Aquatic and Terrestrial Sensor Networks

David Harrigan and Michael Routhier

ABSTRACT

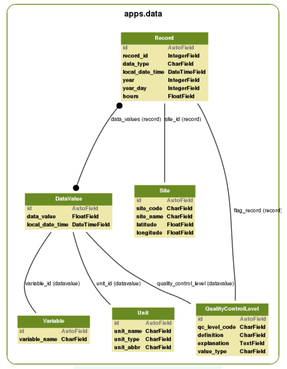
The NSF funded New Hampshire EPSCoR Ecosystems and Society Project seeks to understand the effects that humans have on the state of New Hampshire's ecosystems. In order to do this, this project employs an ecosystem sensor network inclusive of over one hundred aquatic and ten terrestrial sensor stations around the state. Considering the scope of this project, the development and the deployment of a web based application to compile, query, visualize, and disseminate data from these stations was identified as being key to the success of the project. Because of this, an EPSCoR Research Experience for Undergraduates (REU) project was conceived and completed for the purposes of building a data portal and web interface to meet this need. The resulting web presence of the REU project is called the Aquatic and Terrestrial Sensor Networks website and is accessible on the World Wide Web at *http://sensor.sr.unh.edu*. The following poster describes the methods, tools, and data used for the production of this website.

BACKGROUND

The Aquatic and Terrestrial Sensor Networks website consists of data-upload, quality assurance and control, and data visualization tools, as well as a secure project database. The site will ultimately be accessible via the EPSCoR Data Discovery Center, the main cyber-infrastructure interface for the New Hampshire EPSCoR Project. The Data Discovery Center's goal is to combine all EPSCoR project websites to make query, analysis, visualization, and archiving across these services' data possible. The main audience of the EPSCoR Data Discovery Center and the Aquatic and Terrestrial Sensor Networks website will include researchers, scientists, educators, and volunteers, interested in how future development, increases in human population, and climate change will affect our air, land, and water ecosystem services locally, regionally, and globally. Ecosystem services are benefits that humans receive from their ecosystems such as the production of clean drinking water or the natural decomposition of waste.

METHODS

The project website consists of two components: the backend and the frontend. The backend consists of all web server activities such as accessing the database and sending a response back to the client. The frontend is what clients typically see, such as HTML and CSS - or the actual web page and interactive content executed on the client side such as Javascript.



Database Design

Some data file variables that are processed on the server include temperature, nitrate level, conductivity, and pH. The major obstacle in the design of the backend was not knowing what variables would be provided to the server. Inspired by the CUAHSI[1] Hydrologic Information System database schema, a database model was created using a Python based web framework called Django. This model was used because it is flexible enough to process any kind of variables, units, sites, and quality control levels. The sensor data files are processed with a file parser which examines the contents of a given file, and saves them in the database. All of the backend was designed using Python, Django, and PostgreSQL for the database.

For the frontend, several Javascript libraries were used including: Dygraphs[2], to graph the data that is stored in the database, and Leaflet[3] to map the registered stations. The site is wrapped in a CSS framework, Bootstrap.

DATA

Aquatic sensor data is collected in 15 minute intervals, terrestrial sensor data is collected in 12 second intervals both formatted as a comma separated values file. Each row represents all the sensor values collected at that single time slot.

RESULTS

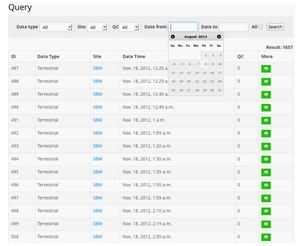
The results of this project culminated in the creation of a set of tools that allow for the data ingest, querying, mapping, and graphing of project data.

Data Ingestion

An SFTP portal was set up on a dedicated EPSCoR server at the EOS Earth System Research Center, Laboratory for Remote Sensing and Spatial Analysis to help researchers easily upload and stream their sensor data files directly to the project site. The files that will come into the site will be quality controlled previous to upload, although the project database will be able to support any level of quality controlled data, and will mark each entry accordingly. Since the data will be uploaded periodically, a solution was agreed upon to do a monthly check of all uploaded files to make sure that there were no errors made upon upload such as the inclusion of duplicate files or duplicate records within a file.

