



Vojnotehnicki glasnik/Military Technical Courier
ISSN: 0042-8469
ISSN: 2217-4753
vojnotehnicki.glasnik@mod.gov.rs
University of Defence
Serbia

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Vojnotehnicki glasnik/Military Technical Courier, vol. 70, no. 3, 2022

University of Defence, Serbia

Available in: <https://www.redalyc.org/articulo.oa?id=661772310010>

DOI: <https://doi.org/10.5937/vojtehg70-37492>

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Design and implementation of a smart sterilizing device to solve the doorknob contamination problem

РАЗРАБОТКА И ИСПОЛЬЗОВАНИЕ УМНОГО СТЕРИЛИЗУЮЩЕГО УСТРОЙСТВА ДЛЯ РЕШЕНИЯ ПРОБЛЕМЫ ЗАГРЯЗНЕНИЯ ДВЕРНЫХ РУЧЕК

ДИЗАЈН И ПРИМЕНА ПАМЕТНОГ УРЕЂАЈА ЗА СТЕРИЛИЗАЦИЈУ У РЕШАВАЊУ ПРОБЛЕМА КОНТАМИНАЦИЈЕ КВАКА НА ВРАТИМА

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DOI: <https://doi.org/10.5937/vojtechg70-37492>

Redalyc: <https://www.redalyc.org/articulo.oa?id=661772310010>

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Received: 22 April 2022

Accepted: 24 June 2022

ABSTRACT:

Introduction: In 2020, the World Health Organization announced that Corona virus (Covid-19) is a global pandemic. Since then, social distancing and sterilization have become essential as precaution measures to decrease the infection. The risk of Covid virus spread led people, industries as well as governments to implement several approaches to control the transmission rate of the virus. During their daily life activities such as work, shopping, eating, etc. people touch a lot of surfaces and also open a large number of doors. This is considered to be one of the fastest ways to spread viruses because many people touch door handles which are generally rarely cleaned.

Method: In this paper, the implementation of a cost-effective smart device has been presented. The device sprays ethanol onto a doorknob from an ethanol sterilizer after any person touches the knob. The sensor detects a hand touching the knob, after that a signal is sent to the Arduino for processing, and then after a 4.5-sec delay, the Arduino sends a signal to the water pump to pump ethanol alcohols through the nozzle directly to the knob.

Results: The device shows precise and accurate results regarding the number of uses and the temperature of the surrounding ambient.

Conclusion: The system is applicable in offices and public buildings. Due to its functionality, it can be of great assistance in decreasing the contamination of doorknobs.

KEYWORDS: smart sterilizer, arduino, actuators, doorknob, water pump.

Р е з ю м е :

Введение/цель: В 2020 году Всемирная организация здравоохранения объявила мировую пандемию коронавируса (Covid-19). С тех пор социальное дистанцирование и стерилизация стали необходимыми мерами предосторожности для уменьшения распространения инфекции. Риск распространения коронавируса побудил людей, промышленные предприятия, а также правительства внедрить несколько способов контроля над скоростью распространения вируса. Во время своей повседневной деятельности на работе, в магазинах, при приготовлении пищи и пр. люди прикасаются к большому количеству предметов, а также открывают большое количество дверей. А именно это и считается одним из самых быстрых способов распространения вирусов, поскольку многие люди трогают дверные ручки, которые в основном не так часто дезинфицируются.

Методы: В данной статье представлено применение выгодного умного устройства, которое распыляет спирт на дверную ручку после каждого контакта. Датчик обнаруживает прикосновение руки к ручке, после чего посылает сигнал в Arduino для обработки, а Arduino после 4,5 секунд посылает сигнал водяному насосу, который через сопло направляет струю прямо на ручку.

Результаты: Устройство показывает верные и точные результаты, учитывая количество контактов и температуру окружающей среды.

Выводы: Система хорошо подходит для применения в офисах и общественных зданиях. Благодаря своей функциональности она превосходно помогает уменьшить загрязнение дверных ручек.

К л ю ч е в ы е с л о в а : умный стерилизатор, Arduino, приводы, дверная ручка, водяной насос.

