Temperature
Classroom temperature reporting system for UMCP campus
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Abstract

Terperature is a heating and cooling efficiency reporting application designed to help UMD faculty and staff eliminate costly waste and reduce harmful emissions. Terperature works by providing a simple system allowing people on campus to report heating and cooling inefficiencies through a web interface. The system collects data about the time and building in which the users experienced excesses of heat or cold and aggregates the information so it's easy to understand and analyze on a campus-wide basis. The information is available to all and improvements are made apparent so progress can be monitored. Terperature is implemented using well-known technologies including HTML, Java Server Pages, and Flash. Usability tests reveal that most test subjects found the site to be generally useful, and easy to use, and identified future improvements. A fully functional version of the application has already been implemented and it is our hope that the final project, including the improvements outlined will be made available as a production-quality service to all students, staff and faculty of UMCP.

Credits

Aaron Cordova
- Initial design ideas
- User needs: Tasks, scenarios
- First prototype design
- Implementation of high-fidelity prototype
- Usability test
- Final paper

Nicholas Dobson
- Initial design ideas
- Creation of wiki page
- User needs: Tasks, scenarios
- First prototype design
- Task list and questionnaire
- Implementation of high-fidelity prototype
- Usability test
- Final paper

Min Kyu Song
- Initial design ideas
- User needs: references
- First prototype design
- Task list and questionnaire
- Usability test and analysis
- Final paper

Malcolm-Jamal Ray
Introduction

The Problem

One of the largest uses of energy on the University of Maryland campus is climate control -- heating and cooling the numerous buildings, dormitories, and facilities to maintain comfortable temperatures. Unfortunately, even a quick survey of students reveals that this goal is not being achieved. Classrooms are regularly too hot or too cold, causing discomfort, distraction, and perhaps most importantly, large energy wastes, costing the university large sums and taking a heavier toll on the environment.

The obvious direct solution to this problem would most likely involve improved thermostat systems or a widespread temperature monitoring solution. However, such improvements would likely be very expensive, and may fail to accurately represent subjective temperature experiences in large rooms or buildings. They would also likely take a long time to implement, considering the physical installations required.

Previous Work

In researching our project, we could not find any systems with a similar purpose for reference. However, we did find information about the effects of temperature on student performance and commercial system that measure and control temperatures in buildings.

1. NUS (National University of Singapore) Campus Sustainability Committee
   <http://nus.edu.sg/csc/programmes/energy/conservation-tips.html>
   Site features tips to reduce energy consumption. Campus Sustainability Committee recommends temperature at 23 +/- 1 degree Celsius, which is 71.6 ~ 75.2 degree Fahrenheit. It also recommends that all windows and doors should be closed to separate air-conditioned and non-air-conditioned areas, and that doors or windows that cannot be closed should be reported.

2. Teachers.net
   Teachers.net is a website where elementary teachers report education issues. I found classroom temperature report from some teachers. This is not about sustainability, but it does pertain to temperature reporting issues. There is no reporting system that teachers report their classroom temperature problems.

3. cefpi.org
   <http://www.cefpi.org/epa_temperature.html>
   The experiment demonstrates whether classroom temperature has an impact on student performance. This study shows that students perform best when classroom temperature is at 72 degree Fahrenheit.
4. CALPIRG (California Student Public Interest Research Group)
   <http://www.calpirgstudents.org/reports/energy/energy-reports/new-energy-for-campuses-
   energy-saving-policies-for-colleges-and-universities#q3Uu4Z9SL1XpXxl_eD3QKg>

   CALPIRG published a guideline “New Energy for Campuses: Energy Saving Policies for
   Colleges and Universities.” This guideline doesn't mention specific ways to reduce energy
   consumption via temperature control but does discuss general ways to save energy.

