# Light-o-Stat: An Automated Louver System

**Brian Kish**
Carnegie Mellon University
5032 Forbes Avenue
CMU SMC 6633
Pittsburgh, PA 15213

## ABSTRACT

This paper describes an automated louver system prototype that was developed for the "Making Things Interactive" course taught by Mark Gross at Carnegie Mellon University. The project offers an opportunity for architects to manipulate light within a building. A set of mechanized louvers are used to filter daylight that enters a room. Similar to a thermostat where a user is able to specify temperature, the Light-o-stat allows an occupant to set the amount of light they want in their room. The louvers respond to the users request and maintain a consistent level of daylight entering a space.

## INTRODUCTION

Daylight is a wonderful asset to architecture and yet it is always a difficult task for architects to successfully deal with. Many architects devote their entire careers trying to design buildings that sensitively respond to light. Daylight is continually changing throughout the day and the year. It is a dynamic force that our buildings need to respond to and embrace. East and West facades of buildings can get very intense light in the mornings and evenings and this can cause unpleasant conditions inside a building if there is glazing on any of these facades.

The Light-O-Stat system views daylight in a similar fashion as we often treat temperature in a building. The thermostat in a room allows the user to precisely adjust the temperature in a room. Unfortunately, there isn't a similar type of automated technology that allows occupants to adjust the amount of daylight that they desire in a space. This system allows the occupant to choose the amount of daylight that they want and the louvers will continually respond to exterior lighting conditions to keep the interior space at the specified level of light.

## POTENTIAL USES

There are various types of buildings that can be very sensitive to the amount of daylight they require. First, a passive solar house, which aims to maintain thermal comfort throughout the sun's daily and annual cycles whilst reducing the requirement for active heating and cooling systems [1], needs to implement a shading device to maintain a lower temperature in the summer. The strategy of placing a lot of glazing on the Southern exposure of a house allows for solar heat gain during the winter, but can cause negative impacts during the summer, when the house needs to be cooled. Therefore, controllable louvers could be a very important asset. Second, libraries could benefit from lighting control to allow readers the proper amount of light to read a book. Third, museums always need methods to control daylight as to not damage fragile works and to create a proper viewing environment. Last, computer clusters or laboratories need to have proper glare control for users to be able to see their monitors. There are many instances where natural daylight control is needed in buildings.

## RELATED WORK

There are countless architecture projects that address light in the buildings concept. The following projects start to specifically illustrate the issues that are being addressed in the Light-o-Stat.

Jean Nouvel takes the idea of suncreening to another level in his project L'Institut du Monde Arabe in Paris, France [2]. This cultural center houses a library, exhibits, and functions dedicated to the historical relationship between Arab Culture and France. The minimal composition of forms gives way to an elaborate sunscreen on the South facade that consists of 30,000 light-sensitive apertures that are designed to regulate daylight and transparency in the library. This project generated a lot of interest due to its use of 'smart materials' in it building enclosure system. It was designed to help people read in the library, but it not perfectly effective. The changing light conditions were very drastic and not very practical for readers because of a very distinct pattern that the facade cast on the interior space as seem in Figure 1. Furthermore, this project was controlled by a computer and had no user interface for the occupants in the library.

The Technische Universitat Darmstadt team used louvers to regulate interior light and collect solar energy in their first place winning entry to the U.S. Department of Energy's 2007 Solar Decathlon [3]. The 800 square foot house had louvers on the East, South, and West Facades that contained Photovoltaic panels to collect electrical energy. The louvers not only generated electricity, but they also reduced the energy consumption of the house by properly shading the interior spaces during times when the house was in cooling mode. The horizontal louvers were mechanized to be able to move and track the sun throughout the day to gain the most energy possible. They were controlled by a computer within the house and it was programmed for that specific day of the year. The louvers were not able to react and change to actual daylight conditions. The only user interface that existed was the ability of the occupant to move the large panels that housed the louvers to open or close the house as seen in Figure 2.

