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COVID-19 Community Relief Project: Design and Development of Disinfection Booth with AR/VR Companion App

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Abstract

As the novel coronavirus (COVID-19) outbreak has been declared as a global pandemic since March 2020, engineering technology students at Sam Houston State University designed a disinfection booth to minimize the exponentially increasing morbidity rate through contacting with the contaminated surfaces such as individual clothes. The portable disinfecting booth, which is constructed with PVC and attached disinfectant spray tank, can reduce the infectious rate significantly by removing the infectious respiratory droplets lasting on clothes and skin by using disinfectant spray against the SARS-CoV-2. The booth is equipped with a motion detecting sensor that activates the sprinkles when a person is detected in the booth, to provide efficient use of disinfectant. The cost effectiveness and construction simplicity encourage high school and other community relief organizations to produce on their own from the provided tutorials. Additionally, to cope the social distancing as well as the transition to working and studying from home, a Virtual Reality and Augmented Reality simulative application has been developed to assist and teach the public on the booth function and COVID – 19 viruses. The aim of this application is to demonstrate the function of the booth as well as present the information associated with the COVID-19, while users remain social distancing and working from home due to the ongoing pandemic.

Introduction

The spread of novel corona (COVID-19), from the end of 2019 to the beginning of 2020, WHO declared a global pandemic in March 2020. Several countries shut down social gathering places to minimize the morbidity and mortality rate associated with the novel coronavirus. However, to avoid socio-economic recession due to lockdowns and shutdowns, countries all over the world started to move onto the transition phase which is the “new normal.” The new normal mandated people to maintain personal hygiene, face covering, and rigorous sanitation of public gathering places, such as schools, hospitals, public transportation *COVID-19 and Your Health*, 2020) In May 2020, the Center of Disease Control and Prevention (CDC) published the document informing the possibility of fomite transmission associated with SARS-CoV-2 (CDC, 2020).

Contact transmission, which includes infection spread through direct contact with an article or surface that has been contaminated, is one of the principal transmissions. Infectious droplets lasting on surfaces can lead to human transmission as people touch those contaminated surfaces and then touch their nose, mouth, and eyes (CDC, 2020). With, surface disinfecting has been considered with deliberation. In the transition phase, public places such as grocery stores and school campuses are locations where people have the most access. It is vital to reduce the risks of fomite transmission including infectious droplets on clothes garments.

Researchers all over the world have been investigating means to design and construct a wide variety of sanitation booths to disinfect the surface of clothes, garments, and other accessories with aerosol (Bankok Post, 2020; Baran, 2020; Canova, 2020; Vietnam Times, 2020). However, these constructed booths are costly and require significant investment. Therefore, this project discusses the development of a cost-effective disinfection booth as part of the community relief efforts as well as the engagement of undergraduate students in the project. This project proposes to minimize the exponentially increasing morbidity rate associated with fomite transmission. Furthermore, the disinfection booth is designed on a portable platform to increase the mobility and installation of the structure.

Literature Review

Disinfecting booth has become an advanced phenomenon all over the world (Bangkok Post, 2020; Baran, 2020; Canova, 2020; Vietnam Times, 2020). In March 2020, the municipal government of the Philippines installed the disinfectant booths in public markets and hospitals ("Mariveles installs disinfectant booths in the public market, hospital", 2020). Similarly, the government of Jakarta, Indonesia set up several disinfecting chambers outside crowded public places such as shopping malls (Bankok Post, 2020). Vietnam Institute of Occupational Health and Environment (2020), in collaboration with Hanoi University of Science and Technology piloted in medical examination areas (Vietnam Times, 2020). Moreover, Hong Kong International Airport installed sanitization pods for facilities to checked temperature and practice sanitizing procedures on clothing and carry-on items (Baran, 2020). Specifically, Denver Broncos – the NFL team in the U.S. has installed a misting booth spraying a disinfectant on players as an additional precaution to help battle the COVID-19 at their facility (Canova, 2020). These and other similar disinfecting booth projects inspired our students at Sam Houston State University to develop a cost-effective disinfecting booth for public gathering areas such as buildings across campus, local high schools, parks, etc.

