Autonomous Surface Disinfection Robot to Combat SARS-CoV-2

Monthly Report - February

IEEE REGION 3
ORLANDO SECTION

Overview

This project was proposed in November 2020 with a timeline scheduled for completion in November 2021. The objective is to create an autonomous robot that is capable of navigating a space (such as a hospital room) and disinfecting all of the accessible surfaces in the room using germicidal UVC radiation. The major challenges of this project include the following:

- Design a robust mechanical system that can be transported safely and easily
- Design an electrical system to provide sufficient power to the DC computer components as well as the AC lighting equipment (UVC bulbs)
- Program the robot to navigate tight spaces without colliding with its environment
- Implement a safety system that will automatically shut off the UVC radiation in the presence of humans
- Ensure that the UVC radiation being supplied by the robot is potent enough to inactivate the SARS-CoV-2

The majority of the work for this project is expected to completed in two cycles: first, a research/design/prototyping phase between January and April 2021, and then an implementation phase between August and October 2021. The time period between November 2020 and December 2020 was set aside for preliminary research and recruiting a team to work on the project. Because of the team's school and work commitments, the time period between May 2021 and July 2021 is currently planned to be spent mostly on research and acquisition, although some physical testing will still take place.

OVERALL PROJECT TIMELINE

2020

November - December

- Research UVC technology
- Divide subcomponent teams

January

- Select UVC lamps
- Begin electrical designs
- Research necessary sensors

February

- Prototype with sensors and lamps
- Continue circuit design
- Begin mechanical design

March - April

- Prototype with sensors and lamps
- Design complete circuit
- Design complete mechanical system

May - July

- Purchase mechanical components
- Prepare material for presentation (publication, donation, etc.)

August - September

- Assemble robot gradually
- Verify robot's performance at every stage of assembly
- Upgrade components if testing reveals necessary changes

October

- Purchase finalized PCBs
- Test robot in diverse environments

November

- Complete final testing
- Make final preparations for the project's real world implementation

2022

Progress

As the timeline dictates, we have spent the month of January working on selecting the electrical components that will be necessary for the project. We are using a top-down approach to selecting components. The first step is identifying the requirements of inactivating the SARS-CoV-2. After finding the electrical power needed to do this, it is possible to select UVC lamps to purchase that output the necessary power. After identifying the specifications of the UVC lamps that will be used, it is possible to select ballasts that are compatible with the lamps. After selecting the ballasts, it is possible to determine the specifications of the battery and power inverter that will be necessary to run the AC components of the robot.

As such, the majority of our research this month has been spent on determining the exact amount of radiation necessary to inactivate SARS-CoV-2 populations. UVC radiation absorption is measured in dosage (J/m^2), which is a function of the UVC power emitting from the bulb, the distance between the bulb and the surface, and the amount of time the surface spends absorbing radiation. Higher doses can inactivate virus populations by 99.9999% or higher, whereas lower doses inactivate virus populations by less. Our goal is to demonstrate inactivation of >99% of SARS-CoV-2 populations.

The dosage necessary to disinfect a surface by 99% differs between different types of viruses, bacteria, and other pathogens. Because of the novelty of the SARS-CoV-2, little data exists from studies directly measuring the dosage necessary to inactivate the virus in question. As a result, our research team collected data from several different sources to determine for ourselves a suitable benchmark for inactivation dosage.

Source	Dosage (J/m^2)	Inactivation Rate	Notes
Suraj	25	99.997%	Due to propietary information, no published paper exists
Storm	76.41	~100%	
Inagaki	37.5	87.4%	
Inagaki	375	>99.9%	
Kowalski	47	90%	Average results from multiple studies on coronaviruses
Kowalski	27	90%	Average results from multiple studies on SARS-CoV-2
Heßling	37-106	90%	Measured using general coronaviruses, not SARS-CoV-2

Average Dosage (90%)	Average Dosage (>99%)
45.75	158.8033333

There is significant variance in the data that has been published up to this point, so our team has elected to move forward with a very conservative estimate of 250 J/m^2 necessary for a >99% inactivation rate. This figure is well above the thresholds given by our sources. If we use 250 J/m^2 as our benchmark for inactivation, we should achieve a real inactivation rate even better than our goal.

The UVC lamp we intend to use in the project is the Philips TUV T8 30W 1SL/25. This lamp has a UVC output of 12.0W. OSRAM, a company that produces similar germicidal UVC lamps, has a published guide on how to calculate the number of lamps necessary to achieve a desired dosage output in a given time period. This guide includes information on a lamp with very similar specs to the lamp we have selected. One of the figures it gives is that a 30W bulb (like ours) typically has an irradiance rating of ~1 W/m^2 at 1 meter away from a given surface. It is likely that our robot will never need to irradiate a surface that is >1 meter away from its center, so the 1 W/m^2 figure can be used in our calculations as a single lamp's estimated irradiance.

Based on the sample calculations in OSRAM's paper, we have developed the following formula for designing our robot:

$$number\ of\ lamps = \frac{dosage\ (J/m^2)}{lamp\ irradiance(W/m^2) * time\ spent\ irradiating\ (s)}$$

In this case, the dosage is set at 250 J/m^2, and the lamp irradiance is set at 1 W/m^2. Therefore, the variables are the number of lamps necessary and the amount of time necessary, which are in inverse proportion to one another.

For example, if we were to construct a robot with 6 UVC lamps, we would need an estimated 41.6 seconds in order to achieve our desired inactivation on a surface 1 meter away. If we wanted to achieve the desired inactivation in only 20 seconds, then the robot would require 12.5 lamps. These figures are directly calculated through the formula above.

