Department of Electrical and Computer Engineering
Howard University

Cornell Cup Submission

Green Lighting

Team members:
Ameer Baker
Chidi Ekeocha
Shamir Saddler
Ravindranath Jaglal
Isaac Collins

Instructor: Charles J. Kim

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Project Summary

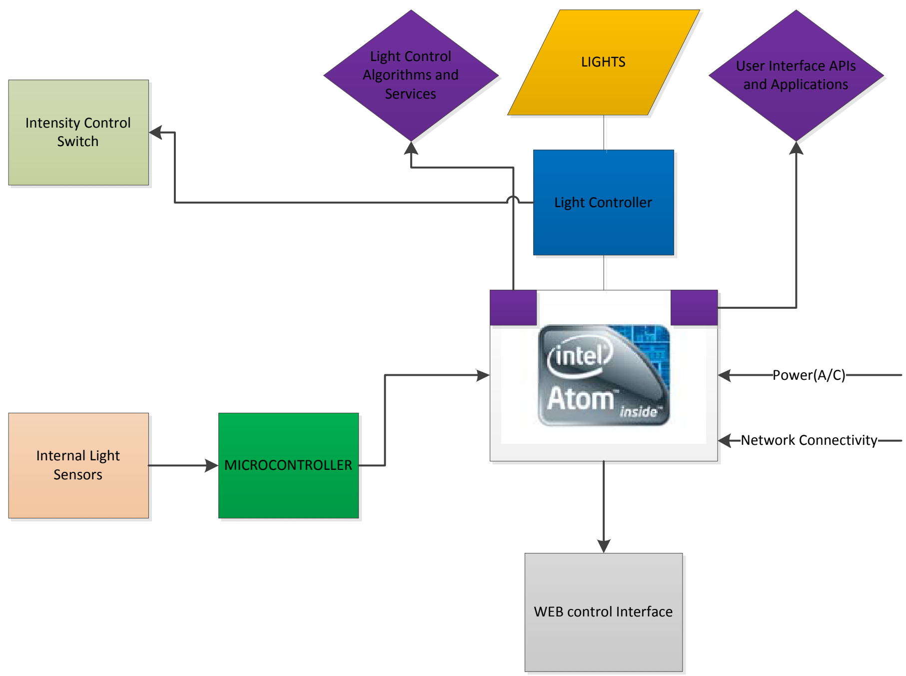
The goal of this Green Lighting project is to implement a system that will enhance the work environment in a given room by regulating the intensity of the lights throughout the day, while minimizing energy costs. This is to address the energy costs associated with maintaining standard or optimal lighting conditions for a workspace. The system will consist of light sensors connected to low-end microcontrollers for each relevant sector of the room which link back to a Tunnel Creek board which will process the data, make decisions as to how the intensity of each light fixture should be varied to maintain lighting standards, or user preference, and command the instruction to the lighting control circuitry. In addition to a physical override circuit, the user will have access to a web interface via which the main system controls for each room can be manipulated, thus making it easier to manage the entire building's lighting from one terminal. The system will allow the users to experience appropriate lighting throughout the course of the day therefore creating a productive and enjoyable working environment while simultaneously saving energy cost for the respective institution. A prototype of this embedded system will be implemented and demonstrated to evaluate its effectiveness in workplace productive and energy cost saving.

Challenge Definition

It is a well known fact that many major college campus buildings and office facilities use an abundance of energy throughout any given workday resulting in high energy cost. In a standard office building or university classroom all the lights in a room tend to be on at maximum efficiency throughout the day when in reality, in a common situation where windows occupy the room, the intensity of the light doesn't need to be as high during the morning hours as it may be in the evening. As a complete solution to this challenge, we propose to solve this issue by implementing a system that can cut consumer power usage and promote a "green" environment by implementing a system that will regulate the light intensity inside the perimeter of a given room, to maintain lighting standards, or user preference in order to create a productive and enjoyable working environment while simultaneously saving energy cost for the respective institution. We feel this will be a worthwhile project to take up after we conducted research on the cost and power consumption of some of the offices on our school campus. We not only plan to demonstrate how we can save energy and reduce power consumption, but also we would like to display how much we can cut a University's operation cost annually by implementing this system in their school buildings. Furthermore we anticipate on this project being so effective that it will confidently set the standard on how university and business facilities regulate power and energy utilization. From a design standpoint, the system should be so discrete that the only people who are aware of its existence are the energy companies and the building maintenance personnel. From an implementation standpoint, the system will be able to read the intensity of light coming into a given room, compare the data to the light sensors inside the room, and fixate the amount of light being distributed throughout the room to maintain a constant level of light in the room without unnecessarily having all the light in the room on at maximum level. Finally from a consumer standpoint, a good solution will cut the respective institutions expense by providing a modest cut in energy bills every month which will add up overtime and within a few years of implementation, save the university thousands of dollars in energy costs. We strongly believe that when you can find ways to save money in operation costs, the advantages trickle down to the buildings frequent occupants. The benefits are endless when you are saving a significant amount of money in energy costs over a short period of time, giving the establishment more flexibility to invest in itself and its surrounding community.

