AUTOMATIC-DISINFECTION SERVICE BY AGV-COBOT SYSTEM FOR COVID-19 PANDEMIC

Nirachorn Iamsawan
Department of Industrial Engineering Mahidol University, Nakhon Pathom 73170 Thailand, E-mail: nirachorn66@gmail.com

Eakkachai Warinsiriruk
Department of Industrial Engineering Mahidol University, Nakhon Pathom 73170 Thailand, E-mail: eakkachai.war@mahidol.ac.th

Jukkapun Greebmalai
Department of Industrial Engineering Mahidol University, Nakhon Pathom 73170 Thailand, E-mail: jukkapun.gre@student.mahidol.edu

ABIGYAT Babu Prasai
Department of Industrial Engineering Mahidol University, Nakhon Pathom 73170 Thailand, E-mail: abigyat_prasai@hotmail.com

Yin-Tien Wang
Department of Mechanical and Electro-Mechanical Engineering Tamkang University, New Taipei City 25137, Taiwan, E-mail: ytwang@mail.tku.edu.tw

ABSTRACT

COVID-19 pandemic is a serious situation around the world. People have concerned about some viruses spreading in public areas. To restrain the spreading of the virus, a solution to the virus disinfection has been performed by chemical solutions and some thermal processes. The ultraviolet-C light is a non-consumable disinfection method that can disinfect the virus by the sufficiently UV-C does. Therefore, the sterilizing process should be able closely to access through the target area for avoiding insufficient UV-C does. This research has the objective of introducing an automatic UV-C disinfection with the AGV-Cobot system service for the COVID-19 pendemic. AGV was employed for running on the scheduled routing by programming or real-time IoTs remoting. Cobot has a controllable human-motion function to provide the UV-C lamp closely scan on the target surface with an object recognized machine vision. The invention unit was tested for verifying the scanning parameter that has the capability for killing some mock-up virus in the patient's room in hospital. From the experiment, the virus was perfectly killed at 3-log reduction with a UVC-to-surface distance of 1 cm and a velocity of 1 cm/s. With this needed speed and base on the experiment results, sterilize the standard patient's room that has an area approximately 32 m^2 in the hospital by AGV-Cobot with UV-C disinfection can be able in under 40 minutes. Meanwhile, the scanning time that emitting UV-C light to all furniture in the patient's room is under 25 minutes which has utility approximately 71.43% without any residues without any residues.

Keywords: UVC, Disinfection, AGV, Cobot, COVID-19.

1. INTRODUCTION

Some the virus disease could spread through person-to-person transmission, especially in the pandemic situation caused by a highly virulent strain of the virus, such as smallpox, H5N1 avian influenza in the past, and COVID-19 in the present. Their all are serious situations due to widespread mortality and morbidity. To restrain it, public health interventions should focus on preventing or interrupting this virus spreading. In the past, McDevitt (2007) presented that ultraviolet-C (UV-C) germicidal light which has wavelength 254-nm was used for air disinfection via the upper-room. However, upper-room UV-C light could sanitize only the circulated air. Meanwhile, a virus could also infect the object or surface that is touched by an infected person. Van (2020) found that remnants of SARS-CoV-2 were found to live on cardboard for over 24 hours and plastic for 3 days. To prevent transmission and restrain a virus as much as possible, the concept to use a UV-C lamp for sterilizing has occurred because of the ability to disinfection in a short time and neither chemical nor thermal effects left on the target area.

Pannika (2020) have been studying the effectiveness of innovative robotic UV-C to eliminate Pseudomonas aeruginosa as a surrogate for SARS-CoV-2 by placed the innovative robot in the center of the experiment room. The result shows that UV-C could eliminate the virus but also have several risks. For instance, the density of UV-C light could insufficient by the far distance, may have other things interpose between UV-C light and the virus which cause blocking UV-C light then the disinfection does not occur and also danger for the people who involve around, Brubaeher (1996) and Bånrud (1999) UV-C can cause dermatitis and corneal inflammation if receive in excessive amounts of density which is dependent on the distance and the exposure time.

From above, this paper introduces an integrating automated guided vehicle (AGV) and the collaborative robot (Cobot) for UV-C disinfection base on an original idea of focus UV-C intensity, scan closely on the target surface to obtain sufficient intensity by camera vision, scan with appropriate speed to provide UV-C dose on the target surface and the utilization of scanning service with the automated concept in the large area by smart AGV with GPS mapping technology.

