Processor Hardware/Software Interface
EECS 113

Final Project

University of California, Irvine

Assigned: May, 26, 2022

Due: June, 10, 2022 by 11:55PM

Designed by

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1 Building Management System

1.1 Warnings

- "Before connecting power, get into the habit of checking that there is nothing conductive in contact that could cause a short circuit with you Raspberry Pi. A quick check that there is nothing nearby could save you from damaging your Pi."
- "Electricity can kill! Only experiment with low voltage and currents, and never work with mains. If you are ever in doubt you should check with someone suitably qualified."
- "Be extremely careful when working with circuits (especially 5V) that connect to the GPIO pins as they are not protected on the Raspberry Pi and the external power supply."

1.2 Project Description

In this project, you are going to implement a Building Management System (BMS). BMS is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. Your implemented BMS will be able to do the following:

- Display status on a LCD
- Control room temperature (HVAC)
- Report energy bill for HVAC
- Control the ambient lighting
- Monitor perimeter's entrances

1.3 Project Specification

Abbient light control: Your BMS should be able to detect human presence in the room and subsequently turn on the lights (represented by **GREEN LED**). Use the PIR sensor to implement this function. To save energy, turn off the lights if no movement is detected for **10 seconds**. Ambient lighting status should always be displayed on the LCD (on/off).

Room temperature (HVAC): There are two input data for the HVAC system: the temperature and the humidity. Your BMS should retrieve ambient temperature from the DHT-11 sensor **once every 1 second** and **average the last three measurements** to eliminate possible mistakes in measurements. Round the measurements to the nearest number. Although DHT-11 can provide the humidity as well, we do not trust the measurements (!) and will get the local humidity from the CIMIS system. Check Appendix section to learn more about CIMIS data. Based on the nearest station to you (Irvine station if you live in Irvine), humidity value needs to be extracted from CIMIS data. Calculate a weather index using the following equation:

$weather_{index} = temperature + 0.05 * humidity$

example: $weather_{index} = 71 + 0.05 * 80 = 75$

Round the measurements to the nearest number. This weather index is also referred to as the "feels like temperature". It is more useful since the more humidity in the air, the hotter it feels. We try to compensate the humidity feeling by adjusting the input temperature. Compare the weather index with the user input temperature and enable the HVAC accordingly. User should be able to seamlessly set the desired temperature in range of [65 - 85] degrees using **two push buttons**. That means, the input buttons should be checked frequently (for instance 3 times per second). To avoid constant switching between the heater **(RED LED)** and the AC **(BLUE LED)**, you must implement a hysteresis-like function that will set the AC on only if the weather index is **3 degrees** above the desired temperature. Same goes for the heater (**3 degrees below the set temperature**). To conserve energy, the HVAC should be turned off temporarily while the doors or windows are open. Display concise information, including the weather index, the desired temperature and the HVAC status (off/AC/heat) on the LCD. **Any action** regarding the HVAC system should be announced on the entire LCD. For instance, when the AC is turning on, the entire LCD should be erased and a single notification should appear as "AC is on" for **3 seconds**. The display goes back to normal after 3 seconds.

Energy bill generator When HVAC is active, it consumes energy which respectively costs money. Your BMS should be able to generate a report, showing the cumulative KWh energy consumption, as well is the overall cost. We assume that the AC consumes **18000 watts** and the heater consumes **36000 watts**. You can round up the numbers to **two decimal point** e.g. 1.23 Kwh. The cost of electricity per kWh is **50 cents**. The BMS should show the utility bill report every time the HVAC state changes (e.g. from off to AC or from AC to off). For instance, when the AC switches off, a simple report pops up as follows: "energy: 4.56KWh , cost: $2.34".

Security system: The room has one entrance (door) and one window, both of which are equipped with security sensors, and represented by **one push button** (one button for both). Display a warning message such as "door/window open!" or "door/window closed!" on the entire LCD for **3 seconds**. Do not forget to turn off the HVAC while the door/window is open. Also, always display the door/window status as open/closed or open/safe on the LCD.

Here is an example of how LCD should report the status:

1.4 Bonus Points

(10%) Implement an internal clock system. On system startup, the current time is retrieved from the system or the internet (date is not required). You will then implement an internal clock function that generates the actual time in 24 hours format and display it on the LCD. Your code should be able to generate a tick once every second and update the time accordingly. Also, create a log file, containing all events occurrence, along with the time stamp. Save your logs in a log.txt file on the same directory as your code files.

Here is an example of the log file:
13:53:01 HVAC AC
13:53:32 DOOR OPEN
13:53:32 HVAC OFF
13:53:45 DOOR SAFE
13:53:45 HVAC AC
13:54:12 LIGHTS ON

(5%) This project represents your hardworking and creativity! Try to be creative with other sensors and components in your RPi's package or the way the information is displayed on the LCD to make it more user-friendly or extend the functionality! Mention your ideas on the report and implement them in your code.

1.5 Hardware Requirements

- Temperature and humidity sensor (DHT-11): See Chapter 21 in the tutorial
- PIR sensor: See Chapter 23 in the tutorial
- LCD: See Chapter 20 in the tutorial
- Push buttons
- LEDs

Note: Please download the Freenove Ultimate Starter Kit for Raspberry Pi tutorial from the following link:

http://www.freenove.com/tutorial.html

Hardware set up: In this part, you need to set up the circuit. Make sure not to break anything, else your Raspberry Pi IC or any device can burn out.

