# REMOTE SENSOR DEVICES FOR TIME-SEQUENCED ARCHAEOLOGICAL CONSERVATION DATA COLLECTION

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Abstract. We developed two remote sensing systems for the UNESCO World Heritage Site of Chavin de Huantar. The first is a small sensor capable of being fitted into the uncovered galleries, where it gathers temperature and humidity data for the sake of understanding the microclimates that form upon unearthing these galleries. The second is a water level sensor made with the hope of understanding the hydraulic intention involved with the Mosna River.

## 1. Introduction

Generally, access to monitoring systems on archaeological sites is rare due to budget costs and environmental conditions. In Chavn de Huantar in particular, it is difficult to obtain electronic devices, and constant electricity is not reliable.

However, monitoring systems of all kinds are needed in various parts of Chavn. Obtaining long-term data could help conservationists learn about the changing conditions of the site and apply the best preservation methods. After discussing with Professor John Rick and local hydraulic engineers, we recognized that there were two situations that most urgently needed monitoring systems. The first is the Mosna River's changing water levels and second is the fluctuation of temperature and humidity within the galleries over the seasons.

In this report we have written what our solutions are to the problems we found and the next steps to our projects. The more technical details (circuit schematics, code, board layout, etc.) are included in our journals and manuals. We plan to make minor changes and edits to them during the research seminar class in the fall to best prepare the next group of engineers in Chavn.

## 2. Mosna River Project

2.1. **Context.** The Mosna River flanks the eastern border of the monument, between the valley and the eastern mountain range. During the Chavn era, it was connected to the site with an elaborate system of canals. In fact, the Chavn people were able to engineer a way to change the shape of the river, pushing it away from the monument to create more land for the site. This, along with natural disasters (such as the Aluvin in the mid 1900s, and annual floods) have changed both the width and geography of the Mosna over time. Hydraulic engineers and conservationists in Chavn are interested in seeing how the Moana?s water levels change over time. With this information, they are able to determine how the river base?s height is changing, and how these changes will affect the geography of the monument. By having long term data on the river height, conservationists and engineers would be able to predict the impact the river will have on the site over time and to take direct action on this.

2.2. **Strategy:** Our solution is a solar-powered river monitoring system that sends water level data online. It consists of a 3 meter pole, with 60 mini sensors attached to it (1 every .05 meters). The mini sensors are circuits that we waterproofed with epoxy, all packaged in a bottle cap. They detect water presence, and we chose our packaging method because of its durability and low cost. We then wire all of these water sensors to a few multiplexers, which determine which sensors are ?on? (which ones detect water) and which ones are ?off? (no water presence detected). By knowing which sensor is ?on,? we can determine the current height of the river. The multiplexers and sensors are then wired to an Arduino micro controller (which interprets the water level). Finally, all of this is wired to an IoT micro controller (called the Electron by Particle) which sends the data online.

This monitoring system would be mounted on a rock in the Mosna. Because it is in the middle of the river (which is far from the monument), it is difficult to connect it to power. Thus, our solution is to wire the pole to a solar panel that would be sitting at the bank of the river (which is less shaded).

## 3. Gallery Sensors Project

3.1. **Context.** The second problem that we identified is a development of one of last year?s Stanford Engineering in Chavn projects. Chemical engineers have been analyzing the mortar within the galleries, ducts, and canals underneath the monument. They have discovered that the material (chemical composition, water levels, etc.) have been changing over time, probably with the exposure of oxygen after being excavated. Thus, they are looking for a way to record long term temperature and humidity fluctuations within the galleries. This data could help archaeologists understand how the underground environment changes with excavation and how to preserve it as best as possible. Since these galleries are underground, the temperature and humidity changes are not as intuitive as they sound, meaning that they don?t match external temperatures. They form an elaborate underground system with its own unique environment, making temperature and humidity often very different from what archaeologists originally predict.

