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Smart HVAC Control Using IoT

This summary of my Fall 2019 Research contributions discusses a live implementation of my work using a testbed at Rensselaer Polytechnic Institute (CII 7003 Smart Conference Room). By implementing and evaluating an integrated system for collecting user preferences, as well as integrating occupant localization in the Smart Conference Room (SCR), we are able to setup a foundational preference system, which can provide a more efficient energy-consumption solution, as well as more features to users in the SCR and anyplace that seeks to implement a similar efficient building or room. I personally feel the best way to explain the new contributions is to describe a technical walkthrough of the room as a whole, when being run live in the SCR. To explain, this summary will be divided into two components: scheduling and setting up SCR meetings, as well as how the room operates when a meeting is in session.

To begin with, integrating the schedule of meetings with the Smart Conference Room greatly increases the room's overall efficiency and usefulness of operations. First, by being aware of when meetings occur, we can maintain the room in an energy-efficient state when meetings are not in session. Additionally, knowing what temperature to set the room to before a meeting begins provides more functionality to the controlling the temperature in the room, as a whole. We implement these goals with a SCR Schedule Website,[1] that functions similarly to a Calendar application. Building off of a PHP and MySQL calendar created by Steven Cano in the spring of 2019, I was able to give this website the ability to keep track of the meeting attendees when setting an event.

From here, once an event (SCR meeting) is set in the SCR, it pushes the meeting, and the info about it, to the preference server[2] in the Smart Conference Room. First, the preference server analyzes the attendees of the meetings. If the attendees already have preference accounts in the SCR, they will retrieve them, otherwise, the server will create accounts for new attendees, and set their temperature to a previously decided default temperature (currently this temperature

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[1] https://github.com/zacknawrocki/HVACWebsite

[2] https://github.com/zacknawrocki/HVAC-and-Lighting-Preference-System/blob/master/coordinator/src/coordinator.py

is 70 degrees Fahrenheit). The coordinator than threads the process of setting the temperature to the average of these attendees' preferences before the meeting begins, so its web framework can still manage other requests it may receive from other devices communicating with it in the SCR.

Deciding when a temperature should set for the meeting is essential in providing efficient pre-heating-pre-cooling functionality in the SCR. Running tests throughout the semester based off Zaid Tariq's MPC Indoor Thermal Management algorithm, everything is in place to quickly implement this solution, once the starting pre-heating/pre-cooling time is solved. Currently, the default is 10 minutes before a meeting, however the solution to this algorithm will provide a more energy-efficient and accurate alternative. Lastly, it is important to mention that these temperatures are set by communicating with a HVAC Server, which consists of a library created by Toufiq Imam, which can control everything from setting and receiving temperature, to controlling the fans and CO_2 emissions from the room.

From here, the next component is the meeting itself, and how the room operates when the meeting is in session. Once users walk into the SCR, they are immediately tracked, using previously implemented Time of Flight (ToF) sensors located throughout the room. Using the Time of Flight Sensors, we can track meeting attendees in the SCR. Not only are ToF Sesnors more affordable and less privacy-invasive than traditional tracking systems (Patent US9363859B2 from Lighting Enabled Systems & Applications (LESA) Engineering Research Center),[3] they can be far more accurate, by measuring the distances and positions of occupants through lighting.

From here, the challenge was to tag the meeting occupants in the SCR. When attendees enter the room, they can login to one of the tablets powered by Raspberry Pis, which serve as preference clients[4] for users in the SCR. An attendee logs in, or if not mentioned when scheduling a meeting on the SCR Schedule Website, can either temporarily login as a guest, or create personal account while at the meeting. Users can both modify their ideal temperature preferences, as well as their lighting color temperature preferences. From here, we tag the occupants by communicating with the ToF Tracking Coordinator Server.[5] Not only does the

[3] https://patents.google.com/patent/US9363859B2/en
[4] https://github.com/zacknawrocki/HVAC-and-Lighting-Preference-System/tree/master/preference-client
[5] https://github.com/zacknawrocki/Miscellaneous-SCR-Projects/blob/master/tof_tracking/coordinator.py

server tag the user, but it also manages the data, so the tracked occupant, as well as information about the occupant, can be retrieved and used to expand upon.

The ability to easily control this data from a coding standpoint will be important for this upcoming semester, which leads me to explaining the final step. Excluding a quick algorithm implementation and fixing a tracking bug, the remaining task is to now analyze the tracked and tagged meeting attendees, and provide them with their temperature preferences throughout meetings, based by their current status, or change in status, when it comes to their location in the room and temperature preferences. Overall, the foundational code and servers are ready to go live. From here, it will be an exciting challenge to work with the algorithm based on temperature satisfaction from occupant tracking.

I have attached links to any relevant code, as well as a presentation of the demo (the PowerPoint used during my presentation, as well as a brief video that demos this semester's work).

Resources

Repositories

HVAC and Lighting Preference System

https://github.com/zacknawrocki/HVAC-and-Lighting-Preference-System

SCR Schedule Website

https://github.com/zacknawrocki/HVACWebsite

Miscellaneous SCR Projects

https://github.com/zacknawrocki/Miscellaneous-SCR-Projects

Demos

Video Presentation

https://www.youtube.com/watch?v=q9ZZscRmoVI

PowerPoint Presentation

https://drive.google.com/open?id=1SxRX3ymB28FspxNcsvEFOCbHkGepVQ5E