iSENSE: A Collaborative Web Environment for Data-Sharing and Citizen Science

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Abstract

The Internet System for Networked Sensor Experimentation (iSENSE) is a web system that enables users contribute and visualize geographically distributed sensor data. Using classroom probes and other sensor hardware, users can view and analyze data from other contributors, and combine data from multiple sources to examine regional, national, and global phenomena. To facilitate the collection of meaningful data, we have prototyped a low-cost data-logging device—the Portable iSENSE Network Point, or PINPoint—which features a range of on-board sensors, a GPS receiver, and a connector for external sensors. By pooling their data on the web, users can, create an expanded sensor network, and engage in collaborative research on STEM topics ranging from human health to environmental science and energy conservation. This paper describes the system and our formative work with educators and students.

Background

Electronic sensors and probes are common in high school classrooms and university science labs around the country, but students typically use these instruments in isolation, with a single probe attached to a single personal computer, generating a local and private pool of data. Moreover, classroom probes are often used in uninspired ways—for example, to measure a known physical property of matter or to confirm a law of motion.

In contrast, when given the opportunity to observe, measure, and analyze real-world phenomena, students actively construct knowledge about the world. As a result, they become more invested in the learning process, learn more, and retain more of what they learn (Pizzini et al., 1991; Brown, 1992). Moreover, through inquiry-based activities, students gain a practical understanding of and appreciation for the scientific method, developing the ability to formulate hypotheses, test those hypotheses, and analyze the results of their investigations (Chin & Kayalvizhi, 2002; Feldman et al., 2000; Ruopp et al., 1993).

Classroom probes are widely used in high school and university science labs to help students engage in inquiry-based STEM learning (NEAP, 2002). When data from the probes are transmitted to a desktop, laptop, or handheld computer, they can then be analyzed and plotted with locally installed software. This combination of active data collection, followed by visualization and modeling, has been shown to enhance students' understanding of observed phenomena and related STEM topics (Adams & Shrum, 1990; Hegedus & Kaput, 2004).

Inspired by contemporary "Web 2.0" technologies, we developed the iSENSE system to create new learning opportunities. iSENSE allows students to collect sensor data and share it on the web. We are working closely with educators at the university and high school levels to create meaningful contexts for collection and analysis of sensor data, and encourage our students to become citizen scientists, as they measure phenomena in the world outside their classrooms.

The remainder of this paper presents the design of the iSENSE system, including the web site and our PINPoint data collector, describes several of the contexts in which the materials have been used, and presents initial evaluation results.

The iSENSE System

There are two major elements to the iSENSE system: the hand-held "PINPoint" data collecting device, and the iSENSE web site. In a typical case, data collected using the PINPoint are uploaded to the web site, but data from any source (e.g., manually recorded data, or data from historic databases) may also be imported into the iSENSE site.

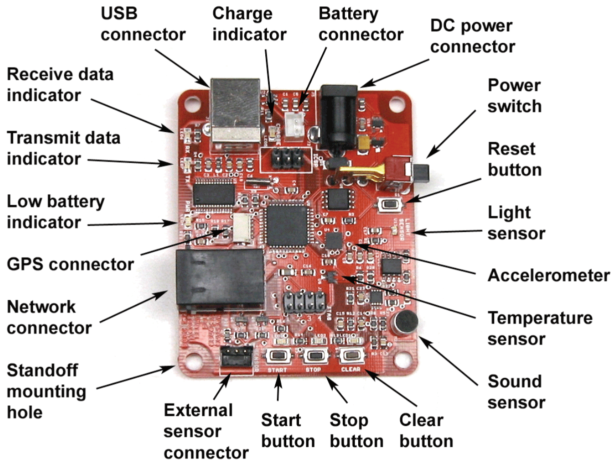

Figure 1: The PINPoint data logger.

Below we first describe the PINPoint and then the web site.

The PINPoint

The Portable iSENSE Network Point (PINPoint) is a compact data-logging device designed for use with the iSENSE web system (Figure 1). It features light, temperature, and sound sensors, a three-axis accelerometer, and connectors for a GPS receiver and an external sensor. The device has 2MB of flash memory—sufficient to store more than 12,000 data readings. The unit's rechargeable lithium-ion battery has a life of about 12 hours per charge.

Operating the PINPoint. The PINPoint is easy to operate. To start, a user simply powers on the device and waits for the GPS unit to fix its position. The PINPoint signals a satellite lock by displaying a steady green LED. To start recording data, a user presses the Start button once. A green LED flashes on and off to indicate that data are being recorded.

