Application of Robotics UV-light Device In Averting The Spread of Coronavirus.

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Abstract: This research focused on *robotic ultraviolet light (RUV light) for sanitizing the environment due to the outbreak of the Coronavirus pandemic devastating the whole world. The prototype Robotics UV-light device was proposed in this research to relieve mankind of sanitization of the ecosystem since SARS-CoV-II is highly infectious. The robotic Ultra-violet system was developed using perception subsystems as well as cognition subsystems, all linked together to perform the needed functions. Nine perceptions recognition subsystems were deployed with a remote controller for the driving as well as monitoring of the system for optimum performance while in operation. The Robotics was built with four lamps of ultra-violet lights such that while in operation, the targeted environment gets sanitized at the same time. An extra lamp was attached at the top end of the robotic device which is used to fumigate the upper part of the wards where the other lights could not reach. One of the inbuilt perception subsystems collects information on the extent of sanitization and then via the cognition subsystem shuts down the system automatically. If by chance a novice approaches the ward(s) where the robotic system is working, another perception subsystem will perceive human presences and through the cognitive device raises a mimic human tone programmed, "this place is not safe now, quickly shift". If within ten nano-seconds and the novice still resist the warning, then the machine shutdown automatically. The performance of this electromagnetic light has an efficiency of 99.99 percent over both bacteria and viruses including Covid-19.*

Keywords: Coronavirus pandemic, ultra-violet light, Electromagnetic light, Robotic, SARS-CoV-2, sanitizer.

1. Introduction:

The world over is witnessing another serious pandemic since the last H1N1 virus pandemic in the year 1918 followed by H2N2 pandemic of 1957-1958. This recent pandemic called covid-19 by World Health Organization on March 11th, 2020, raised its ugly head in Wuhan Laboratory China by December 2019, though it has not spread to other places. At the onset of the outbreak WHO and other scientists gave the pandemic an interim name as 2019-nCoV (Laboratory testing of coronavirus, 2020)(Novel Coronavirus, 2019)(Novel Coronavirus, 2020). It was later that organization called the International Committee on Taxonomy of Virus renamed the pandemic as SARS-CoV-II. On further research was done by (World health organization 2019), the research came to terms with earlier researchers that the virus is a respiratory disease activated by unembellished acute respiratory syndrome coronavirus II, hence, in support of the name SARS-CoV-II. The infectiousness of COVID-19 ranges from mild with no symptom(s) to severe ailment that may lead to the death of its victim. The symptoms seen with severe COVID-19 patients range from high fever, general body weakness, acute cough to a sore throat. Other signs include headaches and body pains, a state of anosmia, ageusia as well as vitiligo, diarrhea and finally may lead to dyspnea. To checkmate the blowout of the disease which spread like a wildfire, several efforts from different health specialists were made but to no avail. Many unlucky persons still fall under the cold hands of that wicked disease. Funny enough the disease is a respecter of no man, neither color, race, age nor social status; it only the immunity level in its victim does it respect. All activities ongoing previously in the world were brought to a standstill instantly; be it social, economic, or even global activities. To that effect, many nation's economies both giants and weaklings were capsized.

As in the case of most contagious diseases, the transmissibility of SARS-CoV-II – the beta version of coronavirus that caused COVID-19 happened by one-on-one interaction with the carrier or any object touched by the carrier and also by airborne routes. Hence, from research, SARS-CoV-2 was been destroyed or destabilized by aerosols within a short span of at least 3hours (Van et al, 2020). The news of the high rate of mortalities as a result of Covid-19, all hands were on deck to combat the nemeses ravaging the world over. So many measures were adopted to minimize the wild spread, some of such measures were, use of liquid disinfectants either to wash hands or just to spray in the hands, masking of mouth and nose, staying 6 feet apart

54　in any public gatherings including other personal hygiene practices. On the other hand, some drugs were
55　recommended for anybody that contacts the deadly disease. Such drugs include Paracetamol tablets, Vitamin C
56　natural or synthesized D_3, and B complex natural or synthesized, Vapor or capsules for the stream,
57　hydroxychloroquine tablets or chloroquine tablets, and dexamethasone. Other devices recommended for the
58　intensive care unit (ICU) were Oximeter, oxygen cylinder, and breathing exercise. In addition to the sanitary
59　measures, social distancing, Moez Guettari, (2020) advocated for environmental fumigation, thorough testing of
60　individuals, and quarantine of any alleged person for two weeks. Furthermore, two genetically engineered
61　antibody from a single clone were made available for treatments (Bamlanivimab, was a product from Eli Lilly;
62　with a combination of Casirivimab and Imdevimab, manufactured by Regeneron company) were given
63　emergency endorsement for use by the American Food and Drug Administration (FDA) in November 2020.