Proposed Solution

The proposed solution to the light efficiency problem will comprise the application of all the available light energy control resources that available today, as mention in the current status of art above i.e. turning of lights, using efficient electric lights, and dimming the lights in the room space. This would be achieved using the sun's energy to complement the room's overall intensity at all times of day. In addition, the overall system would be sensitive enough to respond to the differences in intensity experienced with daytime and nighttime; to area wise differences due to a passing cloud or obstacle; to closing the blinds in one part of the room. The consumers of this system will also be given the power to control the overall light intensity of the room, as well as area wise intensity via control switches locally, and remotely via computer programs on the internet or local area network. The major components and logic required to achieve this feat as mentioned above include;



- Light sensors across the perimeter of the entry points of sunlight to monitor and respond to the intensity of light outside at all times of day. Night time light sources may be strong enough to complement the light intensity of the room, but is not only dependent on the moon's positioning but also on other artificial light sources that may be present outside the building at the time.
- Light sensors across the vertices and edges of the room, or around the major areas of interest of the room/environment. This will yield the ability to maintain a uniform intensity across the room, as well as area wise control of light intensity within the room, by comparing the feeds from both sets of sensors and modifying the power feeds into the lights based on the algorithms we apply.
- Microcontroller kits to interface with the sensor packs (both inside and outside the room) and retrieve all the raw data from the sensors to be processed digitally by the Intel atom processor.

- The Intel processor, which will house a Linux or Windows operating system that will be the base upon which the applications will written to process the incoming data from the USB kits. This will also serve as the web server to host a web interface that can be used to control/model the entire room both locally and from remote locations.
- Base Intensity controller/switch that will provide the ability to control the default intensity of individual sectors in the room, as well as the default intensity of the entire room as a whole.

Scenario Considerations

In addition to the manual control of the area wise light intensity in the room, some of the scenarios that were considered for the passive response of this light energy/efficiency control system include;

- **Response to Clouds passing by the air space of the building at every giving point in time:**
  Clouds are natural sources of shades that could affect the influence of outside light from the sun in a room. The system will respond by increasing and/or decreasing the light intensity based on the dynamics of the clouds as picked up by the sensors at the time. Depending the on the size of the room, the cloud may only cast a shadow on some part of the room, or may be large enough to cast a shadow that covers the area of the room.

- **Response to Daytime/Nighttime transition:**
  Obviously, we get most of our sunlight during the day, and the least during the night. This transition between day and night is also not instantaneous. As noon approaches, the environment gets lit up more by the sun, and dims down as nighttime approaches. The exact times of day when the intensity of light outside is at its maximum, rate of change of light and darkness also varies all year round based on the earth's position in it revolutionary orbit. Across the progression of a day, the room will respond accordingly to the slow change (increase, and decrease) of the exterior light intensity at all times.

- **Response to miscellaneous obstacles interfering with the exterior light intensity:**
  Anything can cast a shadow on any given area at any point in time. The system should respond by increasing the affected areas accordingly.

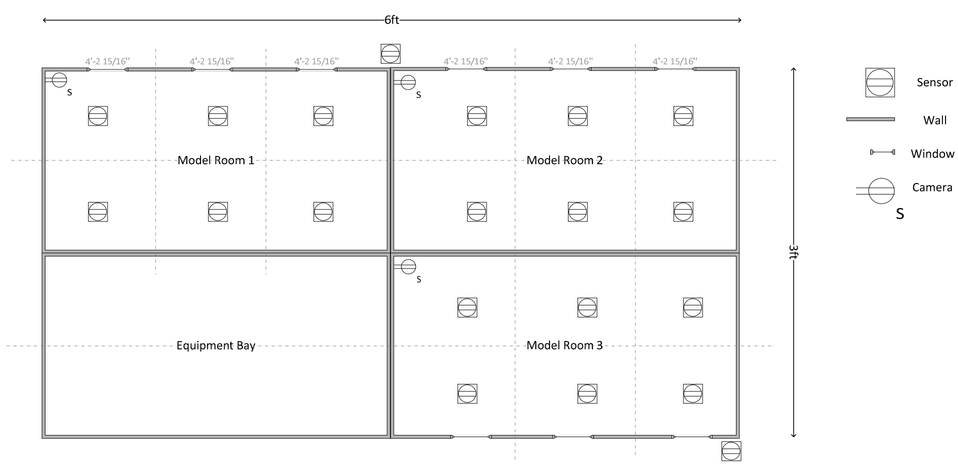
- **Response to closing windows/blinds;**
  The consumer will still have the ability of restricting vision into the room, or whatever reason one will have for closing the windows, without affecting the intensity of light in the room or the affected area at the time.
- **Response to physical interactions with the sensors.**
  The sensors have to be in positions where they could be obstructed by individuals. To avoid errors in the received data, the sensors will be programmed to distinguish between actually shade, and physical obstructions.

