

Maximum Speed Analysis of Mobile Robot for SARS-CoV-2 Disinfection Using UVC Lights

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Abstract - Covid-19 is a disease caused by a new type of coronavirus, namely SARS-CoV-2 (Severe Acute Respiratory Syndrome-Coronavirus-2). Covid-19 attacks humans in the respiratory system ranging from mild flu-like symptoms, to lung infections such as Covid-19 pneumonia spreads very quickly, namely through droplets, aerosols, etc. which are not visible to the naked eye. With these conditions, so an innovation is needed to prevent and overcome it with UVD robots. UVD Robot (Ultraviolet Disinfection Robot) is a robot that can disinfect viruses in a room with UVC light. UVD Robot Robot can be controlled automatically or manually so that it can be controlled from several meters. UVC (Ultraviolet C) light with a wavelength of 254 nm has the ability to prevent viral replication at the appropriate dose, distance, and time. The way UVC light works is to damage the structure of the DNA and RNA viruses so that they cannot replicate themselves. This research is based on the speed and trajectory of the UVD robot in order to obtain an effective configuration without reducing the ability of the UVD robot.

Keywords: COVID-19, UVC lights, UVC rays, UVD robot, Irradiance test, UV dose.

I. INTRODUCTION

December 2019 the world was shocked by the news about Covid-19 (Corona virus Diseases 2019) which was first discovered in Wuhan, China. The number of Covid-19 cases worldwide as of November 25, 2022 reached 645,038,117 cases with 623,871,759 declared recovered, 6,633,041 dead, and 14,533,317 active cases. In addition, Indonesia has a total of 6,634,648 cases with 6,411,220 declared recovered, 159,565 dead, and 63,863 active cases and placing Indonesia in the 20th rank with the most Covid-19 cases in Asia [1].

Covid-19 is a disease caused by a new type of corona virus called SARS-CoV-2 (severe acute respiratory syndrome-coronavirus-2). Covid-19 can cause respiratory system disorders, ranging from mild symptoms such as flu, to lung infections, such as pneumonia. (Merry, 2020). SARS-CoV-2

attacks humans in the respiratory system. The physicochemical properties of SARS-CoV-2 are largely unknown. SARS-CoV and MERS-CoV can survive in vitro for 48 hours in a dry environment for up to 5 days below 20°C with 40%-50% humidity [2].

Covid-19 which has been going on since the beginning of 2020 has had a negative impact on several sectors, especially the economy. The President of Indonesia stated that in the second quarter the Indonesian economy was minus 5.32 percent, whereas previously in the first quarter it was still growing positively at 2.97% [3]. In addition, more than 3.5 million workers were forced to be laid off and laid-off [4]. The government carried out several stages of easing known as PSBB (Large-Scale Social Restrictions) to slightly help the country's economy. However, unexpectedly, there were new clusters of distribution, especially offices, reaching 3,084 people, while the community had to work to meet their daily needs, even more so during this pandemic [5].

Therefore, every human being needs awareness to protect himself from the spread of the coronavirus. There are many ways that can be done to prevent and overcome the spread of the coronavirus, starting from the appeal for the use of masks, always washing hands, prohibited from being close together, to spraying disinfectants. The economic, education, and tourism sectors need to be restored little by little because they are vital sectors for the country—examples of recovery that can reopen shopping malls, schools, tourist attractions, transportation, etc. Therefore, a new health protocol and normality are needed for Covid-19 to make people feel safe when doing activities. One way that can be used is to use ultraviolet C (UVC) light with a wavelength of 254 nm. UVC light has a shorter wavelength than ultraviolet A (UVA) and ultraviolet C (UVC) light, so the shorter the wavelength, the greater the intensity. UVC rays have been applied to sterilize hospital equipment, operating rooms, and laboratories. UVC rays can prevent virus replication with the appropriate dose, distance, and time. The workings of UVC rays are to damage the DNA and RNA structure of the virus so that it cannot self-replicate [6-8]. Innovation in the application of UVC rays with UVD Robot. UVD Robot (Ultraviolet Disinfection Robot) is a

robot that can disinfect a room with UVC light. UVD robots can be controlled manually and automatically. UVD Robot is an option because of its good mobilization in a room and reduces the direct interaction of UVC rays with humans [9].

This final project was conducted to examine the speed and shape of the trajectory of the UVD robot in order to obtain an effective configuration without compromising the ability of the UVD robot. With the UVD robot, it is hoped that it can help restore shopping centers, office spaces, and schools effectively so that activities can return to normal calmly without any doubts.