3.2. **Strategy.** Our solution is an improved version of last year?s sensor. It consists of an RTC timer, an SD card reader, an Arduino Nano, a temperature sensor, a battery charger, as well as an LED light and button for user friendliness and troubleshooting. When the sensor is plugged into an electricity source, the LED will either blink or stay on. If it is blinking, this means that the sensor is missing an SD card and thus needs one. Once the LED stays on, this means that the sensor is ready for recording. Then, the user can press the button and the LED light will turn off - this is when the sensor starts recording data. It will collect the temperature, humidity, and timestamp of the current environment every 12 minutes. All of this information is kept in the SD card in a txt file which can immediately be converted to an Excel spreadsheet. Furthermore, we have MatLab code that turns the data into graphs, for conservation analysis purposes.

## 4. Building the Mosna River Sensor

We designed our sensor by using a series of small water-detection circuits that are placed at decimeter intervals on a pole. Observe, we developed the following circuit to detect water:

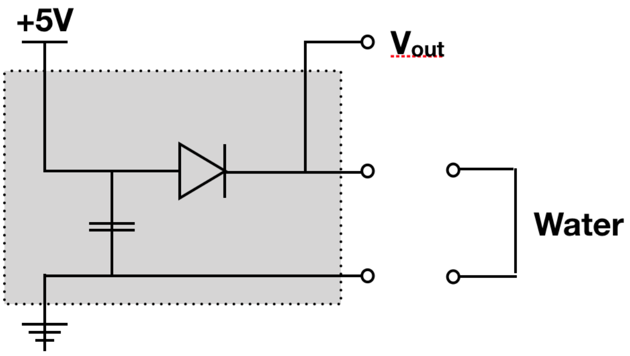


Figure 1. Small Water Unit

Of course these water units needed to be made waterproof. Thus, we thought of a small container that would could cover with epoxy resin. This lead to the design choice of bottlecaps.

We spent the first few weeks of the program primarily designing and conceptualizing the river monitoring system. We were able to make a basic prototype in the lab (see Figure 2) and created and waterproofed all 60 individual water sensors. The sensor pole is also ready - all of the sensors are stuck on it and it is waterproof. However, since we were also simultaneously building 5 gallery sensors, we ran out of time in installing the system.

## 5. Building the Gallery Sensors

For the gallery sensors, we used the following materials:

- Arduino Nano
- DHT22 Temp / Humidity Sensor
- RTC Chip
- SD Breakout Board

FIGURE 2. Small Water Unit

- Single LED
- Button
- Several wires and resistors
- Adafruit MicroUSB Lipo Battery Charger
- Lipo Battery 3.7 V
- AC to MicroUSB Charger

These were then assembled using solder to make the final sensors. This can be seen in Figures 3 and 4.