2. METHODOLOGY

2.1 The Innovation Integrate AGV-Cobot

The innovative integrate AGV-Cobot consist of three main components as follows:

AGV: An automated guided vehicle as known as AGV is a robot that follows markers, tapes, or magnets on the floor, or uses a vision camera or sensors for navigation. The AGV in this paper is MiR 200TM which has dimensions 58x89x60 cm, take a payload up to 200 kg, max performance time is 10 hours or 15 km running time, max speed of 1.1 m/s forward, 0.3 m/s backward, and battery charging time up to 3 hours. Two Lidar sensors are installed at the corner which could create the map and detect the obstacle around itself, also could identify the position of itself by a GPS system. With this intelligent software thus the AGV has high efficiency for automates navigation with safely maneuvers around people and obstacles which make more trustable and comfortable for people who are involves.

Cobot: A collaborative robot as known as Cobot is a robot that could work along with people in a shared space. The material, shape, and program of Cobot was defined by considering safety when working with a human. Besides efficiency safety, the Cobot in this paper is TM5-700 which has a vision camera that can detect the object and recognize a specific mark for precise positioning.

UV-C Lamp: Two of the 15 Watt UV-C lamp has been used and covered by an aluminium case that could reflect the UV-C light thus the target surface would obtain more emit light beside this the cover also protects people who involve from the UV-C radiation. The cover has dimensions 16.0 x 46.2 cm.

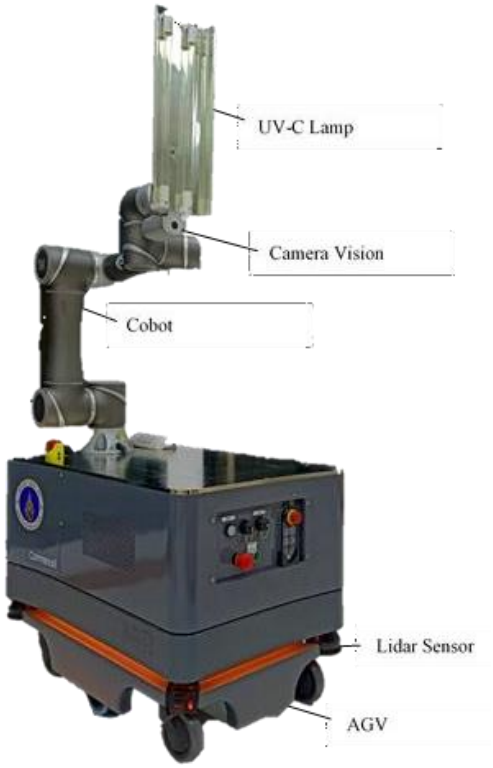

Figure 1. The innovative integrate AGV-Cobot with UV-C lamp for disinfection.

These three main components were integrated as shown in Figure 1. Sterilization begins with the AGV move to the predetermined position with GPS positioning capabilities and mapping and obstacle avoidance abilities by lidar sensors. Then the Cobot, which has a UV-C lamp attaching with an end-effector, move to the initial point before search a specific mark that has been memorized by the vision camera. When successful for searching a specific mark, the UV-C which attaching on the end-effector of the Cobot will scan along a target surface at a specified distance stably and precisely.

2.2 Testing Moveable UV-C for Disinfection Effects

The virus sterilization testing was executed inside an acrylic black box that has built up. Inside of the black box, there is a slide rail that installed a motor for moving the UVC lamp in purpose to simulate the scanning situation. Dengue virus 2 laboratory strain 16681 was used as a virus for testing. The virus was injected on a foil and was dried by an air-drying method. A foil was placed on a plate which in the center of the black box and has a distance from the UV-C lamp 1 cm. The testing was determined in four-speed conditions viz 0.6, 1, 5, and 10 cm/s. After scanning, a survival virus can be counted by the plaque assay method. The result of sterilization testing can be presented in form of log reduction.

2.3 Operate AGV-Cobot with UV-C Lamp for Disinfection on Large-Service Area

In order to test the utilization of AGV-Cobot with UV-C for virus disinfection performance, the patient's room was used to be testing place. The patient's room has an area approximately 32 m2 with a total of five furniture viz bed, bedside table, sofa, refrigerator, and storage cabinet. A patient's room plan can be shown in Figure 2.

