ECE 445

SENIOR DESIGN LABORATORY

RROPOSAL

MetaProject: Proposal for ECE 445

Team #15

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1 Introduction

1.1 Problem

To effectively manage and reduce the carbon footprint of the Haining International Campus at Zhejiang University, it is critical to present energy consumption and emissions data in a way that is not only clear and accessible but also engaging and interactive. While the campus collects data on electricity, water, and gas usage, this information is not currently visualized in a format that students and faculty can easily understand or interact with. This lack of intuitive visualization and interactivity limits efforts to raise awareness about the environmental impact of campus operations, foster a culture of sustainability, and showcase the effectiveness of emission reduction initiatives.

Furthermore, traditional systems fail to integrate renewable energy sources into their operations, missing the opportunity to demonstrate how sustainable energy can mitigate emissions in real-time. Therefore, a robust carbon emissions visualization platform that incorporates renewable energy systems and interactive features is essential. Such a system will not only enhance engagement and awareness but also provide a practical showcase of renewable energy integration, contributing to the campus's long-term environmental goals.

1.2 Why is it important?

Addressing the carbon footprint of the Haining International Campus is vital for several reasons, encompassing environmental, educational, and technological aspects:

- **Raising Awareness:** An interactive and engaging carbon emissions visualization system can foster awareness among students and faculty about the environmental impact of their daily activities. By clearly illustrating energy consumption patterns and emission trends, the system encourages behavioral changes that contribute to sustainable practices on campus.
- **Driving Sustainability:** By integrating renewable energy sources such as wind turbines and solar panels, the system not only offsets some of the campus's energy consumption but also provides a tangible example of how sustainable energy solutions can be implemented in real-world scenarios. This supports the university's broader mission of becoming a low-carbon, environmentally-friendly campus.
- **Enhancing Decision-Making:** Advanced data analysis and predictive capabilities empower campus administrators to make informed decisions about energy use and emission reduction strategies. Predicting future trends allows for proactive planning and the identification of inefficiencies in energy consumption.
- **Educational Value:** The interactive features of the system, including the touchscreen panel and conveyor belt model, provide a hands-on educational experience for students and faculty. This fosters a culture of sustainability while also serving as a powerful educational tool for understanding carbon dynamics, renewable energy,

and the importance of emission reduction.

- **Setting an Example:** As a modern and innovative institution, Zhejiang University has the opportunity to lead by example in sustainability efforts. A cutting-edge carbon emissions visualization platform demonstrates the university's commitment to addressing climate change, inspiring other institutions to adopt similar solutions.

1.3 Visual Aid

The Visual Aid for the project is designed to combine interactive visualization with renewable energy integration, providing an engaging and educational experience for users. The system is built on a sand table model that visually represents the carbon emission dynamics of the Haining International Campus. The updated features emphasize interactivity and the use of renewable energy sources, making the visualization both functional and sustainable.

- **Interactive Carbon Flow Visualization:** The sand table includes an interactive conveyor belt system that simulates the flow of carbon emissions across various campus sources. Users can control the speed, direction, and behavior of the conveyor belt via a touchscreen panel. Along the conveyor paths, LED indicators dynamically change color based on emission levels, with green representing low emissions and red representing high emissions. This visual representation enables users to intuitively explore and understand carbon emission patterns and their impact on the campus.

- **Renewable Energy Integration:** Functional wind turbines and solar panels are integrated into the sand table model to generate renewable energy. These energy sources power the visualization system, including the conveyor belt, LED indicators, and data processing modules. The solar panels store energy in lithium batteries during the day, while wind turbines provide additional power when wind conditions are favorable. This integration demonstrates the practical application of sustainable energy sources in real-time, reinforcing the importance of renewable energy in reducing carbon emissions.

