eGreenhous

A mobile sensor package for real-time greenhouse monitoring

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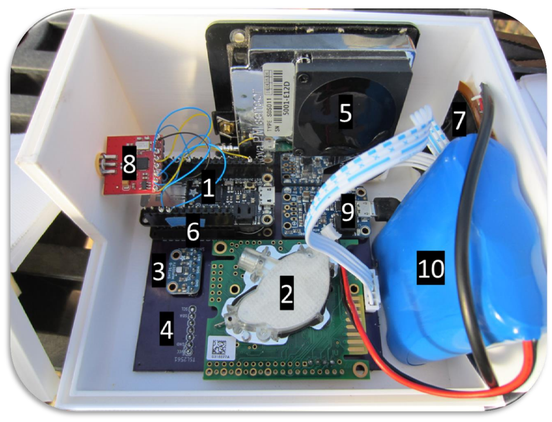
Abstract

Increased demand for precision agriculture is reflected by a global rise in greenhouse food production. To maximize crop efficiency and yield, commercial greenhouses require live monitoring of growth conditions. Recent advances in open-source hardware allow for environmental sensing with the potential to rival lab-grade equipment at a fraction of the cost. This study introduces a high-resolution sensor package that costs less than $400. Consisting of microcontrollers and small open-source hardware, the sensor package can be deployed on the HyperRail, a modular conveyance system developed in Oregon State University's OPEnS Lab. The system can then provide data from multiple sensing locations at the cost of a single package. Sensor data, including CO_2, temperature, relative humidity, luminosity and air quality, is saved to a microSD card. A wireless GFSK nRF connection to a network hub allows the broadcast of a live stream of these data online. Results from calibration in the lab show that the Senseair K30 CO_2 sensor ($85) can be calibrated within 10 ppm of industry standard equipment costing thousands of dollars. The flexibility and affordability of this package can make precision agriculture more accessible where conventional monitoring systems are not feasible.

Open-source hardware

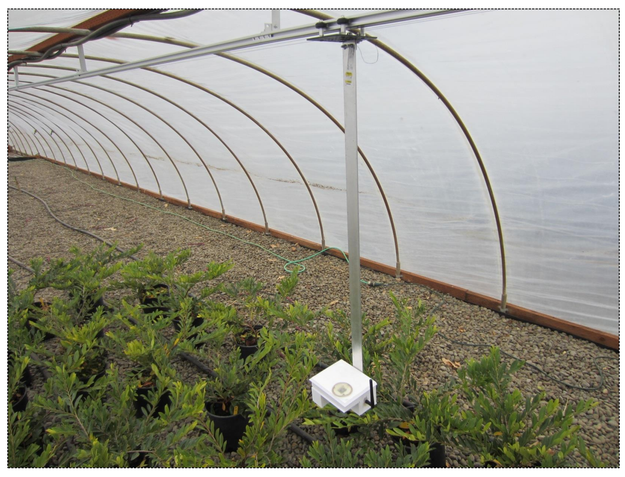
- Programmed in C++ with the Adafruit Feather microcontroller at its core, similar to the Arduino.
- A wireless charging transmitter and receiver.
- A custom 3D-printed enclosure designed for water-resistance and HyperRail attachment.
- Wireless data using 2.4-GHz GSFK nRF.



eGreenhouse hardware

1. **Processor:** Adafruit Feather Adalogger
2. **CO_2:** Senseair K30 (30 ppm ±3%)
3. **Temp/RH:** Adafruit SHT31-D (± 3˚C, ±2% RH)
4. **Lux:** Adafruit TSL2561 (0.1 – 40,000)
5. **Particulate Matter:** Nova PM SDS011 (0.3 µ g/m^3)
6. **RTC:** Adafruit DS3231 Featherwing
7. **Wireless Charging:** Adafruit Universal Qi
8. **Transmission:** Nordic Semiconductor 2.4 GHz nRF
9. **Power Management:** Adafruit PowerBoost 1000C
10. **Battery:** Adafruit 6600 mAh lithium ion battery
11. **Data:** Adalogger, microSD, Google Sheets