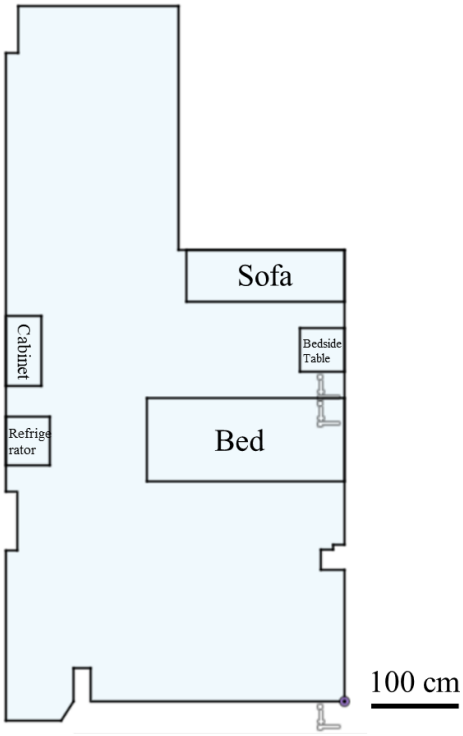

Figure 2. Patient's room plan

After the AGV-Cobot is programmed to disinfect a patient's room, The AGV-Cobot automatically works to sterilize scanning all the furniture in the patient's room. Start with storage cabinet, sofa, bedside table, bed, and refrigerator respectively. The important parameters for finding scanning time are the distance and the velocity of scanning. The velocity of scanning can be identified from the virus sterilization testing. While the distance of scanning can be found from the distance of scanning of each furniture which depends on the area of the target surface. For example,

1. If the surface of the target object is smaller than the UV-C lamp, no movement of the Cobot arm is required.
2. If the surface of the target object is bigger than the UV-C lamp and within the reachable distance of Cobot arm, square scanning path is followed to cover the entire surface as shown in Figure 3.

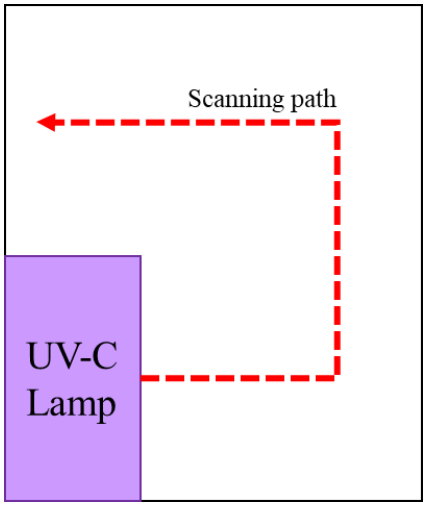

Figure 3. Square scanning path of UV-C lamp by Cobot arm.

3. If the target surface is beyond the reach of Cobot arm movement then a combination of Cobot arm and the AGV is done in order to cover the scanning of the entire surface as shown in Figure 4. The total distance of scanning for each furniture in the patient's room can be shown in Table 1.