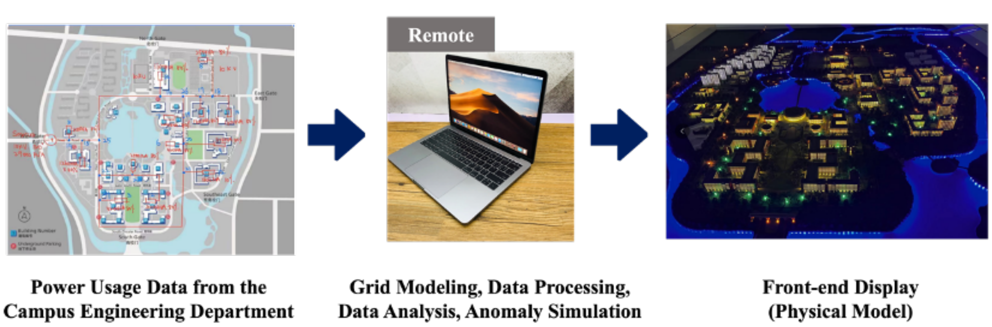

Figure 1: Interactive visualization system with renewable energy integration.

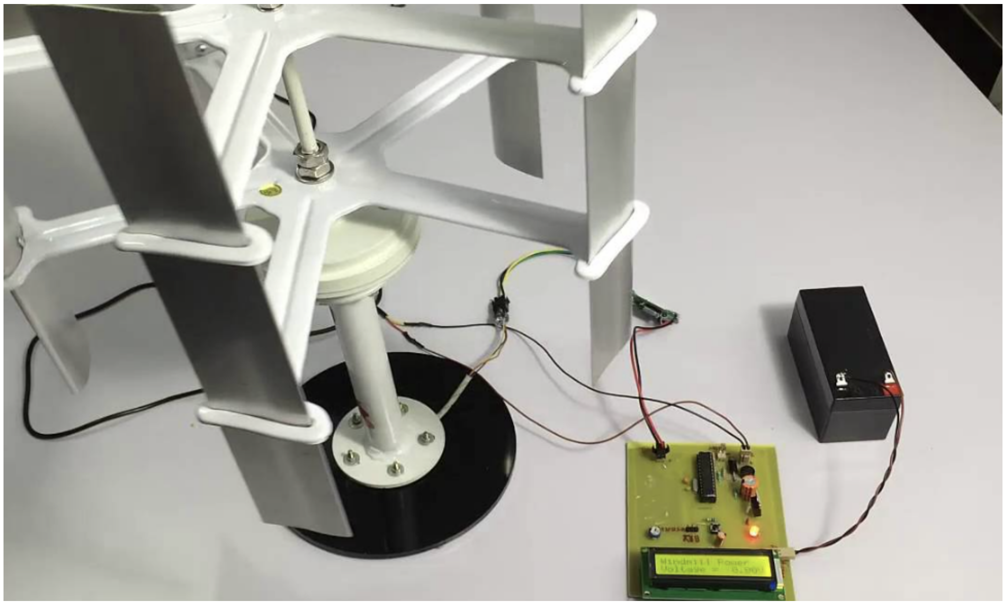

Figure 2: Interactive visualization system with renewable energy integration.

1.4 How will you solve it (high level)?

Our proposed solution is to develop an innovative and interactive carbon emission visualization platform powered by renewable energy. This system will integrate the following components:

- **Interactive Carbon Flow Visualization:** A conveyor belt system on a sand table will represent the flow of carbon emissions across campus. Using LED indicators and 3D-printed objects, the system will provide a dynamic and intuitive visualization of carbon dynamics.
- **Renewable Energy Integration:** Functional wind turbines and solar panels will be incorporated into the system to generate sustainable energy. This energy will power the visualization and data processing modules, showcasing the practical application of green energy in real-time.
- **Interactive Control System:** Users will be able to control the conveyor belt's speed, direction, and behavior via a touchscreen panel or mobile app. This interactivity will enhance user engagement and allow users to explore historical and real-time carbon emission trends.
- **Data Analysis and Prediction System:** Advanced data analysis will be implemented using machine learning models (e.g., LSTM and Random Forest) to process historical and real-time carbon emission data, predict future trends, and support campus decision-making for emission reduction.

