Weather Adaptive Windows
(Originally FA17 #27 and FA19#22)

Kaiwen Zhao
Canlin Zhang
Yihao Deng

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TA: Yichi Zhang

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1. Introduction

1.1 Objective

Opening and closing windows may seem to be a trivial job in our daily life. However, if people forget to adjust the position of windows in some events like storms, it could lead to serious damage to their properties by flooding.

In this case, if the windows can function automatically, it would mitigate the risk of flooding by closing up before storming. Moreover, it would be very convenient and comfortable for customers if the windows can adjust position themselves to regulate the room temperature by allowing a certain amount of breeze to enter the room. This would come in handy when people are sleeping at night. As being integral to the smart-home technology, windows also need to be developed in a way that it will work in a Wi-Fi network.

Therefore, we propose a weather-adaptive window that is able to communicate wirelessly and automatically with APIs online by using weather data and with users, and make adjustments itself accordingly.

1.2 Background

We are living in an era that every piece of furniture is starting to be redesigned into IOT devices with some extent of automation and ability to be connected with the IOT network. The idea to integrate windows and shades with some level of automation is clearly not an exotic idea given that many people now have the enthusiasm to make everything automated. There is also a report showing that automation of windows would have a market worth millions of dollars[1]. Nevertheless, there are only a few solutions for automated windows while all the components needed could be found on the market for reasonable cost. Therefore, we would like to design our own solution for an automated window and shade system.

1.2.1 Difference from the Past Project

- The past project implemented sensors for detection of the ambient environment, which may provide incorrect data due to sensor failure and are very costly. Our design would just fetch weather data over APIs online and decide the opening angle of the window based on the weather data. Current weather data has been increasingly accurate, and for telling the current weather in a neighborhood, these weather data will suffice.
- The window also contains an automated blind limiting sunlight passing the window (which is a different type from the past project).