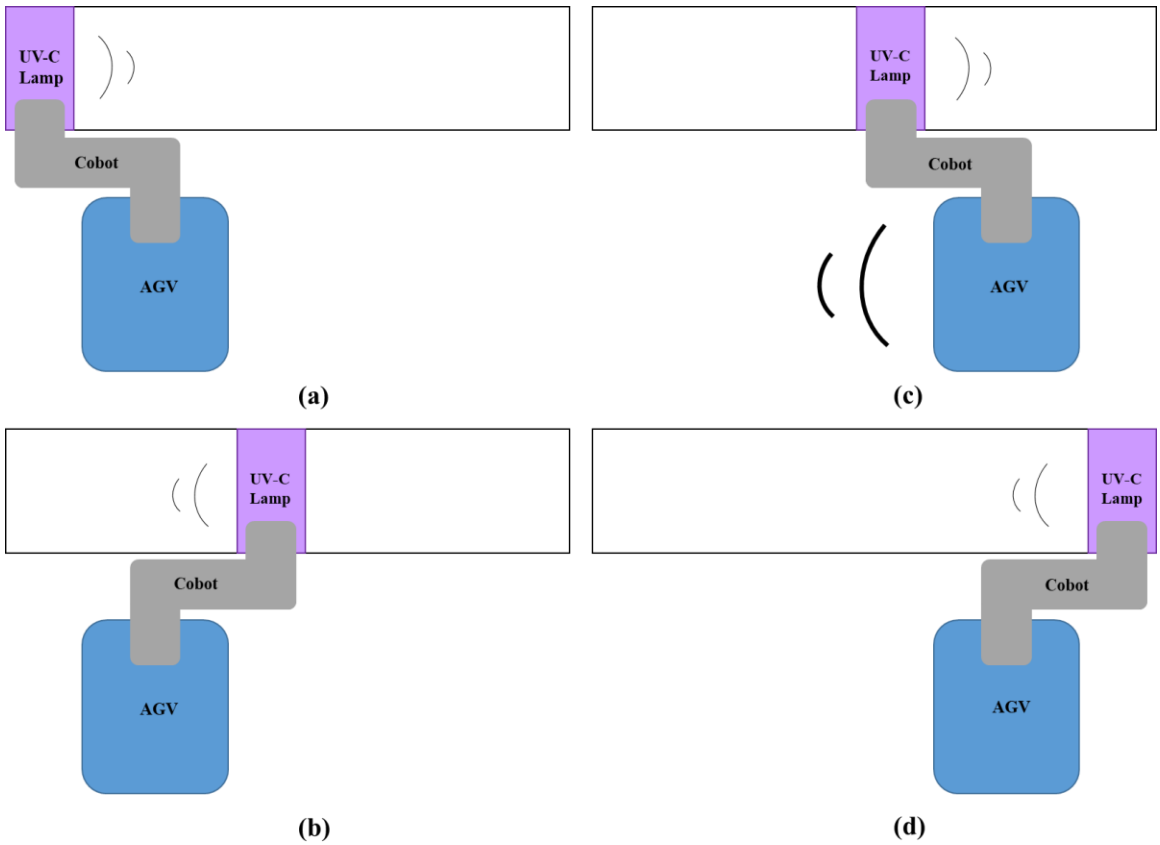

Figure 4. Step of scanning large surface. (a) and (b) shows the movement of the Cobot arm. (c) and (d) shows the movement of AVG and the movement of Cobot arm respectively.

Table 1. The total distance of scanning for each furniture.

Furniture	The total distance of scanning (cm)
Storage Cabinet	278
Sofa	360
Bedside Table	114
Bed	450
Refrigerator	121

3. RESULT AND DISCUSSION

3.1 The Virus Sterilization Testing

The result from measuring the intensity of motionless UV-C light at fixed exposed distance 1 cm is 22.90 mW/cm^2 and the result from the virus sterilization testing by used the black box with a movable UV-C lamp can be shown in Table 2.

Table 2. The result from virus sterilization testing.

Velocity (cm/s)	Log Reduction
0.6	4
1	3
5	1
10	1

From the testing, found that slow scanning was able to sterilize more than faster scanning. Which can sterilize equal or more than 4 log-reduction (99.99%) at velocity 0.6 cm/s, equal or more than 3 log-reduction (99.9%) at velocity 1 cm/s, and equal or more than 1 log-reduction (90%) at velocity 5 and 10 cm/s.

To raise the level of confidence and safety thus the velocity at 1 cm/s, which could be able to sterilize at 3 log-reduction (99.9%), was considered as standard speed for sterilization scanning by UV-C lamp.

3.2 Utilization of Operating AGV-Cobot with UV-C Lamp for Disinfection on Large-Service Area

From the test of sterilization scanning in the patient's room in a real hospital by allowing the robot to move automatically according to the preset program, found that UV-C light-emitting time takes not more than 25 minutes on 6.17 m2 for all furniture. However, there are still additional times for the movement of the AGV and the Cobot's specific mark detection by using a vision camera, which increases the operating time per patient room.

For example, AGV needs to change a direction movement because of an obstacle detected, or the vision camera is unable to find a specific mark for the first time due to changing of light or a specific mark was ruined thus the vision camera has to detect again.

These various factors cause affect the total working time of the AGV-Cobot. By the way, it was found that working time per 32 m2 area of the room would take up not more than 35 minutes (including scanning time). The utility is approximately 71.43%.

4. CONCLUDE

The innovative integrated AGV-Cobot with UV-C lamp for disinfection that was created in the COVID-19 period can automatically work to sterilize scanning all the furniture in the patient's room. At the distance 1 cm from the target surface and the velocity 1 cm/s for scanning speed, could be able to disinfect Dengue virus 2 laboratory strain 16681 equal or more than 3 log-reduction (99.9%). The scanning time that emitting UV-C light to all furniture in the patient's room is under 25 minutes which has utility approximately 71.43%.

5. FUTURE WORK

- Experiment with another AGV type to reduce the uncertainty time value that was obtained, due to the sensor of AGV detects an undefined obstacle. For instance, AGV that follows markers that have precise direction and more exact time.
- In this experiment, the distance from the UV-C lamp to the surface was fixed at 1 cm. In the future, the more determined distance will be considered in the purpose to find how different in virus disinfection.

6. REFERENCES

Bånrud, H., & Moan, J. (1999). Use of short wave ultraviolet radiation for disinfection in operating rooms. Tidsskrift for den Norske Lægeforening: Tidsskrift for praktisk medicin, ny række, 119(18), 2670-2673.

Brubaeher, J., & Hoffman, R. S. (1996). Hazards of ultraviolet lighting used for tuberculosis control. Chest, 109(2), 582-583.

McDevitt, J. J., Lai, K. M., Rudnick, S. N., Houseman, E. A., First, M. W., & Milton, D. K. (2007). Characterization of UVC light sensitivity of vaccinia virus. Applied and environmental microbiology, 73(18), 5760-5766.

Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., ... & Lloyd-Smith, J. O. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. New England Journal of Medicine, 382(16), 1564-1567.

Vorapaluk, P. (2020). Effectiveness Study of Disinfection of Microbes by Innovation Robotic UVC Radiation: Response to COVID-19 Pandemic. Thai Journal of Anesthesiology, 46(3), 8-15.