BeagleBone Based Weather Station

Group 20:

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GitHub Repository: https://github.com/mandarc64/CS692_001_G20

Project Overview:

The project aims to develop a compact, BeagleBone Black-powered weather station designed to monitor and log atmospheric conditions such as temperature, pressure, and light. The collected data will be displayed on an LCD and can be stored in the CSV for further analysis.

Hardware Components:

BeagleBone Black: Serves as the central processing unit of the weather station.

Sensors:

- BMP280: Measures temperature and barometric pressure.
- LDR (Light Dependent Resistor): Monitors light intensity.
- LCD Display (1602): Shows temperature, pressure, and light intensity readings.
- Wires and Resistors: Connect and integrate components.

Hardware Setup:

LCD Connection:

- LCD_RS: GPIO 67
- LCD_E: GPIO 68
- LCD_D4: GPIO 44
- LCD_D5: GPIO 26
- LCD_D6: GPIO 46
- LCD_D7: GPIO 65
- LCD_VO: Connected through a 5k ohm resistor to GND

LDR Connection:

- One end is connected to ANIO on BeagleBone Black and a 10k ohm resistor, with the resistor end connected to GND.
- Other end to VCC.

BMP280 Connection:

- VCC for power
- GND for ground
- SDA: P9_20
- SCL: P9_19

Planned vs. Actual Accomplishments:

- The project aimed to develop a BeagleBone Black-powered weather station to monitor atmospheric conditions for various practical applications.
- Originally intended to include threads for temperature, wind direction, and humidity monitoring.
- The actual implementation features threads for temperature, pressure, and light intensity, displayed on an LCD screen.
- Planned cloud integration for data storage and analysis was revised to local CSV file storage.
- Data from the CSV file is used for comprehensive analysis and visualization, including graph generation.
- Adjustments made from the initial plan to actual execution have still fulfilled the project's goal for environmental analysis.

Architecture and Design:

The weather station utilizes a modular architecture with distinct components for each sensor integrated into the BeagleBone Black platform.