1. Structure

The generic booth design includes a chamber, enclosed with a misting system, which has an in-built motion sensor detector a person and automatically sprays the disinfectant chemical. Regardless of the cost of the disinfectant chemical, the price to construct the booth could be an obstacle for nonprofit organizations to manufacture. Therefore, PVC pipes are glued together to maintain low-budget booth construction.

2. Disinfectant

Several disinfectants and sanitization methods have been considered. Hypochlorous acid (HClO or HOCl) is is widely used as a disinfectant and is formed by the electrolysis of hydrochloric acid water or sodium chloride (non-iodized salt) water. The U.S. Environment Protection Agency (EPA) has registered hypochlorous acid as an active ingredient in many recommended disinfectants against COVID-19 (EPA, 2020). Hypochlorous acid is also an endogenous substance in all mammals playing a key role in the innate immune system fighting against pathogenic infection (Kettle & Winterbourn, 1997). Hypochlorous acid with its antimicrobial activity has been proved to result in denaturing and aggregating pathogenic (disease-associated) proteins, which makes the pathogen harmless, or destroys viruses by its chlorination mechanism. Studies have been conducted to confirm its capacity for inactivating a broad range of pathogens, from bacteria and fungi to virulent pathogens such as norovirus, avian influenza virus, and Newcastle disease virus (Hakim et al., 2015, Park et al., 2007; Taharaguchi et al, 2014). Thus, it has become the main active agent in most anti-microbial products. Furthermore, as mentioned above, as hypochlorous acid is a naturally endogenous substance in the human and animal body, it is safe to use hypochlorous acid in healthcare, food contact, pesticide, and general sanitation (EPA, 2020). Electrolyzed oxidizing (EO) water containing chlorine oxidants, which include HOCl as well as ion OCl, have been applied in foodservice fields as a promising sanitation method to eliminate pathogenic organism on foods and surfaces in food service areas (Venkitanarayanan et al., 1999). Various experiment protocols have been conducted, such as liquid-based application – soaking food in the solution, or fog-based application – spraying foods or surfaces with the solution. Rinsing the target objects after the treatment is not mandatory as the solution, if produced appropriately, will not leave any harmful residue on the target objects. Many disinfectant products approved by EPA (EPA, 2020) with HOCl as an active ingredient can be used on various surfaces: porous and non-porous as well as food contact with optional post-rinsing. Thus, HOCl is confirmed to be safer than most of the popular disinfectants containing biocidal agents reducing coronavirus infectivity on surfaces, such as alcohol-based disinfectants or hydrogen peroxide – which are flammable and irritant to skin and eyes respectively (CDC, 2020; Kampf, 2020). Also, HOCl generating system is affordable, applicable, and readily available. One possible method is to electrolyze water with a coordinated concentration of non-iodinated salt (NaCl). This method has been utilized to produce a good solution with 50-100ppm HOCl which can be an alternative for alcohol-based hand sanitizers to reduce costs and dermatitis risks as well as fire risks.

The project uses the atomizing (fog) or misting as well as aerosol spraying technique to dispense HOCl to the experimental environment (Guentzel, 2008; Hakim et al., 2015; Park, 2007; Yang et al., 2013). This technique can help to dispense solution into smaller particles, solution molecules might be suspended in the environment longer due to their low settling velocity rate. Thus, the probability to contact and inactivate pathogens may increase as the recommended aerosol size is less than 20 μm.

