Disinfecting UV Box

Isaac Manuel Kuri Mendoza
Embedded Systems Engineering
Universidad Politécnica de Yucatán
Km. 4.5. Carretera Mérida — Tetiz
Tablaje Catastral 4448. CP 97357
Ucú, Yucatán. México
Email: al1709071@upy.edu.mx

Ernesto Cuauhtémoc Sánchez Rodríguez
Centro de Especialidades Médicas del Sureste
Calle 60 número 329 B X 35 y av. Colon
Colonia Centro.
CP 97000.
Email: Cuau57@hotmail.com

Sharleen Morales
Universidad Politécnica de Yucatán
Km. 4.5. Carretera Mérida — Tetiz
Tablaje Catastral 4448. CP 97357
Ucú, Yucatán. México
Email: sharleen.morales@upy.edu.mx

Abstract

Given the growing need to disinfect everything around us, because of the Covid-19 pandemic. The development of devices and tools to do it has been taken place at an astonishing rate. Wanting to capitalize on this trend it was decided to help the hospital staff in the disinfection efforts by creating a device that could serve a potential barrier between the virus and the staff.

The document describes the process of creating a box with common materials that is cheap and able to do quick work of any of the germs residing in the things that are put into it. It is also going to be superior in quality and safer than the ones available in the market. UV disinfection has been common over decades. But these devices make use of the disinfecting properties of UV light and the use of smart micro-controllers to control the power consumption and safety features. One user error while using UV light can result in bodily injury.

The development while straightforward given the availability of all the tools needed to complete the project. It took longer than usual because of the restrictions lifted because of the Covid-19 pandemic. We ensure the safety of everyone in the team making use of online platforms to develop the project and keep everyone informed and productive. Only seeing each other to exchange the needed tools and materials.

Index Terms

UV-C, Disinfection, User Safety, Waterfall development model.

Disinfecting UV Box

I. Introduction

UV radiation is commonplace since the beginning of last century. It has many applications, the most common one is to treat water in facilities that need a clean supply. It also helps with many applications in industry, dentists offices and nail polishing saloons.

The focus of the project is to disinfect common things that can fit inside the box that is being designed. The main disinfecting agent is the UV light. But small amounts of Oxone will be generated as a side effect of the UV lamp technology. The lamp works with exited gas at high voltage. Oxone is generated with an arc of electricity that breaks down oxygen molecules. This means that the Oxone will be generated in enough quantities to be smelled by humans and also to have disincentive properties. These devices where not that common before the Covid-19 pandemic. But over the following months there has been a resurgence of them. To a point where even the prices of the UV-C lamps have skyrocketed.

The product being developed works by using a simple solid-state relay that can turn on and off an UV lamp with the signals of a microcontroller. Also, a magnetic sensor will check if the lid of the box is open. This wil ensure the safety of the operator because UV-C light will damage the eyes and skin of anyone who comes in contact with it. That is why the box will not work if the lid is open the same can be said if it where to be opened while disinfecting. Also, if the box where to be left plugged in, the microcontroller is able to enter sleep mode. This is useful to save energy.

The development of the project meet some caveats mainly because the team was unable to meet at the same time and work together, given the situation of the Covid-19 pandemic. But the project has been come along fairly well, even though a little more slowly than expected. Finally, the team didn't have permission to use the laser cutter at the UPY, this complicated everything quite a bit. In UPY would have been safer to do the work. We where left with two choices cutting it manually or going to a place where it would be costly and also exposing ourselves in such a facility.

II. Objectives

The project main objective is delivering a device, capable of using the UV light to disinfect certain area of an object. The project called "Camara de desinfección UV" in charge of the Doctor, chief of the hyperbaric medicine, Ernesto Cuauhtémoc Sanchez Rodriguez in the General Hospital Agustin O'Horan. In a period of 3 weeks (120 hrs.)

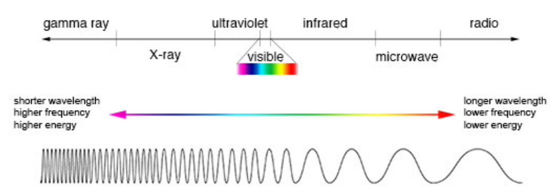
The planification was done on time as well with the simulation. In addition, the CAD show the viewer the actual model size with the correspondent measures. The flow control was also done with the intention to demonstrate the pre-logic in the code to ensure the function.

Everything planned was done, the purchase of the components, the planning etc… because of the simplicity and versatility, the machine was accurately designed. However, the suddenly and deliberate appearance of the virus COVID-19 produced, in the state of Yucatan, the implementation of immediate isolation for all the population. This disadvantage delayed the physical build of the project which was scheduled to be delivered as fast as possible. The first impediment was the lockdown, the team could not get any physical progress due this issue and therefore, the project had to be done at the official installations with the supervision of the doctor in charge at the general hospital, O'Horan. For these unexpected reasons, the physical project needed to be halted for undefined time. However, the team decided to finish the physical task, but the machine would not be delivered in immediate time, due the fact that the hospital might not be letting in non-essential personal.

