Dark Sky Sim: An Open-Design Dark Sky Simulator

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This article describes the key steps on how to construct the Dark Sky Simulator, the outcome of the Dark Sky Sim project. The Dark Sky Simulator is a "physical simulator" to demonstrate the effects of light pollution on the starry sky and the concept of proper lighting. The simulator consists of an LED sky model simulating the starry sky and LED model streetlighting. The simulator creates for users a first-hand experience of light pollution caused by various light fixtures. The simulator was successfully completed, and information on how to construct a simulator with simple tools and inexpensive components are made available online for free. Building the simulator is a very exciting STEM project involving hands-on construction and programming skills in addition to learning astronomy concepts, making it a useful resource for both educational and outreach communities. The project was funded by the International Astronomical Union Office of Astronomy for Development (IAU OAD).

Introduction

STEM projects form an important part of the educational process in science. Dark Sky Sim took the opportunity to combine astronomy and environmental concerns about light pollution into a STEM project that includes learning about astronomy, construction and programming. The environmental issue of light pollution that lies in the heart of this project will be crucially important in the years to come, and through the dark sky simulator students and citizens can learn about the issue while at the same time learn programming and astronomy.

Most people have never seen a truly dark sky, which is undeniably the best way and most immediate way to perceive the issue of light pollution. Photographs and videos are useful in demonstrating what a dark sky looks like, but as they don't involve a deep engagement with a dark sky, they aren't as effective. To solve this problem of experience, the project team members concluded that a physical simulator with interactive controls would be the best way to demonstrate the issue of light pollution without a dark sky. This simulator was designed to be educational through both the construction skills one practices and the information one learns, during which one gains first-hand experience with the constellations and how they are affected by light pollution.

Light Pollution

Dark skies are becoming increasingly rare for citizens living in urban areas. According to *The New World Atlas of Artificial Night Sky Brightness (Falchi, 2016)*, about 80% of people worldwide and 99% of Americans and Europeans cannot see the Milky Way from their homes. Light pollution, however, is not simply about night sky heritage and inability to see the stars. We now know that it is a complex environmental issue affecting plants, animals and us human beings, disrupting our sleep cycles and contributing to serious health conditions *(Chepesiuk, 2009)*.

Light pollution is unique as an environmental issue in that it can theoretically disappear instantly if we simply turn off the lights, unlike other important issues such as global warming or microplastic pollution which we can't simply make disappear even if we take all appropriate measures today. This doesn't mean that light pollution is easy to solve, due in part to the years of societal perception of public lighting and, of course, that we don't want to turn off the lights completely[1].

Overview of the Construction

The dark sky simulator consists of a wooden box, an interchangeable sky background, a scale model setting and electrical components as shown in Figure 1. These create a diorama of a desired scene, such as a park at night.

Building the simulator is accomplished in three stages: the construction stage, the electrical wiring stage and the programming stage. A full explanation of the complete construction, including building materials and code, is freely accessible on the Dark Skies Sim website[2].

Construction

Assembling the Simulator Box

The simulator box is the frame for the sky and houses the electrical components. Users construct the box and scale-model base using plywood, glue or screws, and metal furniture corners (a complete list of materials is in Box 1). The base is roughly 60 cm x 50 cm, half of which is covered by a box that is roughly 60cm x 25 cm x 45 cm. Metal furniture corners at the front of the box hold the interchangeable plexiglass "sky" that is added later.

The scale-model scene of the simulator may be glued to base in front of the box. A park, for example, could be created with green velvet paper for the ground with model figurines, benches and trees. Light fixtures can be created by inserting LEDs through a short black straw and be attached to the base.

Figure 1. *Overview of the simulator. Image credit: Dark Sky Sim project*

Making a Sky Background

A sky background is created with a 60 cm x 45 cm sheet of plexiglass. Making it requires some astronomy knowledge or the use of a planetarium software. It is advised that the sky background depicts an area of the sky that is of significant interest, such as the winter constellations around Orion, the circumpolar constellations or the Summer Triangle asterism. The depicted part of the sky can be of constellations visible from a specific location, especially if the simulator is being used with a local scope. Depending on the project, two alternate night sky scenarios (e.g. winter and summer sky) may be helpful in fully showing what is lost through light pollution.

To transfer the constellation onto the plexiglass, a screenshot from the planetarium software can be printed on transparent paper of appropriate size (such as two A4 pages). The constellation pattern can then be transferred into the plexiglass by drilling holes into the plexiglass using an electric drill at slow speed. The diameter of the drill tip should be such that the LEDs can be wedged in the holes.

For simulating the stars, LEDs can correspond to the stars they represent. White HI LEDs can be used for the most relatively prominent stars, while white LO LEDs can be used for less-prominent stars. Orange LEDs can represent stars that are particularly orange or red in appearence like Betelgeuse and Antares.

Electronics

A breadboard for electronics is used to hold the wiring and lights for the back of the simulator box (Figure 2). The LEDs are controlled through an Arduino*3 board, a commonly used programmable circuit board that is easy to use for beginning programmers. The code is processed through the board and controls the brightness, and sometimes colour, of the LEDs of the “stars” and “streetlights”.