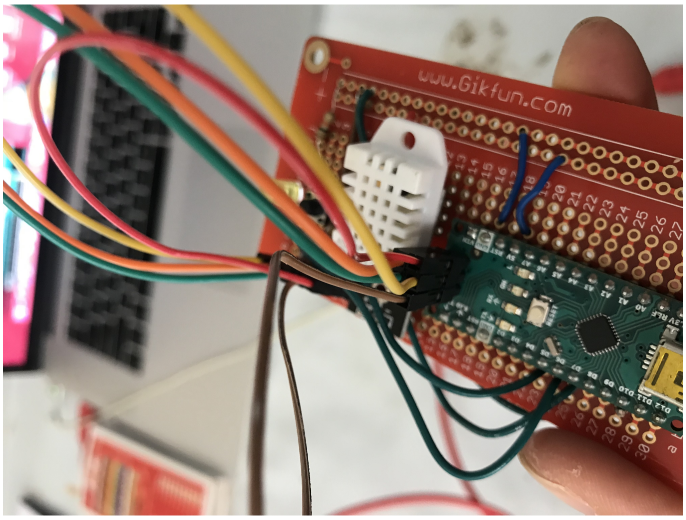


FIGURE 3. Top Wiring of Sensor

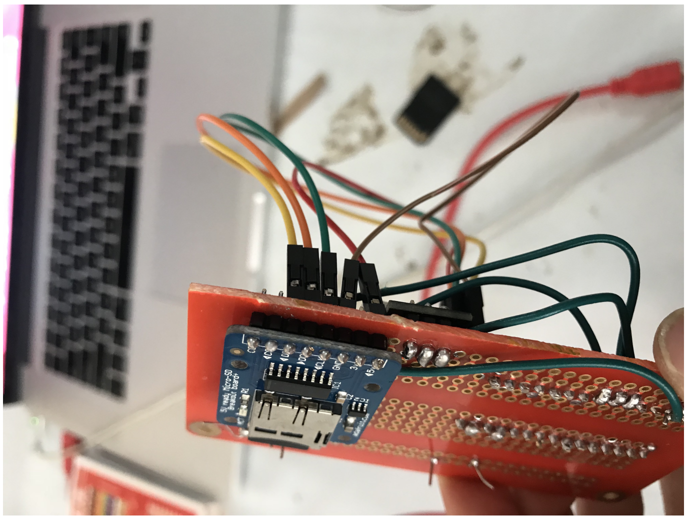

Figure 4. Bottom Wiring of Sensor

We then boxed the sensor in order to install the sensors into the gallery. (See Figures 5, 6 and 7)

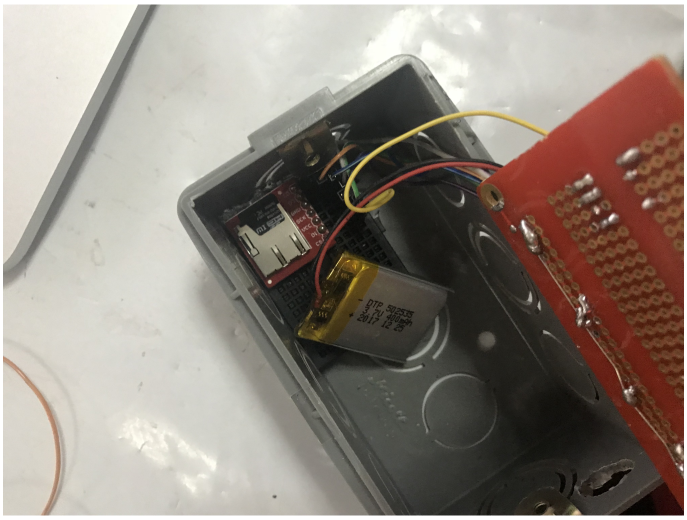

Figure 5. Encasing the Board with Battery (1)

Lastly, we the help of some of the archeologists, we installed the sensors within the galleries of Chavin, where they will stay to collect data for the next year.

## 6. Results

In the beginning of the program, we took out one sensor (Belinda) that the engineering team installed last year. It was in a duct in Doble Mnsula. From

FIGURE 6. Encasing the Board with Battery (2)

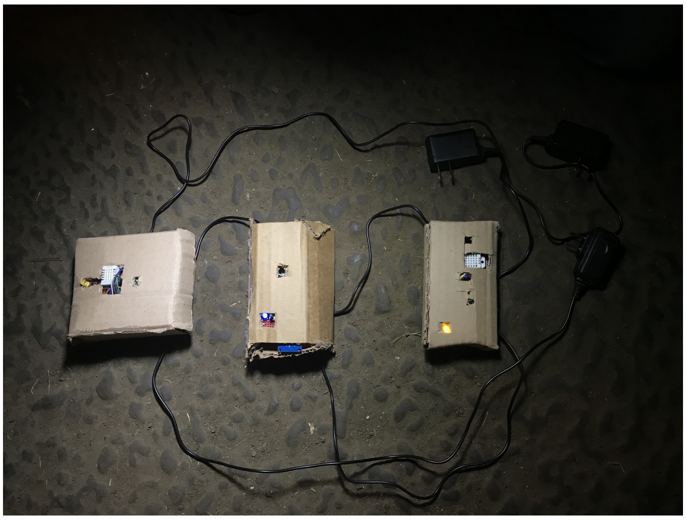

FIGURE 7. Three Completed Gallery Sensors Boxed using Cardboard

it, we were able to obtain the data from the past year (see Figure) which John was able to analyze with conservationists at the cultural center. A total of 30697 data points were collected, consisting of temperature and humidity taken every 15 minutes. These results are compiled into Figures 1 and 2.