64　In the event of environmental disinfection, Otto et al, (2011), mojarad et al, (2017) and Darnella el al, (2004)
65　classified the cleansing procedures into chemical and physical types. According to references above ecological
66　factors like temperature if $\geq 65℃$ deactivates the virus. It was also observed that alkalinity $(pH >$
67　$12)\ or\ acidity(pH < 3)$ incapacitates the virus. Other factors to be considered for effective fumigation were
68　the quantity of calcium and magnesium dissolved in water, the quantity of soluble and particulate organic
69　matter, topographical space, other chemical compounds available in the liquid indicates the decontamination
70　tactics to adopt. Moez Guettari, (2020), opined that chemical decontamination tactics contain some reagents
71　grouped based on their nature: (1) acidic nature: acetic acid and citric acid; (2) alcoholic nature: C_2H_6O or
72　CH_3CH_2OH and C3H8O or CH3CHOHC; (3) aldehydic nature: formaldehyde and gluteraldehyde; (4) alkalic
73　nature: NaOH or AI(OH)$_2$, Na$_2$CO$_3$, and Ca(OH); (5) biguanides nature: chlorhexidine; (6) halogenic nature: Cl
74　or I$_2$ composites; (7) oxidizing agents; and (8) quaternary ammonium compounds.

75　Of recent, many companies have produced vaccines in curtailing the wild spread of the virus, though not yet
76　accepted by many people. Debates are still ongoing as regards the vaccines' effectiveness and efficacy. Hence,
77　this project was conceived to investigate the effectiveness of ultra-violet light in curbing this dreaded virus. Bai
78　et al (2020) opined that since the pandemic is a more or less airborne virus a more pragmatic approach is
79　adopted in pursuit of it. Hence, this research then adopted spraying ultra-violet light by machine, thereby
80　minimizing the spread. Six species of human coronaviruses were in existence from literature, though a species
81　mutated to give additional new strain. As opined by some academicians that four of the six human coronaviruses
82　have mild symptoms, though still under dispute (King and Anthony, 1971). Such species of human
83　coronaviruses include (King and Anthony, 1971) OC43 (HCoV - OC43) called $β − CoV$, human coronavirus
84　type HKU1 (HCoV-HKU1) or is called $β − CoV$. Another human coronavirus species is 229E (HCoV-229E
85　also called $α − CoV$, the last of them all is human coronavirus NL63 (HCoV-63) $called\ α − CoV$. Some
86　possibly severe symptoms that three human coronaviruses produce were "mid-east respiratory syndrome-related
87　coronavirus" known as (MERS-CoV) or β-CoV, severe acute respiratory syndrome-related coronavirus called
88　(SARS-CoV) or β-CoV, severe acute respiratory syndrome coronavirus II (SARS-CoV-II) or β-CoV.

89　Even though several regulatory procedures had been put in place, yet the virus continued to spread like a
90　wildfire unabated. This reason gave the research the impetus to look into robotic UV light as a means of
91　averting the menacing of this pandemic. The light from electromagnetic waves can efficaciously neutralize
92　microbes or viruses in the air that spread SARS COV-1. It is on record that sickness like measles, tuberculosis,
93　eczema, acne, and psoriasis, etc., were been caused by some of these microbes like bacteria, fungi, pathogens,
94　parasites, viruses, spores, dust mite, which for some decades ago, UV-light has been proved to have reduced the
95　spread of them. Therefore, UV-light efficacy needed to be appraised in the deactivating of Covid-19 growth.