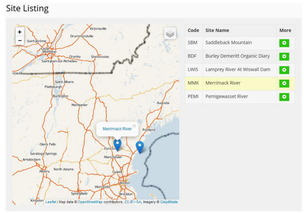
Querying

Due to the multiple sensors involved in this project and the chosen fine time interval of the collected project data, there is a potential for the development of a very large database with millions of records. One of the key components in maintaining and navigating through a website with millions of entries Is to have a feature rich query system. The project database used for this project can be queried by data type (Aquatic or Terrestrial), station, quality control level, and date range. Flags and drop down menus have been employed within the interface to facilitate easier querying. Both the visual appeal and the backend load time were carefully considered during the design of the query tools.



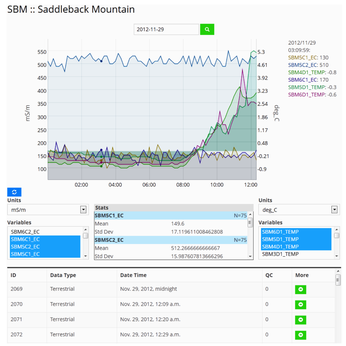
Mapping

A web-mapping interface was created and deployed on this site to allow for spatial navigation between stations. Additionally, the map interface is a helpful way to visualize the size of this project 's sensor network and its distribution of sensors around the state. This interface also acts as a portal to individual station profile pages where a user can view each station's data in more detail. To get to a station profile, a user can simply click on a station name listed to the right of the map, or they can click on the individual point marker on the map. Either will open a popup menu that links to the station's profile. When users search for a site on the map clicking on each point to see the station name could be tedious. So when a user hovers over a point on the map the corresponding site name is highlighted on the menu for the ease of navigation.



Graphing

When working with scientific data of multiple variables, it is often advantageous to graph these variables over time or against each other to better visualize patterns and anomalies within the data. This project's graphing tool can be used to analyze each station's data in this way. Data can be graphed by variable for a given date. Variables and units can be set per axis via user selection pull down menus. Once data is graphed, users can further analyze the detail of their data with a zoom tool and through the use of mouse hover allowing for the display of the date and the values of selected variables at any position on the graph.



TECHNOLOGIES USED

Python / Django	Python Virtual Environment
Javascript / jQuery	HTML / CSS
PostgreSQL	Dygraphs
Leaflet	Bootstrap

CONCLUSIONS AND FUTURE WORK

Through the implementation of this REU project a system was created that will provide EPSCoR Ecosystems and Society Project researchers and volunteers a way to explore and organize their sensor data. Though the site is operational, as of this date, data input has not yet started. Once data is fully loaded into the system, it will then be able to be queried and visualized to better understand the ecosystem services and processes within our state. Ultimately, the Aquatic and Terrestrial Sensor Networks website tool and data will help with the expansion of the larger EPSCoR Data Discovery Center toolset and database. Future development of the website will include the ability to compress and download selected sensor data and the ability to package metadata using an EML, ISO, or FGDC like metadata standard.

OTHER EPSCoR RELATED WEBSITES

The following websites have been developed in collaboration with NH EPSCoR or will provide data to the larger NH EPSCoR Data Discovery Center database.

NH LoVoTECS Network - "*lovotecs.sr.unh.edu*" is a project coordinated by staff and students at Plymouth State University. Their goal is to improve our understanding of New Hampshire's water resources and help develop a technically advanced workforce by providing educational opportunities to interact with large data sets.

CoCoRaHS Network - "*www.cocorahs-albedo.org*" is a community based network of weather observer volunteers. Their goal is to use low-cost measurement tools, provide training and education, and utilize an interactive website to collect high quality snow albedo, snow depth, and snow density data for research and education applications.

NH Granit Lidar Project - "*lidar.csrcdev.com*" provides access to LIDAR datasets and derived products archived within the GRANIT database. By choosing data layers and using the interactive map selection, users can directly download selected LIDAR datasets.

CITATIONS

The following libraries and database schema were used in the construction of the site:

"CUAHSI." *RSS*. N.p., n.d. Web. 26 June 2013.
"Dygraphs." N.p., n.d. Web. 08 July 2013.
"Leaflet." *Leaflet Dev Blog Atom*. N.p., n.d. Web. 25 July 2013.

ACKNOLEDGEMENTS

I would like to express my thanks to the EPSCoR Research Experience for Undergraduates (REU) Program, the New Hampshire EPSCoR Ecosystem and Society Project, the National Science Foundation, and the EOS, Earth Systems Research Center Laboratory for Remote Sensing and Spatial Analysis for financial and in-kind support of this research. Furthermore I would like to thank the coordinator of the REU program Dr. Stephen Hale for the opportunity to further my skills as a computer scientist as well as my REU mentor Michael Routhier and my co-worker Dave Filipovic for their support throughout my research. This research was funded through NSF #0566334.