ABSTRACT:

Увод/циљ: Светска здравствена организација је 2020. године прогласила пандемију вируса корона (ковид 19). Од тада је држање социјалне дистанце и стерилизација од суштинске важности јер представља превентиву за смањивање инфекције. Ризик од ширења ковид вируса навео је појединце, индустрије и владе да примене различите начине како би се брзина трансмисије вируса држала под контролом. Током свакодневних активности, попут обављања посла, куповине или припреме хране, људи додирују велики број површина, а нарочито кваке на вратима, што се сматра једним од најбржих начина ширења вируса.

Методе: У раду је предложена примена исплативог паметног уређаја којим се квака на вратима прска етанолом после сваког коришћења. Након што сензор детектује додир по кваци, сигнал се шаље Ардуину на обраду, а након 4,5 секунди он га прослеђује воденој пумпи која кроз млазницу усмерава млаз етанола директно на кваку.

Резултати: Узимајући у обзир број употреба и температуру околине уређај показује прецизне и тачне резултате.

Закључак: Систем је примењив у пословним и јавним зградама. Захваљујући својој функционалности може бити од велике помоћи при смањивању контаминације квака на вратима.

KEYWORDS: паметни стерилизатор, Ардуино, актуатори, квака на вратима, водена пумпа.

INTRODUCTION

Doorknobs are considered to be the most common places for viruses and infectious bacteria. They are the hotspot of viruses and bacteria since they are the main means for opening doors (Abdelmuktader & El Far, 2019; Chin et al, 2021; Narayana et al, 2021; Umamaheswari, 2020; Woodstock & Karlicek, 2020). Regular doors (non-automatic doors), especially office doors, are opened during the day at least hundreds of times, when each hand touching them contains a number of viruses or germs, which leads to an increase in infections among people. The idea of a smart sterilizing device was realized in order to protect people from germ infections arising from touching contaminated surfaces. The Arduino is an open-source electronic prototyping platform on the basis of flexible, easy-to-use hardware and software. The Arduino controller used in this work has 14 digital input/output pins (6 out of which can be used as PWM outputs), and 6 analog inputs. A low voltage switching relay used to integrate the pump with the Arduino shows the switching functionality (Rossetto et al, 2021; Katkar, 2021; Gheorghe & Stoica, 2021; De Felici et al, 2021; Pranata, 2021).

The PIR sensor is used to detect the radiation emitted from a user-touched door handle and then to send a signal to the Arduino which makes a decision based on the software program uploaded to it (Zemmouri et al, 2017; Youssef et al, 2020; Saravanamoorthi et al, 2017). There are few studies regarding sterilizing devices. Seongkeun Kwak et al (Kwak et al, 2013) used a smart device to control and monitor a pipeline-type UV sterilizer. The device proved to be more convenient and economical than a regular controller. Eddy et al proposed a design and implementation of a smart contactless hand sanitizer-dispensing system (Eddy et al, 2019). Mohammed et al suggested an intelligent system for door sterilization; despite the fact that the idea was only theoretical, it was good and could be executed (Alenzi & Abdudayem, 2017).

Theoretical backgrounds of the solution of modern control engineering design problems are thoroughly discussed and outlined in (Szabolcsi, 2019). In (Szabolcsi, 2020), Szabolcsi introduced several theoretical and practical approaches related to computer-aided design and analysis of modern control systems using MATLAB.

This paper solves the doorknob contamination problem with a cost-effective smart device controlled by an Arduino controller that can squirt ethanol from an ethanol sterilizer towards the doorknob after it is touched by a human hand.

RESEARCH METHOD

The system operation principles depend on the detection of the hand motion over the doorknob. Figure (1) shows the existing system of a smart sterilizing system for doorknobs, while Figure 2 shows the system sketch design in Fritzing software. Fritzing software is open-source software used to design and simulate electronic circuits before they are actually built in. The system contains the controller, the Arduino in this particular case. After the doorknob is touched, the sensor detects the motion over the knob, sends a signal to the controller, and then the controller, based on the information coming from the sensor, commands the water pump (the actuator) to pump ethanol from the sterilizer onto the doorknob to clean it and sanitize it from germs.