96　UV radiation has been adopted in some healthcare units to sanitize surfaces, objects, water, air, and sterilize
97　microorganisms. There are different wavelengths of radiation, UV-light which has much energy, and smaller
98　wavelength when compared with radio waves or visible light. On the contrary, either X-radiation or $γ$-rays have
99　more energy than UV-light. The spectrum of UV-light showed its three regions - the near-ultraviolet (NUV)-
100　closest to optical light and is visible to some insects, birds, dogs, etc., the far-ultraviolet (FUV) has 122-200
101　nanometer, and the extreme ultraviolet (EUV) 10 - 124 nanometer. Man can receive UV light naturally using
102　sunlight or via a man-made device like tanning beds. Lucas (2017) discussed UV-light as electromagnetic
103　radiation, capable of terminating the microbes at the formation stage thereby thwarting its procreation. The
104　scholar further stressed that the origin of the radiation was from the sun, though conveyed as waves at various
105　wavelengths and frequencies. Other sources can generate UV-light other than the sun, fluorescent and

incandescent bulbs, mercury vapor light, halogen light, lasers, discharge lamps, etc. UV-light was further classified by Derraik et al, (2020) into three types namely, ultraviolet A (UVA) having wavelengths of 320-400nm, ultraviolet B (UVB)- 280 – 320 nanometer, and ultraviolet C (UVC) – 200 – 280 nanometers. UV-light according to Hebling et al (2020) could be utilized in sanitizing ecosystems and their environs due to its sensitive nature. Then the actions of the light thereby mitigate the spread of coronaviruses. Referring to Figure 1, (ASHRAE 2019)(UVC LED Disinfection 2013) showcased that smaller wavelengths of UVC not only incapacitate viruses, bacteria, and fungi but also make them un-procreative or even cause sickness.

The efficacy of UV-light was further confirmed by Kowalski (2009) which shows the ability to destroy fungi, bacteria, and viruses in hundreds of laboratory studies. Another scholar showed the vulnerability of SARS-CoV-2 to UV-light, the virus showed high weakness when exposed to UV-light (Heilingloh et al, 2020). The observation of Narita et al, (2018) from Figure 2 revealed that ultraviolet light within the wavelength range of 207 – 222 nanometers is highly effective in conventional germicidal ultraviolet light employed in destroying microbes.
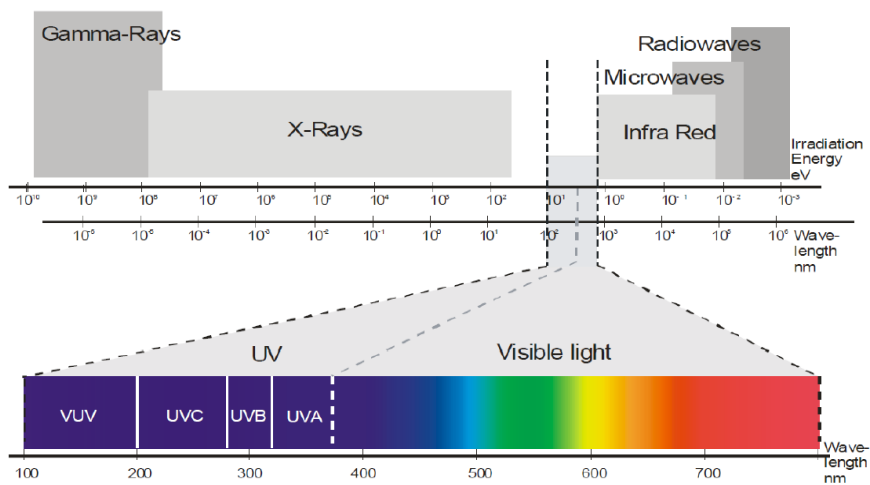
Figure 1: **Electromagnetic Spectrum** (UVC LED Disinfection, 2013)
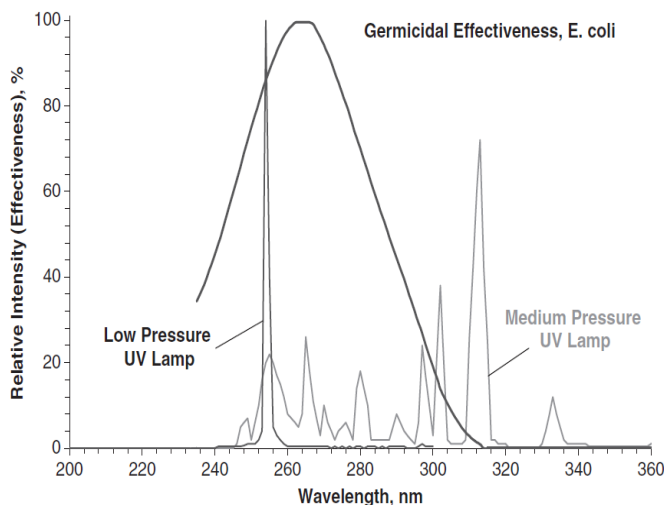
Figure 2: Comparison of germicidal efficiency ultraviolet wavelengths of much (or average) and lower-pressure ultra-violet lamps with germicidal effectiveness for E. coli, (Luckiesh 1946)(IESNA, 2000).

