Measurements Laboratory Project 2
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TEMPERATURE AND HUMIDITY MONITORING AT THE LOWE ART MUSEUM

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ABSTRACT

This study aimed to analyze the temperature and humidity of the Lowe Art Museum on the campus of the University of Miami, assessing how well the temperature and humidity conditions align with ideal standards for art. Using an Arduino Uno with a DHT22 sensor, 47 data points were collected across different locations within the museum. A calibration test confirmed the presence of a consistent offset in the sensor readings, thus suggesting equipment limitations and systematic errors in the experiment. Analysis of the data revealed discrepancies between the recorded and ideal values. Created heatmaps visualized a trend of higher temperature leading to a lower humidity across the museum. External perspectives were considered to find the greenhouse effect leading to higher temperatures and art materials causing humidity fluctuations. These findings emphasize the importance of environmental monitoring to ensure optimal conditions in a museum setting. Potential solutions for the museum are stated.

1. INTRODUCTION

The Lowe Art Museum located at the University of Miami's campus stores a variety of art pieces. Given material composition and age, it can be inferred that artifacts may require specialized attention for preservation.

2. MATERIALS AND METHODS

2.1 Rationale

The aim of this study was to compare the variance of temperature and humidity in each exhibit in correlation to what type of art is maintained in these rooms. However, after getting in contact with the museum curation staff, it was revealed that the whole building is kept at the same temperature and humidity, which contradicts the initial vision. The adjusted study focused on the difference between the temperature and humidity found in each exhibit with the ideal values the museum provided.

2.2 Experimentation

For this experiment, an Arduino Uno and DHT22 sensor was used to collect experimental values of temperature and humidity.

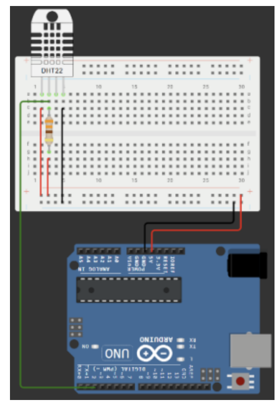

FIGURE 1: ARDUINO SCHEMATIC

The Arduino was powered by a laptop and was coded to output values every two seconds. The recordings were taken at different points in each room depending on the size and potential obstructions of airflow.

FIGURE 2: MAP OF MUSEUM

In total, 47 data points were extracted. As shown in Figure 3.

FIGURE 3: DATA COLLECTION LOCATIONS

3. RESULTS AND DISCUSSION

3.1 Sensor Calibration

Firstly, the sensor needed to be tested for accuracy and potential systematic error. To do this, a calibration test was set up by creating a controlled environment where theoretical temperature values are known, and the Arduino ran simultaneously to find what the DHT22 would output. This small data collection led to Table 1. Testing of the humidity sensor was neglected as there was no way to control humidity.

TABLE 1: CALIBRATION TEST DATA (°F)

Experimental	Theoretical	Difference
71.09	69.00	2.09
72.14	70.00	2.14
74.18	71.00	3.18
75.23	72.00	3.23
76.51	73.00	3.51
78.05	74.00	4.05

Once these values were acquired, a linear regression was run plotting the experimental against the theoretical in Figure 4.