III. State of the Art

UV Radiation

All radiation is a form of energy, most of which is invisible to the human eye. UV radiation is only one form of radiation and it is measured on a scientific scale called the electromagnetic (EM) spectrum.



UV radiation is only one type of EM energy you may be familiar with. Radio waves that transmit sound from a radio station's tower to your stereo, or between cell phones; microwaves, like those that heat your food in a microwave oven; visible light that is emitted from the lights in your home; and X-rays like those used in hospital X-ray machines to capture images of the bones inside your body, are all forms of EM energy.

The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation. The other types of EM radiation that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet light, X-rays and gamma-rays.

Types of UV Radiation

UV radiation is the portion of the EM spectrum between X-rays and visible light. The most common form of UV radiation is sunlight, which produces three main types of UV rays:

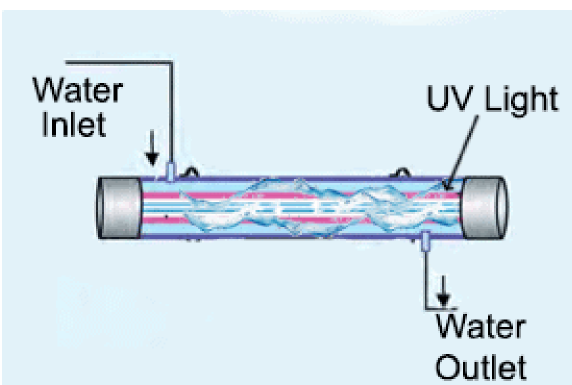
- UVA
- UVB
- UVC

UVA rays have the longest wavelengths, followed by UVB, and UVC rays which have the shortest wavelengths. While UVA and UVB rays are transmitted through the atmosphere, all UVC and some UVB rays are absorbed by the Earth's ozone layer. So, most of the UV rays you come in contact with are UVA with a small amount of UVB.

Like all forms of light on the EM spectrum, UV radiation is classified by wavelength. Wavelength describes the distance between the peaks in a series of waves.

Applications

Ultraviolet light in the UV-C band (200–280 nm) is also known as ultraviolet germicidal radiation and is widely used for sterilizing equipment and creating sterile environments, as well as in the food and the water industry to inactivate microorganisms. UV-C radiation has been used to treat water since 1909 and offers a safe and effective disinfection process for drinking water.



This property of UV-C radiation as a disinfectant as seen a raise in popularity since the Covid-19 pandemic started. One of the uses is for Bus disinfection, where these vehicles are put inside a tunnel with special lamps that emit UV-C radiation. This can be combined with other methods to make a quick and through disinfection of big areas.

Also, in order to protect healthcare workers during the COVID-19 pandemic, Juan Humberto Sossa Azuela, a researcher at Mexico's National Polytechnic Institute (IPN) is working in the development of a robot that will disinfect hospital areas for patients with coronavirus using ultraviolet light.

Finally, the application for UV-C disinfection that inspired the project. Was the use of a low power source of light to disinfect a small enclosed area along with all the objects inside. These can be from clothes to even a cellphone. It depends on its size. These products tend to be expensive, and are not safe for the end user, because sometimes they fail to turn off when the lid is open. This can expose the user to dangerous levels of UV-C radiation that can cause burns to their skin and eyes.

Several factors determine the effectiveness of the UV light, such as:

The intensity / wavelength of the UV radiation. The UV LED is an 8 Watts; the standard measurement is 550 mm long lamp. The area of disinfection is 2 m^2, this delivered by the 8W. The wavelength, according with the UV light provider, ensures that has a range of 185 – 260 nanometers (nm). This entails that the UV is in the category of Ultraviolet C.

According to the research done by Lindblad M., Tano E., Lindahl C. and Huss F. from the Department of Plastic and Maxillofacial Surgery, Uppsala University Hospital, the Department of Medical Sciences, Section of Clinical Bacteriology, Uppsala University. Intellego Technologies AB and the Department of Surgical Sciences, Uppsala University. The Ultraviolet-C (100-280 nm) has the highest disinfectant capacity (peak-effect wavelength of 265 nm). The UVC light is absorbed by the Ribonucleic Acid (RNA) and Deoxyribonucleic acid (DNA) in cells and microbes which induces "apoptosis" in the D-/RNA structures that result in their inability to replicate. [1]

External factors that can protect the microorganism. For example, organic material will absorb the penetration and block reflection of UVC, which surfaces should be cleaned manually to remove organic substances before decontamination.

The length of time is exposed to UV. Several microbes have been proved to be susceptible to inactivation using UVC light. The Research article: "Evaluation of an automated ultraviolet radiation device for decontamination of Clostridium difficile and other healthcare-associated pathogens in hospital rooms" claims that the amount of inactivation is directly proportional to the UVC dose, and this in turn is the result of the intensity and duration exposure. [2] The farther away the light source, the less UVC will reach the target, so only a quarter of the UVC remains when the distance doubles. UVC has a short wave-length and high energy, this enables for it to function the best in a direct line and a short distance. The UVC have high energy radiation which is bound to the inverse square law where the propagation of light intensity decreases exponentially with increasing distance from the light source. This means that objects in proximity to the light source will hence a higher exposure hence shorter disinfection cycles compared to objects further away. At some degree, the UV light can reflect odd surfaces to reach even the backside of objects. This capacity depends on the material to be disinfected.

