Steam Heat Retrofit for Coover Hall

sddec18-02

Jevay Aggarwal - Technical Lead

Thomas Devens - Project Plan Lead

Kenneth Wendt - Webmaster

Sarah Coffey - Reporting Lead

Joseph Filbert - Client Contact Lead

Liz Wickham Kolstad - Design Document Lead

Lee Harker - Client and Advisor

Problem Statement

- Many buildings on campus, such as the old parts of Coover Hall, utilize steam heat in the winter
- Currently, the only control mechanism is a manual valve
  - There is no way to accurately control the temperature
- Our goal is to implement local and remote controls

Requirements

- Retrofit will be motor-driven and controlled wirelessly
- One retrofit, remote controller, and temperature sensor per valve
- Ability to control all connected valves en masse
- Temperature will be held within +/- 1 degree
- Motor and communication errors will be reported automatically
- Errors will be reported timely (within 30 minutes)
- Remote control battery lasts for a semester
- Access to authorized users only

Considerations and Constraints

- Variety of steam valves within Coover Hall; retrofit should be capable of fitting on any of them
- User interaction with end-system should be minimal
  - Should not require much human intervention
- A single steam valve controls multiple rooms, which means there are multiple users per valve

Market Survey

- Smart home thermostat
  - Ties into existing HVAC system, not compatible with our steam valve
- Danfoss motor retrofit
  - Only fits on thermostatic Danfoss valves
- Belimo
  - Cost prohibitive and not networked

Fig. 1: Nest

Fig. 2: Danfoss

Fig. 3: Belimo

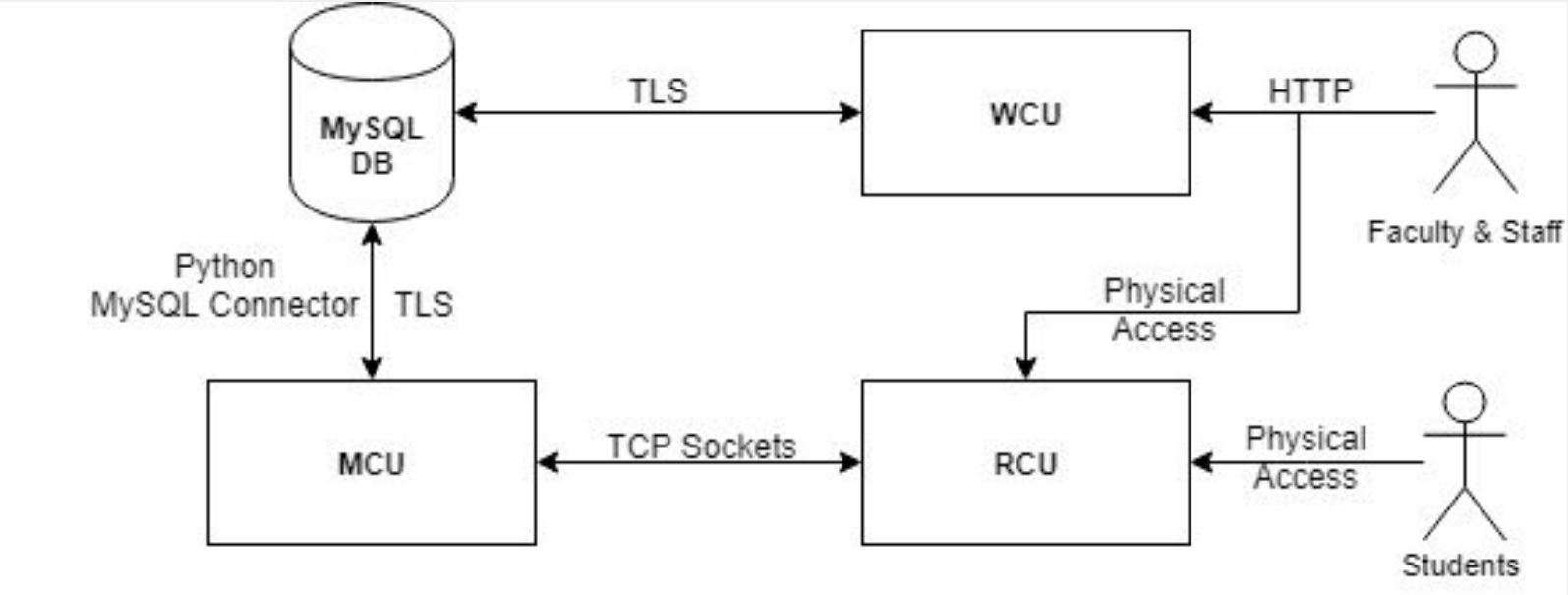
Risks and Mitigation

- Valve damage possible
  - Old and rusted, often leak; exacerbate issues with continual readjustment by the motor
  - Add error detection and response
  - Disable control if error occurs
- Security
  - Networked components could be vulnerable to attack
  - Authentication
  - SSL keys