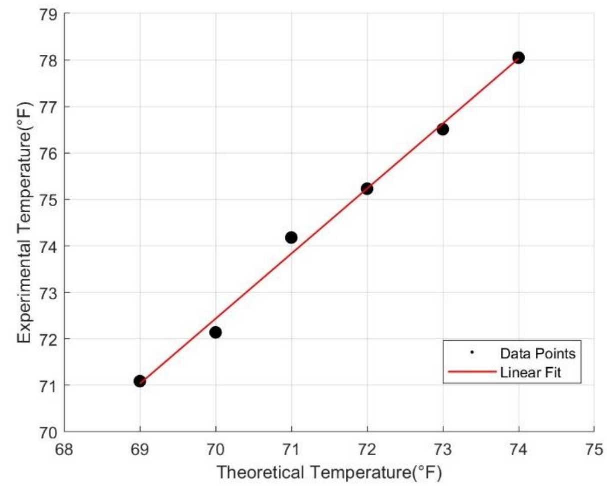

FIGURE 4: LINEAR REGRESSION OF TABLE 1

This output an R^2-value of 0.9935, corresponding to an R-value of 0.9967 which is the correlation coefficient for the data. This R-value is strong positive which means that it can be confidently assumed the values recorded on DHT22 have a consistent offset. This offset was then calculated using the average of the differences in temperature which comes out to a value of 3.03°F. This offset wasn't displayed in Figure 5 which highlights sources of error. After data collection, it was discovered that the temperature control systems fluctuate by ±3°F, thus, showing that the offset may hold true depending on what the true temperature is in each room. Additionally, the sensor may have developed this offset from the total wear and tear that has been applied over time. Time of day also might have played a role affecting external temperature, humidity, and cloud cover. For personal errors, timing mistakes are possible as the sensor may not have been allotted enough time to adapt to new locations or calibration time not being consistent would affect the findings. For the data analysis the actual data was plotted.

3.2 Data Analysis

The museum had data loggers in each exhibit. Surprisingly, these were not all reading the constant value provided which was 70°F. For analysis purposes, even after seeing these varying numbers it was assumed the value remained constant. The findings are demonstrated by creating line plots with markers that show the experimental and ideal temperature and humidity values shown in Figures 5 and 6 respectively.

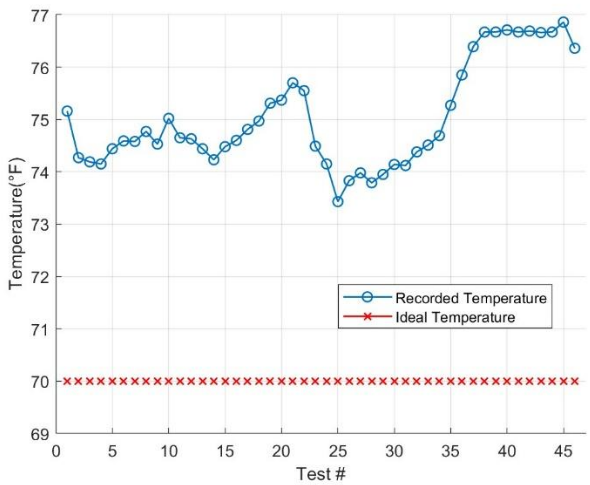

FIGURE 5: LINE PLOT OF RECORDED TEMPERATURES

In Figures 5 and 6, it was observed that there is a large gap between the experimental and ideal values found.

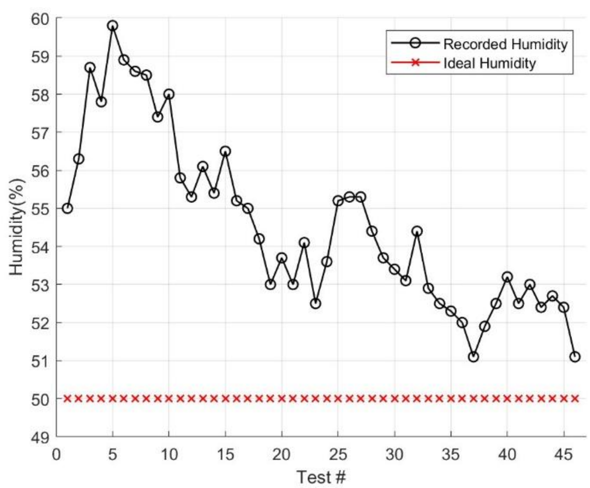

FIGURE 6: LINE PLOT OF RECORDED HUMIDITIES

Using these plots, it was clear that standard statistical testing was pointless for the data since there was a significant difference in sample mean and sample variance. This showed that either the sensor was reading offset values, or the museum displayed inaccurate readings. To further refine the data, a simple heatmap was created for average temperature and humidity.