5. UIC (University of Illinois at Chicago) Office of Sustainability
   <http://www.uic.edu/sustainability/campus_initiatives/energy.html#hvac>

   UIC also suggests ways to reduce energy consumption, but does not mention report
   temperature monitoring. One specific way to monitor building temperature is using a digital
   controller for all buildings. The digital control allows people to control and monitor
   temperatures in buildings remotely.

6. GOLIATH - The effects of moderately raised classroom temperatures and classroom
   ventilation rate on the performance of schoolwork by children. (RP-1257)

   This article said something similar to NUS report. Specifically when temperature is dropped
   from 25 to 20 degree Celsius, which is 77 to 68 degree Fahrenheit.

7. ACR - SmartButton, SmartReader series
   <http://www.acrsystems.com>

   The SmartButton and SmartReader series are powerful and accurate data loggers designed
   for easy monitoring and recording of temperature data. Using this device one can keep an
   objective temperature record of a building easily.

8. VERITEQ - Precision Temperature Data Logger
   _kt=d3c658af-6af4-4670-956c-f3a969da9fec&gclid=CMfl1sj1_5UCFQrFGgod05x_EA>

   This is another device that can measure temperature in the building. This device
   automatically generates logging data.
Project Design

Temperature Approach

Rather than using a hardware based approach to campus-wide temperature monitoring, the Terperature project relies on a different source for data collection; the work is done by the very students using the classrooms. Using a website based interface, students can access the system and report temperature ratings for any room in any building on campus, while in that room from a laptop or mobile web device. This data is then aggregated and presented with a campus map overlay to clearly display which rooms in which buildings are the most inefficient, allowing campus staff to change climate control settings and ultimately improve efficiency.

The Terperature interface design is broken up into two components, with different purposes and requirements: a temperature reporting page, and a temperature data access page.

Transition Diagram

Temperature Reporting Page

The effectiveness of Terperature is wholly dependent on comprehensive, regularly supplied rating data from students, faculty, staff, and anyone else whose finds this tool useful. Without sufficient data it will be difficult to extract reliable conclusions about the actual temperature state.

The most important consideration for this user interface element is speed. Users must be able to access the system and enter a temperature rating for a room in under a minute. This serves two purposes: first, to make the process of entering data as convenient and easy as
possible to encourage user participation, and secondly, to minimize disruption as users are expected to be involved in class related tasks. A simple and fast loading webpage is paramount here, and will also cater to students who don't have laptops but have internet-enabled cell phones.

**Temperature Data Access Page**

Unlike the temperature reporting page, the emphasis of the data access page is not speed. Instead the goal here is to provide users with a rich interface of options and visual interactivity to study, filter, and ultimately download detailed aggregated information gathered by the Temperature system. Also unlike the reporting page, the access page is expected to be used primarily by campus faculty, and will be designed with this group in mind.

**Help Documents**

1. Data Entry Page
   The data entry page is used to report temperature ratings for rooms that are either too hot or too cold. To report a temperature, select the building and room and click the corresponding button.

2. Data Access Page
   The data access page is used to view temperature reports and download compiled data. The campus map view is the primary component of this page. Buildings are overlaid with blue or red circles, indicating the temperature by color and intensity by their opacity. You can hover over any bubble to see a popup with the building name and a summary of temperature ratings. The display can be filtered to a specific building by clicking that building, or selecting a building in the drop down menu. It can also be filtered by date using the starting and ending date selectors. The Download button will compile the currently filtered data into a CSV file and download it to your computer for more detailed analysis.
Development Process

To develop our interface, each team member independently designed a low fidelity prototype based on our basic requirements. We used this approach to promote independent thought and creativity, with the ultimate goal of combining the best elements of each interface into our high fidelity testing prototype.

Prototype 1 (Nick Dobson)

The first page (Figure 1) serves as the data entry page. Users first select the building they are in. This selection changes the second combo box to the list of rooms in that building. The user then selects the room number from the second list, and clicks either the "Hot" or "Cold" button. A dialog box (not pictured) appears confirming the submission. The dialog box restates the building, room number, and temperature selection, with the question "Is this correct?" and "OK" and "Cancel" buttons.