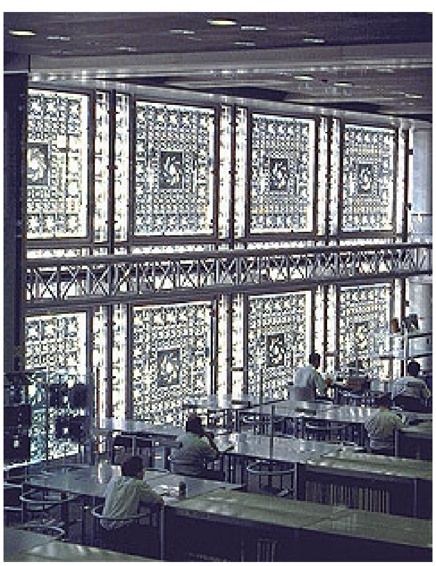

**Figure 1: Interior view of library in L-Institut du Monde Arabe. [1]**

**Figure 2 : Technische Universitat Darmstadt 2007 Solar Decathlon House [2]**

A much different approach to daylight can be seen in the Daylight Museum by Tadao Ando [4]. This museum is completely daylit with no artificial lighting and it closes at dusk every day. Ando was inspired by the artist, whose work the museum was designed for, that was only able to work during the hours the sun was up. The museum deals with light in a purely formal way without any louvers or special surface treatments as seen in Figure 3. However, it once again raises

**Figure 3: Daylight Museum by Tadao Ando [3]**

the question of if a museum should affect the way that art is observed or if it should provide a completely benign environment to experience the art. There is no way for a user to interact or change the intensity of light in the space, but it is experienced differently throughout the day.

Jeffrey Giacomel of Arlington, Texas is the inventor of automatic louvers that respond to heat[5]. The system uses a actuator that uses one memory alloy spring to sense when it is heated above a predetermined temperature. When it becomes overheated, the system automatically closes a set of louvers to help cool the building. This project is very similar to the Light-o-Stat in that the louvers respond to an existing condition, except it is heat instead of light. However, there is not a user interface that is involved and the temperature required to close the louvers is already set when someone purchases the product.

## HOW IT WORKS

The primary feature of the Light-O-Stat is the louvers that are capable of modulating daylight. The louvers are mechanized and are able to move along their longitudinal axis using servos. They would be placed on the exterior of a window. It is more effective to place shading devices on the exterior of a window to allow for more effective cooling in the summer. If the louvers are placed on the inside, like most commercially available venetian blinds, the heat from the sun is already trapped inside the glass and is beginning to add heat to the building.

There is a light sensor (photoresistor) that is placed inside of room that louvers are applied to. This is used to sense the actual light conditions within the space. A dial is located on the louvers to allow the user to set the amount of light they want in their room. The louvers will either open or close to adjust the amount of light in the room to within a specified range of what the user entered with the dial. Once there is the correct amount of light in the room, the louvers will stop moving.

The system also communicates to the user how well it is able to respond to their requests using three LEDs. It glows a blue LED to communicate that the room is still too dark for their requests. It glows a white LED to tell them that room has the correct amount of light that they requested. It glows a blue LED to tell them if the room is still too bright for what they wanted.

## THE MECHANICS BEHIND LIGHT-O-STAT

The design and implementation of the Light-o-Stat happened over a two month period as the final term project of the “Making Things Interactive” course at Carnegie Mellon. The main construction of the project consists of six arcylic louvers that are mounted within a Red Oak wood frame. The louvers have a vertical implementation because this specific version was envisioned to be on a East or West Facade of a building. The dimension of the prototype is 20" high and 24" wide. The mechanical portion of the project is housed within a 4" by 24" area located the bottom of the frame (Figure 4). Each of the louvers are 3" wide by 18" tall and are mounted 3 1/4" on center.

**Figure 4: Exposed back of louvers**

The louvers consist of 1/4" thick acrylic that was cut using a laser cutter. They are mounted to wooden dowels at the top and bottom and pivot within holes that are drilled in the frame. Each of the dowels at the bottom of assembly have a 3" diameter spur gear mounted on them (Figure 5). There are no intermediate gears, so the louvers turn opposite of each other. In a future iteration, there would be intermediate gears between all the louvers so they could all turn in the same direction. The six louvers are powered by two HS422 standard deluxe180 degree servos that are mounted to frame with super glue and wood blocks. Each of the servos run off of 5.0v DC power.

