Sensor Networks, Dataloggers, and Other Handy Gadgets
Using Open-Source Electronics for the Christina River Basin CZO

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Introduction

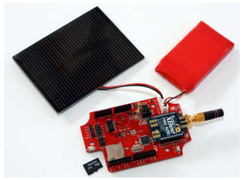
- The search for biogeochemical “hot spots” and “hot moments” that control ecosystem-level processes requires large multi-sensor measurement arrays.
- The recent developments in open-source electronics prototyping platforms allow environmental observatories to deploy sensors at massive scales by reducing data logging and communications costs by more than an order of magnitude.
- One popular hardware platform, called Arduino, has dozens of low cost boards that connect together in a modular framework, allowing the user to quickly create devices for a wide range of applications.

Open-Source Datalogger Hardware

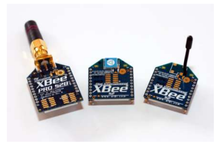
- The Open-Source nature of Arduino means the cost is extremely low compared to similar commercial options. The large user community provides support along with constant innovation and development of new hardware and applications.
- There are many different types of Arduino-compatible hardware variations, with several being very well suited for wireless sensor networks and dataloggers.
- Low powered simple logging nodes collect and transmit basic sensor data short distances to data radio hubs, and the hubs relay the data to a base station.
- High-powered radio units connected to a versatile microprocessor board collect sensor data and transmit long distances via a self-healing mesh network back to base stations.
- Standalone loggers with just a memory card can be used in areas when there is radio mesh network.

Standalone logger with memory card: $40

18-bit A/D converter: $12



Solar-powered node, high power radio: $80



Xbee radio modules: $20-$35

16 channel multiplexer: $5

6-channel soil moisture probe logger: $60

Compatibility and Integration

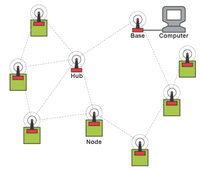
- Arduino nodes can also act as “cable replacement” modules by wirelessly transmitting or logging data that can normally be sent on a cable between a sensor and a computer.
- Almost any device that outputs data can be interfaced with an Arduino-based circuit, and that data can be instantly transmitted through the wireless mesh network.
- Commercial dataloggers like the Campbell CR1000 can easily join an Arduino/Xbee mesh network by simply connecting a radio module and adding a few lines of code to the existing CR1000 program so it can transmit the same data that it stores in its internal memory.

Xbee base station

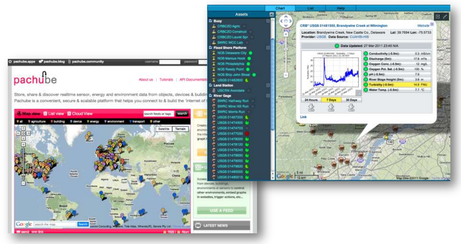
Serial output to radio

Wireless Datalogging & Mesh Networks

- Self-healing mesh wireless networks are robust and reliable, with nodes spaced hundreds of meters to several kilometers apart.
- The logging nodes conserve battery power by sleeping most of the time, then waking periodically to take measurements from the sensors, and then transmitting their data through the mesh back to the base before going back to sleep.
- Each node is also equipped with a removable memory card to store all local sensor data in the unlikely case there is a failure in the mesh network.



A Basic Mesh Network



The CRB-CZO will host its data on a custom interactive web site. Free data-hosting web sites like Pachube offer real-time cloud based logging and graphing.

- At the base station, the incoming live streaming data can be displayed on a computer, stored in a database, and plotted on a web page for near-real-time viewing and analysis.
- Nodes can also be reconfigured or reprogrammed remotely through the mesh network.

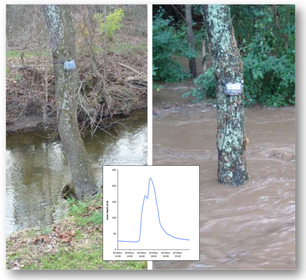
Sensor Networks: Cost vs. Coverage

- High-quality commercial sensors are relatively inexpensive and easily available. Most sensors have standard outputs such as analog voltage or digital serial signals that are easily interfaced with the Arduino hardware.
- User customization of the Arduino node interface hardware and software means virtually any sensor can be used.
- One Arduino logging node can interface with many different types of sensors at the same time by using multiplexers.
- A 16-channel, solar-powered Arduino datalogger node with self-meshing wireless communications and waterproof enclosure costs $150.

Some of the commercial sensors that can easily connect to Arduino loggers: soil moisture, conductivity, redox, CO_2 probes, pressure transducers, and oxygen sensors. These are the same sensors used with commercial dataloggers, so we can collect the same high-quality data with our custom loggers.

- By significantly decreasing the cost of the datalogging and communication hardware, resources can be focused on installing more high-quality sensors for greater spatial coverage.
- Researchers, students, and individuals can easily build and deploy customized inexpensive dataloggers without the need for electronics experience, complicated software, or specialized tools.
- Implementation of open-source electronics hardware will transform our ability to deploy sensors, field instruments and other electronic “eyes and ears” to unprecedented levels.

Practical Implementations of Arduino Hardware

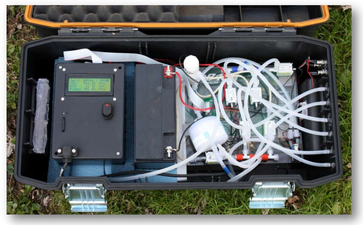


Radio Reporting Stream Gage
An Arduino logger with Xbee radio sends live stream depth data to a base station that posts it to a web page.

Pressure Transducer Readout & **Portable Soil Moisture Probe Tester**
Useful for testing probes during deployment.

Remote Streamwater Sampling System
(Also known as Dial-a-Pump) Researchers can remotely trigger a pump by calling the prepaid phone and then following the interactive voice menus to select pump options and hear live sensor value readouts.

The **Dial-a-Pump** controller operates a bank of large solenoid valves in order to fill multiple barrels for sampling the stream water during different parts of a storm.



Portable 3-chamber Soil Respirometer
The Arduino circuit displays live data from a LI-COR CO_2 analyzer, logs the data to a memory card, and operates solenoid valves and pumps to control the flow of air through custom respiration chambers.

60-chamber Respirometer Controller
Similar to the portable respirometer unit, this Arduino logger controls a LI-COR analyzer, pumps, and 120 separate solenoid valves that sample the rate of respiration in 60 jars of soil samples.

For More Information

- The main Arduino webpage: http://arduino.cc/en/
- Visit the CRB-CZO Arduino Project webpage where we will share details of our projects, schematics, and source code: http://www.stroudcenter.org/research/projects/czo/arduino.shtm

Funding by NSF’s Earth Sciences Division
(NSF EAR 0724971 and others)