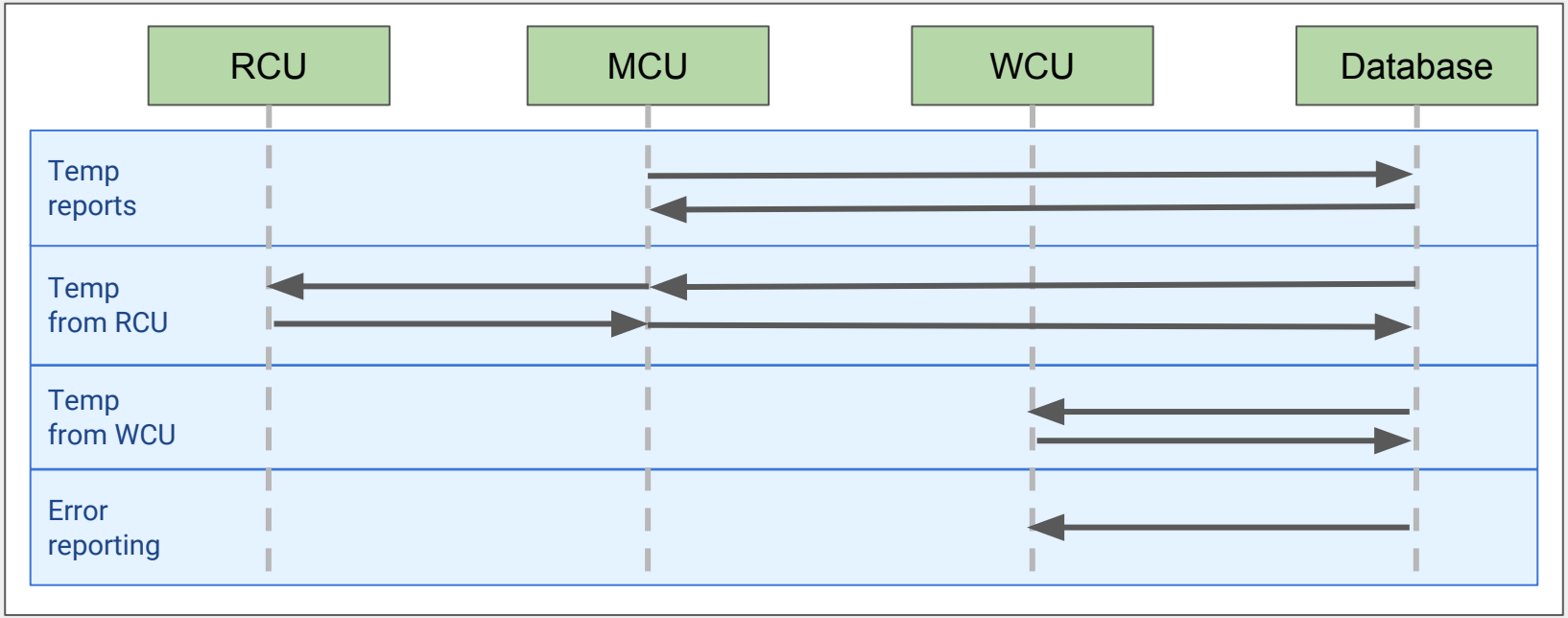
Deliverables

- A system to control the position of the valve to ensure a stable temperature in the room
- A device in the room able to change the set temperature and view the current temperature
- Individual and mass control of valves via web interface
- Error detection and reporting
    - Notify staff when the valve encounters an error preventing normal operation

Design Overview

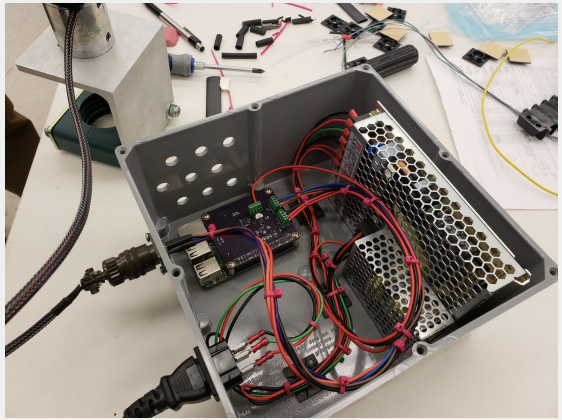


Information flow



MCU Design

- Main controller: Raspberry Pi
- Temperature Sensor: MCP9808
- Motor Driver: DRV8871 DC motor driver
- Main functionality:
  - Interact with RCU/WCU
  - Control motor
  - Read temperature in room
- Error Code Reporting:
  - Valve Stuck
  - Valve Broken