However, some factors, associated with its antimicrobial mechanism, must be taken with deliberation. Firstly, the stability of the solution is also crucial to the concentration (parts per million – ppm) of the ion OCl – active ingredient in the solution. Researchers have shown that HOCl solutions should be stored in cool, dark places and minimized the air-contacting. The water used to make the solutions should contain as few other organic or inorganic ions as possible to assure optimal virucidal activity. Secondly, the concentration of HOCl in a disinfectant must be at an appropriate number. In fact, the lower the efficacious concentration, the less efficacious its virucidal activity is. Depending on the structure of the pathogens, the concentration should be adjusted to maximize HOCl's efficacy as the HOCl can decontaminate inert surfaces with noroviruses and other enteric viruses in 1-minute and 10-minute contact time with the concentration of 200 ppm and 20 ppm respectively (Block & Rowan, 2020). Finally, an appropriate period of contact time is also required to let the compound achieve its effectiveness. Depending on the contact surfaces – dry or wet, porous, or nonporous, the contact time would differ.

Methodology

Researchers modeled the disinfecting booth frame with Creo Parametric and constructed it with PVC pipes. Freshmen to senior-level engineering technology students actively constructed the booth prototype during the lockdown (Figure 1). Furthermore, due to its light-weight feature, the booth is expected to be mobile and transferable. However, the stability and sturdiness were low, thus researchers have used brackets and wood studs to stabilize the frame (Figure 2a & 2b).

Figure 1: ET students building the booth.

The booth was integrated with a sprayer controlled by a microcontroller – Arduino Uno. The micro-controller was programmed with an HR-SRC motion sensor that can detect motion two feet away from the top of the booth and launch the spraying system thenceforth (Figure 4). Arduino board controls the following: detect a person, turn spraying system on, spray the person, and then turn off again. The sensor and microcontroller are connected to a relay that switches the sprayer once the signal is received. The circuit panel includes the microcontroller, the sensor, the spraying system, and the relay as a system switch. The booth automatically launches when the sensor detects an approaching person (Figure 5).

Figure 2a. Brackets added top corners

Figure 2b. Brackets added to the bottom corners.

Figure 3. Completed Stable Frame.

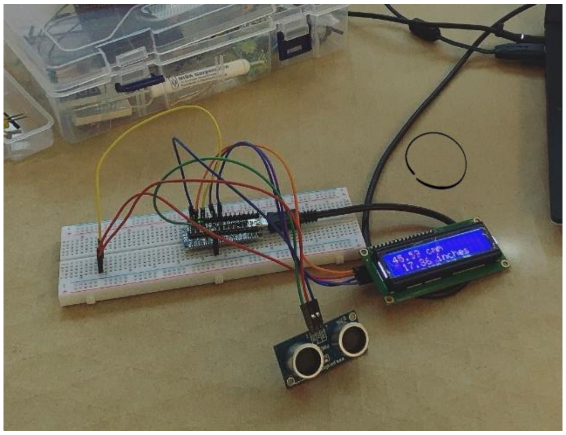


Figure 4. The circuit prototype with sensor

The booth sprays all-natural, chemical-free, non-toxic FDA approved HOCI solution that is 100% safe for humans. It has been used in the medical field for over a century before antibiotics were available, HOCI was used to irrigate and disinfect wounds in World War I. This test prototype booth is equipped with a single spray nozzle, located on the ceiling of the booth. The production model will contain additional three spraying nozzles on each side of the booth, allowing a wide coverage of disinfectant of the person. The booth provides harmless gentle mist on the body of a person; however, it is still recommended to close their eyes for maximum comfort.

Figure 5. Photo taken during testing.

Data Collection

A questionnaire includes instructions for users regarding the concept of the booth, aiming to collect their satisfaction rate based on the guidelines of the disinfection booth. Researchers analyzed the collected data to investigate the satisfaction rate corresponding to the concept of the disinfecting booth during the era of COVID-19. The survey includes 3 questions, and a question aims to collect additional qualitative data as shown in Figure 6 and Figure 7. The questionnaire was surveyed on 19 students in a university where classes have been operating back to new normal and all the protocols have been adjusted following CDC guidelines (CDC, 2020).