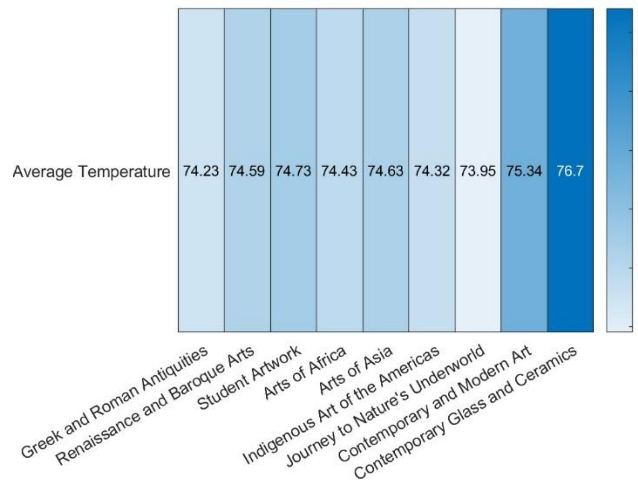

FIGURE 7: AVERAGE TEMPERATURE BY EXHIBIT (°F)

Figure 7 signifies the temperature increase in the "Contemporary and Modern Art" and "Contemporary Glass and Ceramics" exhibits. On the other hand, Figure 8 reveals that the highest humidity is in the "Greek and Roman Antiquities" with 57.5% and "Renaissance and Baroque Arts" with 58.67% which is greater than the average of 55.2%

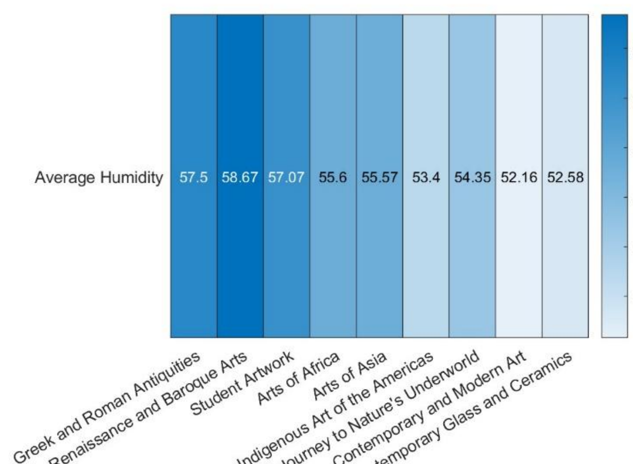

FIGURE 8: AVERAGE HUMIDITY BY EXHIBIT (%)

Where the temperature was found to be lower in Figure 7, is the point of greatest humidity in Figure 8. This led to testing to examine whether the deviation in temperature and humidity was only by particular exhibit or by larger sections of the museum. To represent this, top view overlaying heatmaps were created.

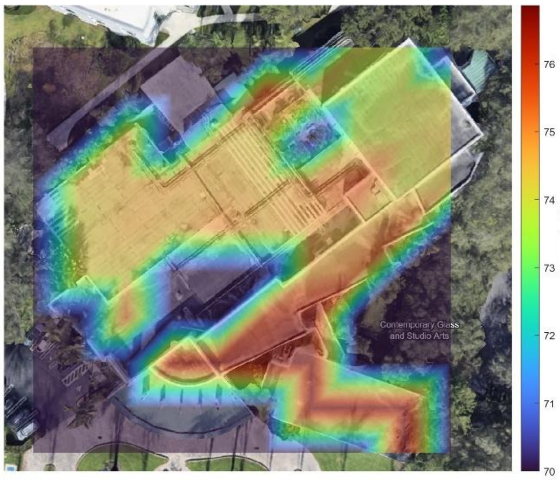

FIGURE 9: TEMPERATURE TOP VIEW HEATMAP

Figure 9 highlights the bottom right section with a dark red color, depicting the greatest temperature. This color spreads over multiple sections of the museum, thus signaling there must be an external factor causing this increase in temperature. Inversely, Figure 10 highlights the region of the museum for greatest humidity.