2 System Design

2.1 Block Diagram

The following block diagram illustrates the overall system architecture, highlighting the interactions between the four main subsystems: Green Energy, Interactive Control, Carbon Emission Visualization, and Data Analysis and Prediction.

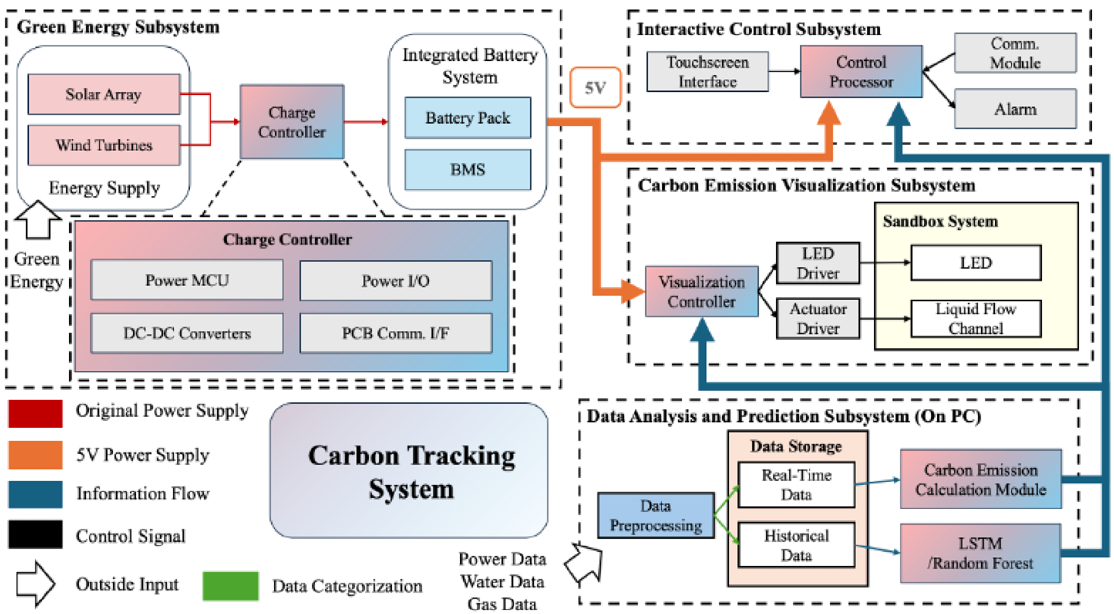

Figure 3: Block Diagram of the Carbon Tracking and Visualization System.

2.2 Block Descriptions – Functionality and Requirements of Each Component

2.2.1 System Summary

The system is designed for carbon tracking and visualization. It integrates renewable energy sources (solar and wind), manages energy storage, provides a user interface for control and monitoring, visualizes carbon emissions on a physical model, and performs data analysis and prediction. The system is divided into four main subsystems:

- **Green Energy Subsystem:** Generates renewable energy using solar panels and wind turbines, regulates power flow, and stores energy in a battery system.
- **Interactive Control Subsystem:** Provides a touchscreen interface for users to interact with the system and manage its operations.
- **Carbon Emission Visualization Subsystem:** Displays real-time carbon emissions on a physical sandbox model with dynamic elements such as LEDs and actuators.

- **Data Analysis and Prediction Subsystem:** Processes data, calculates carbon emissions, and predicts future trends using machine learning models.