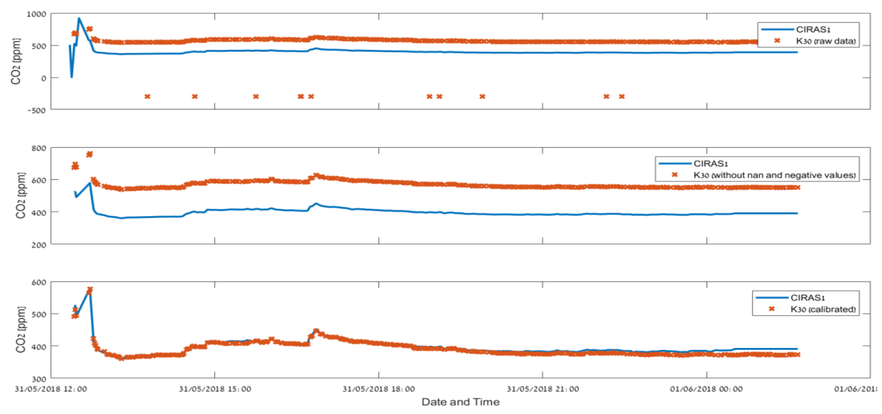
Deployment



	A	B	C	D	E	F	G	H
1	Date	Time	deviceID	CO2	Lux	Temp	RH	Particle
2	August 3, 2018	11:05:32 AM PDT	TestDevice42	510	24	26	48	2
3	August 3, 2018	11:08:04 AM PDT	TestDevice42	504	24	26	48	2
4	August 3, 2018	11:08:20 AM PDT	TestDevice42	505	24	26	48	2
5	August 3, 2018	11:08:36 AM PDT	TestDevice42	506	24	26	48	1
6	August 3, 2018	11:08:53 AM PDT	TestDevice42	505	24	26	48	1
7	August 3, 2018	11:09:08 AM PDT	TestDevice42	504	24	26	48	2
8	August 3, 2018	11:09:24 AM PDT	TestDevice42	504	24	26	48	3
9	August 3, 2018	11:09:40 AM PDT	TestDevice42	503	24	26	48	2
10	August 3, 2018	11:09:56 AM PDT	TestDevice42	503	24	26	48	2
11	August 3, 2018	11:10:12 AM PDT	TestDevice42	503	40	26	48	2
12	August 3, 2018	11:10:28 AM PDT	TestDevice42	503	40	26	48	2
13	August 3, 2018	11:10:44 AM PDT	TestDevice42	503	6	26	48	1
14	August 3, 2018	11:11:48 AM PDT	TestDevice42	834	71			
15	August 3, 2018	11:12:04 AM PDT	TestDevice42	624	86			
16	August 3, 2018	11:12:20 AM PDT	TestDevice42	552	71			
17	August 8, 2018	3:10:49 PM PDT	TestDevice42	564	136			
18	August 8, 2018	3:11:06 PM PDT	TestDevice42	564	136			
19	August 8, 2018	3:11:14 PM PDT	TestDevice42	564	121			
20	August 8, 2018	3:11:32 PM PDT	TestDevice42	564	121			
21	August 8, 2018	3:11:41 PM PDT	TestDevice42	563	136			
22	August 8, 2018	3:11:59 PM PDT	TestDevice42	563	136			
23	August 8, 2018	3:12:07 PM PDT	TestDevice42	563	151			
24	August 8, 2018	3:12:25 PM PDT	TestDevice42	563	136			
25	August 8, 2018	3:12:33 PM PDT	TestDevice42	563	121			
26	August 8, 2018	3:12:51 PM PDT	TestDevice42	562	136			
27	August 8, 2018	3:12:59 PM PDT	TestDevice42	562	136			
28	August 8, 2018	3:15:11 PM PDT	TestDevice42	558	121			
29	August 8, 2018	3:15:29 PM PDT	TestDevice42	558	136			
30	August 8, 2018	3:15:37 PM PDT	TestDevice42	558	136			
31	August 8, 2018	3:15:55 PM PDT	TestDevice42	558	121			