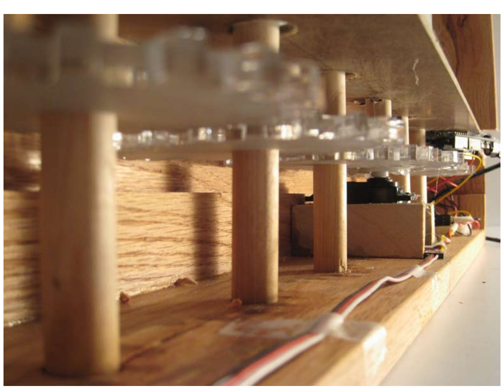

**Figure 5: Laser-cut Gears, 180 degree servo, Arduino Micro controller**

The electrical control in the Light-o-Stat is provided by an Arduino Diecimila that is plugged into a wall outlet with an input of 9.0Vand 0.66A. The Arduino, which is mounted in the bottom assembly with the spur gears, supplies all of the power to the servos.

The sensing of light level is done with a photoresistor that is tethered to the louver assembly. The photoresistor is placed within the room and gives a direct reading to the actual amount of light that the louvers are allowing to enter the space. Currently there is only one photoresistor assembly, but in actual implementation there would be several and the amount of them would vary by the size of the room. The averaging of their values will allow for a more accurate light reading for the entire room.

The user interface consists of three LEDs and a potentiometer as seen in Figure 6. The potentiometer allows the user to enter level of desired light by setting the threshold higher or lower. The three LEDs tell the user what state the project is in.

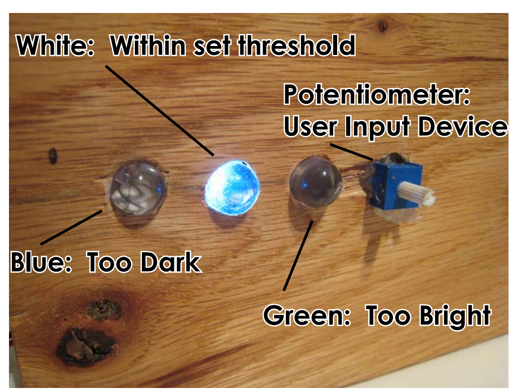


**Figure 6: User Interface of Light-o-Stat**

The programming behind the project uses 3 basic states to inform the system of what to do. This is illustrated in a state diagram in