The page is designed for quick use and to be mobile-user friendly. Fonts and buttons are large to be easy to read on small screens, and to make all functions easy to quickly locate and understand.

The second page (Figure 2) serves as the data look-up and analysis page. It hosts considerably more options and features than the entry page. First the user selects a building. This updates the floor box with the floors for that building. The user then selects a floor.

The time range section offers several time filtering options. The "Last ____" allows users to specify how many hours, days, weeks, months, or years they want to view data from, depending on which radio button is selected.

If hours is selected, all of the below options are disabled. If “days” is selected, the time range tools are enabled, which can either allow all time or a range of time. If “weeks” or “months” is selected, the time range and day selection sections are enabled. If years are selected, the month selection tools are enabled as well. This cascading selection system allows users only to have to fine tune time selection when necessary.

Once a time is selected, the floor plan diagram is updated to reflect the selected information.
Rooms are colored based on an averaging of temperature ratings and the color density is based on the number of ratings. This accentuates rooms with the most extreme ratings, helping to quickly identify inefficiently insulated spaces.

Finally, the large "Download Data" button allows users to download a complete set of data from the time selected, with each event marked with a time-stamp. The file provided will be CSV (comma-separated values) format, which can be quickly imported into almost all spreadsheet applications.

Prototype Design 2 (Min Kyu Song)

Since this service targets a campus, we expect most of user to be students. The website will therefore feature a login service. When students make user account, they can provide schedules for the semester. Students also can change the schedule for every semester. Only signed in users can report classrooms/buildings temperature. All users can search data.
When User sees Temperature website first time, user can sign in and also user can search class temperature report. User can search by course names and building names.

If the class has several sections, then it will provide choices for right section using radio buttons. Otherwise, it will show a class name, on, classroom location, and also report just like the picture on the left.

If a user searches by the building name, then it will provide an aggregate temperature report and also it will provide choices for specific using also radio buttons. It will show the ground plan with colors which looks like a picture of the data entry page.

*Figure 5*

When a user signs in to the service, it shows a registered class schedule automatically. If there are any temperature reports, then it will change the colors of the part of schedule according to classrooms. Searching service moves to right side of webpage to accommodate the different layout.

Users can report temperature opinion once a week per class. Users cannot express their dissatisfactions by continuous reports to prevent system abuse. An automated service aggregated report would be generated once per two weeks. The old data will be deleted. So, report can keep up with temperature policy changes, such as the season changing.
The first view, Building Report View, allows a user to select a building from the list. Alternatively, it is possible to automatically detect which building a user is in using the iPhone's location functions.

The only action remaining then is for the user to select 'hot' or 'cold'. The application automatically records the time and IP address of the report, and only allows one update per IP address per every hour or so, to help prevent multiple reports. A small pop-up confirmation window will also be required.

The idea is, as soon as users are cognizant of a heating inefficiency, they will be able to send a report in as few as three 'touches': one to access the app, (the building is located automatically), one to report 'hot' or 'cold', and one to confirm.
The high fidelity prototype of the temperature reporting page is visually very similar to the low fidelity design. The only front-end change is the addition of the “Temp Entry” and “Data Access” buttons, which allow the user to navigate to the other page of the interface. After selecting the building and room, pressing the hot or cold button logs the information (and the time) in a database. The user is then taken to a “Thank You” screen, pictured below.
Unlike the data entry page, the data access page is a hybrid of several prototype designs. Replacing detailed controls is a Flash based campus map, which displays glowing red or blue circles over buildings with higher opacity depending on the number of ratings. The display can be filtered to only show data for a specific building, as well as by a start and end date. The large “Download Data” button compiles a CSV (comma separated values) file of the data specified by the filters and allows the user to download the file.

