Smart blind control system

Solution definition

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# Overview

Customer’s interior blind is installed on the inside of a window and creates an insulation buffer between the glass and the fabric on the blind. The blind fully seals the window, so is very good for insulation. It is necessary to develop a product that helps people conserve energy at home and in high offices/apartments by intelligently and automatically closing to keep the house cool in summer or opening to warm the house in winter.

Currently use for interior blinds:

* 240VAC tubular motors with wireless remote (radio, not Infrared)
* 240VAC tubular motors with hardwired switches
* Solar tubular Motors with an integrated 12V DC motor, wireless receive and battery, combined with a solar panel and wireless remote.
* Manual spring balanced operation

Would like to develop a motor system or an interface to the motor with some intelligence:

1. Detect temperature differences between the outside and the inside of the home.
2. When the temperature outside is high and the temperature inside is increasing then lower the blinds to restrict the temperature increase.
3. When the temperature outside is cool but the sun shining and the blinds are closed, then open the blinds to try and warm the house.
4. Ensure that this only happens when there is nobody in the house (motion detection). If motion is detected (people are in the room, allow the blinds to return to an open position (potentially the last position?).
5. Create an alert (e.g. soft beep) when the blind will actually do something on its own and set a configurable timer for the actual event to occur after the alert
6. Detect sun glare and lower blinds as required. (Please investigate how it can be possible to detect glare at the correct angle for the sun ie there is glare from lunch time until the evening, but only when the sun is low do we want to lower the blinds – more thought required here how this can be achieved/setup/configured?)
7. Allow connection to the blinds for users to control setup and settings (app development, website?).
8. Collect data about the use of the blind and send back to servers.
9. Allow central control of many blinds (office buildings, high rise apartments, etc.) Setting up of group control etc…
10. Check battery health and solar panel on the DC motors.
11. Set open and close timers
12. Most if not all of this should be configurable at setup of the system by the consumer/installer.

# System architecture

Blind control system should be logically organized as set of installations (or users). Each installation contains one or more rooms where motorized blinds are installed. Each room has dedicated room controller (RC), set of sensors and blind motor controllers.

Proposed smart blind control system should contain following components:

1. Room controller
2. Sensors
3. Motor controllers
4. Control server
5. Configuration database
6. Web server

Further, these components are described in detail. Figure below shows how these components are tied together.



Figure 1. Smart blind control system design

## Room controller

Purpose of room controller is to coordinate various sensors and change blind position when some conditions are met.

It is proposed to use OEM board with embedded microcontroller and Wi-Fi module, such as Raspberry Pi 3, to reduce the hardware cost and development time.

During the installation procedure, authorized personnel assigns user credentials to the room controller. These values are used to connect to the configuration database.

Room controller periodically connects to the control server and queries for blind control rules from the configuration database for the specified installation and room.



Figure 2. Room controller design

User inside the room should be able to connect to room controller via standard web browser. Web page with current status of the room sensors should be displayed. It also should be possible to control the blinds via the room status page by pressing buttons “Open blinds” and “Close blinds”.

Every action, manual or automatic, with the blinds should be logged at the control server. Log information should include timestamp, room name, rule name, action and sensor values at the moment of action.

Later Android/IOS application could be developed to allow more comfortable control from the mobile phones.

For the security reasons, room controller should not accept incoming requests from the devices outside the client’s internal network by setting up firewall rules.

## Hardware sensors

Sensors are used to control various physical parameters that can be used in control rules. Sensors are connected to the room controller by wire. (for this trial…no problem. Not sure though that the room controller is always going to be the best spot for the sensors especially if they are wired. The sensors can potentially be on the motor controller up on the blind?)

There are no technical restrictions to have wireless sensors. We can add support for them in the later stages.

Following sensors are necessary:

1. Inner temperature sensor
2. Outer temperature sensor
3. Motion detector
4. Light sensor

In addition to hardware sensors, special “virtual” sensor for the time of the day should be added to support scheduling actions at the specified time.

## Motor controller

There are two ways to control motorized blinds:

1. Remote control simulation
2. Use dedicated motor controller

Remote simulation should use IR or radio transmitter connected to room controller to simulate motor’s remote control buttons. It is simple, non-invasive way to control the blinds, but requires knowledge about communication protocol between remote control and motor.

Another way is to develop special motor controller that is physically connected to the motor and receives commands from room controller via Wi-Fi network (what sort of setup for the consumer/installer would this require? I like the idea though. How many blinds/motors can be connected to one room controller and how will this be configured/auto found?) or wired connection.