Taking the work of Rutala W., Gergen M., Weber D. from the Division of infectious Diseases, Bioinformatics, University of North Carolina at Chapell Hill in their test, the effectiveness of UV-C radiation in reducing the counts of vegetative bacteria on surfaces was more than 99.9% within 15 minutes, and the reduction in C. difficile spores was 98.8% within 50 minutes. In rooms occupied by patients with MRSA, UV-C irradiation of approximately 15 minutes' duration resulted in a decrease in total CFUs per plate (mean, 384 CFUs vs 19 CFUs; $P < .001$)

The researchers concluded that the UV-C device was effective in eliminating vegetative bacteria on contaminated surfaces both in the line of sight and behind in approx. 15 minutes eliminating the difficile spore within 50 minutes. [3]

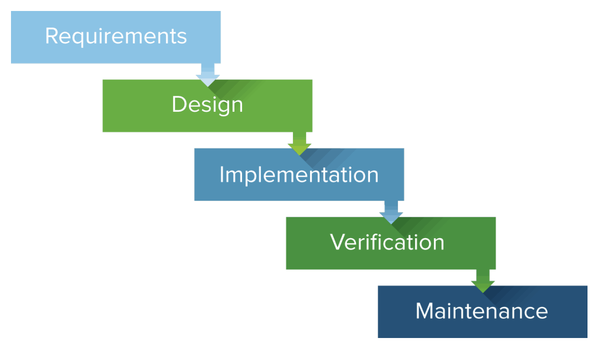
The reflection of the UVC light dependent on the type of surfaces and objects in the room. According to the tests made, despite the effectiveness of the UV light, it is suggested that precautions should be made and not rely only on the decontamination gained from the UVC in areas that are not in a direct line of sight with the light source. The doses range were from 15.9 mJ / cm^2 to 1068 mJ / cm^2, it seems that the disinfection may be reached in the more common bacteria's [4] (Table 1)

IV. Methods and Tools

A. Development methodology

Embedded systems projects are driven to successful only if there is a methodology guiding until the end. Every team project should be leaded with all the contributors on the same channel, there a bast amount of methodologies to meet all requirements and the project get developed as it was considered. In this particular case, the project was analyzed by the team as a short project with all the needs are very consistent, the deadline is appropriated for us to work step by step in the first iteration. Waterfall is a solid methodology used by thousands of engineers around the word for being an industry framework to develop short software development.

Waterfall methodology follows a sequential, linear process and is the most popular version of the systems development life cycle (SDLC) for software engineering and IT projects. It is sometimes planned using a Gantt chart, a type of bar chart that shows the start and end dates for each task.Some advantages of the waterfall methodology are the well thought steps we must go through, the documentations of each stage are written down to provide a clear vision of the project, the time we have to the next step and communication with all developers.



- Requirements is the first stage where we must establish all the needs of the final project, it is crucial to cover all points the project needs as the waterfall methodology is linear and there is no way to get back to a preview stage, because of that the customer has the main participation of transmitting carefully the idea.

- Design involves developers in a phase to connect the ideas and requirements the project should have; coding and 3D models are created at the customer ideal with the intention to have a preview of the final project.

- Implementation is done sequentially by the developers and the objective is to create the flow chart the system should look like, the coding and the assemble of the final product must be finished to test.

- Testing is the stage where the customer gets the product to test, usually the project must pass for a (UAT) user acceptance testing before it can be sent to mass production.

• Maintenance stage comes after some days the customer has used the product and find some errors that need to be solved, changed, or omitted to ensure the quality of the product.

B. Tools

The final product claims to be 100 percent automatized to prevent people to the external parts, however the limitations found in the pandemic event did not let us use the appropriated equipment to implement the auto-open door. Even though, the programming stage and the 3D modeling was done in 2 main platforms that are amazingly useful to create from scratch and program with an IDE suitable for our needs, as it comes with very handy tools as templates, debuggers and syntaxis completion.

1) PlatformIO: PlatformIO IDE for embedded development PIO Unified Debugger with a support for the multiple architectures and development platforms that allows you to debug more than 200 embedded boards with Zero-Configuration! Cross-platform build system without external dependencies to the OS software: 800+ embedded boards, 35+ development platforms, 20+ frameworks. C/C++ Intelligent Code Completion and Smart Code Linter for rapid professional development. Multi-projects workflow with multiple panes and Themes support with dark and light colors. Built-in Terminal with PlatformIO Core and powerful Serial Port Monitor.