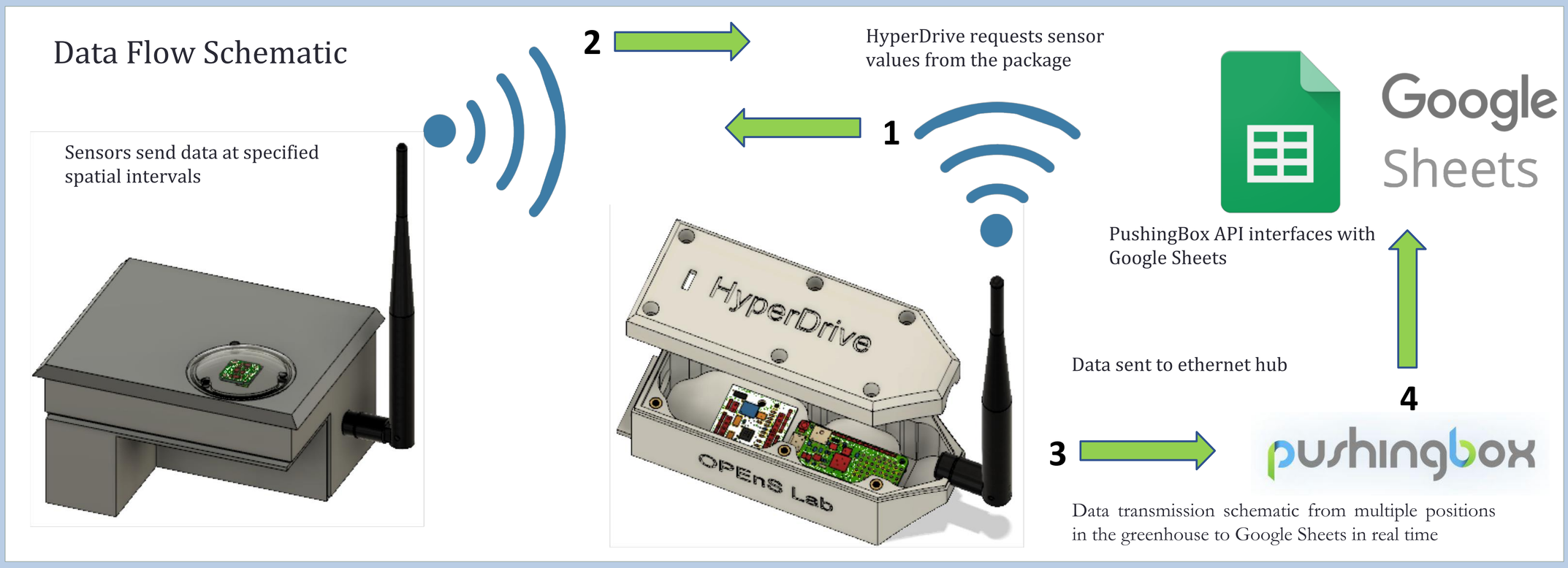
Deployment of eGreenhouse and HyperRail at North Willamette Research and Extension Center (Oregon, USA) (left). Test data showing data from the field sent to Google Sheets via nRF across three nodes spanning over 100 meters (right). The Google Sheets script can be updated from the C++ code to include any relevant columns such as position along the rail. Data can be viewed remotely and plots values in real time. Each data cycle takes under 5 seconds to complete.

CO_2 calibration



Senseair K30 ($85) calibrated with the Portable Photosynthesis Systems CIRAS1 standard lab gas analyzing equipment. Mean CO_2 levels were within 10 ppm after adjustment on average with R^2 = 0.94.

From greenhouse to Google



Conclusions

- **Calibration** shows the $80 K30 performs within 10 ppm of gas analyzers costing thousands of dollars.
- **Preliminary testing** indicates the sensor package, wireless charging, and nRF transmission are robust and integrate successfully.
- **Future potential** for expansion to include actuators to adjust greenhouse controls.
- **Soil Moisture and NDVI** are promising additions to the eGreenhouse sensor suite (Low-cost RFID tag soil moisture sensors).
- **Full-scale deployment** is in progress to capture the spatial variation of CO_2. The sensor package is running every 15 minutes, saving locally to microSD while more robust and affordable nRF modules are explored.

Acknowledgments

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