II. METHODS

The analysis for finding the maximum speed of the UVD robot such that the coronavirus in a room can be destroyed is conducted first by calculating the irradiance and duration, measuring the UVC light irradiance. The calculation and measurement data are then used in computer simulation for analyzing the effect of two different trajectories on the UVD robot maximum speed when the robot is used for disinfection an empty room with size of 10 x 10 meters

2.1 Calculating irradiance and duration

Calculation of irradiance on the surface with a distance of 1 meter and the time required to destroy SARS-CoV-2 using Keitz Formula [10] which consists of E as Irradiance (W/m^2), P as the output power (W), D as distance between the lamp and wall (meter), L as the UV lamp length (meter), and α as the angle formed between lines L and D .

The schematic for testing is shown in figure 1. The testing requires three UV lamps with an output power of 59.4 watts each on the surface of the lamp tube. The length of the lamp is 1.198 meters, and the distance between the surface and the robot is 1 meter, the irradiance on the surface exposed to UV light is $4.92 W/m^2$. According to Martin's research in 2020, the median UV dose used was $3.7 mJ/cm^2$ and the upper limit was $10.6 mJ/cm^2$ [6]. The time required for virus disinfection with 2 different doses will be different but the distance required remains the same based on the Keitz Formula; thus the calculation of duration at the median dose ($3.7 mJ/cm^2$) uses equation 2.

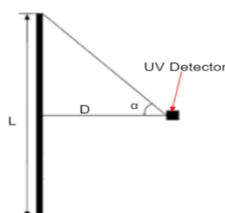


Figure 1: UVC light irradiance test setup

$$E = \frac{P (2\alpha + \sin 2\alpha)}{2\pi^2 D L} \tag{1}$$

$$E = \frac{59.4 \text{ watt} (2\alpha + \sin 2\alpha)}{2\pi^2(1)(1.198)}$$

$$E = 4.92 W /m^2$$

$$t = \frac{Z}{E} \tag{2}$$

$$t = \frac{37 J/m^2}{4.92 W/m^2}$$

$$t = 7.52 s$$

Where Z = UV dose of $3.7 J/m^2$ and irradiance of $4.92 W/m^2$ on the surface, the duration or time required for disinfection is 7.52 seconds.

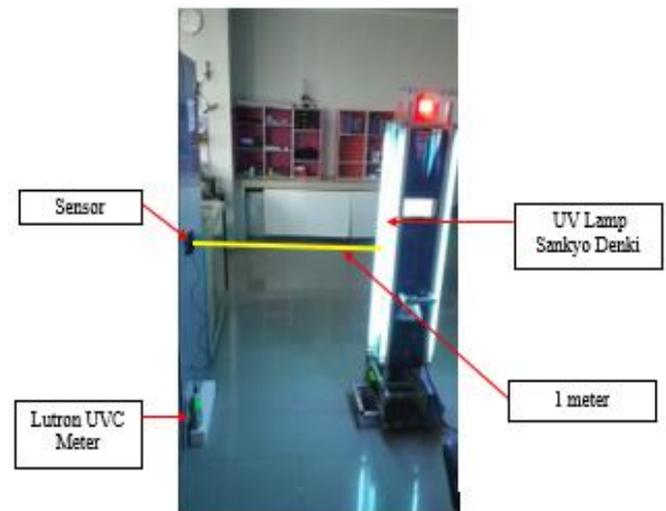


Figure 2: UVC light irradiance test setup

2.2 UVC Light Irradiance Measurement Test

Tests were conducted to determine the actual irradiance value measured using the Lutron UVC Light Meter. As shown in figure 2, testing activities were carried out in the Robotics and Automation Laboratory at Diponegoro University.

The irradiance test setup begins by gluing the sensor as high as 95.9 cm from the ground because the UVC lamp length is 119.8 cm so that the sensor is positioned parallel to the center of the UVC lamp, which is 59.9 cm plus the robot base height is 36 cm. After that, place the UVC lamp 1 meter away from the sensor. Next, start the UVC meter to calculate the intensity, turn on the UVC lamp using the remote, and the test lasts 60 seconds for each session.

III. RESULTS AND DISCUSSIONS

3.1 Experiment

The test was carried out with a distance between the lamp and the sensor as far as 1 meter and carried out three experiments to conclude, and then each conclusion lasted 1 minute.