2.2.2 Green Energy Subsystem Components

1. Solar Array

- **Function:** Converts sunlight into electrical energy.
- **Connections:** Output connects to the Charge Controller.
- **Contribution:** Provides a primary source of renewable energy.
- **Requirements:**
  - Peak Power Output: 5kW.
  - Output Voltage: 24V DC.
  - Operating Temperature Range: -40°C to +85°C.
  - Efficiency: ¿18

2. Wind Turbines

- **Function:** Converts wind energy into electrical energy.
- **Connections:** Output connects to the Charge Controller.
- **Contribution:** Provides a secondary source of renewable energy.
- **Requirements:**
  - Combined Peak Power Output: 2kW.
  - Output Voltage: 24V DC.
  - Cut-in Wind Speed: 3 m/s.
  - Rated Wind Speed: 12 m/s.
  - Survival Wind Speed: 50 m/s.

3. Charge Controller

- **Function:** Regulates the flow of energy from the solar array and wind turbines to the battery system and the load.
- **Connections:** Inputs from Solar Array and Wind Turbines; Output to Battery Pack and 5V power supply line.
- **Contribution:** Ensures efficient and safe charging of the battery and provides power to the system.
- **Requirements:**

- Input Voltage Range: 18V - 30V DC.
- Output Voltage: 24V DC.
- Maximum Current: 50A.
- Efficiency: ¿95
- MPPT (Maximum Power Point Tracking) capability.

4. Integrated Battery System

- **Function:** Stores energy generated by the renewable sources.
- **Connections:** Input from Charge Controller; Output to 5V power supply line.
- **Contribution:** Provides backup power and stabilizes the system's energy supply.
- **Requirements:**
  - Capacity: 10kWh.
  - Voltage: 24V DC.
  - Technology: Lithium-ion.
  - Cycle Life: ¿2000 cycles.

2.2.3 Interactive Control Subsystem Components

1. Touchscreen Interface

- **Function:** Provides a graphical user interface for system interaction.
- **Connections:** Connected to the Control Processor.
- **Contribution:** Enables user input and displays system information.
- **Requirements:**
  - Size: 7-inch diagonal.
  - Resolution: 800x480 pixels.
  - Touch Response Time: ¡100ms.

2. Control Processor

- **Function:** Processes user commands, manages system data, and controls other subsystems.
- **Connections:** Connected to Touchscreen Interface, Comm. Module, Alarm, and the communication bus (to other subsystems).
- **Contribution:** Provides the central control and processing for the system.

- **Requirements:**
  - Clock Speed: 500MHz.
  - RAM: 256MB.
  - Flash Memory: 1GB.

2.2.4 Carbon Emission Visualization Subsystem Components

1. Visualization Controller

- **Function:** Processes data and controls the visual display components.
- **Connections:** Receives data from the Data Analysis and Prediction Subsystem; Connected to LED Driver and Actuator Driver.
- **Contribution:** Translates data into visual representations.

2. Sandbox System

- **Function:** Physical model to visualize the data.
- **Connections:** Connected to the Visualization Controller.
- **Contribution:** Provides a tangible and intuitive representation of carbon emissions.

2.3 Risk Analysis

This section identifies the block or interface posing the greatest difficulty or risk to implement, justifies the choice, defines acceptable tolerances, and relates it back to high-level requirements.

2.3.1 Highest Risk Component: LSTM/Random Forest (within Data Analysis and Prediction Subsystem)

1. Justification: The LSTM/Random Forest component presents the highest risk due to several factors:

- **Data Dependency:** The accuracy and reliability of the prediction models are heavily dependent on the quality, quantity, and consistency of the input data (historical power, water, gas usage, and potentially weather data). Inconsistent data, missing values, or unexpected changes in usage patterns can significantly degrade prediction accuracy. Obtaining and maintaining a high-quality dataset over the long term is a challenge.
- **Model Complexity:** LSTM and Random Forest models are complex machine learning algorithms. Tuning these models (selecting appropriate hyperparameters, network architecture for LSTM, number of trees for Random Forest, etc.) requires significant expertise and experimentation. There's a risk of overfitting (the model per-

forms well on training data but poorly on new data) or underfitting (the model is too simple to capture the underlying patterns).

