Design of Smart Drawer System for Implementation to Medical Robot Logistics Transportation

Arjon Turnip, Rahardian Bagas Satrio, Gilbert Faintbright Yohanes, and Endra Joelianto

***Abstract*— CoViD-19 pandemic hugely impacted the healthcare system, especially at the health facility. Numerous health care workers (HCWs) died because of CoViD-19 infection. This problem encourages the design of Medical Robot – control Intelligent Assistive Technology (MR-IAT) to reduce contact between HCWs and patients. The proposed system was a drawer system with a linear motor actuator equipped with UV-C lamp to disinfect the drawer and its inside part. The UV-C disinfection starts when the drawer is closed, and the disinfection stops when the drawer is open or the radiation time has been fulfilled. The actuator controlled the drawer position. The research results show that the design succeed and can be used effectively as the drawer system for MR-IAT robot.**

***Index Terms*— CoViD-19, drawer, UV-C, disinfection, robot**

I. Introduction

COVID-19 pandemic has caused many problems in various fields of work. One that suffered the most was the health management system, which consisted of the healthcare facility, health service, and logistics management for the healthcare facility. The pandemic caused an immense increase in the necessity for health facilities and services, but the availability of health facilities and services decreased. Healthcare workers (HCWs) also severed from the CoViD-19 pandemic. The easy-infecting virus caused HCWs susceptible to virus from CoViD-19 patients, which increased the mortality rate of the HCWs. A study showed that out of 98 HCWs, 19 of those infected by CoViD-19 virus, and ten among those infected didn't imply any sign of virus infection [1].

One of HCWs roles in hospitalization was to monitor the patient's health condition. Every patient needed to be monitored numerous times a day. But in this CoViD-19 pandemic, plenty of hospitals still used conventional patient monitoring, resulting in the HCWs being mandated to do direct monitoring to the patient regularly. This could worsen the infection rate of CoViD-19 virus either to the HCWs or the patients. Therefore, a revolutionary system that reduces contact between patients and HCWs is urgently needed. One of those solutions is an automatic robot that substitutes the role of the HCWs [2][3].

The first medical robot was an industrial robot designed in 1984 to perform brain biopsies using the help of computerized tomography (CT) imaging. Developments of medical robot usually focused to help doctor in surgery [4]. Medical robot could be designed as wheeled robots, legged robots, flying robots, manipulator robots, wearable robot, and exoskeleton robot [5]. The existence of CoViD-19 pandemic urged for a specialized medical robot that could perform works usually done by the HCWs. Some of those workers are telemedicine which is monitoring patient condition by HCWs without direct contact of each other, logistic and service which is medical logistics transportation such as medical devices, foods and medicines, and disinfection which is purification of patient room and medical logistics from bacteria and viruses [3][6][7]. A medical robot could also be designed as a social robot specialized to reintroduce the patient to social interaction abilities which are lost due to extensive periods of self-isolation in the hospital [2][3].

Medical robots' purposes as disinfection agents can be categorized as patient room cleaning and medical logistics cleaning such as medical devices, foods, and medicines. Some of neutralizing agents can be used for disinfection are alcohol, hydrogen peroxide, formalin, and sodium hypochlorite. But alcohol and hydrogen peroxide are flammable, so those agents are not eligible for disinfection of small rooms without proper ventilation. Formalin is also hazardous if used as a neutralizing agent. It could emit toxic gas, whereas sodium hypochlorite is dangerous because it has a strong corroding effect due to its high alkaline level. Therefore, an ideal neutralizing agent could be in the form of a non-physical agent, such as ultraviolet (UV) radiation [8][9].

UV rays are characterized based on wavelength. The first one is UV-A with 320-400 nm wavelength, UV-B with 280-320 nm wavelength, and UV-C with 100-280 nm wavelength. UV-A and UV-B rays are usually radiated naturally from the sun, whereas UV-C rays are made from mercury or xenon vapor gas lamp. Disinfection effect to the virus by UV ray happens in 200-320 nm wavelength interval, which covers both UV-B and UV-C spectrum. Even though those UV types can be used for disinfection, a study showed that UV-C ray with 254-267 nm wavelength has higher effectivity due to high light intensity at low wavelength. UV-C radiation can penetrate the cell membrane of bacteria and viruses and

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damage those DNA and RNA, effectively prevent replication and render them non-infectious. But, UV-C could also penetrate human cells and damage those. Therefore, UV-C radiation is considered effective for small rooms without proper ventilation or disinfection of medical logistics [9][10].

UV-C radiation effectivity can also be considered from irradiation dosage calculated by multiplication of irradiation power with radiation time. A study showed that effective irradiation dosage was between 20-100 mJ/cm2 [11]. Another study showed a 3 mJ/cm2 implemented by UV-C lamp radiation with 222 nm wavelength and 0.1 W/m2 irradiances for 30 seconds effectively kill 99,7% SARS-CoV-2 [12].

II. Methodology

The research was conducted around Universitas Padjadjaran residence. This research is limited to design a drawer system actuated by linear actuator for actuating system integrated with UV-C lamp for virus and bacteria disinfection agent. This drawer system is designed for Medical Robot control Intelligent Assistive Technology (MR-IAT).