To stop recording data, the Stop button is pressed once. An amber LED lights to indicate that recording has stopped and that data are saved in memory. Pressing the Start button again appends more data to the previous data set. Data can be erased from the PINPoint's memory by pressing and holding the Clear button for three seconds.

Retrieving Data from the PINPoint. Data are retrieved from the PINPoint using a program called "PINCushion." The user connects the PINPoint to the computer with a USB cable. From the software, the user clicks the upload button; data are retrieved from the PINPoint and saved as a comma separated value file for easy upload to the iSENSE web system.

The iSENSE Web Site

At the iSENSE web site, registered users may define experiments and collect and contribute data. Anyone may view and analyze iSENSE data, using the system's mapping and graphing tools.

Data Structure

iSENSE provides a simple framework for organizing collaborative experimentation using classroom probes and other sensor hardware:

- An *experiment* is a placeholder for iSENSE data. Each experiment has a title, an experimental design, and one or more data fields. Each data field is associated with a particular sensor, a unit of measurement, and a description indicating what the sensor will be used to measure.
- A *session* is a series of data points contributed to iSENSE. Each session has a title, a collection procedure, and a street address. When contributing data, users are required to match the session's data values to the experiment's data fields. All iSENSE data must be contributed in the context of an experiment.

Finding Experiments

A variety of methods are available to identify experiments and data of interest. Users may search for experiments based on their keywords ("tags"). The web system also features a user-rating system, whereby ratings of 1 star (low interest) to 5 stars (high interest) may be assigned to any experiment. Experiments may be sorted based on their rating, the total number of data sessions contributed, and the date of the most recent activity.

Contributing Data

After identifying an experiment of interest, users may contribute their own data. When contributing data, users must assign a name to each data session and describe how the data were collected. If the data do not include GPS readings, a street address is used to indicate where the data were collected. Data may be contributed either by uploading a CSV file or by manually entering values. If the data are uploaded in CSV format, users are prompted to align the column headings with the experiment's data fields.

Viewing Data

Several visualization (viz) tools are available.

- *Map*. The Map viz tool displays data on a Google Map, with individual readings represented by a map pointer. Users can pan and zoom, as in any Google Map, to view data pointers in different locations. Clicking on a pointer displays the associated data values in a pop-up box.

- *Annotated Time Line*. The Annotated Time Line shows how data values change over time, with a line connecting each value. If multiple sessions are displayed, each session is represented with a different color line. A scroll bar along the bottom adjusts the start and end times in the time line.

• *Scatter Chart*. The Scatter Chart plots data points on an X and Y plane according to any two attributes. This tool can be useful for detecting correlations among data values, interpolating or extrapolating trends, and identifying outliers.

• *Bar Chart*. The Bar Chart viz tool displays rectangular bars with lengths proportional to the values that they represent.

• *Motion Chart*. The Motion Chart uses multiple visual cues to show relationships among data points. In addition to their X and Y positions, the size and color of the points on the Motion Chart can be linked to values. Moreover, a Motion Chart can be animated to show changes in data over time. The Motion Chart is best suited for representing complex data, collected from multiple sources over long periods of time.

Users explore data by selecting one or more sessions from a given experiment and choosing and customizing visualizations to discover relationships in the data. After creating a visualization, a user can save it and share it with others.

Classroom Activities with iSENSE

We have developed the iSENSE system in conjunction with science teachers and other education practitioners. A workshop with 12 teacher-participants was held in August 2008, and a second workshop with 50 teacher-participants was held in June 2009.

Classroom implementations have been accomplished in a university social science course, in a regional high school, and at two summer programs (one for middle school students, and the other for incoming first-year college students).

In each case, students used the PINPoint devices to collect tabletop or environmental data, uploaded their data to the iSENSE web system, and used the system's visualization tools to create visual representations of the shared data.

• I would feel comfortable interpreting scientific data
• Scientists make different interpretations based upon the same observations.
• Scientists follow the same step-by-step scientific method
• Scientists question each other's data interpretation

Figure 2: Sample Questions from Pre/Post Survey

Evaluation

A pre/post survey was implemented to assess student learning, and a structured interview protocol was used to gather feedback from participating teachers. The survey measures students' self-efficacy with regard to science and their ideas about the nature of science (see sample items in Figure 2).

Preliminary results indicate that activities involving the iSENSE technology increased students' understanding of the nature of science and their perceived self-efficacy in conducting scientific inquiry. Moreover, teachers reported that iSENSE helped students pose more sophisticated scientific questions, persevere in scientific investigations, and feel empowered to engage in citizen science.

Future Work. As the iSENSE technology is now stable, we plan to support more in depth and widespread use, motivate students to pursue real-world scientific studies, and evaluate these deeper learning outcomes.

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