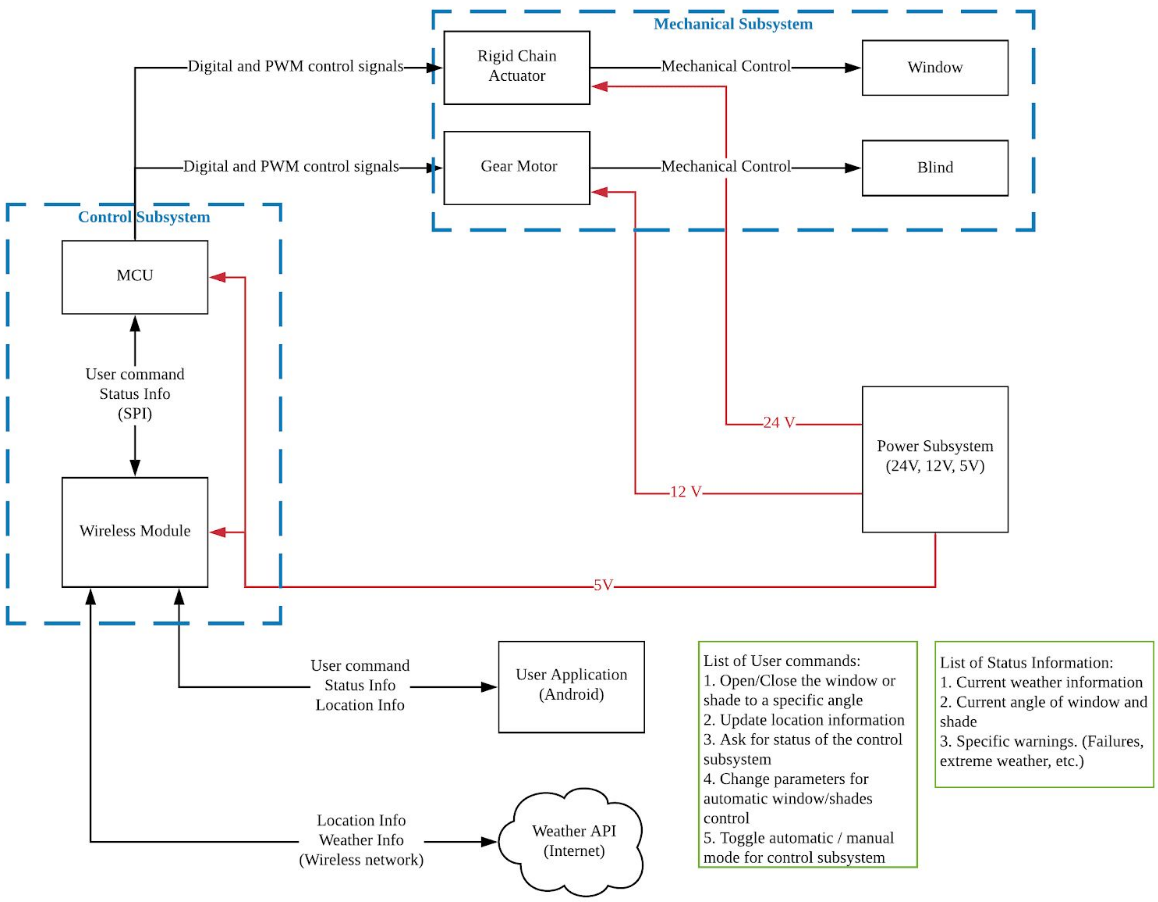
1.3 High-level Requirement List

- The control subsystem can correctly fetch local weather data from the Internet and process the data into according commands.

- The user can view the status of the window and control the angle of the window as well as the angle of shade slats from an Android application.
- The window can open/close to specific angles and the shade slats can adjust to angles according to local weather data from the Internet based on the user's location.

2. Design

2.1 Block Diagram



2.2 Control Subsystem

The control subsystem is an MCU board and a wireless network module that controls the mechanical subsystem and communicates with the user application (mentioned in the next sub-chapter).

The control subsystem accepts and processes user inputs from the user application, gathers weather data through the Internet and sends corresponding control signals to the mechanical subsystem.

The MCU should have enough performance to process data packets and send control signals to the mechanical subsystem. The MCU should also contain I2C and SPI interfaces. Therefore, we thought PIC32 would be a good microcontroller to consider. [2]
For the wireless network module, it should be using 802.11 b/g/n protocol, since these are the common protocols used by home wireless networks. In this case, we thought ESP8266 would be a good module for this purpose. [3]

2.2.1 Microcontroller board (MCU)

The role of the MCU is three-fold.
First, the MCU controls the mechanical subsystem using PWM and digital signals.
Second, the MCU communicates with the user application using a wireless network.
Third, the MCU gathers weather information through a wireless network (from the Internet) and processes the weather information to generate control signals for the mechanical subsystem.

Requirement 1: The MCU must be able to precisely control the open/close of the window and shades: The MCU must be able to control the open/close of the window and shades to a specific angle either from calculation of weather data or user commands.
Requirement 2: The MCU must be able to report status information to the user application and accept user commands from the user application. Status information contains current weather data and the current angle of the window and shades.
Requirement 3: The MCU must be able to gather weather data, including wind, temperature and humidity, from the Internet based on the location provided by the user.

2.2.2 Wireless network module

The role of the wireless network module is connecting the control subsystem with the user's Android phone and the Internet. This will allow users to enter commands and provide essential information for the control subsystem, also this will enable the control subsystem to fetch weather data from the Internet.

Requirement 1: The wireless module must be able to connect to a wireless network using 802.11 b/g/n protocol.
Requirement 2: The wireless module must be able to connect to the MCU through SPI interface.

2.3 User Application

The user application is an Android application which will connect to the control subsystem using wireless network. (802.11 b/g/n) User can enter information required by the control subsystem and have high-level controls and adjustments to the control subsystem.

2.3.1 Location information

The user application accepts user inputs on the exact location (specified by address) of the window and shades. The control subsystem will gather weather data based on location information given by the user and the location it finds based on IP address.

Requirement 1: The user application must be able to accept user inputs of location, containing exact addresses and latitude/longitude information.
Requirement 2: The user application must not keep the user inputs after the current session for information safety.

2.3.2 Full Auto control parameters

The user application allows its user to adjust certain parameters of the control subsystem for fully automated control of the window and shades.

Control parameters include: The maximum angle to which the window can open, the precipitation probability till which the window will stay closed, the temperature threshold till which the window will open or close, etc. This will allow the user to have more fine-grain automated control for the window and shade.

Requirement 1: The user application must be able to accept user inputs, process the data and send these data to the control subsystem.

2.3.3 Manual control mode

The user application allows its user to have full manual control of the mechanical subsystem. The user can open/close the window and shades to specific angles. In this mode, automated control of the window and shades will be disabled.

