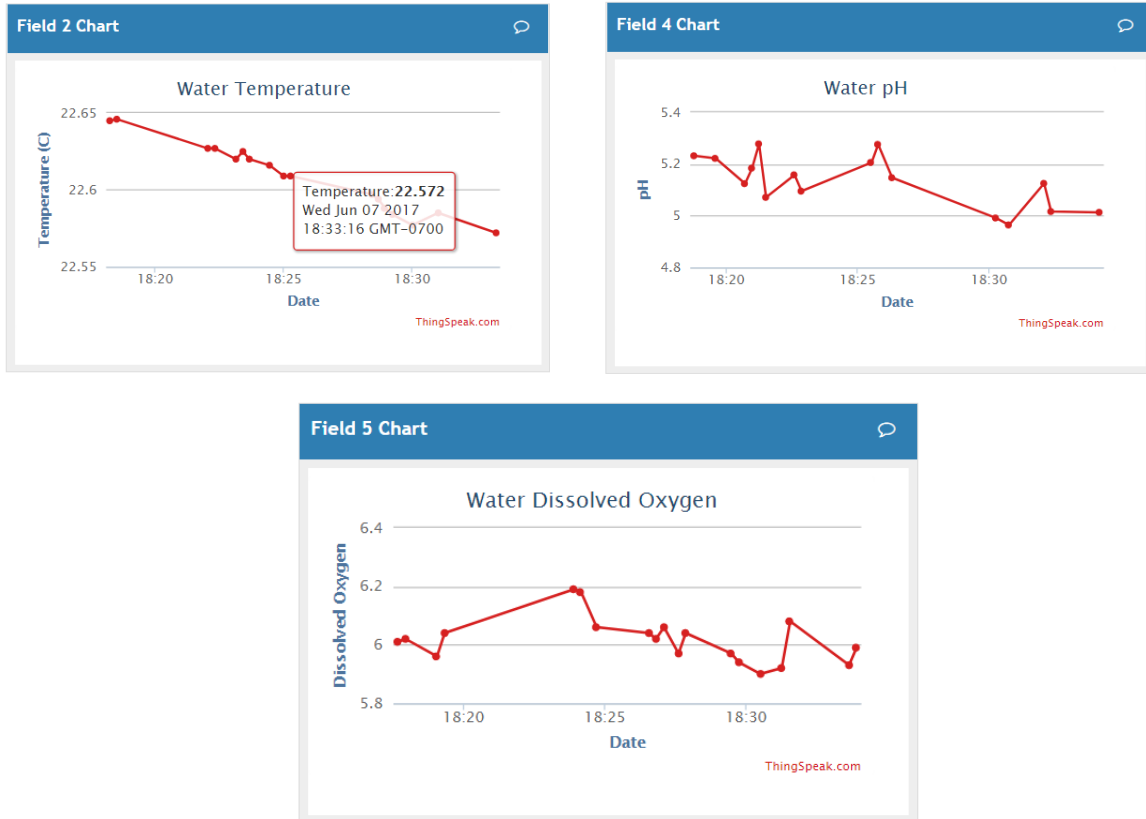


Figure 2 Real-time variation of water temperature, pH, and dissolved oxygen in the aquaponic system

Spring 2017:

Two abstracts submitted to the IEEE Global Humanitarian Technology Conference, 2017 have been accepted; ‘Remote Environmental Monitoring using Internet of Things (IoT)’ and ‘An Internet of Things (IoT)-based Aquaponics Facility’. Full papers will be submitted in June 2017.

References:

1. Klocke, Norman L. and Hergert, Gary W., "G90-964 How soil holds water" (1990). Historical Materials from University of Nebraska Lincoln Extension. Paper 725.