Of course, Kitagawa et al (2020) discovered that ultraviolet light of wavelength 222 nanometer, even though safe for human life but it still deactivates coronaviruses. The researchers experimentally exposed the covid-19 virus to 222 nanometers UV-light at 0.1 Mw per cm^2 and observed that after 30 seconds viruses were all dead. Hence, the wavelength of UV light matters much in achieving the desired result. A contradictory result arose as some researchers showcased that ultraviolet B produced better results in deactivating viruses.

132 Some inherent disadvantages of ultraviolet lights when exposed to include skin burn, skin cancer, more so it
133 produces wrinkles on the body, age spots, eye burn, it is also capable of causing damages in genetics or DNA,
134 hence resulting in a mutation in the victim(s) (Trevisan et al, 2006)(Zafna et al, 2012)(Setlow et al,
135 1993)(Balasubramanian et al, 2000).
136 The human risks involved in the use of UV-light do not affect its efficacies in the sanitization of environs,
137 personal protective equipment (PPE), treatment of water, and as well as sterilization of medical equipment.
138 Even though UV light has these advantages to its credit, caution should be employed while in use even though it
139 is a good approach for microbes to be exposed to ultraviolet light (Kowalski, 2009), and also such exposures
140 combat seriously with various strains of viruses thereby incapacitating them (Budowsky et al, 1981). Of recent
141 xenon lamps which generate broad ultraviolet spectrum were now employed for germicidal Naunovic et al,
142 (2008); but farhad et al (2010) claimed that for "scrubbing" health care environs, equipment and lab UV
143 germicidal irradiation (UVGI) has been utilized for years now.
144   2. **The operational mechanism of the prototype ultra-violet robotic device**,
145 The prototype Robotic UV-light system was implemented using nine perception subsystems as well as cognition
146 subsystems. The main element in the perception subsystem is the sensors. Six of the sensors were in charge of
147 the robotic movement, where the other three remain performed different assignments for the effective
148 performance of the device. One of the other three remaining perception subsystems monitors the degree of
149 sanitization of the environs of which within 15-25 minutes the fumigation will be over. At this point, the
150 cognition subsystem will then determine the next action to be taken by the robot. The second perception
151 subsystem in conjunction with the cognition subsystem perceives human presence when the sanitization process
152 is ongoing, a mimic human tone programmed, "this place is not safe now, quickly shift", will then be initialized.
153 Waiting for 0.12 seconds and such individual respond not to the warning, the cognition subsystem then activates
154 stoppage of the device on its own. The third perception subsystem with its counterpart in the cognition
155 subsystem monitors ultraviolet at the upper/head of the robotic device for the sanitization of the upper part of
156 the wards where the fumigation is taking place.
157 The UV light was designed to look like a lamp with a shining surface that reflects all the light intensity at an
158 angle of 180° frontwards. There are four of these lamps around the robotic device, which cover all the environs
159 to fumigate. As soon as the robot system gets to its target place of work, through the remote controller, the
160 device will be set to work making some movements appropriately. Then, the perception and cognition
161 subsystems monitor as well as taking decisions determine the degree of fumigation takes appropriate action at
162 the due time. Figure 3 depicted the prototype ultraviolet light system.
163
164   3. **UVC light models**.
165 In modeling of ultraviolet-light, Chick (1908) in his work gave the fundamental rate model of sanitization and
166 the formula is as shown in Eq. (1)

167
$$\frac{d\Xi}{dt} = -m\Xi \qquad (1)$$

168 where Ξ is the number of the microbes at time t(sec) and m is the rate of observed sanitization. Furthermore,
169 following the work of Kamiko et al (1989), Eq. (1) is transformed to be Eq (2);