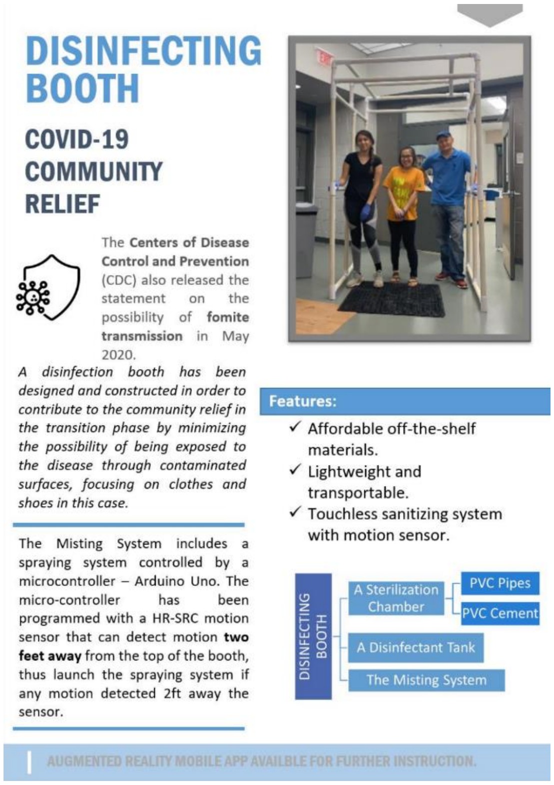
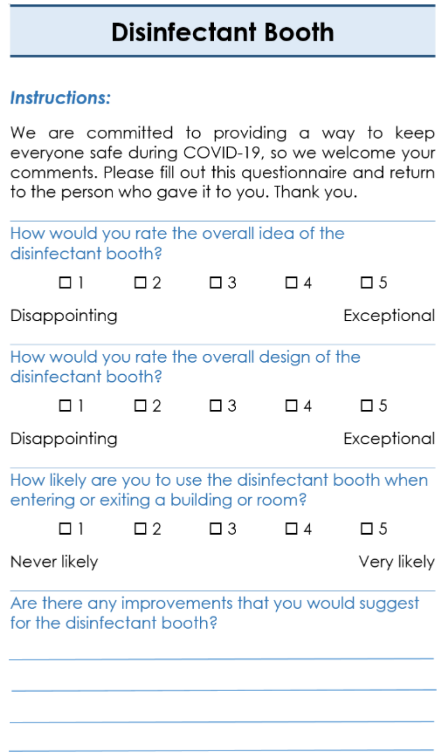


Figure 6. The booth pamphlet



Disinfectant Booth

Instructions:

We are committed to providing a way to keep everyone safe during COVID-19, so we welcome your comments. Please fill out this questionnaire and return to the person who gave it to you. Thank you.

How would you rate the overall idea of the disinfectant booth?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

How would you rate the overall design of the disinfectant booth?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

How likely are you to use the disinfectant booth when entering or exiting a building or room?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Never likely Very likely

Are there any improvements that you would suggest for the disinfectant booth?

Figure 7. The survey questionnaire

Furthermore, companion Augmented Reality/Virtual Reality application (Figure 8) has also been developed with the pamphlet as an image target. When users track the pamphlet with mobile device camera or wearing a VR headset, the instruction video and additional information regarding COVID-19 will be activated.

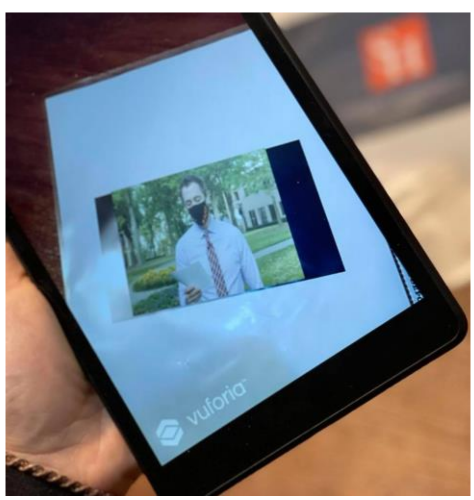


Figure 8. AR App shows the information video from university regarding COVID-19 updates.