2 Assignment Deliverable

- Submit a project report with all the details of your design, including steps, pictures, code, and notes in a **.zip** file on Canvas.
- Each student needs to create and submit a video of up to 5 minutes. In the video, please report on the following:
  - First state your name and your student ID.
  - Display your code and go over the major functions of your code.
  - Test your system and demonstrate all implemented functionalities. Examples include but not limited to:
    - turn off HVAC by opening the door
    - change temp by using a hair drier
    - change temp when the door is open to show the HVAC won't turn on
    - show that light timer resets every time something is detected.
  - If you added any features, please provide tests for them as well.

Appendix: CIMIS Data

For this project, we will use California Irrigation Management Information System. Check it from here: https://www.cimis.water.ca.gov

Here is some information about this program:

The California Irrigation Management Information System (CIMIS) is a program of the Office of Water Use Efficiency (OWUE), California Department of Water Resources (DWR) that manages a network of over 120 automated weather stations in the state of California. CIMIS was developed in 1982 by DWR and the University of California, Davis to assist irrigators in managing their water resources efficiently. Efficient use of water resources benefits Californians by saving water, energy, and money. CIMIS topology diagram Data Collection and Transmission CIMIS weather stations collect weather data on a minute-by-minute basis, calculate hourly and daily values and store them in the data-loggers. A computer at the DWR headquarters in Sacramento calls every station starting at midnight Pacific Standard Time (PST) and retrieves each day's data.

In case of a communication problem between the central computer and a given station, the computer skips that station and calls the next station. After all other stations have reported the polling computer comes back to the station with a communication problem trying to establish a connection at predetermined time intervals. The interrogation continues into the next day until all of the station data have been transmitted.

Data Processing Once the data is transmitted, the central computer analyzes it for quality, calculates reference evapotranspiration (ETo - for grass reference and ETr - for alfalfa) and other intermediate parameters, flags the data (if necessary), and stores them in the CIMIS database. Evapotranspiration (ET) is a loss of water to the atmosphere by the combined processes of evaporation from soil and plant surfaces and transpiration from plants. Reference evapotranspiration is the loss of water from standardized grass or alfalfa surfaces over which the stations are sitting. Irrigators have to use crop factors, known as crop coefficients, to convert ETo/ETr into an actual evapotranspiration (ETc) by a specific plant.

Since most of the CIMIS stations are sitting on standardized grass surfaces, reference evapotranspiration is commonly referred to as "ETo" in this web site. However, it is worth mentioning that a few CIMIS stations are sited on standardized alfalfa surfaces and therefore evapotranspiration from such surfaces is referred to as ETr.

Data Retrieval Estimated parameters (such as ETo, net radiation (Rn), dew point temperature, etc.) and measured parameters (such as solar radiation (Rs), air temperature (T), relative humidity (RH), wind speed (u), etc.) are stored in the CIMIS database for unlimited free access by registered CIMIS data users. In the past, users were accessing the CIMIS database via the dial-up and telnet systems. CIMIS then developed an older version of its current web site, during which time users were able to access the database using the dial-up, telnet, and/or the web systems. Once the web site became fully functional, the dialup and telnet options were terminated. Currently, the web system is the only platform for retrieving the CIMIS data. In addition to the web, CIMIS developed an ftp site for those interested in automated access of the data. However, the ftp site only provides daily data for the previous 7 days and monthly data for the previous 12 months. Also available at the ftp site is one year's worth of rolling daily ETo data. This means that the beginning and ending dates of this data advance forward by one day everyday.

Selecting Representative Stations The CIMIS weather stations are randomly distributed throughout the State of California. It is very important that the selected station represents the same microclimate as the area of interest. Some resources available to assist you in this regard include the CIMIS web site, local water districts, farm advisors, consultants, and CIMIS staff.

Contact information for CIMIS staff at the Sacramento headquarters and the DWR districts are provided in the CIMIS Staff link on the Home Page. Questions regarding the selection of a CIMIS station, installation of new station, missing data, and/or information on how to use the data can be directed to the CIMIS staff in your DWR district. There are four DWR districts in California. To find out in which district your County lies, click here, for district location maps. If you have problems contacting the CIMIS staff in your district, you can Contact Us at headquarters in Sacramento.

Trends in CIMIS Data Users Although CIMIS was initially designed to help agricultural growers and turf managers administering parks, golf courses and other landscapes to develop water budgets for determining when to irrigate and how much water to apply, the user base has expanded over the years. In addition to those mentioned above, current CIMIS data users include local water agencies, fire fighters, air control board, pest control managers, university researchers, school teachers and students, construction engineers, consultants, hydrologists, state and federal agencies, utilities, lawyers, weather agencies, and many more.

The number of registered CIMIS data users has also been growing steadily over the years. Currently, there are over 6000 registered CIMIS data users. It is worth mentioning here that this number reflects only those that are primary users of the CIMIS data. It has been established that many users get the CIMIS data from these primary users for various uses. Examples include local water districts and consultants providing the CIMIS data to their clients. Therefore, there are secondary and tertiary CIMIS data users that have not been accounted for by the figure presented here.