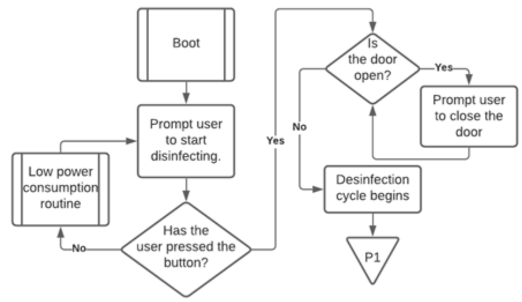
2) Fusion 360: Fusion 360 is for product designers, mechanical engineers, electrical engineers, and machinists. It unifies design, engineering, PCB design, and manufacturing into a single platform. It allows you to connect your disconnected product development process to deliver high-quality products to market faster and positively impact your bottom line. Fusion 360 is a fully integrated CAD, CAM, PCB, and CAE software that includes generative design, 2.5, 3, 4, and 5 axis machining, and advanced simulation, and is available on PC or Mac. Fusion is incredibly easy to use and things are laid out nice and easily. Having everything available in a team cloud makes working in a team much easier. If one member of engineering has done a model or drawing, I have the ability to view that drawing with ease.

V. Development

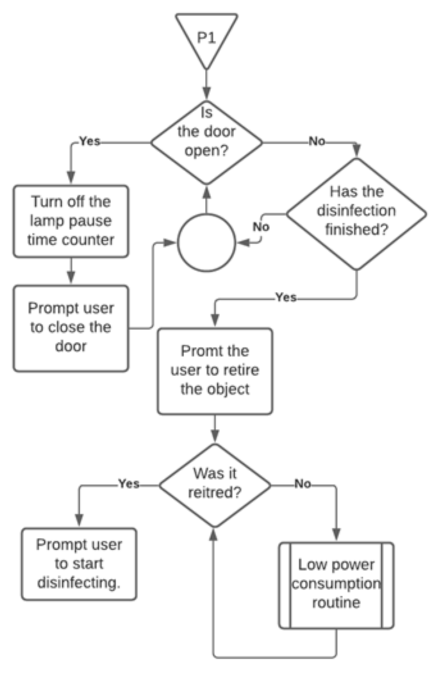
A. Flow Control

The product is based on a state machine to operate, as the system is not based on a RTOS. The linear nature of micro controllers and limited memory for development demand for it. State machines are used broadly in the industry and in consumer products as they allow for sequential logic to be implemented and to implement a decision path for the devices to take.

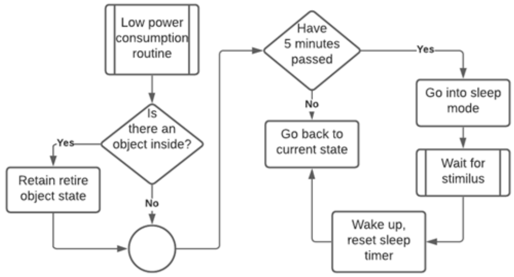
1) Boot process: When the device is first turned on it must go through the process of bootloading itself and to clean registers to start the operation. Since this is a state machine when it boots the state is the default state. Here the user is prompt to start disinfecting. Because the project uses a dangerous wavelength of UV that is dangerous to the human flesh and eyes, the machine must check for the box to be closed in each step of operation.



2) Disinfection process: During the disinfection process the light will be turned on and due to O3 being emitted because of the UV light generated by the device. The disinfection process is timed constrained and must complain with averages of 15-40minutes of operation to effectively disinfect such objects. During the disinfection process the system must check if the door is opened so the light turns off in the case of such accident to prevent skin and eye damage to the user. Once the disinfection finishes the device will prompt the user to remove the object from it. This flag is removed once the door is opened.



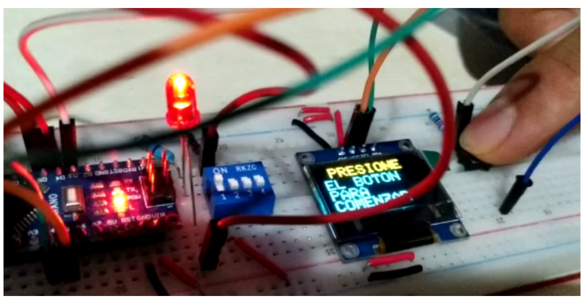
3) Low power consumption routine: The device is designed in such a way that it can be left turned on, because of this it must go through a process to determine if it should go into low power consumption. This is to prevent unnecessary waste of energy and to save the OLED from burning out due to it being turned on. Once the device goes into sleep it must wait for a stimulus to occur or for it to be rebooted to go back to the current state of operation.



B. Interface

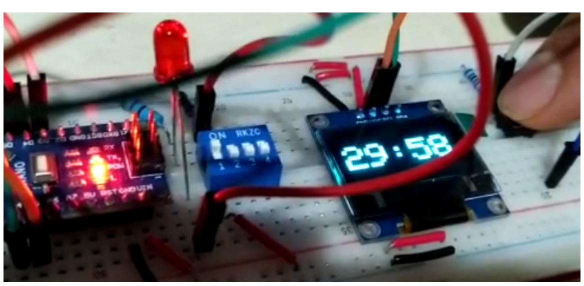
The interface consists of an OLED screen and a button. This can be seen in the following figure.

1) Home screen:

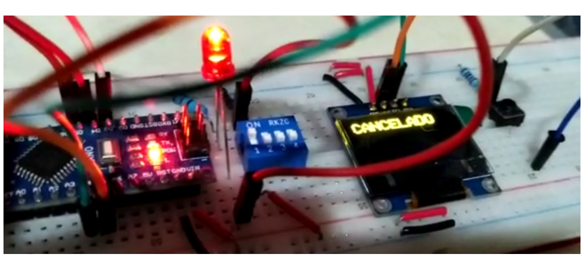


Because of this the navigation within the user interface is sequential. Long presses are used to cancel a current disinfection, or to activate the always on mode. The following images show the prompts shown to the user.