Table 1: Irradiance Test Results at 1 meter Distance

No	Experiment	t (s)	E (W/m ²)
1	Experiment 1	60	2.34
2	Experiment 2	60	2.39
3	Experiment 3	60	2.41
Average			2.38

Based on the test results, in experiment 1, within 60 seconds, the average irradiance was 2.34 W/m²; in experiment 2, within 60 seconds, the average irradiance was 2.39 W/m²; and in experiment 3, within 60 seconds, the average irradiance was 2.41 W/m². Thus, the irradiance that can be used for the simulation process is 2.38 W/m².

3.2 Zigzag Trajectory Simulation

Figure 3 is a zigzag trajectory simulation which is the limitation of the first problem. It shows a room measuring 10 meters x 10 meters and several signs. The red crosses are waypoints, namely as a sign of the direction where the robot will move. The 10 waypoints consist of T_a(1,1), T_b(9,1), T_c(9,3), T_d(1,3), T_e(1,5), T_f(9,5), T_g(9,7), T_h(1,7), T_i(1,9), and T_j(9,9). In addition, there are yellow circles as an indicator where the sensors are placed to measure the irradiance and dose received by the sensors. Sensors are placed at points indicated by letters of the alphabet. For example, A(X,Y) means that the sensor is placed at the X, Y coordinates, namely A(1,0); thus B(5,0), C(10,0), D(10,2), E(10,3), F(0,2), G(0,3), H(10,0), and I(10,10).

The simulation was carried out using the map in figure 3 to determine the speed and time needed to reach the target dose so that SARS-CoV-2 can be destroyed.

The simulation results in table 2 and figure 4 reveal that the UVD Robot with a power of 28.7 Watts having the spiral trajectory requires a speed of 0.11 m/s and a total disinfection time of 416 seconds to destroy SARS-CoV-2 with a medium dose of 37 J/m². In addition, UVD Robot requires a speed of 0.03 m/s and a total disinfection time of 1495 seconds to destroy SARS-CoV-2 at an upper limit dose of 106 J/m².

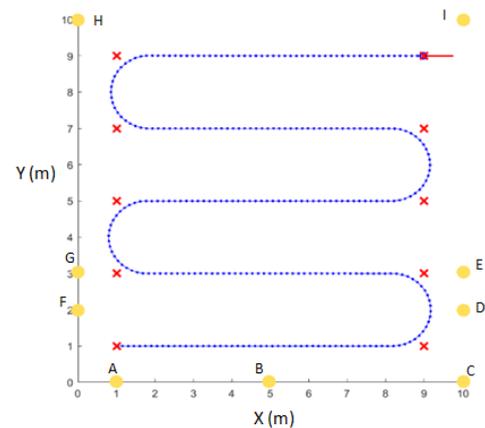


Figure 3: Zigzag simulation mapping

Table 2: Simulation result on a zigzag trajectory

No	v (m/s)	Time (s)	Z _A	Z _B	Z _C	Z _D	Z _E	Z _F	Z _G	Z _H	Z _I
Medium Dose 37 J											
1	0.13	354	51	81	37	74	67	51	65	37	32
2	0.12	381	56	88	40	78	70	55	70	40	34
3	0.11	416	60	96	43	83	76	59	76	44	37
Upper Limit Dose 106 J											
1	0.05	902	130	210	92	175	162	126	157	92	83
2	0.04	1125	162	262	115	216	200	157	195	114	104
3	0.03	1495	216	349	152	282	263	208	257	151	137

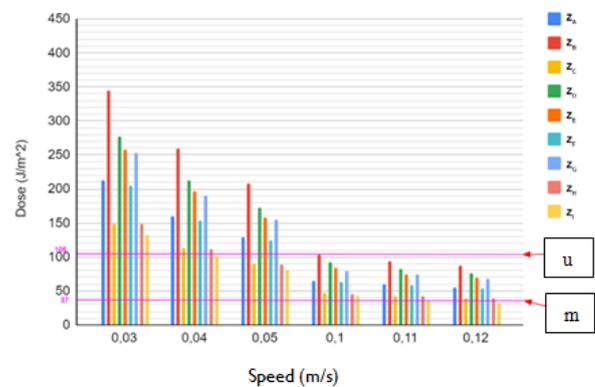


Figure 4: Effect of robot speed with a zigzag trajectory on the UV dose
Note: u = upper limit dose, m=medium dose