RCU Design

- Main Controller: Adafruit Huzzah with ESP8266
- Battery operated
- Connects to the MCU using TCP sockets and sends the change in temperature
- Displays current temperature, set temperature and errors when received from the MCU on a Quad-Alphanumeric LED Display with I2C
  - Doesn’t accept temperature changes when error detected
- Generic push buttons allow changing the temperature
- Switch to turn the RCU on/off

WCU Design

- Website: http://thermostat.ece.iastate.edu
  - Utilizes Spring Framework
  - Simple controls
  - Individual/mass valve control
  - Valve errors
  - Web server hosted by ETG
- Error reporting through email notifications
  - Python & Bash scripts that query the database for active errors
  - Periodically re-sends the email notification until error is resolved

Resources and Cost

- MCU
  - Parts $134.14
  - PCB $28.20
- RCU
  - Parts $43.75
  - PCB $9
- Valve Mount
  - Parts $80.87
- Project Total
  - $295.96

- Second Semester Man Hours
  - Hardware 164
  - Embedded Software 226
  - Web Development 132.5
- Total 406.5

MCU Testing

- Motor control
  - Relative valve position control
- Connection
  - Database
  - RCU
- Integration
  - MCU responds to temperature changes from RCU and WCU

RCU Testing

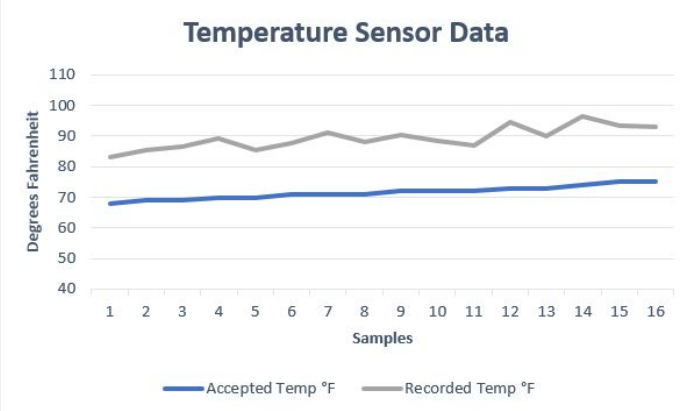
- Display
  - Makes sure the right temperature is displayed
- Connection to MCU
  - Make sure the temperature or the error code is received
- Temperature change
  - Temperature changes with each button press

WCU Testing

- Usability
  - Client approved
- Error reporting
  - Injected error cases into the database at different times
  - Verified the email was correct and received promptly

Notable Results

- Simulated a semester of normal use
  - Greater than 50% battery left after 149 adjustments and power cycles
  - Confirmed battery had more than sufficient capacity
- Temperature sensor is impacted by placement
  - Results show the sensor should be moved out of the box
  - Avg. difference = 17°F, Max. deviation = 5°F



Current Status

- MCU functionally complete
  - Temperature sensor reading needs calibration
  - Further testing is needed to support motor and valve errors
    - Stuck Valve
    - Broken Valve
- RCU complete and ready for packaging
- WCU fully functional
  - No authentication currently enabled

References

Adafruit-DRV8871-Breakout-PCB

PCB files for the Adafruit DRV8871 Breakout

Format is EagleCAD schematic and board layout

For more details, check out the product page at

- https://www.adafruit.com/product/3190

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Fig 1:
https://store.nest.com/product/thermostat/T3007ES

Adafruit-MCP9808-Breakout-PCB

PCB files for the Adafruit MCP9808 Breakout

Format is EagleCAD schematic and board layout

For more details, check out the product page at

- https://www.adafruit.com/products/1782

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Fig 2:
https://store.danfoss.com/en/Heating-and-District-Energy/Danfoss-Link---Smart-Heating/Room-Sensor/Type%3A-living-connect/p/014G0542

Adafruit-Feather-ESP8266-HUZZAH-PCB

PCB files for the Adafruit Feather ESP8266 HUZZAH

Format is EagleCAD schematic and board layout

For more details, check out the product page at

- https://www.adafruit.com/product/2821

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Fig 3:
https://www.belimo.us/shop/en_US/config?code=WGVL%2BEVX120-3&siteName=Belimo+US+Official+Site

Questions?