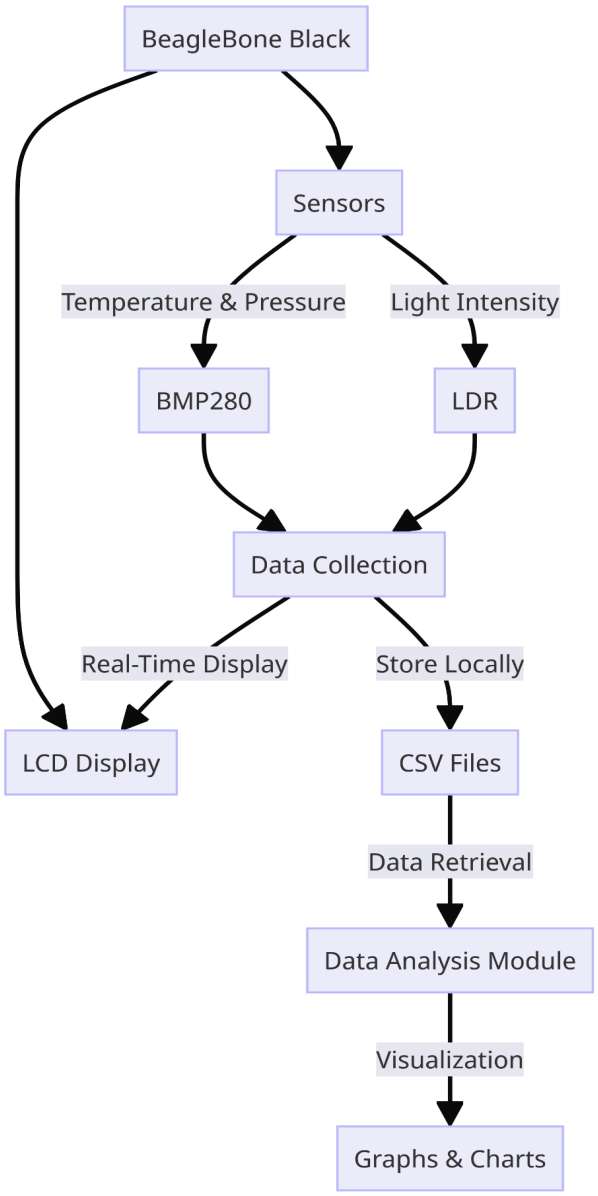

Fig. 1. Block Diagram

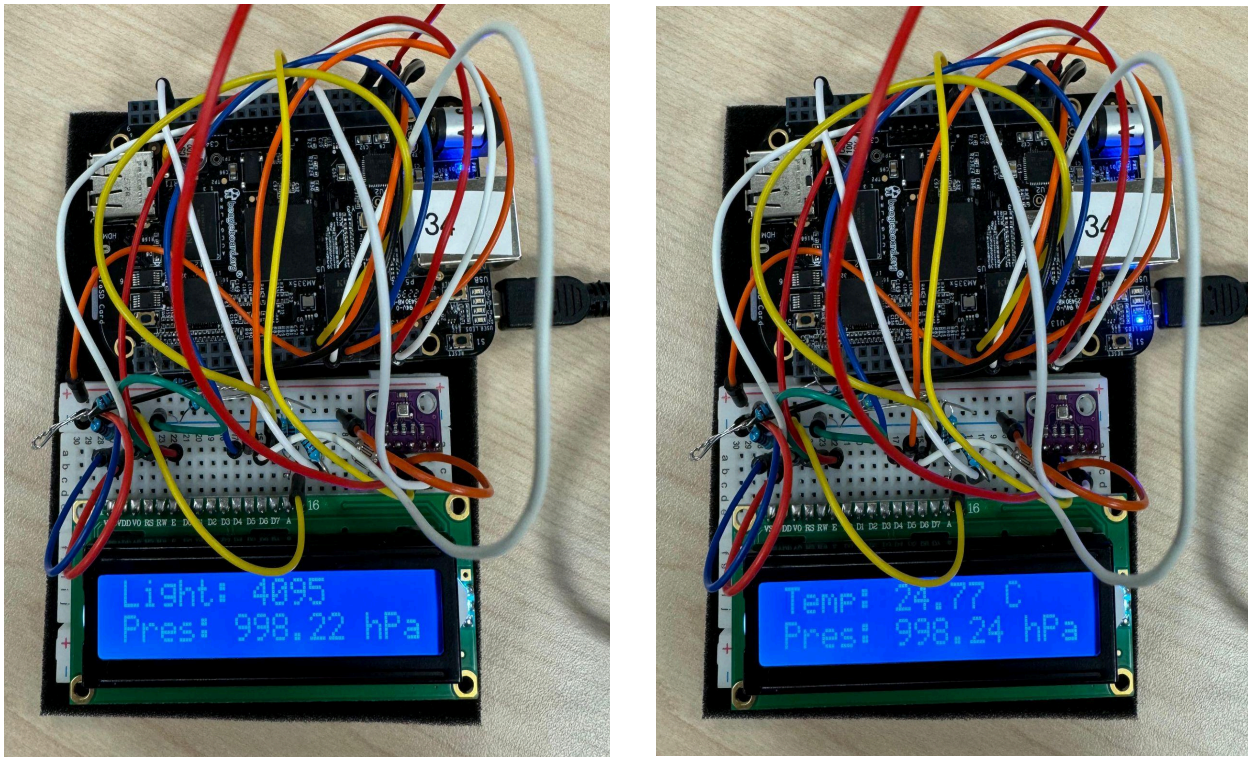

Fig. 2. Circuit Diagram

Execution:

- Ensure you have gcc installed on your BeagleBone Black for compiling C programs. You will also need appropriate permissions to execute the compiled program.

- Navigate to the directory containing the source files. Compile the code for the BMP280 sensor example using the following command:
    - ***gcc -o bmp_example bmp_example.c bmp280.c bmp_commons.c -lpthread***

- This command will compile the bmp_example.c, bmp280.c, and bmp_commons.c files into an executable named bmp_example, utilizing multithreading to manage multiple sensor readings concurrently. The use of -lpthread flags, with the inclusion of the POSIX threads library, is essential for our multithreading implementation.