The rationale for this design was to simply the process of finding the hottest or coldest buildings quickly, and then allowing the user to do further data analysis with the more detailed CSV file, whereas the prototype design would overwhelm the user with options. We omitted the classroom based view due to the limited time of implementation and the complexity of fully creating such a system (considering it would need to interface heavily with the existing...
University of Maryland scheduling system). However, such an interface would be a valuable asset to the service, making it far more useful for student users attempting to prepare for classes.

We chose not to implement a separate mobile user interface for this revision of the project, due primarily to time constraints. The data entry page was designed to be mobile friendly, so that users can report data easily from a mobile device. However the map view is Flash dependent, and not supported on mobile devices.

**Usability Testing Process**

Each team member scheduled two or more usability tests. The usability test questionnaire contains three parts, such as pre-tests, tasks, and post-tests. The pre-test are designed to see how long subject spends time on campus and how much subject is dissatisfied of the temperature on-campus. The tasks contain five tasks that test the accomplishment of our webpage and subject's comprehension about the webpage. The post-test are designed to rate the webpage and ask few comments from subject about their impression.

Subjects completed the pre-test first. After they finished pre-test, subjects performed each task we provided. During the tasks, subject could ask some questions about their task and the way to accomplish them. Also, subject could leave any comments during the tasks. After the tasks, subjects filled out the post-tests. Subjects could express their satisfaction and dissatisfaction about the user-interface.

**Usability Test Questionnaire**

Figures 11-1, 11-2, and 11-3 (see below) display the actual task list, pre-test survey and post-test survey used in our usability study.
Task List and Questionnaires

Task 1
Rate LeFrak Hall, room number 1105, as hot.

Task 2
Rate Cambridge Hall, room number 0102, as cold.

Task 3
Using the campus map view, restrict data to the last 4 weeks and find the hottest building.

Task 4
Using the campus map view, restrict data to be from May 30, 2006, to January 31, 2008 and find the coldest building.

Task 5
Download temperature data.
# Temperature Pre-Test

**Gender**
- **MALE**
- **FEMALE**

**School Year**
- **FRESHMEN**
- **SOPHOMORE**
- **JUNIOR**
- **SENIOR**
- **GRADUATE**
- **OTHER ( )**

How many credits are you taking this semester?
- __________ Credits

Do you live:
- **ON CAMPUS**
- **OFF CAMPUS**

Do you feel buildings on campus are usually too hot or cold, or are they usually comfortable?
- **T O O H O T / T O O C O L D**
- **C O M F O R T A B L E**

If you answered TOO HOT / TOO COLD, are buildings usually:
- TOO HOT
- TOO COLD
- BOTH

Do you frequently carry extra clothes or otherwise alter your behavior to accommodate building temperatures? (Excluding clothes for outdoor conditions)
- **Y E S**
- **N O**

If so, how often?
- ____________________________________________________________

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*Figure 11-2*
Terperature Post-test

How would you rate the interface design overall?
Very Bad (1) - Bad (2) - Neutral (3) - Good (4) - Very Good (5)

How would you rate the temperature entry page?
Very Difficult (1) - Difficult (2) - Neutral (3) - Easy (4) - Very Easy (5)

How would you rate the information on the map in the data access page?
Very Unclear (1) - Unclear (2) - Neutral (3) - Clear (4) - Very Clear (5)

How would you rate the ease of navigation across the interface?
Very Hard (1) - Hard (2) - Neutral (3) - Easy (4) - Very Easy (5)

In your opinion, what is the best feature of the interface?

_____________________________________________________________________

In your opinion, what is/are the worst feature(s) of the interface?

_____________________________________________________________________

Do you have any suggestions to improve the worst feature(s)?

_____________________________________________________________________

Do you have any other suggestions or comments about the interface?