Our intention is another group of students return to retrieve the data of the now installed gallery sensors and make the data available electronically.

Figure 8. Installed Sensor in Doble Mensula Gallery

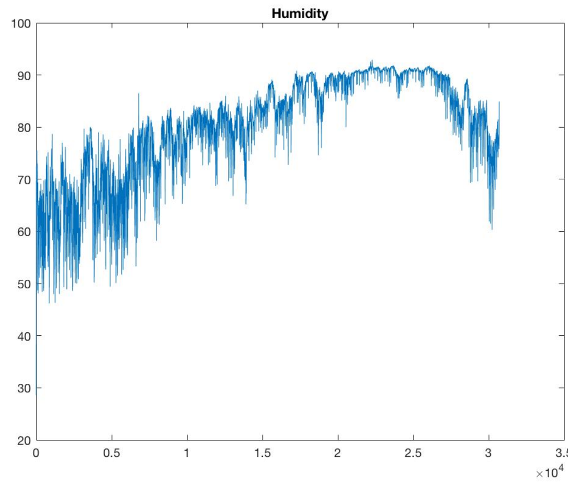


Figure 9. Humidity Time-Sequence for August 2017 through June 2018

## 7. Discussion and Next Steps

As a team, we were able to tackle various other small projects. We discovered that the roofing team was trying to measure how strong the light was under the roof and outside the roof throughout the day, and thus had to measure it manually every hour. The measuring process was tedious because they needed to hold the light meter in a certain angle, and they could never get more than one point of data at one time. We decided to help them by building two light sensors (that collected light data in volts, which they would translate to lumens, their desired units) that pushed the data onto the computer with a push of a button. With the

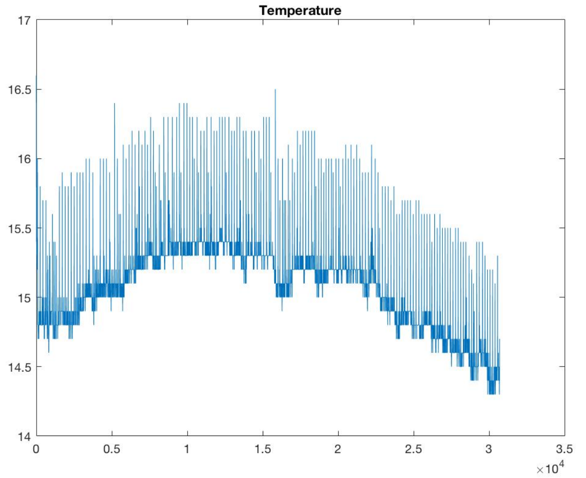


Figure 10. Temperature Time-Sequence for August 2017 through June 2018

light sensors, they were able to collect different data at the exact same time, and easily make a graph displaying their results.

Throughout the past two months, we were surrounded by top engineering, archaeology, and conservation experts in the world. Through them, we were able to learn a variety of new things. For example, we worked with an archaea-acoustics researcher (Dr. Miriam Kolar) in conducting field research on the sound acoustics in the monument?s main plaza. We spent time with hydraulic engineers in understanding how the river?s shape morphed over time. We helped a Stanford PhD student in cleaning and identifying animal bones for her zoo archaeology research. And of course, we discovered the tedious process of excavating and how much it can pay off in the long run. Our fellow engineering team members, archaeology students, and John and Rosa shared so much knowledge with us, allowing us to have an incredibly interdisciplinary learning experience.

We hope that students return to the site in the next year to both pull our sensors and retrieve the data, as well as install newly completed gallery sensors as well as the remained of our solar powered river monitoring system.