170
$$\frac{d\Xi}{dt} = Y\zeta\Xi \qquad (2)$$

171 here ζ depicted the ultraviolet intensity measured in (μW per cm^2) and Y is the microbes vulnerability factor
172 measured in $(cm^2\mu^{-1}Ws^{-1})$. The vulnerability constraints fluctuate with ecological situations, such as
173 atmospheric relative humidity (Ko et al, 2000)(Mcdevitt, 2012). From observation, ultraviolet C efficacy
174 declines with growing atmospheric relative humidity (Mcdevitt, 2012).
175
176 The drive current of ultraviolet intensity, ζ (μW per cm^2) was given in Eq. (3)

177
$$\zeta = \left(\frac{log_e\left(\frac{B_{262}^0}{B_{262}}\right)}{\tau}\right) \times \left(\frac{\aleph}{2.303 \times 1000 \times \beth_{262} \times \varphi}\right) \text{ (μW per cm}^2) \qquad (3)$$
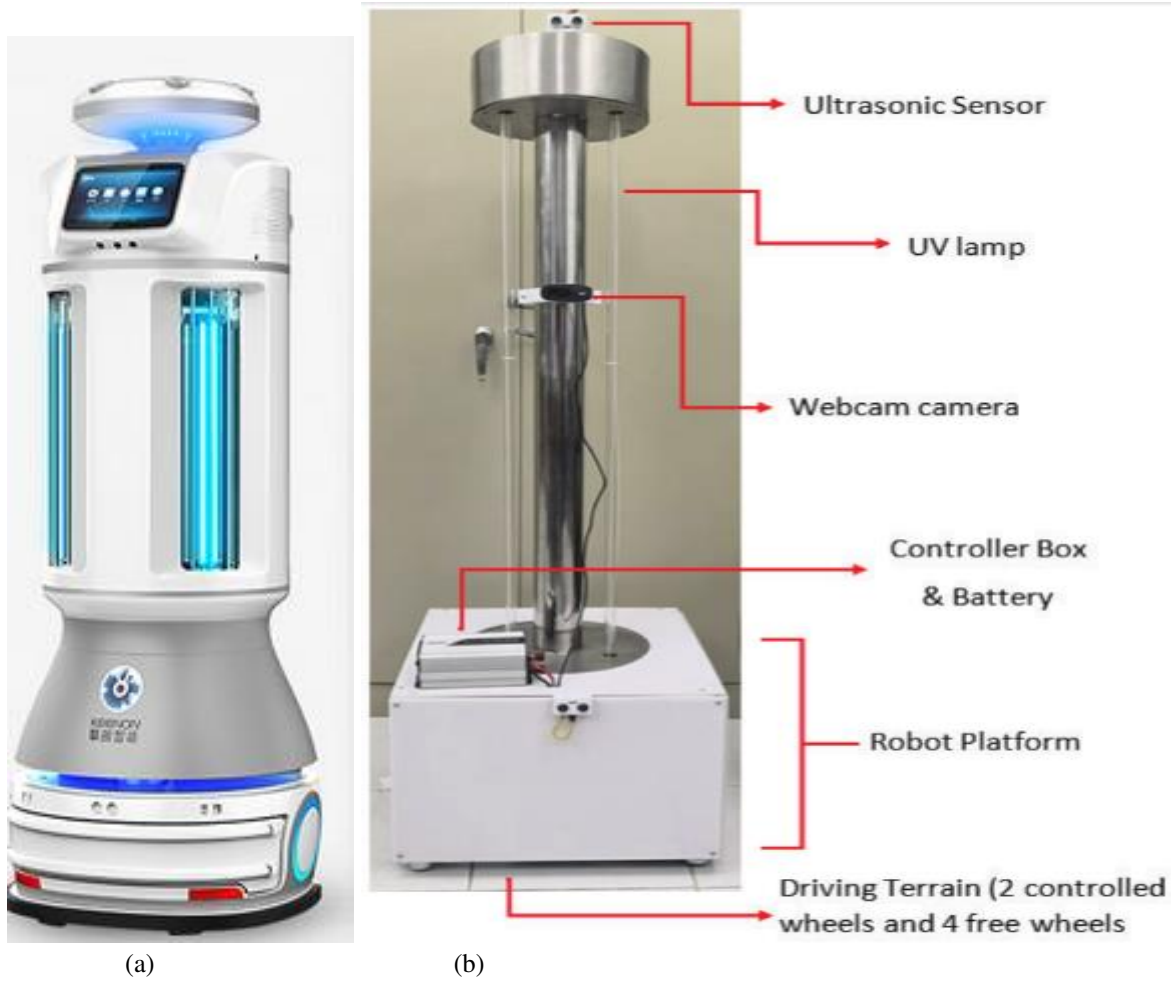
<div align="center">(a)   (b)</div>