_____________________________________________________________________

Figure 11-3
Pre-Test

The pre-test questions examine gender, school year, current credit amount (i.e., how often a subject is in class), opinions on campus temperatures, and frequency of carrying extra clothes to prepare for hot or cold classrooms. Based on the pre-tests, most subjects feel too cold or too hot in the buildings on campus and carry extra clothes often. Based on this we can see that current climate control measures are not performing to the subjective satisfaction of students. Since most of the cases subjects are dissatisfied with are opposite the season, such as buildings being too cold in summer and too hot in winter, the university is wasting energy now. Also, frequent change of temperature may create health problems and people perform better when they work in the right temperature. If the university can provide comfortable temperatures to students and faculty, they will not only perform better but the university can save large sums of energy (and money) every year.

Information of each test subject follows:

- The first subject is a male graduate student who takes 4 credits in this semester. He lives off-campus and feels cold on campus. He carries extra clothes twice a week.
- The second subject is a female senior who takes 16 credits. She lives off-campus and feels cold and hot both depending on the season. She carries extra clothes very often.
- The third subject is a female senior who takes 12 credits. She lives off-campus and feels cold on campus. She carries extra clothes every day.
- The fourth subject is a male senior who takes 14 credits. He lives off-campus and feels neither cold nor hot neither on campus.
- The fifth subject is a male graduate student who takes 3 credits. He lives off-campus and feels comfortable about the temperature on campus. However, he carries coats everyday in case of cold classroom temperatures.
- The sixth subject is a female sophomore who takes 9 credits. She lives off-campus and feels cold on campus. She carries extra clothes on every school day.

The first test subject wanted to navigate little bit before he started. He also asked more explanation about the tasks and webpage. He finished first two tasks quickly without more questions. However, for the third task which subject needed to go to 'Data Access' page, he asked where he could perform the task. After the explanation from a tester, he commented that 'Data Access' is a "bad name". He also complained about map size and he could not see the detail from the small map. After few second, he could figure out the way to zoom in the map but couldn't figure out the way to zoom out. Task 3 and task 4 took more time since he spent more time to learn about the webpage. However, he could finish the tasks without further questions. He also finished task 5 without any questions. During he was filling out post-test, he said that "This webpage is very easy to see but still need a few examples and explanations for the Data Entry page.

The second test subject tried to start without any explanation about tasks and webpage. She finished tasks 1 and 2 quickly. However, she couldn't figure out how to accomplish tasks 3 through 5. After the explanation from tester about how to navigate the Data Access page, she tried to perform task 3. However, she could not find the way to set the date. She was confused
The third test subject accomplished task 1. She immediately searched the menus for the desired values and found them quickly and also she clicked the correct temperature button. After she completed task 1, she asked if they should click the browse "Back" button to return to the same page for the second task. She performed similarly to task 1. She was confused about how to get the Data Access page. She asked the "Data Access" button was how to get to the map page. She suggested label should be clearer. In adjusting start and end dates, she commented that the calendars are difficult to navigate. She expressed confusion when data displayed did not change and also expressed confusion about how to complete the task, although they did indicate the correct hottest building. After she finished task 3, she performed the calendar actions of task 4 faster, but she commented that there was now no data on the map and making the selection of the coldest building impossible. For the task 5, she clicked the "Download Data" button without difficulty. However, she expressed confusion about no download beginning.

The fourth test subject navigated menus without difficulty and clicked the correct button. He finished task 1 very easily. He clicked browser back button to start task 2 without prompting and again he performed task quickly. For task 3 he selected dates and began moving around the map. He complained about the method of zooming in and out, and general non-interactivity of the map. However, he correctly located the hottest building. After he experienced task 3, he selected dates quickly for task 4. As with the third subject, he also commented that with no data coldest building selection was impossible. He performed task 5 quickly. Also he questioned if something should have been happening after click "Download Data."