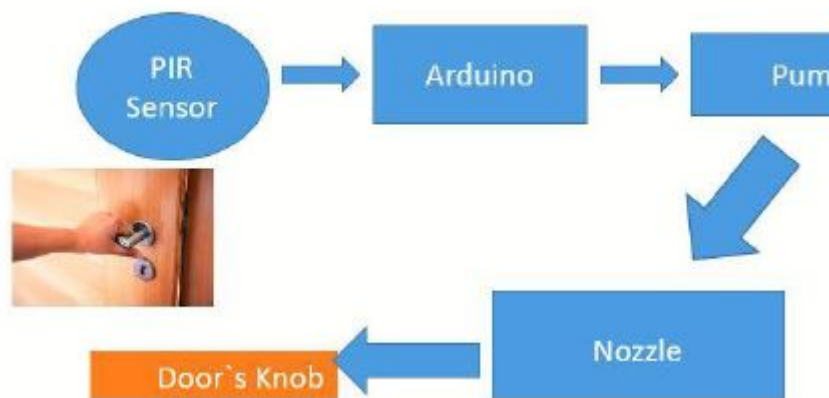


FIGURE 1

Existing system of a smart sterilizer

Рис. 1 – Существующая система умного стерилизатора

Слика 1 – Постојећи систем паметног стерилизатора

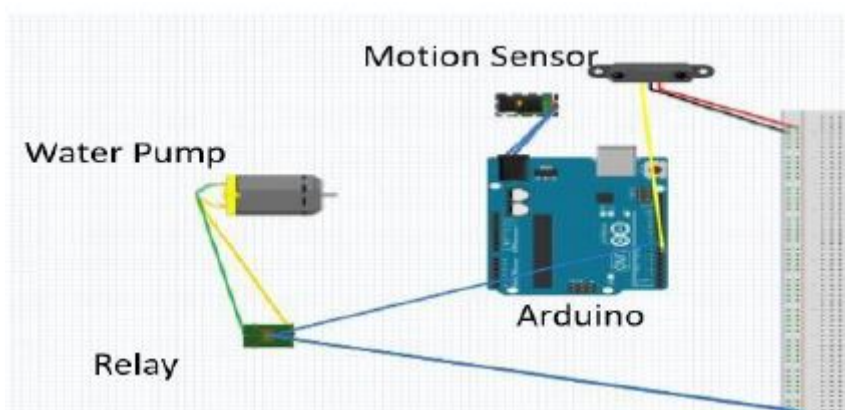


FIGURE 2

System hardware sketch

Рис. 2 – Эскиз системы аппаратного обеспечения

Слика 2 – Скица хардверског система

SYSTEM DESIGN

A. Arduino:

The Arduino can be described as the brain of the system. It is open-source hardware; it consists of sets of analog and digital pins that can be interfaced with various expansion boards, sensors, and actuators (Satam et al, 2021). The Arduino controller is widely used in different applications because of several reasons such as its price, its speed, the easiness of its use, etc. The controller board is shown in Figure 3.



FIGURE 3
Arduino

Рис. 3 – Arduino
Слика 3 – Ардуино

B. PIR sensor:

A Passive Infrared Sensor - PIR (as shown in Figure 4) is an electronic device that detects infrared light radiated from objects. It differs from an active IR sensor which consists of both emitter and detector, the emitter radiating infrared light and the receiver detecting the reflected radiation coming from the object. On the other hand, the PIR sensor consists of a detector only. When an object approaches the sensor, the detector detects the radiation coming from the object itself. The PIR does not radiate energy for detection purposes, it only detects the radiations coming or being reflected from objects (Simeon et al, 2018; Jindal et al, 2019). The sensor used in this research is Hc-SR501.

The sensor measures 1.2 * 0.9 inches. The front side is covered by a white Fresnel lens, the purpose of it being to increase the performance of the lens as well as to protect it. The other side is the PCB circuitry and other components required for processing information received from the sensor.