The system proposed in this paper is a smart drawer system for implementation in MR-IAT. This system's purpose is a transport of medical logistics to the patient without direct contact with the HCWs. This drawer system is equipped with automatic linear actuator for drawer operation and UV-C lamp for drawer disinfection.

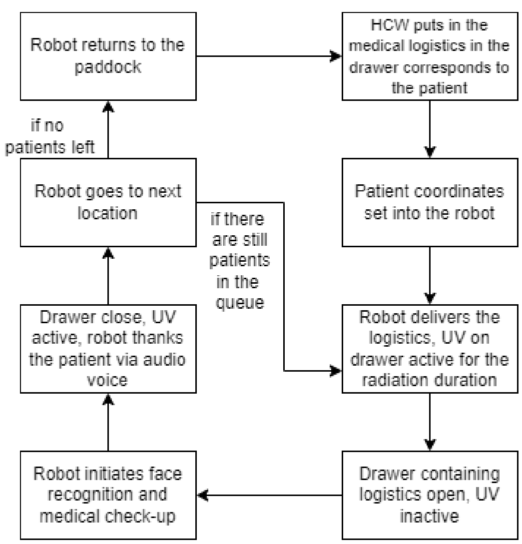

Fig. 1. Work diagram of the drawer system on MR-IAT

The work diagram of the MR-IAT is shown on Fig. 1. First, the HCWs allocates the medical logistics to the robot, then he/she will set the patient coordinates as delivery destination, in which the robot will go to that location. When the drawer is closed, the UV-C lamp will radiate the inner drawer to neutralize it from pathogens, CoViD-19 virus included. When the robot arrives at the patient, the patient undergoes the medical checkup then the drawer that contains the medical logistics will be open for 1 minute. After the drawer closes, the UV-C lamp turns on to disinfect the drawer content or the inner drawer itself if the drawer is empty. Finally, the robot will thank the patient, saying "Thank you, and get well soon" via audio voice. The robot then goes to another patient and repeats the process until all logistics are delivered to the corresponding patients, then it goes back to the starting point.

III. Result and Discussion

The flowchart of the drawer system for MR-IAT is shown in Fig. 2. UV-C lamp turns on, then it will turn off automatically so it will preserve energy and so the UV-C dosage radiated to the cargo on the drawer will not exceed the ideal value. When the lamp is on, if there is an interrupt to open a drawer, then the UV installed on that drawer will turn off, and the drawer will stay open for one minute, then the drawer will close, and the lamp will be on again. UV lamp stays on even if the drawer is empty with the purpose of drawer disinfection after use.

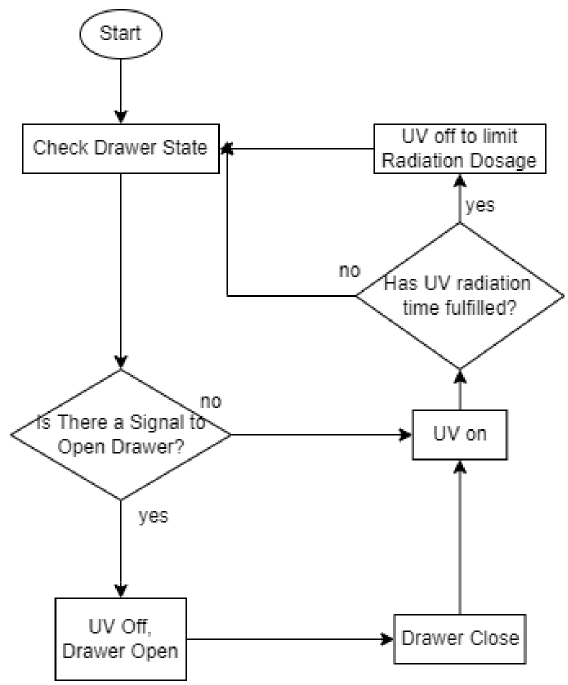

Fig. 2. Flowchart of the smart drawer system

Physical implementation of the drawer system in MR-IAT is shown in Fig. 3, whilst the circuit scheme of the system is shown on Fig. 4. The drawer system consists of the drawer, drawer rail as the moving part of the drawer, linear actuator for driving the drawer in and out, and UV-C lamp for drawer disinfection. The drawer rail is placed along the side of the drawer, whereas the actuator is placed beside the drawer. If there is a signal to open the drawer, the actuator will drive the shaft out, opening the drawer. When the drawer is closed, the actuator shaft will be pulled in, closing the drawer.

The UV-C lamp is an 8 W, 220 V mercury lamp. It is powered through a relay for on/off control. It's on and off command is controlled by the drawer state, whether it is open or closed, and the radiation time. The radiation time is estimated with Keitz equation:

$$T = \frac{2\pi^2 DLE_D}{\eta P_E\left(2\arctan\left[\frac{L}{2D}\right] + \frac{4DL}{4D^2 + L^2}\right)} \tag{1}$$

with T is irradiation time in second, E_D is irradiation dosage in J/m^2, D is the distance of disinfection from lamp center in meter, L is the lamp arc length from electrode tip to electrode tip in meter, η is the lamp efficiency, and P_E is the lamp electrical power input in watt [13][14].