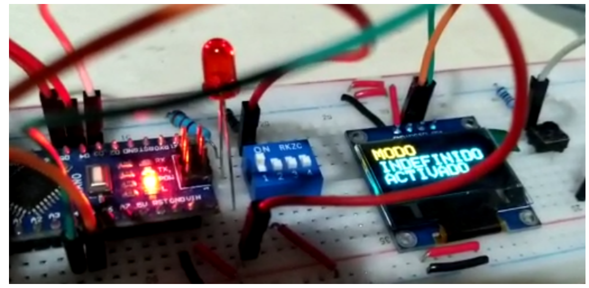
2) Disinfection timer: Once a disinfection begins, a timer is prompt.



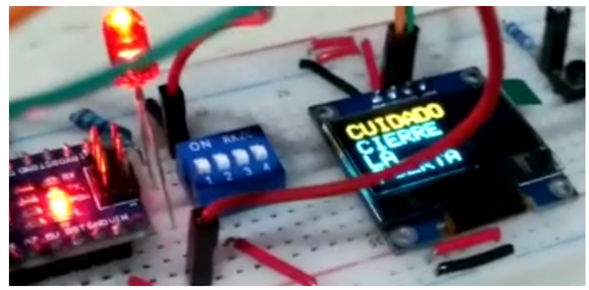
3) Cancel Disinfection: Canceling a disinfection process prompts a cancel.



4) Always on mode: Long pressing in the home screen results in this state.

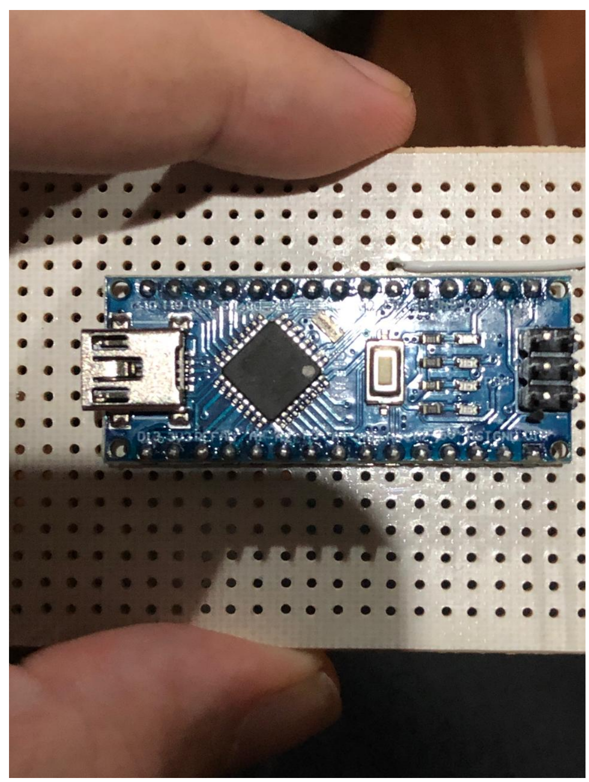


5) Warning: Warning for the user due to door being open.



Box Assembly

The way that the UV lights are controlled is with an Arduino Uno. The code as described earlier will wait for the signal to turn on the UV light.



But it is needed a power supply for the microcontroller and the relay, the circuit that will be used will be a simple cellphone charger.

The relay is used as a simple relay, this is because the machine will turn on and off slowly. This relay can do the work easily and manage the light load.

Now to build the box first strong wood was used and the first step was taking the measurements and go with a wood worker to cut it. The built of the container was done with plywood of 1.50 cm thick, with a measure of 90 centimeters height and 50 cm width. To assemble it, approximately 15 to 25 nails were used and obviously several imperfections came into sight. Unfortunately, the plywood had several curvatures due the fabrication built process, for this reason, wood putty was used to repair the gaps between the woods. The pieces of the cut wood when put together looked as follow:

Then it was time to cover the inside with aluminum tape in order to make the box reflective. This reflective design will try to cover most of the inorganic object inside. According to the researched papers, the object will not be fully disinfected, must be changed in position proportional to the previous time of UV light dose to achieve proportional effect in all sides. The paper tape was a simple reflecting tape which is used commonly to reflect danger and important working zones.

Even when this is made with the intention to be used in a hospital. The students involved decided to make It as robust as possible. The team wants the maximum durability of the device with the less money expended.

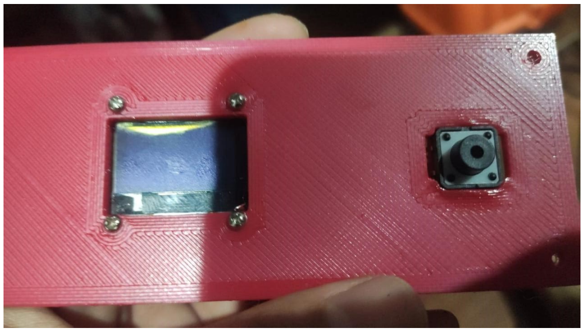
This is the box with the aluminum foil and painted. The red small box in the front it the control unit with a button and the display. For the top of the box it was decided to use a piston for it to open smoothly and the and for the easy of use if the user.