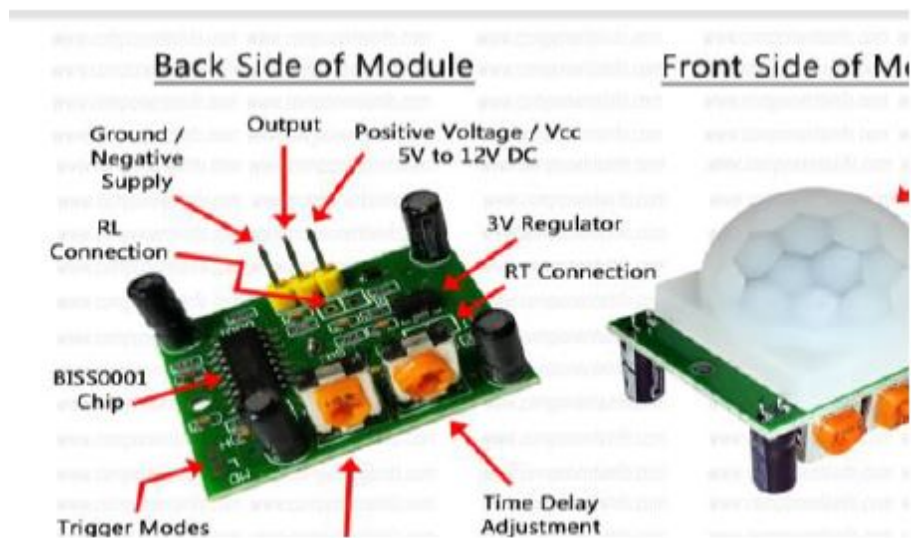


FIGURE 4
PIR sensor

Рис. 4 – Датчик PIR

Слика 4 – ПИР сензор

C. Water gear pump:

A water gear pump can be defined as a positive displacement-rotating pump that moves fluids with the assistance of inbuilt gears. It consists of two gears which can create a vacuum force to boost the liquid within the gear. The pump also has other parts such as a shaft, a rotor, and a casing. The water gear pump working principle is easy to explain. The pump uses the gear rotating actions to move the liquid. The liquid seal will extend by the pump case to generate suction at the pump inlet. The drawn liquid can be included in the rotating gear cavities and moved to the ejection. There are two types of gear pumps: external and internal ones. They are widely used. The external gear pump consists of two gears: an interlocking one and an identical one. The interlocking gear is held up with separate shafts.

The internal gear pump has two gears different in size. The rotor is a larger gear (Ivanov & Ivanova, 2020; Du et al, 2019).

The water pump in this system pumps 100 ml of ethanol. The authors did some calculations regarding the time the pump should be ON as well as the position for the pump inside the device i.e. "the distance between the pump and the nozzle spray". The pump model used in this research is CH370-6A. Table 1 shows the pump specifications.

TABLE 1
Water pump specifications

Model	CH370-6A
Rated voltage	6 DCV
Rated current	380mA
Inflation time	10 s
Pump flow rate	2 L/M
Pressure	50mmHg
Life test	30000

Таблица 1 – Технические характеристики водяного насоса
Табела 1 – Спецификације водене пумпе

Table 1 shows that the pump flow rate is 2 liters per minute. However, for the system, the amount flow rate needed is 1 ml of alcohol. In order for this to be achieved, the ON time for the pump should be taken into account. A simple proportion math ratio is done as follows.

$$\frac{\text{Pump flow rate}}{60 \text{ sec.}} = \frac{1 \text{ ml}}{x} \quad (1)$$

$\frac{2}{60} = \frac{0.001}{x}$, from that $x = 30$ ms which means the pump should be ON for 0.03 seconds in order to pump 1 ml of ethanol.

The next step is to determine the distance between the pump and the nozzle inside the device.

$$\begin{aligned}
 Q &= \frac{\text{Volume}}{\text{Time}} \\
 \text{Volume (V)} &= Q \cdot t \\
 V &= 0.001 * 0.003 \\
 V &= 3 * 10^{-5} \text{ liter}
 \end{aligned} \quad (2)$$

$$V = Area * distance$$

$$Distance (d) = \frac{Volume}{Area} \quad (3)$$

The diameter of the pump hole is 10 mm

$$Area = \pi * r^2$$

$$A = 8 \text{ mm}^2$$

$$d = 0.37 \text{ m} = 37 \text{ cm} \quad (4)$$

From the above, the distance between the pump and the nozzle is 37 cm.

D. Relay:

An electromagnetic switch is used to turn the circuit on and off using a low-power signal (Figure 5). The relay came in two modes, Normally Open and Normally Closed. Normally open (NO) means that, when the relay is not energized, the contact is open. The same principle applies for the Normally Closed (NC) mode: NC means the contact is closed when the relay is not energized. (Tin et al, 2021; Alabed et al, 2021)



FIGURE 5

Relay

Рис. 5 – Реле

Слика 5 – Релеј

E. Liquid Crystal Display (LCD):

One of the flat panel displays uses liquid crystals in its operation. Liquid crystals do not directly emit light. Instead, they use a backlight or a reflector to create images. The LCD combines two states, solid and liquid, as shown in Figure 6. The characters can easily be shown on the LCD screen. (Kobayashi et al, 2021)



FIGURE 6
LCD

Рис. 6 – ЖК-дисплей
Слика 6 – ЛЦД

F. Spray nozzle

A spray nozzle is a device that disperses liquids into a spray. The three uses for the nozzle are: liquid distribution, widening the liquid surface area, and producing impact force on a solid surface.