Data Analysis

Table 1 illustrates the approximate cost of making the booth without tax. All costs are calculated without tax, based on supply websites in December 2020. As shown above, the cost of making the booth can be approximately $400 without the cost of the disinfectant. On the other hand, the starting cost for a commercially available disinfecting booth varies between $5,000 to $100,000 with delivery.

Table 1. Cost estimate as in December 2020
(based on www.HomeDepot.com, www.arduino.cc and www.aihskc.com)

Materials	Count	Price per unit	Total
1 ½” x 10ft Sch. 40 PVC Pipe	10	$6.41	$64.10
1 ½” PVC Sch. 40 Tee	17	$2.08	$35.36
1 ½” PVC Sch. 40 Elbow Fitting	6	$1.66	$9.96
10” x 12” White Shelf Bracket	4	$2.51	$10.04
40" x 60" Heavy Duty Entrance Mat	2	$67.18	$134.36
10 ft. x 50 ft. Clear 6 mil Plastic Sheeting	1	$26.17	$26.17
Spraying Tank	1	$69.95	$69.95
Arduino UNO R3 Module	1	$23.00	$23.00
		Total:	$372.94

A survey was conducted within the student community at Sam Houston State University with questions regarding the concept of the disinfecting booth. The survey results in Table 2 shows that the mean of the satisfaction rate on the concept of the booth is over 4.11 on the 5-point rating system. Other assessments of the survey were also rated over 3. Moreover, as the survey has a comment field, participants also indicated additional opinions and suggested further improvements on the concept of the booth.

Table 2. Result of the disinfecting booth survey

	N	Mean	Std. Dev.
Question 1	19	4.11	0.94
Question 2	19	3.21	1.18
Question 3	19	3.53	1.50

One of the comments was recorded: “The disinfecting booth has potential for sanitizing people. However, it has a few flaws which could lead to harming the individual using the actual booth. One potential problem is that the individual using the booth will need to have their own PPE as the chemicals used for disinfecting could be hazardous to humans. The chemicals used could also have adverse effects on the clothing of the individual using the booth (i.e., bleach can discolor clothing). Overall, the booth does have potential as it can sanitize individuals that walk through it rather quickly, but the risks of the chemicals used to sanitize could end up harming the individual instead of helping.” Another comment has also stated “The concept of the booth was extremely helpful for this situation to improve the sanitization of the environment. However, I would recommend considering the way that disabilities can access the building without dealing with a small step to get through the booth.”

Conclusion

This study explored a cost-effective construction of a disinfecting booth with PVC Pipes as main materials to make it affordable and accessible to local public communities. Maintaining sanitization has been considered a mandatory requirement for public places since COVID-19 happened. During the period that effective vaccinations have been examined and distributed evenly to the society, the concept of the disinfecting booth is a promising helpful construction aiding general COVID-19 community relief. Together with the AR/VR companion application, this disinfecting booth construction is proposed to be a sufficient relief for the community during pandemics. Users can obtain information on the booth function and COVID-19 pandemic either by touchless method – using their own mobile devices, or from distance – using VR glasses at home. To support the community further, by step tutorials, with detailed diagrams, to construct the booth will be accessible freely to local high schools and other interested organizations to build and use in their premises. Although CDC protocols have changed since the beginning of the pandemic, commercial organizations are still selling similar booths, which can become costly for some organizations. Additionally, this DIY project may increase the self-efficacy of high school students and develop good citizenship via producing the disinfection booth for their communities.

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