MarshVis: Visualizing Real-Time and Historical Ecological Data from a Wireless Sensor Network

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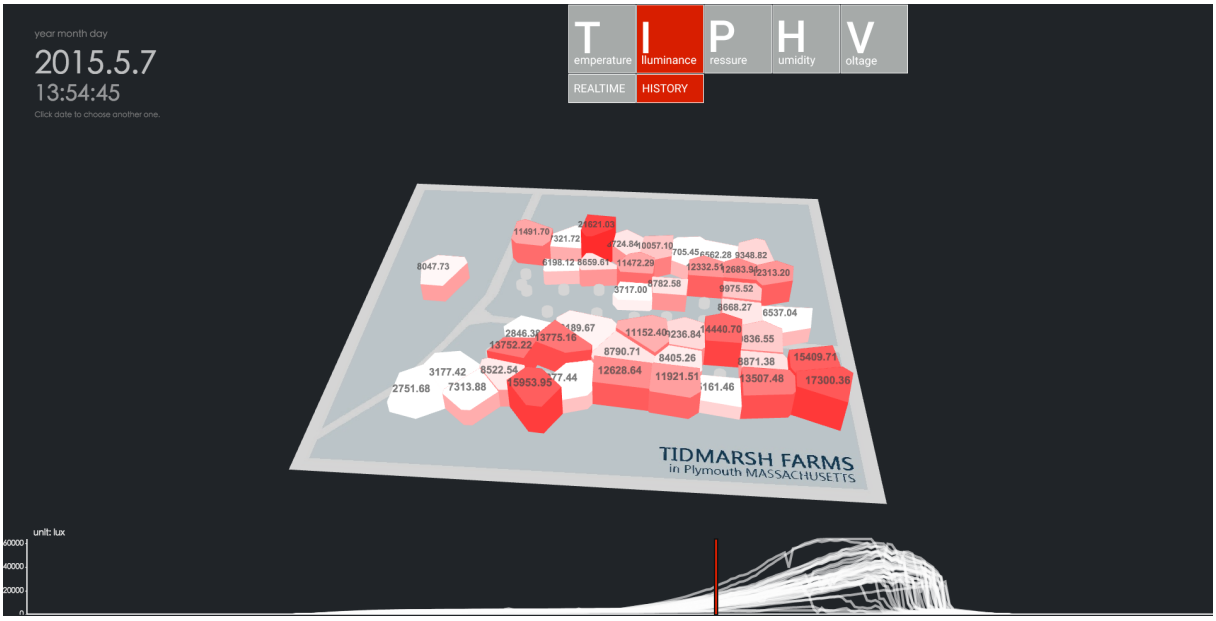

Fig. 1. Illuminance data from the sensor network for one day on the farm.

Abstract—We have been developing a dense sensor network to document ecological processes resulting from a large-scale wetland restoration taking place at Tidmarsh Farms, a decommissioned 577-acre cranberry farm in southern Massachusetts. Every 30 seconds, thousands of data points are streamed to a server, capturing a rich picture of the environment in flux as the restoration proceeds. It has been imperative for us to find ways to represent this information graphically for a variety of users and audiences, ranging from research collaborators studying wetland ecosystems to the visiting public. To achieve this aim, we built MarshVis, a system that visualizes data from the sensor network, highlighting spatiotemporal and inter-sensor relationships while also exposing the system operation. We implemented a number of web-based apps and developed strategies for real-time and historical exploration, as well as dynamic mapping. Our work is motivated by the need for interactive graphical tools that shed light on the delicate, interdependent ecological processes that make a natural environment sustainable. How can we expand the boundaries of public perceptions of natural phenomena at every scale?

Index Terms—Sensor data visualization, environmental monitoring, real-time visual analytics

1 Introduction

Tidmarsh Farms is a 577-acre cranberry farm located in Plymouth, Massachusetts. Beginning in 2010, the farm was decommissioned and began undergoing restoration into a more natural wetland system, allowing this area to serve its ancient function as a flood plain. As part of an initiative called the Living Observatory, we have deployed a wireless sensor network (WSN) to collect environmental data before, during, and after the restoration process. At present, approximately 100 nodes containing a variety of sensors produce thousands of data points that stream to a server twice per minute, 24 hours per day. In this paper, we present our efforts to make these data legible to an audience of both wetland ecologists and the general public, and propose an interactive art installation based on that work.

MarshVis is a data visualization website designed to bring a variety of real-time and historical ecological sensor data to life. Our work is motivated by the need for interactive graphical tools to answer basic questions about the interdependent natural systems that support a marsh. How can we make data meaningful to both expert ecologists and first-time visitors? How can we combine different kind of factors like geolocation, time, and microclimate together? More generally, how can we use visualization to tell a compelling story about the densely sensed natural phenomena on one site, with the broader goal of creating greater connections between the public and a changing natural world?

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2 MarshVis

Our web-based software tool allows users to explore the diverse ecological data produced by the wetland sensor network. As an installation artwork, MarshVis consists of a combination of a central projection area showing real-time data and playing live audio from the site, along with interactive stations with LCD monitors. Graphs and anima-

tions on the screens allow visitors to navigate through the data as well as explore the status and operation of the network and physical sensor devices.