Figure 3: (a)The prototype robotics ultraviolet-Light System, (b) UV sterilisation robot (Chanprakon et al. 2019).

where B_{262}^0 and B_{262} is the solution absorbance of actinometer which occur before and after being irradiated at 262 nm, $\dfrac{log_e\left(\frac{B_{262}^0}{B_{262}}\right)}{\tau}$ $(per\ second)$, is the gradient linear trendline of the curve of $log_e\left(\frac{B_{262}^0}{B_{262}}\right)$ with time, τ is time measured in seconds, $\aleph$ is the photo emitted energy at 275 nanometers is 7.23 exp(19), the result gives the energy per mol of the photon (JE^{-1}) when multiplied by Avogadro's number; $\exists_{262}\ is\ 8\times 10^3\ measured\ in\ (per\ mole, per\ cm)$ depicts the molar annihilation uridine coefficient at 262 nm (Cataldo 2017) and φ is the quantum yield (number of events/number of the photon absorbed) of uridine photohydration which is 0.016 $(molE^{-1})$(Kuhn, 2004) and 2.303 is log_e10. The model assumed that throughout the ultraviolet exposures the quantum yield remains constant.

Having determined the ultraviolet intensity ζ, the ultraviolet fluence (ψ) measured in (μJcm^{-2}) irradiated over each exposure time can be calculated using Eq. (4), taking into account changes in the effective dose caused by impurities which reduce the effective dose to the organism:

$$\psi = \zeta \times \frac{1-10^{-B275\times r}}{B_{275}\times r \times \ln(10)} \times \tau = \zeta\tau \quad (\mu Jcm^{-2}) \tag{4}$$

where r represents the radius of the reactor bowl measured in centimeter

The Power $\chi(\mu W)$, of the discharged ultraviolet Clamp, determines the dose received by surface unity at a given distance υ in centimeter from the sanitizer which was Eq. (5) (Owens et al, 2005).

$$\psi = \frac{\chi\tau}{2\pi\lambda\upsilon} \ (\mu Jcm^{-2}) \tag{5}$$

where λ is measured in centimeter and τ time in seconds were respectively the length of the lamp and the exposure time, so the exposure time can be estimated according to Eq. (6):

$$\tau = \frac{2\pi\lambda\upsilon}{\chi} \ (seconds) \tag{6}$$

203

4. Mathematical Model of the Robotic device

This research work focused on robotics ultraviolent light systems due to the effect of ultraviolet light on human health if not used with care. With this prototype ultraviolet light, human direct involvement in the sanitization of environs will no longer be there. The only thing needed is to notify individuals when and where the sanitizations will take place and at the same time the duration of the exercise by pasting a notice there. It was expected that the robotic device was built with four ultraviolet light lamps around the robotic device for the purification exercise hence the device modeling will consist of the physical behavior of the system, based on cinematic and kinematic energy.

The body movement without taking note of the force/torque that was pressing on its body or causing the movement is regarded as kinematics to the robotic mechanism. The procedure of plotting a robot manipulator from Joint-space to Cartesian-space (sometimes known as task space) can be regarded as frontward kinematics. This action can easily be determined by the transformation of the data generated from the kinematic of the robotic device's joint-space to the Cartesian space. The coordinate of a robot end-sensory conversion matrix to the base frame generally can be obtained by the use of Hartenberg Denavit's s method (Jazar, 2010). At this juncture, it is worthy to note that the D-H method is concerned with the transformation amongst two end-to-end coordinate settings. Conventionally, when the D-H method is applied, the synchronize settings ϖ_i is converted from the synchronize settings to ϖ_{i-1} by the homogenous transformation matrix $^{i-1}\lambda_i$ (Wee, 2014);