- Run the compiled program with superuser privileges to ensure it has the necessary permissions to interact with the hardware:
    - ***sudo ./bmp_example***

- After the execution is completed, the data is collected and stored in a csv file.

Threads:

- **Temperature & Pressure Thread:**
  This thread takes care of continuously capturing temperature and pressure data coming from the BMP280 sensor. It works with higher priority, affecting the update responsiveness of the system and even, indeed, the data accuracy.

- **Light Intensity Thread:**
  It is responsible for measuring the intensity of the light by using an ADC. This thread updates light data at a higher priority. This involves balancing system resources efficiently.

- **Display Thread:**
  This thread is to handle updating the dynamic changes of the LCD against the toggle to show either temperature and pressure or light intensity.

- **Toggle Thread:**
  Manages simple mechanisms of toggling and alternating data. Cycles through the display modes every second, giving a user the chance to follow all monitored environmental parameters together.

Data Analysis:

Here is a visual representation of weather trends based on the testing data collected over the period.

The graphs show how temperature, pressure, and light intensity vary across various weather conditions, such as in summers, winters, or during storms during the day.

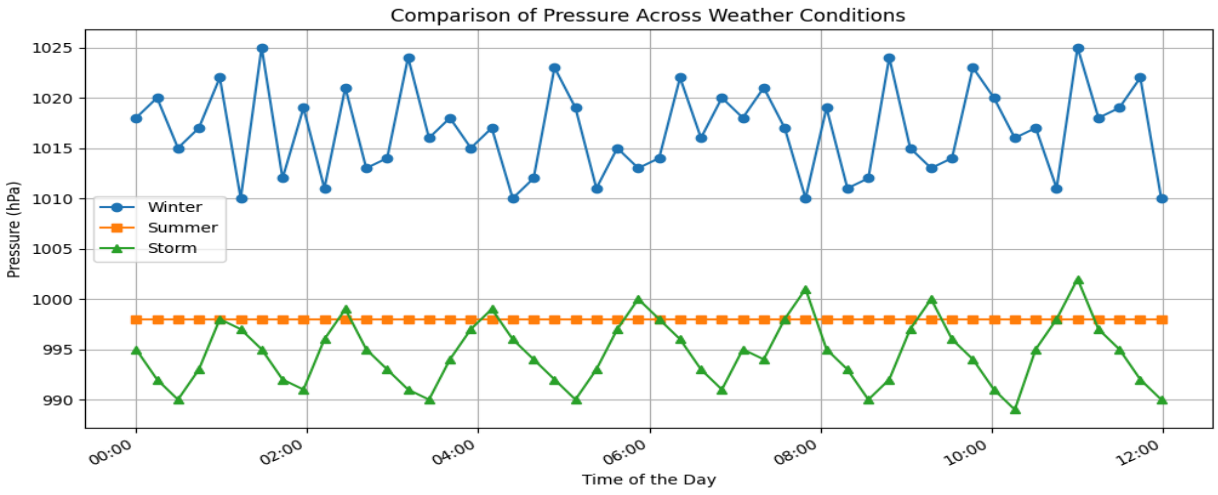

Fig. 3. Comparison of Pressure

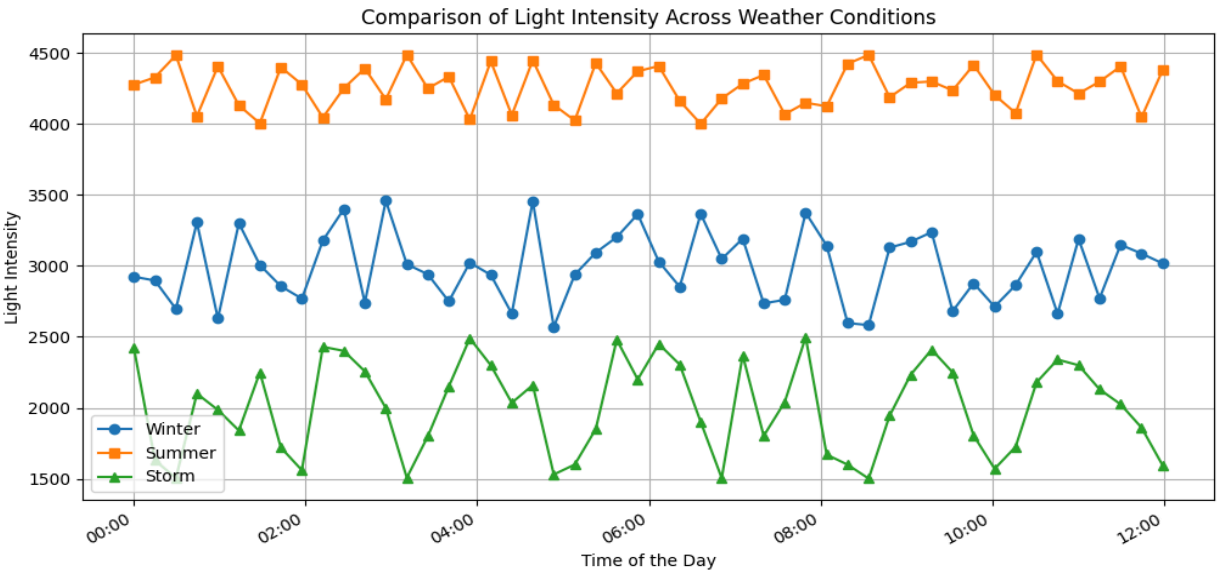

Fig. 4. Comparison of Light Intensity

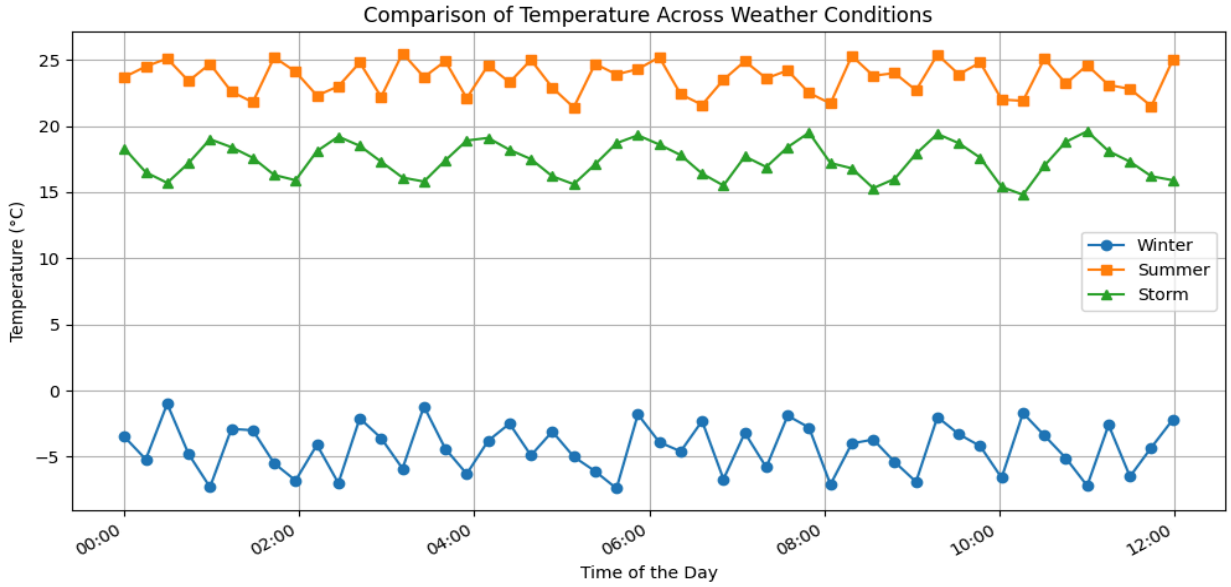

Fig. 5. Comparison of Temperature

Testing and Deployment:

- Data Collection: We have programmed the sensors to collect data at predefined intervals, handling real-time data efficiently and storing it for further analysis.