The fifth test subject was able to perform all the tasks within a short time frame with no errors. However, at the task 4 he did hesitate on the task of going from finding the hottest building to the coldest, and as an experiment, double-clicked to zoom out the heat map to see the entire campus. "This", he commented, "might hang people up". He suggested further clarification of the zoom functionality of the heat map. "Other than that, it seems pretty good." When asked he reported that he would probably use it, since it was so easy, but only if he knew how to find the web page quickly.

The sixth test subject seemed to find the data entry page very accessible for the task 1 and the task 2. However, for the task 3 she had some problems figuring out how to navigate the heat map. After trying a few things first, she then reviewed the page more closely and read the on-screen instructions. After doing this, she was able to zoom in and read the names of the hottest and cold buildings. But figuring out how to zoom out (an additional double-click on the heat map) took a while. She seemed visibly frustrated at this and reported that it would have to be improved to make it worth using. "I like the simplicity of it, and the colors." "I think it would be pretty useful once the instructions for the temperature map are clearer."
Post-test

Test subject reported satisfaction with the data entry page except its name. One test subject pointed out that “Data Entry” was not clear name. Most of the complaints pertained to the map on the data access page. Most of subjects couldn't figure how the data access page works at the first time. They commented that they need more explanation or an example, such as help page, to figure out the way it works, and also the map is small and hard to find the way to zoom out.

Ratings ((1) - very bad or hard, (5) - very good or easy)

<table>
<thead>
<tr>
<th>Question</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the interface design overall?</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4.33</td>
</tr>
<tr>
<td>How would you rate the temperature entry page?</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.83</td>
</tr>
<tr>
<td>How would you rate the information on the map in the data access page?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3.33</td>
</tr>
<tr>
<td>How would you rate the ease of navigation across the interface?</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3.50</td>
</tr>
</tbody>
</table>

Figure 12

Figure 13
Revisions

Based on the comments and rating, we evaluated our prototype. We decided on the following revisions:

<table>
<thead>
<tr>
<th>Revisions</th>
<th>Importance</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make it clear that the map has changed once a new date range or building is selected</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Make zooming in and out easier and more clear</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Perhaps make sure the page retains map settings across refresh (Someone tried to refresh the whole page to see whether the map had refreshed.)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Perhaps add more information (instructions) on the heat map page</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Move the heat map controls off from on top of the heat map</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 14

We will discuss about our considerations further and modify the prototype based on the importance and the effort to modify.
Conclusions

Final Status

The interface back-end is fully functional, and all of the campus buildings are supported by the system. It is not ready to be deployed yet though, as all of the building rooms have not yet been mapped into the system.

Future Work

As stated previously, the only missing feature is a full mapping of building room numbers into the system. However there are several features with room for improvement. The map component could benefit from a smoother interface, and more precise coloring than the glowing spots.

Additionally, the interface would benefit from another page specifically for student users to view temperatures in a schedule format, as was done in one of the prototypes.

One other critical feature is a connection to the existing University of Maryland network, so that students need to provide a username and password to create a temperature entry. Without this safeguard, individuals could potentially plague the system with incorrect data, rendering the results useless.

Recommendations

Given more time to work on the project, Temperature would likely benefit from a much more developed data access and analysis system. Rather than forcing faculty to manually sift through and analyze the data, the system could intelligently perform data mining to extrapolate patterns and make clear, plain-English recommendations about which rooms and buildings require temperature adjustments. This would greatly improve the efficiency of the system, and potentially discover patterns that human users would not.

With enough resources, this automation could be synchronized with thermostats across the campus, removing the need for any faculty involvement. This is the ideal scenario, but would require a sizable investment of time any money to install the hardware necessary.
Acknowledgements

We would like to thank Dr. Ben Shneiderman and Nir Peer, our professor and teaching assistant, for their assistance, lessons, and guidance over the course of developing this project.

We would also like to thank all of our volunteer usability testers, without whom our project would not have been possible.

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GOLIATH


ACR

http://www.acrsystems.com

VERITEQ

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