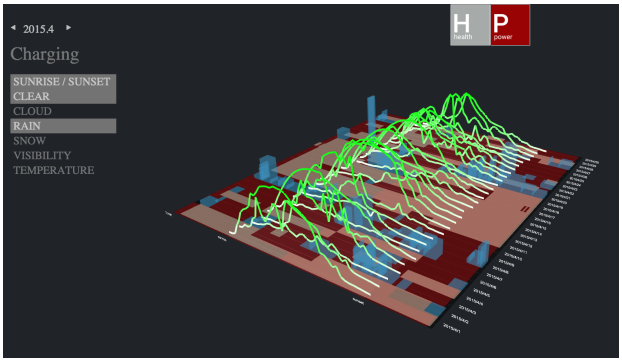

Fig. 2. Relating environmental conditions and solar charging state of the sensor network.

2.1 Data

For accessing the the real-time stream as well as a massive store of historical sensor data, MarshVis was built on top of ChainAPI [2], a hypermedia HTTP API for working with sensor data. Chain API provides an interface to extract, filter, and search specific ranges of data in the database. It also integrates HTTP request/response interactions with real-time streaming using HTML5 WebSockets.

As mentioned before, our system allows for the exploration of both real-time and historical data from Tidmarsh Farms. Data are always tied to a specific geolocation and a specific time. In addition, the entire data structure is organized multidimensionally. Each physical device on the site contains several kinds of sensors, which include temperature, humidity, illuminance, wind, soil moisture, audio and so on. In addition, publicly available data sources like Weather Underground provide general information about the local area, like sunrise and sunset times, weather, etc.

2.2 Interface and Visual Design

MarshVis has a tabbed interface for choosing from among several visualization modes. The analysis tab uses interactive scatter plots to elucidate relationships across sensor types, space, and time. The data tab shows real-time data as it comes in, and provides a calendar and draggable timeline interface for going back in time over years of data. Finally, the device tab offers a number of tools for visualizing the structure and operation of the network itself; users can toggle layers of weather to augment data on the solar charging state of the system, as well as the overall network performance represented by packet throughput over the course of the year.

A key element of our design is the dynamic generation of the visual elements representing each sensor and device. Inspired by prior WSN research [1], we used a Voronoi diagram to automatically generate virtual boundaries for every sensor in the network given a list of GPS coordinates obtained at run-time from the Chain API. Although the graph boundaries do not perfectly represent the detection area of each sensor, the approximation provides users with a useful abstraction for how the physical network is organized. The visual pattern of the Voronoi tesselation divides the larger sensed area into node-defined cells that are then mapped to each node's data.

Using the tesselation, we developed a 3-d graph for illustrating a variety of parameters. Sensor types are color-coded, and values are mapped to saturation and polygon height. In addition to the 3-d bar graphs, we incorporate an interactive line graph to illustrate the relationships between different sensors over time, allowing users to observe trends. Both graphs are clickable and draggable, allowing users to go into more detail about the node (e.g. view photos of the node and surrounding cell) or to explore in time. Dragging the timeline causes both representations to immediately reflect the values of the sensors

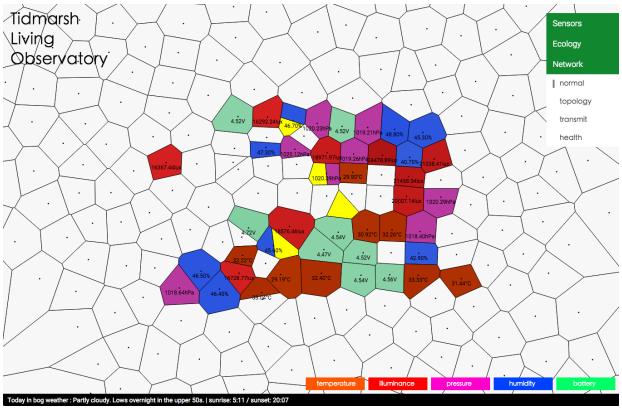

Fig. 3. Sensor cells dynamically generated by Voronoi tesselation.

at the selected time. In the real-time view, the arrival of each new data packet is indicated using bouncing animations on top of the graph cells. This view is designed to be left running in the background, functioning as an ambient display of the real-time situation on the ground.

The analysis tab allows for more fine-grained queries of the data. With simple click-and-drag selections, users can choose sensor value ranges to highlight corresponding values in other sensors, as well as time ranges and geographical areas corresponding to their selection. For example, if a user selects a high illumination range, they system will highlight cells free of tree shade, as well as midday, and sensors measuring higher temperatures corresponding to solar heating.

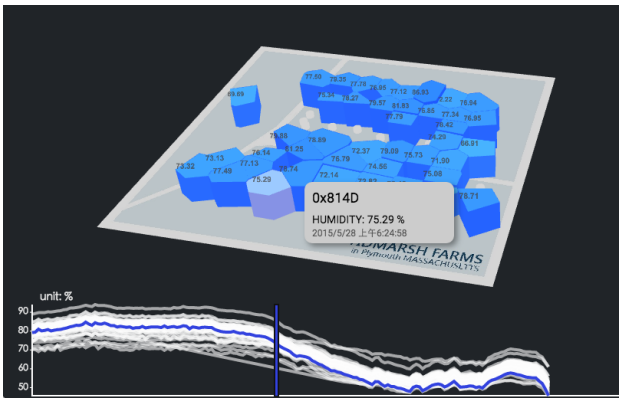

Fig. 4. 3d graph and line chart.

3 Conclusion

MarshVis is an interactive installation and web-based software tool for visually exploring ecological data from a dense ecological sensor network. Our system enables both real-time monitoring and historical queries, with the aim of giving audiences of scientists and amateur visitors a window into the complex, interdependent processes that form sustainable natural systems.

Acknowledgments

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References

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