- **Computational Resources:** Training and running these models, especially LSTMs, can be computationally intensive, requiring significant processing power and memory, particularly for large datasets and complex models. This could lead to performance bottlenecks or increased infrastructure costs.
- **Real-world Variability:** Predicting real-world phenomena like energy consumption and carbon emissions is inherently challenging due to the influence of numerous unpredictable factors (human behavior, equipment failures, unexpected events). The model's accuracy may degrade over time as these factors change.
- **Integration Complexity:** The model needs to seamlessly integrate with the rest of the system. Data needs to flow in real-time, predictions need to be made quickly, and the output needs to be used by other components.

2. Acceptable Tolerances: The following acceptable tolerances have been defined to mitigate risks and ensure system functionality:

- **Prediction Accuracy:** While the target is ¿90
- **Prediction Latency:** The model should generate predictions within a reasonable timeframe. An acceptable tolerance is ¡1 second from receiving the latest input data to producing a prediction. Longer latencies would hinder real-time monitoring and control.
- **Model Training Time:** While weekly retraining is desired, an acceptable tolerance would be retraining every two weeks. Less frequent retraining could lead to a gradual decline in accuracy as usage patterns change.
- **Data Input Frequency Deviation:** The system is designed for 1Hz data input. A tolerance of ±0.1Hz is acceptable, meaning data input rates between 0.9Hz and 1.1Hz are permissible. Larger deviations could disrupt the model's performance.

3. Relation to High-Level Requirements: The risks associated with the LSTM/Random Forest component directly relate to the system's high-level requirements:

- **Overall System Goal:** The system aims to provide accurate carbon tracking and visualization, enabling informed decisions about energy usage and sustainability. Inaccurate or delayed predictions from the LSTM/Random Forest component directly undermine this goal.
- **Data Analysis and Prediction Subsystem Requirement:** This subsystem is explicitly required to perform predictions with high accuracy. The LSTM/Random Forest component is the core of this functionality.
- **Interactive Control Subsystem Requirement:** The Control Processor relies on the predictions to potentially adjust system parameters or trigger alarms. Inaccurate

predictions could lead to incorrect control actions.

- **Carbon Emission Visualization Subsystem Requirement:** The Visualization Controller uses the predictions to update the display. Inaccurate predictions would result in a misleading visualization.

3 Ethics & Safety

Ensuring ethical considerations and safety measures are integral to the success of our project. This section outlines the ethical codes adhered to and the safety concerns addressed during the project development.

3.1 Ethical Considerations

- **Adherence to Ethical Standards:** The project follows relevant ethics codes, such as the IEEE Code of Ethics, to maintain integrity, transparency, and responsibility throughout all stages of development.
- **Data Privacy and Confidentiality:** Data privacy and confidentiality are prioritized, ensuring compliance with regulations such as GDPR, HIPAA, or other relevant standards. Sensitive user data is handled with care, and measures are implemented to secure data storage and processing.
- **Fairness and Inclusivity:** The project team is committed to fair and unbiased decision-making, avoiding conflicts of interest, and ensuring inclusivity in system design and implementation. Accessibility features and diverse user needs are considered to promote equitable usage.

3.2 Safety Considerations

- **Risk Minimization:** All components and processes are designed to minimize risks to users, operators, and the environment. The system's physical and digital elements are evaluated to ensure they meet safety standards.
- **Risk Assessments:** Risk assessments are conducted at each stage of development to identify potential hazards and implement mitigation strategies. This includes reviewing the functionality of hardware components, software reliability, and integration processes.
- **Compliance with Safety Standards:** Compliance with industry safety standards and guidelines is ensured to prevent accidents and ensure long-term reliability. Standards such as ISO 26262 (functional safety) or other relevant regulations are referenced to guide system design and validation.

3.3 Summary

By addressing these ethical and safety aspects, the project aims to deliver a responsible and secure solution that aligns with professional, regulatory, and societal expectations. Ethical adherence and safety measures not only enhance the project's trustworthiness but also safeguard users and stakeholders, ensuring its long-term success.