Typical setup procedure for wireless devices goes like this:

1. Service person presses button on the wireless device to enter setup mode
2. Device establishes temporary WiFi access point with known name
3. Service person connects to this AP, run configuration application and enter name/password for client’s WiFi network and room controller’s network name
4. Configuration application sends entered values to the device
5. Device use received parameters to connect to the client’s WiFi network

Number of devices that could be connected to the room controller are limited by RC’s resources, that are big enough to support dozens of connections. It is also possible to use broadcast messages that don’t require connection between wireless devices and room controller.

After receiving the command, it generates control signals for the motor to open or close the blind. This way requires intrusion into motor hardware.

Decision about the how the implementation should be done will be made after information about motor is received from supplier.

## Control server

Control server is used to process incoming connections from room controller. When connection request is received, it should perform the following actions:

* Checks SSL certificate to avoid unauthorized connections
* Receives user credentials from room controller
* Reads set of rules for specified room from the configuration database
* Send rules back to room controller
* Log information about connection

Control server should also log all information about performed actions received from room controllers and store it in the configuration database.

I have been thinking about this control server. This is something that we would have to maintain for a long time without any assurance that people are using this. I would like to think about this a little more. I guess we can store the rules on the room controller? (well for this prototype I expect you are doing this?) I guess you want to avoid having people access these room controllers from outside. If we make it without internet connection, it will be easier I guess.

Yes, the main reason I added the control server to the system is a security concerns. I am really afraid that giving access from internet to the room controller is a potential security threat. Also, it is a way to operate blinds from the one place. This will be helpful for installations with many rooms. As for the prototype, there is no need for the control server. All rules will be stored directly in the room controller. So, there is time to think and discuss.

## Configuration database

Configuration database should be part of the user’s profile. It is used to store blind control rules and additional information about installation. New database user should be created for each installation. Login and password should be stored into each room controller during installation procedure.

Note that room controllers shouldn’t have direct access to the configuration database. The only way to obtain the information is a request to the control server.

Configuration database may be installed on the control server, web server or dedicated server.



Figure 3. Configuration database schema

Blind control rules are created from one or more conditions and actions. Typical rule may look like this:

IF InnerTemperature > 20°C AND Light > 10000 THEN CloseBlind

Depending on the sensitivity of the light detector and I guess the location, a partial lowering of the blind may make sense. There may need to be a light sensor at the bottom of the blind and the top for this to work well? I am looking for an intelligent system.

I propose to use a sensor like this:

<http://www.vishay.com/docs/84323/designingveml7700.pdf>

It measures the ambient light illumination and works in a wide range, from moonlight to direct sunlight. Of course, it can produce slightly different measurement results, depending on the installation place. However, you can compensate this by adjusting compare values for in the rule editor.

Also, you can add special rules from the partial lowering.

## Web server

Users can define their control rules via dedicated web page in their private profile. Web interface should allow users to create any number of rules. Typical page may look like this:



Figure 4. Web interface, selecting rules

There user can activate or deactivate rules for the specific room. User should be able to select from predefined rules or create its own (or modify existing ones). Rule definition interface may look like this:



Figure 5. Web interface, create new rule

When creating rule definition, user should be able to add check of one or more sensors, compare it with some value and choose action to perform when conditions are met.

# Technical requirements

## Room controller

* Power supply: +5V 2A, DC
* Network: Ethernet and Wi-Fi
* Administration interface: Web server
* LED indication: Power (green), connection status (red/green)
* Sound indication: Beeper

## Sensors

### Temperature sensors

* Temperature range: 0…50°C
* Measurement accuracy: 2%
* Maximum wire range: 5m

### Light sensor

* Sensitivity: 0…83k Lux
* Dynamic range: 23 bit

### Motion detector

* Maximum range: 7m (ok for prototype)
* Angle Sensor: 110°

## Motor controller

* Control functions: ???
* Power supply: ???
* Motor type: ???

TBD after Marc sends me information about motors – will send you a motor. I will send as much info about the test motor before sending it.

## Control server

* Maximum incoming connections: 1000

## Web server

Current customer’s WordPress infrastructure should be used as a web server.

Configuration database and web pages for rules administration should be added.

# Communication channels

There should be two kinds of communication channels: internal and external. I am looking to make this as simple as possible for consumers (in the final product – prototype is different). I understand that security needs to be taken into consideration – this could be taken care of by using a physical button to establish initial connection to avoid username/passwords etc…

I described setup procedure in the motor controller description. Login/password will be send to the device once during setup procedure.