The lack of mobility made the team to take an action into plastic wheels. Those four wheels had a maximum capacity of 15 kg. of load. Overall, the weight was controlled by simple deduction of the plywood planks, with that said we can trust the mobility of the box through all the impediments of the disinfected material inside the structure. It must be taken in account that the screws used in this are between half and entire inch. The entire inch screws went through all the plywood showing the tip outside / inside the structure. This issue was solved by covering it with reflecting tape. In addition, a lever was added to make it easier to lift.

Two hinges were added to control the top of the box open/close. However, there was one imperfection with the piston. Due the weight of the top, the team decided to install a piston to deliver an ease in the lift of the box top. This created “dislocation” of the box top which ended in mayor problem due the box sealed.

This made moving around the device fairly easy. Finally, in this next picture it is possible to observe where the lamp is going to be placed inside the box. The lamp is in the top, as it can be seen in the pictures, all the inside of the box is covered by reflecting tape which according with the papers research only organic objects will absorb the UV-C light irradiation. Nevertheless, this is meant to only clean inorganic material, due the continue usage of non-reusable material in the hospitals, this is meant to be used for easy and fast clean of.

Along with the Control module with an OLED screen and button that was previously explained how they work. This small control box was printed with two holes in which we attached the OLED screen with a push button. As it was already explained the OLED screen, deliver information of the actual action that the disinfection box will take depending on what the user decides to do. The button gives control to the device features already programmed. Inside the control box all the circuits are attached to avoid any malfunction during the move / carry.



With everything in place then it was time for testing and taking notes of the results.

VI. Results

In the end the original design was achieved. A device that can disinfect everything in it's innards by using UV radiation. The design and size changed and new additaments where included. The intention is to make the UV light device manageable. The function was not affected in the process.

In the many test that where made. It was arrived at the conclusion that this device works great with things that have already been cleaned. Everything that is put into it must be free from dust and dirt because this creates crevices that make it difficult for the UV radiation to penetrate. For this very reason, a recommendation was made to use the device as an extra layer of protection. Because of the UV radiation inside the box; if something sterile where to be put inside, then it will be kept sterile for an indefinite amount of time. This was the reason why it was decided to add the functionality of leaving the lamp on indefinitely. This way the user will be free to use it has he pleases.

A bug was found in early testing that made the lamp stay on when the box is opened while the button is being pressed. This was promptly solved and in the end the machine can be deemed safe with a minimum of safety precautions.

The full antimicrobial characteristics of the device are hard to test given that the team has little access to the equipment necessary to do so. But some conclusions can be inferred from the following information:

According the investigation done by the scientists Brenner D., Buonanno M., Welch D., Shryak I. Doing an exposure in aerosols to different doses of UVC light indicate that the survival of the coronavirus diminishes due the amount of it. 222-nm (mJ/ cm^2) seems to be the perfect dose against the COVID (HCoV-229E and HCoV-0C43).(Graphic 1)

Using the number from the graph and the dimensions of the box it is possible to know the minimum amount of radiation that will arrive to to a place in the box taking into account the energy of the lamp. The lamp radiates 8W of energy. This translates to 8 Joules/s this is about $8 * 10^3$ mJ/s. The furthest distance from the lamp calculated using Pythagoras's theorem is 81.242 cm. With this information it is possible to use the following formula:

$$\frac{Intensity}{Distance^2}$$

Substituting the values we get that the minimum radiation at the furthers point in the box is 1.12121 mJ/cm^2. Comparing this result with the numbers from ”Graphic 1” in the ”Appendix A” it can be inferred that it is enough radiation to achieve a fractional survival of the virus population of about 0.001 of the sample size.

The experiment was done with a small simulation in a non-medical area such as the hospital O'Horan which is the ideal place to run, properly, the device. Because, before the start of the project the pandemic scenario by the disease COVID-19 we, the team, had several delays in communication, organization specially because the project had to be deliver physically. However, the Dr. in charge, Cuauhtemoc Sanchez guarantee the delivery due his position in the hospital OHoran.

A. *Highlights*

1) Effectiveness: The effectiveness of UV light to disinfect surfaces has been well documented an many sources of information confirmed our thesis especially against Covid-19 which we aim to fight against. Otter than the UV light itself a retain with air increases the concentration of ozone inside the enclosure meaning that fabrics are also disinfected within themselves.

2) Environmentally friendly: The amounts of ozone this device produces are minimal and should not damage the environment in any significant way. The product is also efficient in power consumption due to the use of micro controllers OLEDs and switchable power supplies. The UV lamp is rated for 8W at maximum output. This disinfection method does not require any consumable other than the electronics themselves ensuring that the device does not create waste, also this design aims for a long life span of the device.

3) Low Cost: Materials used in this project do not exceed the one thousand three hundred pesos mark in raw materials, similar products available with less power and less volume are either at the same price or twice the price they also lack functionality and security measures.