With these calculations finished and deemed acceptable, our team has since been researching the ballasts that will serve to regulate our lamps. When the ballasts are finalized, we will also be able to finalize the specifications of the battery and power inverter that we will be using.

Moving on from the power components, our team has also begun research on the sensors that will be necessary for the robot. One topic that we have begun discussing is the sensor that will serve as a safety switch for the harmful UVC radiation to cease when the robot comes in contact with a person. The initial idea was to perform this task using a camera and computer vision software. Concerns about this solution have led to our team exploring the possibilities of using thermal imaging or motion detectors. Because motion detectors would be the easiest to implement, this is the solution we are currently prototyping. If they do not appear to work satisfactorily, then we will move forward with one of the other potential solutions.

Revised Budget

Item	Price	Quantity	Total Price
LED sockets	$0.89	20	$17.80
UVC Dosimeters	$35.00	3	$105.00
UVC Lamps	$15.99	8	$127.92
UVC Sensors	$21.80	2	$43.60
18 Gauge Wire	$12.79	1	$12.79
Raspberry Pi 4 (4 GB)	$55.00	1	$55.00
GPIO Expander	$8.90	1	$8.90
Motors	$23.29	4	$93.16
Motor Drivers	$11.99	(5 pack)	$11.99
Wheels	$10.46	4	$41.84
LIDAR sensor	$76.99	1	$76.99
PIR Sensors	$8.41	(5 pack)	$8.41
Thermal Camera	$44.95	1	$44.95
Camera	$50.00	1	$50.00
Battery	$40.00	1	$40.00
Battery Charger	$10.45	1	$10.45
Power Inverter	$35.99	1	$35.99
Ballast	$39.95	4	$159.80
Proto bot kit	$23.99	1	$23.99
Robot Base Materials			$200.00
3D Printing			$100.00
PCB Printing			$33.00
Miscellaneous Hardware			$50.00
Miscellaneous Electronics			$50.00
Total			$1401.58

The current state of our budget indicates a total price point of $1401.58. IEEE Region 3 is still funding the majority of the project, but a few alterations have been made that increased the total price. The original budget did not include equipment for sensing UVC radiation, ballasts to regulate the lamps, as well as a few other items. As of now, $347.16 has been spent on items listed in the budget, not including shipping costs.

In the coming days/weeks, we will likely be purchasing the LIDAR sensor, a battery, and a power inverter. Further purchases will be made as necessary, and the budget will be updated accordingly.

Safety Information

All meetings for this project thus far have been conducted through Zoom. Next month, we expect to begin hands-on prototyping that will require in-person presence. When this begins, all participants will be required to RSVP for meetings in advance in order to limit the number of people gathered in a room together. All participants will be required to wear masks at all times.

We expect to begin testing the UVC bulbs in the next month as well. There are health hazards involved with any kind of tests we can conduct using these. As such, we will be researching safety measures we can take in order to ensure that no one involved is exposed to harmful radiation.

Next Steps

The next step for our biomedical team is to design experiments that will verify our bulbs' efficacy. These tests can be done using our dosimeters, as well as our electronic sensors.

The next step for our computer team will be to test the LIDAR sensor and the motion detectors to see how useful the data is that each sensor can gather. These sensors will be tested alongside a basic prototyping robot to add a factor of motion to the experimentation.

The next step for our electrical team is to determine exactly what battery, inverter, and motors will be necessary to run the robot, and then to begin designing circuitry to connect all of these elements.

The next step for our mechanical team will be to select materials for the robot's base, and then to begin drafting 3D designs for the assembly of the robot's frame.

Certification

I, Taylor Barnes, hereby approve of this documentation of the IEEE Orlando Section's pandemic project sponsored by IEEE Region 3, and I certify that the above information is a true and accurate depiction of the project's current progress through the month of February 2021.

1-31-21

Date

Signature

References

Heßling, Martin, et al. "Ultraviolet Irradiation Doses for Coronavirus Inactivation – Review and Analysis of Coronavirus Photoinactivation Studies." GMS Hygiene and Infection Control; 15:Doc08, German Medical Science GMS Publishing House, May 2020, doi:10.3205/DGKH000343.

Inagaki, Hiroko, et al. "Rapid Inactivation of SARS-CoV-2 with Deep-UV LED Irradiation." Emerging Microbes & Infections, vol. 9, no. 1, Informa UK Limited, Jan. 2020, pp. 1744–1747. Crossref, doi:10.1080/22221751.2020.1796529.

Kowalski, Wladyslaw & Walsh, Thomas & Petraitis, Vidmantas. (2020). 2020 COVID-19 Coronavirus Ultraviolet Susceptibility.

Lindblad, Marie, et al. "Ultraviolet-C Decontamination of a Hospital Room: Amount of UV Light Needed." Burns, vol. 46, no. 4, Elsevier BV, June 2020, pp. 842–849. Crossref, doi:10.1016/j.burns.2019.10.004.

OSRAM. 2021. Web. 29 Jan. 2021. https://www.osram.us/pia/products/discharge/p001_pia_product_detail_6.jsp

Storm, Nadia, et al. Rapid and Complete Inactivation of SARS-CoV-2 by Ultraviolet-C Irradiation. Research Square, 3 Sept. 2020. Crossref, doi:10.21203/rs.3.rs-65742/v1.

Suraj, Tharindu. "Disinfecting Robot with Ultraviolet Lights." 21 May 2020. Web. 29 Jan. 2021.