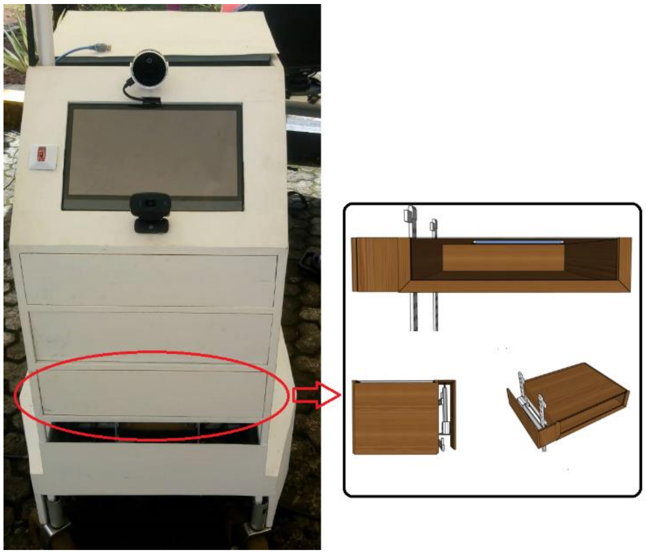

Fig. 3. Physical drawer design

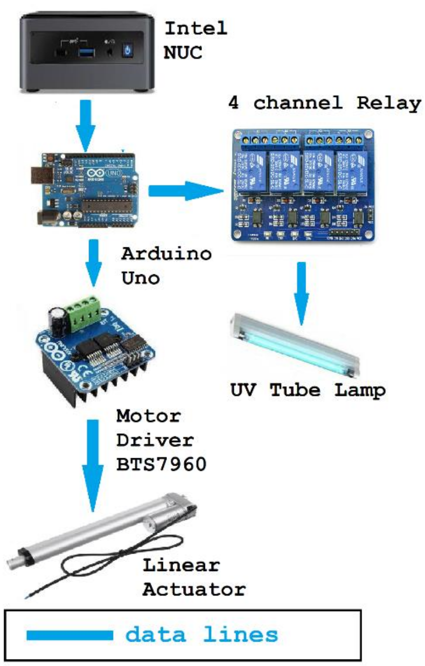

Fig. 4. Schematic circuit of the smart drawer system

Below is the algorithm of the drawer system. To determine which drawer should open, the program reads the drawer state string and convert it to integer number and allocate it to variable “pystate”, If “pystate” is zero, no drawer is open and the UV lamp on all drawer is on on off depending if the UV has fulfilled its radiation time. Suppose it is one, two, or three. In that case, the upper drawer will execute the drawer operation, which is turning off the corresponding UV lamp, opening the drawer for approximately two minutes, keeping the drawer open for one minute with delay function, then closing the drawer, and finally turning the UV back on. The “pystate” will execute for the upper drawer if it is one, two for the middle drawer, and three for the lower drawer. The code is shown in Fig. 5a through Fig. 5c.

```
pystate = Serial.readString().toInt();
```

(a)

```
void open_upper_drawer(){
  analogWrite(openup, 255);
  analogWrite(closeup, 0);
  delay(120000);
}
void close_upper_drawer(){
  analogWrite(openup, 0);
  analogWrite(closeup, 255);
  delay(120000);
}
```

(b)

```
void uv_switch(const int uv,
               unsigned long period_s,
               unsigned long start_UV){
  unsigned long stop_UV=millis();
  if(stop_UV-start_UV<=period_s*1000){
    digitalWrite(uv,LOW);
  }
  else
    digitalWrite(uv,HIGH);
}
```

(c)

```
if(pystate == 0){
    uv_switch(uvup,uv_time,uvup_starttime);
    uv_switch(uvmid,uv_time,uvmid_starttime);
    uv_switch(uvlow,uv_time,uvlow_starttime);
   // delay(60000);
    }
```

(d)

```
else if(pystate == 1){
   Serial.print("State 1 = INITIATED");
   uv_switch(uvmid,uv_time,uvmid_starttime);
   uv_switch(uvlow,uv_time,uvlow_starttime);
   digitalWrite(uvup,LOW);
   open_upper_drawer();
   delay(60000);
   close_upper_drawer();
   uvup_starttime=millis();
   }
```

(e)

Fig. 5. Part of drawer system code, (a) the ”pystate” for determine which drawer to operate, (b) the drawer open and close code, (c) UV timing function, (d) drawer code when idle or currently transporting, (e) drawer operation

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IV. Conclusion

Design of smart drawer system for implementation to MR-IAT was successfully constructed. The linear actuator can open and close the drawer automatically. The installed UV-C lamp light on perfectly at a given duration and can turn off automatically. This drawer system can be implemented to the MR-IAT as transportation media of medical logistics to the patient with minimized direct contact between HCWs and the patient.

Acknowledgment

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