3.3 Spiral Trajectory Simulation

Figure 5 is a spiral trajectory simulation that is the first problem's limitation. The picture above is a room measuring 10 meters x 10 meters with several signs. The red crosses are waypoints, namely as a sign of the direction where the robot will move. The ten waypoints consist of T_a (1,1), T_b (9,1), T_c (9,9), T_d (1,9), T_e (1,3), T_f (7,3), T_g (7,7), T_h (3,7), T_i (3,5), and T_j (5,5). In addition, there are yellow circles as indicators where the sensors are placed to measure the irradiance and dose received by the sensor. Sensors are placed at points indicated by letters of the alphabet. For example, A(X, Y) means that the sensor is placed at the X, Y coordinates,

namely A(1,0); thus B(5,0), C(10,0), D(10,2), E(10,3), F(0,2), G(0,3), H(10,0), I(10,10), J(5,2), K(5,4), and L(5,6).

A simulation was carried out using the map in figure 5 to determine the speed and time needed to reach the target dose so that SARS-CoV-2 could be destroyed.

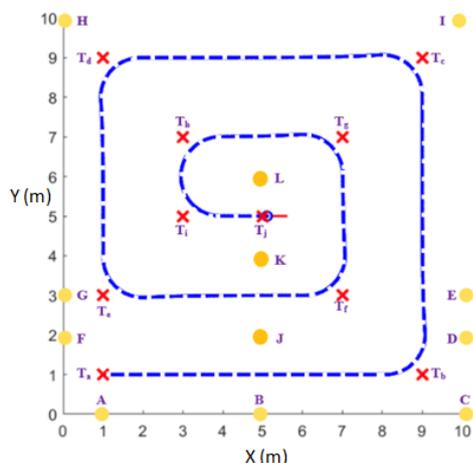


Figure 5: Spiral simulation mapping Effect

Table 3: Simulation result on spiral trajectory

No	v (m/s)	Time (s)	Z _A	Z _B	Z _C	Z _D	Z _E	Z _F	Z _G	Z _H	Z _I	Z _J	Z _K	Z _L
Medium Dose 37 J														
1	0.14	329	47	74	34	74	77	47	58	35	34	121	117	118
2	0.13	354	51	80	37	77	81	51	63	37	37	131	128	128
3	0.12	381	55	87	39	81	87	54	67	40	40	141	137	139
Upper Limit Dose 106 J														
4	0.06	754	108	173	77	154	169	105	130	77	78	281	276	280
5	0.05	902	129	207	92	186	203	125	155	92	92	336	332	337
6	0.04	1125	161	258	115	230	252	156	19	114	114	420	417	424

The simulation results in table 3 and figure 6 reveal that the UVD Robot with a power of 28.7 Watts having the spiral trajectory requires a speed of 0.12 m/s and a total disinfection time of 381 seconds to destroy SARS-CoV-2 with a dose of 37 J/m². In addition, UVD Robot involves a speed of 0.04 m/s and a disinfection time of 1125 seconds to eliminate SARS-CoV-2 at a dose of 106 J/m².

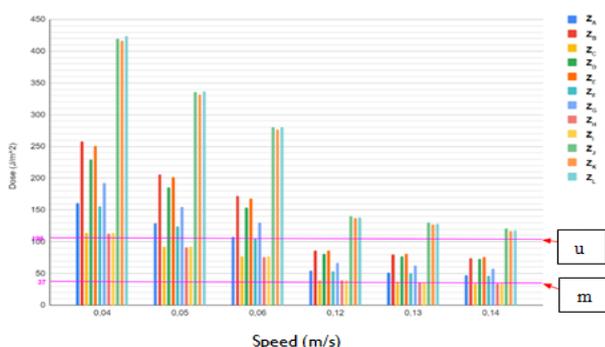


Figure 6: Effect of robot speed with a spiral trajectory to the UV dose
Note: u = upper limit dose, m=medium dose

IV. CONCLUSION

The results of this study reveal that for disinfection an empty room with a size of 10 x 10 meters a zigzag trajectory requires less time than a zigzag trajectory. The zigzag trajectory requires a maximum speed of $v_{max} = 0.11$ m/s and disinfection duration of $t_{T_{A-J}} = 416$ seconds to reach the target medium UV dose, while it needs a maximum speed of $v_{max} = 0.03$ m/s and duration of $t_{T_{A-J}} = 1495$ seconds to reach the target upper limit UV dose. On a spiral trajectory to reach the UV Dose medium target, it takes $v_{max} = 0.12$ m/s at duration $t_{T_{A-J}} = 381$ seconds, and to get the upper limit of UV Dose, it takes $v_{max} = 0.04$ m/s and $t_{T_{A-J}} = 1125$ seconds.

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