Box 1. Components

Main board
1 x Arduino Uno or Mega board
Arduino shields
1 x Arduino power motor shield (e.g. Velleman KA03)

Power supplies
1 x DC 4.5V 1A Power supply
1 x USB 5V 1A Power supply
LED’s
25x white high brightness LED’s
25x white low brightness LED’s
5x orange LED’s
5x blue LED’s

Switches and cables
1x 3-way switch
1x up/down switch
1x large breadboard
50x long jump wires M/F 40cm
50 x short jump wires M/M 10cm
10x very short jump wires for short circuit
1x 5-meter silicon cable 1.5mm2

Scale Models
10 x 1:100 scale model figures
5 x 1:100 scale model benches
5 x 1:100 scale model bikers
5 x 1:100 scale model trees
1x Green velvet sheet
10x white LED’s
10x orange LED’s
5x Black plastic straws
Glue

Simulator Box
2x 45x25x1 cm plywood sheets
1x 60x25x1 cm plywood sheet
1x 60x25x0.5 cm plywood sheet
1x 60x45x1 cm plywood sheet
1x 60x50x1.5 cm plywood sheet
2x plexiglass sheets 60x45x0.3 cm
1x drawer handle
20x 5cm furniture metal corners
1x dark blue spray paint
2x (any dark color of choice) spray paint
20x Wood screws
Wood glue
Tools
Electric drill
Screwdriver
Pliers
Soldering iron
Permanent marker
Scissors

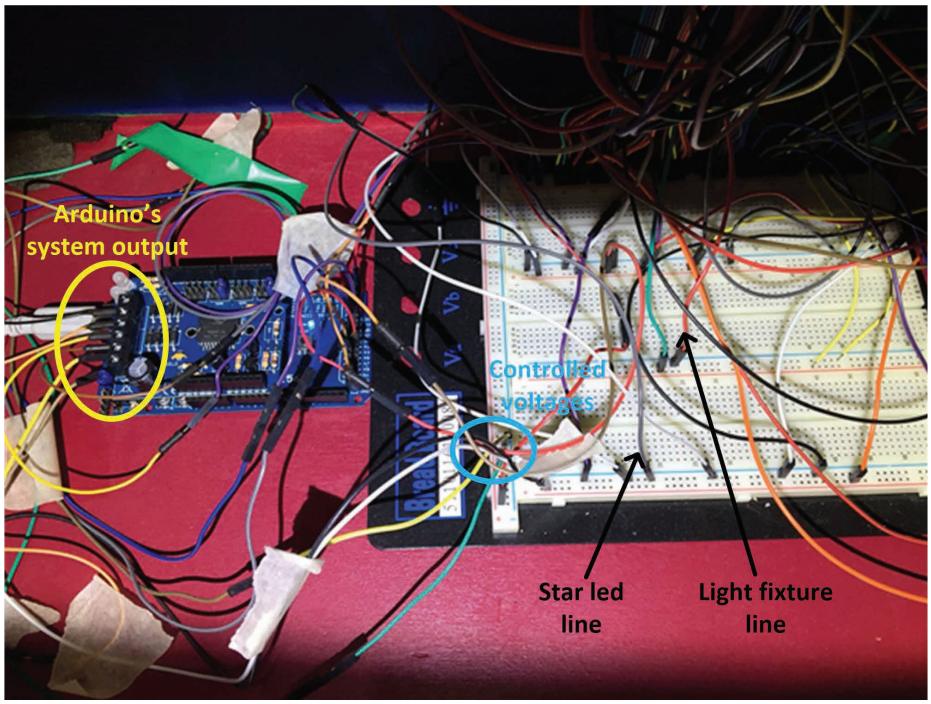

Figure 2. *Wiring of the simulator. Credit: Dark Sky Sim project*

Programming

The user of the simulator can adjust the brightness of the LEDs through the pre-designed code.

The light pollution depends on two factors: The intensity of the light fixtures in the scene and the colour-type of the LEDs that are placed in the scene. The lights can be controlled to three different levels—zero, warm light (3000 Kelvin) and cold light (6500 Kelvin, which is often used to simulate daylight). Cold light is known to cause more light pollution and make stars seem fainter. This and other topics associated with light pollution can be explored through the control of the lighting by the user. The code and more technical details about the programming are available on the project website[2].

Figure 3. *Logo of the Dark Skim Project. Credit: Dark Sky Sim project*

Conclusion

The Dark Sky Simulator is a resource that can be used for both learning and light pollution advocacy. The simulator has been demonstrated at the 2019 Annual General Meeting of the International Dark-Sky Association (IDA) in Tucson, US and was well received as a STEM project for schools as well as dark-sky advocacy. A logo of the simulator was designed (Figure 3) in order to better promote it. The simulator has also been demonstrated for schoolchildren at the 2018 Patras Science Festival in Patras, Greece and for the members of the Greek IDA chapter and Astronomical Society of Patras Orion.

Informal feedback gathered at events and demonstrations regarding its usefulness as a light pollution simulator device has been positive, however many formal educators felt it was too complicated for construction for classroom environment due to their lack of training in programming and electronics. Some people also noted that the simulator is quite bulky. In order to address these concerns, a smaller, more portable version of the simulator is being designed and an automatic programming script will be designed for people unfamiliar with programming.

The open nature of the project means that anyone can modify and improve the design, and the authors will be glad to receive user modifications and improvements.

References

Chepesiuk, R., 'Missing the Dark: Health Effect of Light Pollution', Environmental Health Perspectives [online], vol. 117, no. 1, 2009, p. A20-A27, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2627884/

Falchi, F. et, al, 'The new world atlas of artificial night sky brightness', Science Advances, vol. 2, no. 6, 10 June 2016, e1600377

Notes

[1] More practically, light pollution can also be mitigated with aiming lights downward, only using light that is needed, using warm white bulbs and making good use of our natural low-light eye adaption.

[2] The Dark Sky Sim project website: https://darkskysim.com/

[3] `Introduction` on the Arduino website: https://www.arduino.cc/en/guide/introduction

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Biography

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