## Internal channel

Internal channel is used for communication between various devices inside client’s network. For example, room controller can operate motor controller via Wi-Fi (Direct wifi or on client’s wifi network- setup? What about using bluetooth LE or ANT+? – doesn’t require any setup?) connection or client can access the status page via http channel between mobile phone and room controller.

I propose to use client’s WiFi network. Other technologies are also possible, but will require additional hardware and software development. There are protocols like ZigBee or Z-wave that are designed for this purpose, but my meaning is that they are too advanced for your purpose.

This channel shouldn’t have any security restrictions. It is supposed that anybody who have access to the client’s network, can operate the blinds. How is the room controller connected to the client’s wifi?

During installation procedure, service person connects room controller via wired network cable and uses configuration application to send client’s WiFi network name/login to the room controller.

It is possible however to restrict access to the room controller and/or other components of blind control system via network management policy (by creating restricted ‘guest’ account, etc.)

## External channel

External channel is used to access the blind control system from outer world. For the security reasons, number of external communication channels should be restricted.

Because of aforementioned, only one communication channel, from room controller to the control server, should be used. (not important at this stage, but I don’t understand how the connection will be made between room controller of a customer and their account).

Room controller connects to the control server and sends all information that is required to query data from customer account (user name, password, room id). Control server use this information to login into customer’s account.

Room controller should periodically poll control server for a changing in control rules. When change is detected, room controller reloads active rules for its room. Poll interval could be configured via configuration web page on the room controller.

Firewall rules should prohibit incoming connections from the devices outside client’s network to the room controller. If necessary, VPN connection could be used to connect to the internal network.

# Security

There are two levels of security restrictions are used: communication channel security and user level security.

## Communication channel security

Communication channel between room controller and control server should be protected by using secure communication protocols, such as SSL or TLS. Each room controller should have digital certificate that is verified by control server when connection is established.

Devices without valid certificate shouldn’t be able to connect to the control server.

Secure communication channel guarantees that user credentials cannot be intercepted by listening network traffic.

Also internal communication channels?

No. But design of the system guarantees that no secret information is sent via internal communication channel.

## User level security

Each client who uses the blind control system should have a private profile protected by login/password. These credentials are used to restrict access to web server and configuration database.

Login and password should be stored in the room controller during installation procedure. They are transferred later to the control server to grant access to the configuration database.

# Development process

To have control over development process, it is proposed to split it into stages, with milestones in between. After each stage a meeting with a customer should be planned to confirm that development goes in a right way.

Any significant improvements, modifications or new functionality that aren’t mentioned in this document (solar batteries support, phone application, etc.), should be done only after all three stages are complete.

## Stage 1. Proof of concept

The first stage should include minimal set of modules required for demonstration:

* Room controller with power supply
* All kinds of sensors
* Motor controller

No control server is required, rules are defined directly in the room controller via web interface. This configuration should allow to make a presentation where the customer can see the way how the system will work. Customer should be able to check the status of the room sensors, play with the rules, see how the blinds are operated. Yes. As quick and basic as possible!

No specific PCBs/mechanical parts are necessary on this stage.

Customer should provide working sample of blind motor and, if possible, remote control for it.

## Stage 2. Prototype

When customer approves the concept from stage 1, the next stage should focus on the construction.

Sensors should be mounted on the PCBs and put inside the case suitable for the outdoor disposition.

Room controller should have a housing with connectors where sensors and power supply can be easily plugged in.

Customer should organize a place where typical installation can be done. Installation process should be tested and verified.

I would also like to review the requirements with regards to controllers, sensors and the overall concept with regards to the interaction by consumers/installers of the product. We cannot make it too complicated for people to install and use.

I can describe installation procedure now, but I think it’s too early. I planned to do it after first stage is finished. I understand your concerns and will try to make the setup procedure as simple as possible.

## Stage 3. Serial sample

This is the final stage where ready-to-production set is produced. All prototyped parts should be replaced to their serial analogs. Full integration with customer’s web infrastructure should be performed.

Instruction for service person should be provided where installation of all components is described in details.

Customer should provide the hardware for control server installation.

# Comments

Things to think of for later:

How to power motor controller

Can sensors be placed on the motor controller instead of the room controller?

Is it a simple system for consumers to self install?

Solar panel addition to charge batter for 12V DC motors and motor controllers

Installation trouble shooting/system status information

Size: Everything (except the room controller) should be as small as possible – especially the motor controller. There is limited space in a blind.