4) User Security: The flow control takes measures to ensure user safety. Each cycle of operation checks for the door to be closed as the only true danger of this device is long exposure to UV light. The concentrations of ozone are controlled by switching on and off the device. It is unlikely to cause harm to humans.

VII. Conclusion

This project was born because of the need to combat Covid-19, that can be carried over by objects, and to meet the sanitary standards demanded by new regulations. This new regulations were placed to reduce the risk of being infected by this coronavirus. The team had a set of goals to achieve with this projects but faced many difficulties in doing so. This is due to the Covid-19 pandemic problems such as: limited access to local electronics slowed down the prototyping phase as any mistake meant a delay of three or four days. Not being able to gather in public places and the UPY laboratories, made us take decisions based on manufacturing limitations like the lack of tools and testing equipment.

The original idea for the control box had PCB manufacturing in mind, but due to time constrains because of prototyping it was not possible to do so, but the manufacturing achieved by the team was remarkable considering all this factors into place, mechanical challenges were solved such as the weight of the door with the implementation of an air piston, applying a reflective material to the box just to name a few.

Coding had its own set of challenges as any bug in the code could set on the UV light and cause harm to the user, as the responsible of the design of the control box circuitry and mostly the code, decisions in functionality had to be made to maintain the navigation simple for the user. The use of an OLED and a single button to operate the machine helped to achieve this "ease" of use and intuitive sequential design of the interface. This also makes for less mistakes as only one input has to be considered in each state of operation for an overall good design.

Security was the top priority of the design because of this the control of the machine had to be done in a particular manner, states of the machine could not be segmented in sub states, meaning that the had to be unified in one. The unification of only one control system meant that each control event such as interruptions could be handled with the same state variable, loosing synchronization in the sequence of operation is impossible due to this. This unification was necessary because the security of the user had to be ensured as long term exposure to UV light will cause harm to both skin and eyes of the user, which is unacceptable.

Those challenges written above were only a few and even tough the final goal of manufacturing a functional prototype to be donated was achieved, quality standards could have been higher if the conditions imposed by the pandemic were not in place.

APPENDIX A

TABLE 1

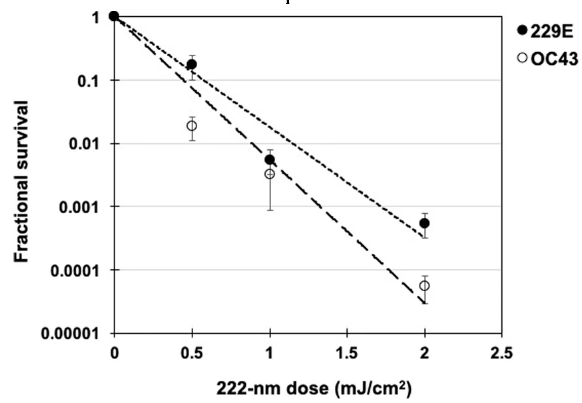
Table 2 – Published UVC-doses necessary for given log reductions for different microbes (adapted from ClorDiSys Ultraviolet Light Disinfection Data Sheet Rev. 10–213). Received UVC-dose not enough to reach X Log_{10} reduction for a specific microbe in locations: ^{D}- In the basin, ^{E}- In the wardrobe, ^{G}- In the drawer of the left ceiling mounted pendant, ^{I}- On the writing surface on the right ceiling mounted pendant, J- Behind the desk chair.

	UVC- dose (mJ/cm^2) necessary for a given log reduction						
	1 Log_{10}	2 Log_{10}	3 Log_{10}	4 Log_{10}	5 Log_{10}	6 Log_{10}	
Spores							Reference
*Bacillus subtilis*ATCC6633	**$24^{D, E}$**	**$35^{D, E}$**	**$47^{D, E, I}$**	**$79^{D, E, I}$**			α
Bacillus subtilis WN626	0.4	0.9	1.3	2			α
Bacteria							
Campylobacter jejuni ATCC 43429	1.6	3.4	4	4.6	5.9		γ
Citrobacter diversus	5	7	9	11.5	13		δ
Citrobacter freundii	5	9	13				δ
Escherichia coli O157:H7 CCUG 29193	3.5	4.7	5.5	7			ε
Escherichia coli O157:H7 CCUG 29197	2.5	3	4.6	5	5.5		ε
Escherichia coli O157:H7 CCUG 29199	0.4	0.7	1	1.1	1.3	1.4	ε
Escherichia coli O157:H7 ATCC 43894	1.5	2.8	4.1	5.6	6.8		γ
Escherichia coli ATCC 11229	7	8	9	11	12		ζ
Escherichia coli ATCC 11303	4	6	9	10	13	15	η.
Escherichia coli ATCC 25922	6	6.5	7	8	9	10	ε
Escherichia coli K-12 IFO3301	2.2	4.4	6.7	8.9	11.0		ε
Escherichia coli O157:H7	<2	<2	2.5	4	8	**$17^{D, E}$**	ι
Klebsiella pneumoniae	12	15	**$17.5^{D, E}$**	**$20^{D, E}$**			δ
Legionella pneumophila ATCC33152	1.9	3.8	5.8	7.7	9.6		θ
Legionella pneumophila ATCC 43660	3.1	5	6.9	9.4			γ
Legionella pneumophila ATCC33152	1.6	3.2	4.8	6.4	8.0		θ
Pseudomonas stutzeri	**$100^{D,E, I, J}$**	**$150^{D, E, I, J, G}$**	**$195^{D, E, I, J, G}$**	**$230^{D, E, I, J, G}$**			λ
Salmonella spp.	<2	2	3.5	7	14	**$29^{D, E}$**	μ
Salmonella typhi ATCC 19430	1.8	4.8	6.4	8.2			γ
Salmonella typhi ATCC 6539	2.7	4.1	5.5	7.1	8.5		ν
Salmonella typhimurium (from human feces)	2	3.5	5	9			μ
Salmonella typhimurium	**$50^{D, E, I}$**	**$100^{D, E, I, J}$**	**$175^{D, E, I, J, G}$**	**$210^{D, E, I, J, G}$**	**$250^{D, E, I, J, G}$**		λ
Shigella dysenteriae ATCC29027	0.5	1.2	2	3	4	5.1	γ
Shigella sonnei ATCC9290	3.2	4.9	6.5	8.2			ν
Staphylococcus aureus ATCC25923	3.9	5.4	6.5	10.4			ν
Streptococcus faecalis (secondary effluent)	5.5	6.5	8	9	12		ξ
Streptococcus faecalis ATCC29212	6.6	8.8	9.9	11.2			ν
Vibrio natriegens	**$37.5^{D, E}$**	**$75^{D, E, I}$**	**$100^{D, E, I, J}$**	**$130^{D, E, I, J, G}$**	**$150^{D, E, I, J, G}$**		λ
Yersinia ruckeri	1	2	3	5			β