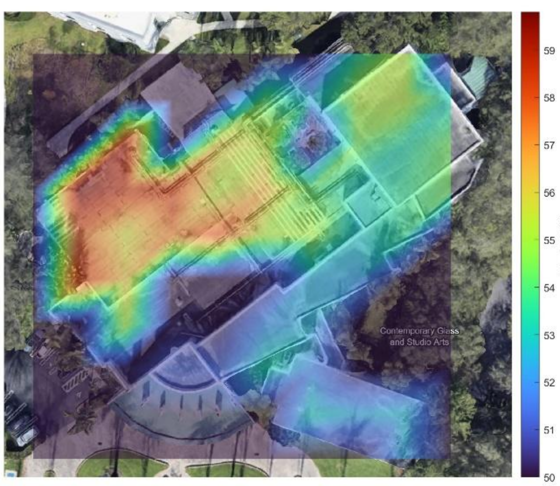

FIGURE 10: HUMIDITY TOP VIEW HEATMAP

This supported the trend of higher temperature leading to lower humidity. After further research there is a tendency for higher temperatures correlating with lower humidity [1].

Following the initial data analysis we considered the possible external perspectives. Discrepancies were identified during the second walkthrough for measurements, and this was likely due to material composition and exhibit architecture as to what may have caused the abnormal humidities in various exhibits as shown in Figure 8 and Figure 10. These are rooted in the material science of the artwork for example the findings show the greatest humidity in the building occurred at Renaissance and Baroque arts where it was later found that almost all the pieces are either created on wood or use oil paint. Increased humidity levels should be addressed. The reason for humidity could be the wood, which has hygroscopic properties to absorb and retain moisture. This ability may also be reversed in scenarios when the air is dry the hygroscopic materials are capable of releasing moisture into the surrounding area [2]. Which in turn leads to a higher presented humidity compared to other exhibits since the wooden pieces play a heavy role in humidity control of that exhibit. However, the cross-linking potential of the oil paint attempts to oppose this dynamic. Oil paint when applied properly is capable of full cross-linking [3]. Due to oil's hydrophobic properties cross-linking makes a solid layer that can significantly reduce the amount and speed of moisture being absorbed and released [4]. This only occurs in ideal settings, the base that the oil is applied to also needs to withstand climate changes. Wood is prone to swelling shrinking and warping caused by fast changes in weathering events. The structural changes in the wooden bases commonly lead to cracks in the paint applied to them [2, 5]. In the Renaissance and Baroque arts section all the pieces have suffered from cracking. Cracking breaks the cross-linking creating channels for the moisture to flow between the wood and surrounding air. And so, the cracking of the oil paint on the wooden bases is what caused the higher humidity since the wood takes control of the humidity. This trend continued in the Journey to Nature's Underworld exhibit. However, this presented a special case scenario and that stems from the architecture perspective where the volume of this room is nearly 3 times the size of the Renaissance and Baroque section specifically with higher ceilings and no doors to separate the exhibits allowing for more dispersion of humidity decreasing concentration and providing the DHT22 with lower comparison readings throughout. Furthermore, the lowest recorded humidities occurred in the Contemporary exhibits in which roots from a combination of artwork material and architectural design that allows for lower humidity. In these exhibits none of the pieces featured the use of oil paint or wooden canvas paired with open concept exhibits with lofty ceilings spreading the water vapor in the air. To prevent any bias checks were also done on the leftover exhibits such as the Arts of Asia and Africa where observations show nearly every piece is enclosed by acrylic which causes the artwork to not affect the humidity in the same manner as the oil and wood. Furthermore, the acrylic enclosure has negligible effects on the humidity proven by their ideal humidities being 30-50% [2]. Another perspective to consider is the country of origin for art. This exemplifies the conditions the piece had to undergo when it was being created and therefore leading to a potential increase or decrease in humidity absorption in the surrounding areas [5]. The Renaissance and Baroque arts all feature European origins such as Italy and Spain. Naturally, these locations have different climate settings from Miami, FL.

and is one of the many fast humidity fluctuations the pieces experienced causing cracking. An alternative view could be from the University of Miami where the art museum is just another facility they need to maintain and so potential causes for these effects may root from the external controlling of the temperature and humidity as well as the tolerances. University facilities may be subject to preset HVAC systems in which case the Lowe Art Museum is set to deal with these standards.