Requirement 1: The user application must be able to warn the user when the user inputs are beyond the realistic operation range or are potentially dangerous. (Opening windows during hazardous weather, the angle of opening is too large, etc.)

2.3.4 Status report

The user application allows its user to gather the current status of the control subsystem. Status information includes the angle of the window and shades, the weather information gathered by the control subsystem and any potential errors and warnings. This will allow the user to check whether the system is performing expected.

Requirement 1: The user application must be able to gather basic information from the control subsystem through wireless network.

2.4 Power Subsystem

The power subsystem should be able to supply up to 24VDC with a power rating greater than 50W for the power of control module as well as the rigid chain actuator and motor in the mechanical module.

It will be an AC-DC converter that would convert 120VAC at 60 Hz to 24VDC with circuit stepping down to target voltages for all the components.

2.4.1 AC-DC converter

The whole system would be powered by this AC-DC switching power supply with a voltage of 24VDC. Meanwell LRS-100-24 would be a good selection.

Requirement: The power subsystem must provide >50W power between 22.8V - 25.2V.

2.4.2 DC-DC converters circuit

This circuit would be composed of several DC-DC circuits stepping down from 24VDC to 12VDC for motor in motorized blind and to 5V for microcontroller and wifi modules. 24VDC would directly supply a rigid chain actuator to operate.

Requirement 1: The power subsystem must provide > 24W at 24VDC.
Requirement 2: The power subsystem must provide > 15.6W at 12VDC.
Requirement 3: The power subsystem must provide > 5W at 5VDC.

2.5 Mechanical Subsystem

The mechanical subsystem would include a top hinged window and a rigid chain actuator to push and pull it. It would also contain a blind with a motor controlling the angle of the slats.

2.5.1 Top hinged window

This is the window to be controlled. It would be a top hinged window.

Requirement 1: The window can be opened by a force smaller than 350N

2.5.2 Rigid chain actuator

The rigid chain actuator is used to push and pull the top hinged window to the desired position determined by the control subsystem and user application. The choice for now is Liwin 350N 24V Electric Window Opener

Requirement 1: Provide 350N with a stroke of more than 400mm.

2.5.3 Motorized blind

The motorized blind would be a regular blind installed with a DC gear motor running at 12V to control the angle of the slats.

Requirement: The motor would provide torque greater than 0.05N-m assume all the slats sum up to 100g and the pitch of the motor is 5mm.

2.6 Risk Analysis

The Wi-Fi network module is critical to this project. This is one of the fundamental changes and improvements to the existing projects. As a replacement of all sensors in the existing projects, it has to at least fulfill the responsibility of temperature and humidity sensors. In order to achieve this, this module has to be able to receive and transmit signals within the common 2.4GHz 802.11b/g/n band.

After knowing the particular frequencies we will be working with, we need to consider the frequency response of the WiFi module with three factors. Depending on the orientation, directivity, and distance from the user, we will select a Wi-Fi module that is able to receive and transmit signals within 100 ft from all directions, and have a PCB layout accommodated with the Wi-Fi module to have the strongest communication signals.

3. Ethics and Safety

There are few safety concerns in our project.

The first one is the power conversion safety issue. The AC-DC converter has an overvoltage CAT III rating which needs to be handled carefully. The power supply with power rating of 100W and 24V falls under the Class 2 of NEC standard, requiring considerations including the location, humidity and being properly grounded[5].

The second concern is the malfunction of the mechanical subsystem. This can happen due to the power shutdown inside the building. However, this event is likely caused by a storm or hurricane, and which will be predicated by the online weather data. So the control system will make decisions ahead of time and close the window to prevent flooding.

The third concern is information safety. For the control subsystem to process weather data, location information is needed. The user enters the location information into the user application, and location information is sent to the control subsystem through wireless network.

The location information contains the exact address of the user, traceable to the exact street name, zip code, city and state, and the longitude/latitude information. This is sensitive information which, if fetched by attackers, might be used for malicious purposes.

To ensure information safety, the source of information must be secure, and the life-time of sensitive information should be kept as short as possible. The user application will delete the location information right after it is sent to the control subsystem, and the location information will be gathered from Android location services API, which provides adequate security. [4]

Since our design will avoid all the sensors in existing projects, there will be no short circuit caused by exposing any sensor outside the window. With the change of the design and the disclosure of any safety issues stated above, we therefore uphold the IEEE Code of Ethics #1[6].

4. References

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