$$^{i-1}\lambda_i = \begin{bmatrix} ^{i-1}\eta_i & ^{i-1}v_i \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \cos\phi_i & -\sin\phi_i Cos\phi_i & \sin\phi_i\sin\vartheta_i & \vartheta_i\cos\phi_i \\ \sin\phi_i & \cos\phi_i\cos\vartheta_i & -\cos\phi i\sin\vartheta_i & \vartheta_i\sin\phi_i \\ 0 & \sin\vartheta_i & \cos\vartheta_i & v_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{7}$$

where $^{i-1}\eta_i$ represent a 3 x 3 matrix portraying spinning and $^{i-1}v_i$ was a 3 x 1 vector depicting to and fro motion. Also, the inverse transformation equation to convert the synchronize setting $\varpi_i(a_i, b_i, c_i)$ to synchronize setting $\varpi_{i-1}(a_{i-1}, b_{i-1}, c_{i-1})$ was

$$\begin{bmatrix} a_{i-1} \\ b_{i-1} \\ c_{i-1} \\ 1 \end{bmatrix} = i - 1\lambda i \begin{bmatrix} a_i \\ b_i \\ c_i \\ 1 \end{bmatrix} \tag{8}$$

Solving the frontward location kinematics of a joint coordinate from the standpoint of the base frame can easily be achieved using a combined transformation matrix as depicted in Eq. (9)

$$^0\lambda_n = {}^o\lambda_1(\partial_1) \ {}^1\lambda_2(\partial_2) \ {}^2\lambda_3(\partial_3) \ \ldots\ldots\ldots \ {}^{n-1}\lambda_n(\partial_n)$$

$$= \begin{bmatrix} z_{11} & z_{12} & z_{13} & z_{14} \\ z_{21} & z_{22} & z_{23} & z_{24} \\ z_{31} & z_{32} & z_{33} & z_{34} \\ z_{41} & z_{42} & z_{43} & z_{44} \end{bmatrix} \tag{9}$$

For $z_{ij} = z_{ji}(\partial\sigma), \quad \sigma = 1, 2\ldots n$

where n denotes the degree of freedom.

The rotational matrix for the three a-b-c axes were as shown in Eq. (10) – (12).

$$\eta_a(\phi) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix} \tag{10}$$

$$\eta_b(\phi) = \begin{bmatrix} \cos\phi & 0 & \sin\phi \\ 0 & 1 & 0 \\ -\sin\phi & 0 & \cos\phi \end{bmatrix} \tag{11}$$

$$\eta_c(\phi) = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{12}$$

5. Discussion

The prototype robotic device comprises four ultraviolet lamps which were fixed centrally in the body of the machine device with one lamp on top with numerous sensors. The robotic device has to master its environment via a mapping process. For this action to take place, light detection and ranging sensors of robotics system played a major role in it surveying the environs and develops an appropriate digital map. Through the help of inbuilt affections in the device, the robot responds impulsively to any stimuli within its environs quickly on its own. Whenever the device is in operation if it senses the presence of any human being via one of the sensors, an inbuilt alarm will be triggered. The alarm is the form of a recorded voice which goes thus, "move out from here, it is unsafe for you" if such a person couldn't move out within 10 nanoseconds, the sensor then triggered shutdown switch of the ultraviolet light automatically. Normally, 15 to 25 minutes were required to sanitize the award/apartment. With the wavelength of 254-nanometer light, microbes were incapacitated to the tune of 99.99% in few a minutes when the robot ultraviolet light discharges 20 $Jm^{-2}s^{-1}$ (Magda et al, 2021). Hence, the involvement of this prototype is better than human cleansing because it will eradicate the hazard that can affect human health. Therefore, applying robotic ultraviolet light minimizes the spread of covid-19 like a wildfire which is the global pandemic drowning the entire world to a halt.

6. Conclusion.

Necessity is the mother of invention, the inception COVID-19 pandemic enhanced innovation on all spheres of life; both public, societal, and medical alike. Deploying robotic devices for decontamination of hospital sensitive equipment as well as its environs and other related surroundings has a greater potential in the future. If appropriately utilized more especially in the health sector, the Robotic ultraviolet light will assist in reducing the health hazards of using improperly sterilized equipment.

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