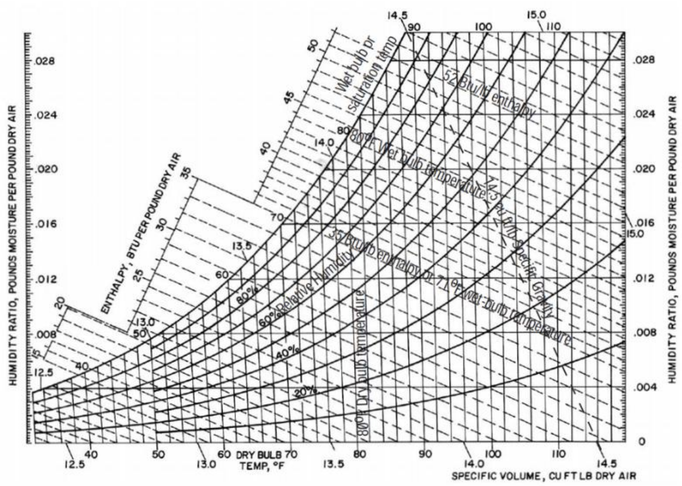

FIGURE 11: PYSCHROMETRIC CHART [6]

Using Figure 11 assists in the explanation of the coordination with the lower temperatures in these areas and inversely for the lower humidities with the higher temperatures found in the Contemporary exhibits. This trend is supported by the greenhouse effect that was found occurring in the Palley Pavilion which features contemporary ceramic and glass pieces. This pavilion is the only exhibit in the entire museum that was designed with windows. These windows cause the greenhouse effect which increases internal temperature as found prior and lower humidity even though absolute humidity is unchanged.[7]

3.3 Solutions

Practical solutions for the museum would be to separate the wooden base pieces into separate areas of the museum. Nonetheless, this contradicts the organization of the exhibits and the featured pieces and so there needs to be a tradeoff either allowing the potential damage to the art through humidity fluctuations or to preserve the art and space out some of the collections focusing on the distancing of the wooden bases.

4. CONCLUSION

In conclusion, this study successfully evaluated the temperature and humidity within the Lowe Art Museum. Data from the DHT22 sensor revealed differences between the recorded and ideal values, indicating external environmental factors and system limitations that may have influenced the data collection results. Calibration testing confirmed a consistent sensor offset, showcasing the importance of accounting for apparatus accuracy. Justification was found for the observance of variation in humidity and potential solutions have been made evident for the museum to consider. Overall, these findings emphasize the critical role environmental monitoring plays in a museum setting, which all museums should take into consideration to continue their mission of showcasing culture and expression through preserved art.

REFERENCES

[1] Western Australian Museum, "Relative Humidity and Temperature", (2018), https://manual.museum.wa.gov.au/book/export/html/89/index.html

[2] Museums Galleries Scotland, "Temperature and humidity in museums", (2024), https://www.museumsgalleriesscotland.org.uk/advice-article/temperature-and-humidity-in-museums/

[3] O'Hanlon, "The Effects of Humidity on Oil Paint Drying and Aging: Insights for Artists", (2024), https://paintingbestpractices.com/humidity-on-oil-painting/

[4] Pizzimenti Silvia, Bernazzani Luca, Tinè Maria Rosaria, Treil Valérie, Duce Celia, Bonaduce Ilaria, "Oxidation and Cross-Linking in the Curing of Air-Drying Artists' Oil Paints", (2021), https://doi.org/10.1021/acsapm.0c01441

[5] Julius Lowy Frame and Restoring Company, "How to Protect Your Artworks from Temperature and Humidity Damage", (2025), https://www.lowy1907.com/how-to-protect-your-artworks-from-temperature-and-humidity-damage/

[6] The Pennsylvania State University College of Agricultural Sciences, "Psychrometric Chart Use", (2023), https://extension.psu.edu/psychrometric-chart-use

[7] Worley, John, "Greenhouses: Heating, Cooling and Ventilation", (2024), https://extension.uga.edu/publications/detail.html?number=B792