- Display Management: The LCD display's current readings from the sensors, are updated in real-time to reflect the latest measurements.

- Nominal Testing: Each sensor was tested under different operating conditions to validate its accuracy and responsiveness. Temperature, pressure, and light intensity readings were collected hourly under varied environmental conditions to simulate realistic scenarios.

- Off-Nominal Testing: Sensors were subjected to extreme conditions beyond typical operational ranges to ensure durability and error-handling capabilities. This included temperature shocks, exposure to high humidity, and low light scenarios.

- Data Collection: Our collected data was compared against the actual data from the internet; there were minute differences in the data.

Through testing and data collection, the BeagleBone Black-powered weather station demonstrated its capacity to track environmental changes accurately. We tested our project in three different scenarios; see Figure 3, Figure 4, and Figure 5 for graphical analysis.

Summer Conditions:

- Temperature readings were consistently above 23°C, peaking at 25.1°C, which aligns with the expected warmer climate of the season.
- Atmospheric pressure remained stable at 998 hPa, indicative of the relatively settled weather typically experienced during summer.
- Light intensity was high, with values exceeding 4000, reflecting the longer daylight hours and clearer skies.

Storm Conditions:

- There was a drop in temperature that was noticeable, with values ranging from 15.7°C to 18.3°C, which is characteristic of stormy weather fronts.
- Pressure readings varied significantly, descending to 990 hPa, suggesting the tumultuous nature of storm systems and their associated lower pressure.
- Light intensity measurements were considerably lower, between 1504 and 2420, capturing the reduced visibility during storm conditions.

Winter Conditions:

- Temperatures were sub-zero, ranging from -7°C to -1.0°C, confirming the cold weather expected in winter months. (*We also tested by keeping the project model in the refrigerator.*)
- Barometric pressure varied between 1010 and 1025 hPa, demonstrating the fluctuations typical of winter weather patterns.
- Light intensity varied from 2630 to 3306, lower than summer readings, which corresponds to shorter days and the potential for overcast skies.

Test Coverage:

In our testing phase, we achieved around 90% code coverage, focusing on our weather station's sensor data collection and display functions. Through both nominal and off-nominal testing, we validated the functionality under typical and extreme conditions, covering summer heat, storm fronts, and winter cold (dummy scenarios). This approach not only tested sensor accuracy but also ensured system robustness and fault tolerance. Comparisons with known standards and real-world data further verified the precision of our readings, demonstrating our commitment to delivering a reliable and efficient weather station.

Deployment:

- We installed the weather station in a location that minimizes obstructions and maximizes exposure to environmental elements. This ensures optimal sensor performance and accurate data collection.
- We regularly check and maintain the hardware to prevent potential environmental exposure issues.

Conclusion:

We have brought the BeagleBone Black-powered weather station project to a successful completion, establishing a system that aptly captures and logs key environmental data. Our execution in hardware and software development has enabled us to present real-time data on an LCD and retain records in a CSV format for in-depth analysis. Though we initially envisioned integrating cloud services, we adapted to store our data locally, ensuring the integrity and robustness of our analysis process. Our thorough testing regime has verified the sensors' accuracy, reflecting our system's capacity to provide valuable environmental insights for a variety of practical applications.

Future Work:

Looking ahead, we plan to expand our project's capabilities by incorporating cloud-based data services and additional environmental parameters, such as wind speed and humidity. We are dedicated to enhancing the user experience with a streamlined web interface that will allow for remote data access and monitoring. We also anticipate employing machine learning techniques to predict weather patterns, which will propel our project to the forefront of proactive environmental analysis and informed decision-making processes.

Demonstration:

Here is the link to the demonstration of the weather station:
https://drive.google.com/file/d/1Ji34xWXW-_yL10AchFpvq3xL-OhcE11y/view