Alternative Designs/Future Modifications

As with every engineering design or problem there are always upgrades that can be made to the proposed solution. Some of these modifications will come as a result of the data acquired from the conducted test. In order to leverage the power of the Intel board, applications can be written to monitor other devices within the room using smart meters to check and report their power consumption. Since the consumer could control literally everything about his lights, he could as well have control over the other appliances in the room. Also, the design or arrangement of the light sensors may vary primarily due the size and shape of the room, as well as the positioning of the windows in the room. Finally the visual presentation of the data and control can also be extended to Mobile applications to give the consumer more flexibility with control.

Demonstration at Intel-Cornell Cup

We plan to make a prototype office ranging between 4 - 5 feet long, 3 to 4 feet wide, and 3 to 4 feet high. Through this model we will demonstrate the impact outside light have on the light intensity present inside the prototype office. We will make sure that the light varies accordingly and that it can be controlled by a web interface and system settings changed based on whatever needed. The model will comprise 4 compartments, 3 of which will contain the lighting and the sensors; the last compartment will hold the Intel board and other peripheral devices that will be used for the demonstration. In addition the compartments will be detachable, to allow to portability of the demo considering its size. Miniature cameras may be used to observe the physical occurrences in the compartments.



Model drawing

Performance measures

We begin the evaluation of this project by first creating a test room containing 'n' amounts of light fixtures which produce a fixed amount of light intensity based on the power being fed through the sources. Once the simulation criteria have been established we will factor in the estimated amount of time the lights are left on per day, including the power spikes associated with turning the lights off and on. In addition to this information we will also take into consideration the degradation factor of the light bulbs being used and conceive a method of calculating the estimated overall power consumption for a years' time. Moving forward with these calculations, we can implement this knowledge in conjunction with power simulation software, in addition to surveys about the effectiveness of the lights, in order to attain a final conclusion on how much energy our system will save the user. In order to deem the green lighting project successful; in comparison to simulation data and surveys, the system should save at least 5% in energy costs as well as produce positive survey results. Comparisons will also be made to similar preexisting studies such as a field study conducted by the Institute of Research in Construction (IRC) in Canada which drew results from the long-term data of a single building using a particular lighting system. This lighting system was a workstation-specific, 3-lamp system with integral occupancy, light sensors and individual dimming controls. The three controls affected the light output of the two lamps directed downwards, while the single lamp directed upwards was always on during scheduled occupancy. (Galasiu, Newsham, Suvagau, & Sander, 2007)

Feasibility and Resources Available

Due to the proposed design of the solution, the selection of devices to be used, and the technical background represented from the members of the group, it is felt that implementing the Green Lighting project successfully is feasible. The timeline that was developed to maintain reasonable progress takes into account what objectives must be met, when they must be met by, and the amount of effort placed on each task. These criteria are essential to the management of the Green Lighting project while moving forward with the implementation, not only to keep structure, but also to evaluate how effective the group's usage of time is. If any task is given low effort (on a scale of 1-7), in the future, any similar tasks will be reevaluated and either negated or assigned higher priority as a means to put forth more productivity. However, it was taken into account that there may be setbacks as far as arrival of materials, or any other uncontrollable factors, thus all proposed "Completion Dates" are tentative and may potentially be adjusted. There are several current technologies which use different methods of conserving energy, whether it is a system which automatically turns off unused devices after a certain allotment of time, light bulbs which are more energy efficient, or ability to control the intensity of a light in a room. These current technologies show that our proposed solution of not only controlling but also maintaining optimal lighting conditions as a means to drastically save energy is possible. The difference between the current technologies available and our proposed solution are the combination of different factors such as what the optimal level of lighting is for comfortable visibility, and the ability to constantly maintain this comfortable and efficient level.

- Special Resources

A scaled test environment would be the only special resource needed. This would ideally include a full-scale room where the final product may be tested and used. This environment can be a lab, a classroom, or any usable room that is available upon request.

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