The bold values are to where the received UVC dose is not enough to reach X Log10 reduction of the specific microbe.

References (α) Mamane-Gravetz H, et al. Environ Sci Technol 2005;39:7845-52. (β) Liltved H and Landfald B. Water Research. 1996;30: 1109-1114. (γ) Wilson BR, et al. Water Quality Technology Conference, Nov 15–19, 1992, Toronto, Canada, pp. 219–235, Amer. Wat. Works Assoc., Denver, CO. (δ) Giese N and Darby J. Water Research, V34, 2000.4007-4013. (ε) Sommer, R, et al. Water Sci. Technol. 1998;38(12):145150. (ζ) Hoyer O. Water Supply 1998,16(1–2): 424-429. (η) Wu Y, et al. Appl Environ Microbiol 2005;71:4140-3. (θ) Oguma K, et al. Water Res 2004;38:2757-63. (ι) Yaun BR, et al. J Food Prot 2003;66:1071-3. (λ) Joux F, et al. Appl Environ Microbiol 1999;65:3820-7. (μ) Tosa, K. and Hirata, T. IAWQ 19th Biennial International Conference, 1998. Vol. 10, Health- Related Water Microbiology. (ν) Chang JC, et al. Appl Environ Microbiol 1985;49:1361-5. (ξ) Harris, G.D, et al. Wat. Res. 1987;21(6):687-692.

Graphic 1



APPENDIX B

The UV doses is the product of the UV intensity; the formula is:

UV Doses = UV intensity μW/cm^3) $\times$ Exposure time (s) The result of this value is expressed in μWSec/cm^2.

ACKNOWLEDGMENT

The team would like to extend their deepest gratitude to the Doctor in charge, Ernesto Cuauhtémoc Sánchez Rodríguez, for his immense patience and accessibility during this turbulent times and for giving us the advices to make our practices available.

In addition, we also wish to thank professor Alejandra Cabrera for his advices and for taking her own time to help to solve administrative problems. Also, we very much appreciate the quick responses by the professor Sharleen Morales Rojas who help us to solve problems related with the report.

REFERENCES

[1] Lindblad M., Tano E., Lindahl C. and Huss F. Ultraviolet-C decontamination of a hospital room: Amount of UV light needed.
[2] https://doi.org/10.1016/j.burns.2019.10.004
[3] Nerandzic, M.M., Cadnum, J.L., Pultz, M.J. et al. Evaluation of an automated ultraviolet radiation device for decontamination of Clostridium difficile and other healthcare-associated pathogens in hospital rooms. BMC Infect Dis 10, 197 (2010).
[4] https://doi.org/10.1186/1471-2334-10-197
[5] Rutala, W., Gergen, M., & Weber, D. (2010). Room Decontamination with UV Radiation. Infection Control & Hospital Epidemiology, 31(10), 1025-1029. doi:10.1086/656244
[6] https://www.sciencedirect.com/science/article/pii/B9780124158467000342
[7] https://www.fda.gov/radiation-emitting-products/tanning/ultraviolet-uv-radiation#:~:text=UVA%20rays%20have%20the%20longest,a%20small%20amount%20of
[8] https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html
[9] https://www.ipn.mx/imageninstitucional/comunicados/ver-comunicado.html?y=2020&n=95
[10] https://www.smartsheet.com/agile-vs-scrum-vs-waterfall-vs-kanban
[11] https://platformio.org/
[12] https://www.g2.com/products/fusion-360/reviews