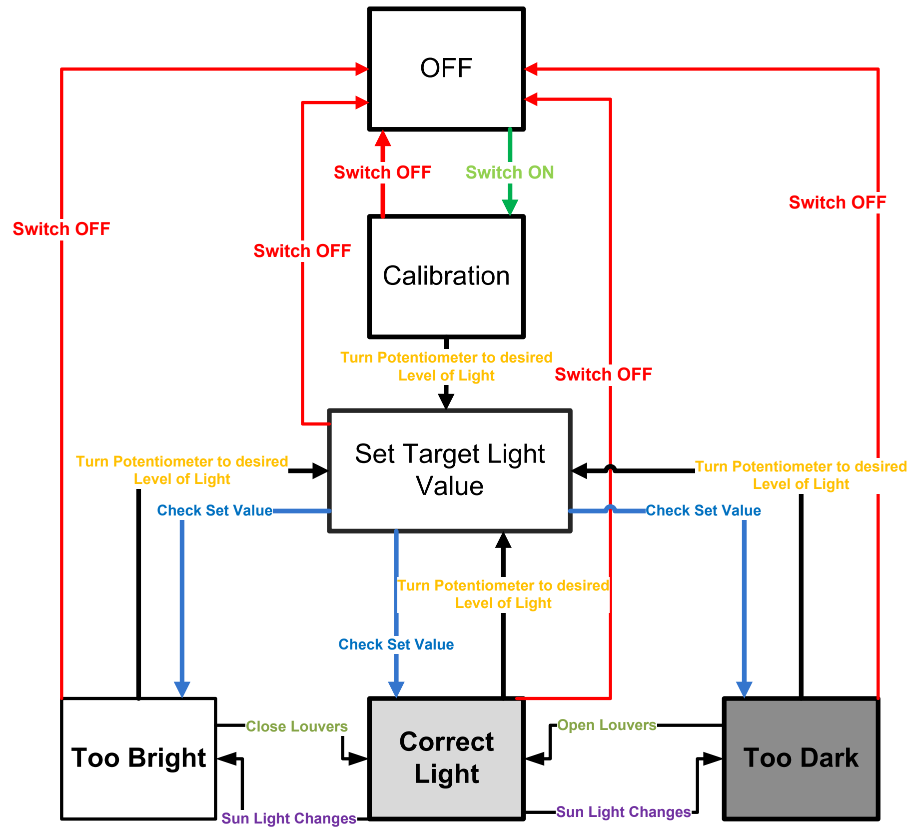


**Figure 7: State Diagram**

Figure 7. The user is able to set what level of light they want using the potentiometer and this gives an input between 0 being bright, and 1024 being dark. If the actual value of light within the room is between -25 or +25 of the user defined value, it will be in the "good" state and the white LED will glow. If the amount of light is too low, greater that +25 of the set value, it will be in the 'too dark' state and the blue LED will glow. If the amount of light is too high, lower than -25 of the set value, it will be in the "too bright" state and the green LED will glow.

The project can switch between these three states in three different ways. First, the user may choose to change their desired level of light to a different value. Second, the amount of sunlight may change due to clouds or other obstructions. Third, the louvers are moving to adjust the light in response to a user request.

The code has a simple response mechanism implemented to assure a constant level of light. It is running a loop that is continually comparing the values of the potentiometer and the photoresistor. There is a 100 millisecond delay implemented to allow the level of light to change and be read by the photoresistor. This helps to reduce static and allow the system to make the right decision that is based off the newly changed level of light. If the value of the photoresistor is not within the threshold set by the potentiometer, it will move the louvers accordingly in attempt to get back to the "good" state. If it is in the "too dark" state, the louvers will open to allow as much light as possible. If it is in the "too bright" state the louvers will incrementally close to allow less light in to try and reach the "good" state again. The state of the louvers could be fully open (figure 8), fully closed (figure 10), or anywhere in between (figure 9).

**Figure 8: Fully Open Louvers**

**Figure 9: Partially Open Louvers**

**Figure 10: Fully Closed Louvers**

## CONCLUSION

The louvers are able to respond to a desired amount of light that the occupant requests by opening and closing the louvers to try and achieve the desired setting. The construction of the louvers was very challenging and in the future it might be worth it to purchase some existing louvers that could be used in an exterior setting. The current prototype is not weatherproof and would benefit from prefabricated components that can withstand the elements.

## FUTURE WORK

There are many possible uses and needs that a louver system like this could respond to. In regards to light, the system could have the capability to better respond to direction of where the light is coming from. If the sun is coming from the left, the louvers respond differently as if it were coming from the right. This would allow for the louvers to directly block the blinding light of the sun and also allow ambient light to enter the space. This was an aspiration for the project but has not yet been realized.

The idea of user preferences can also be taken a step further. Currently, the project addresses the entire room as one space but it could potentially respond to specific spots in the space. For example, in a library where people are reading at different tables and each person prefers a different amount of light. If the entire glazed wall is covered in louvers, the system could figure out which ones need to be moved to directly affect the user that has just changed their light settings.

They are currently only responding to light conditions. However, they could also respond to weather conditions. For example, if the system sensed if it was raining outside it could automatically close the louvers. This would allow occupants to not have worry about closing their windows if they feared that it might rain while they were gone. In hurricane prone areas of the country, heavy duty louvers could be implemented and could sense changes in wind and determine if they should close to protect the windows from flying projectiles.

Another possible use for the louvers is to adjust privacy settings. It is possible that occupants may want privacy but they do not want to give up daylight. The system could then detect motion outside their window and close the louvers whenever someone walks or drives by the building. This could create a very interesting interaction and experience for the passerby.

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