G. Power source

A 9-volt battery is used to power the Arduino controller and the other parts of the system.

EXPERIMENTAL WORK

The functioning principles of the device depend on combining the parts described in the previous section. The device represents a new idea to prevent infections provoked by contamination with germs, or in this case viruses. The functioning of the electronic circuit of the system is explained in a few steps given below:

1. The parts (PIR sensor, Water pump, LCD) are connected to the Arduino.
2. When an object approaches the PIR sensor, the sensor will detect the radiation emitted from the object. Then the sensor sends a signal to the controller.
3. The Arduino will receive the signal, process it, and then send a signal to the LCD and the water pump.
4. After receiving the signal, the LCD will change the default message that appears on its screen from "No motion" to "Motion".

5. The system waits for 4.5 seconds and then the water pump operates: it sucks the ethanol alcohol from the bottle attached to it and sends it to the nozzle. In accordance with the program software, the water pump is on for 30ms.
6. The nozzle will spray the liquid onto the doorknob.
7. An LCD message appears with the text of "No motion "

The Electronic circuit and the complete device are shown in Figure 7 (A to D).

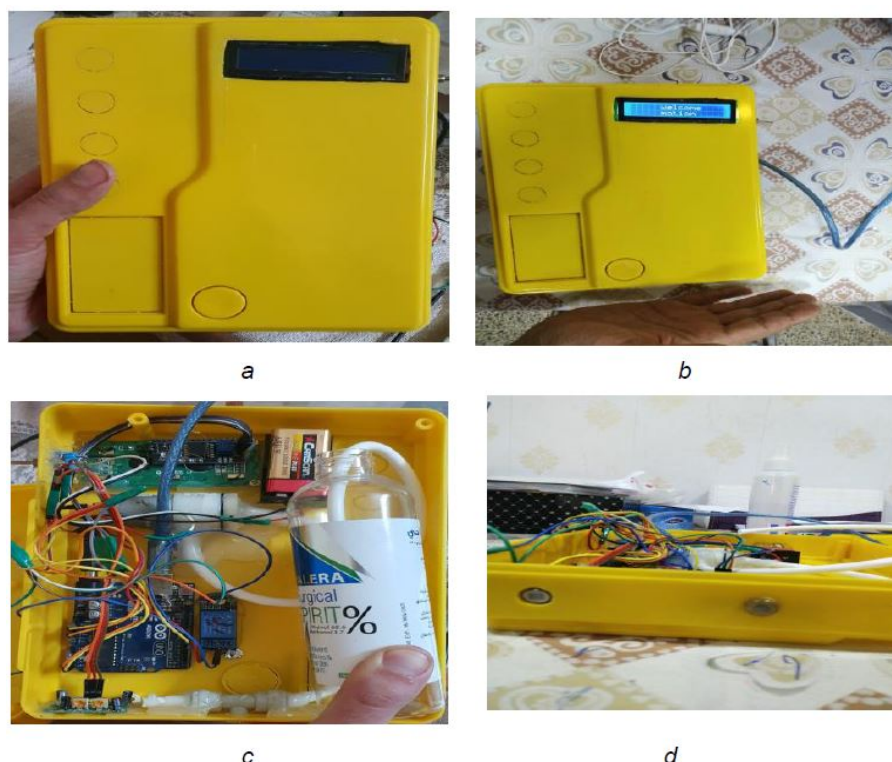


FIGURE 7
Complete system
Рис. 7 – Комплексная система
Слика 7 – Комплетан систем

RESULTS AND DISCUSSIONS

The device proves to be reliable in use and accurate in spraying the sterilizing material (ethanol) in a moment of use. However, we conducted several case studies with the device to prove that.

A. Case study Number 1 (Number of uses)

To measure the effectiveness of the device, we should calculate the number of uses the device can endure. With a simple software code, the PIR sensor also worked as a counter to count the number of people who touched the doorknob. The counter reached up to 589 trials and the device still performed properly as shown in Figure 8. This case depends on the delay time for the PUMP "which in this case was 4.5 sec". Unlike (Vyawahare et al, 2020), we were to indicate the number of users of the device.

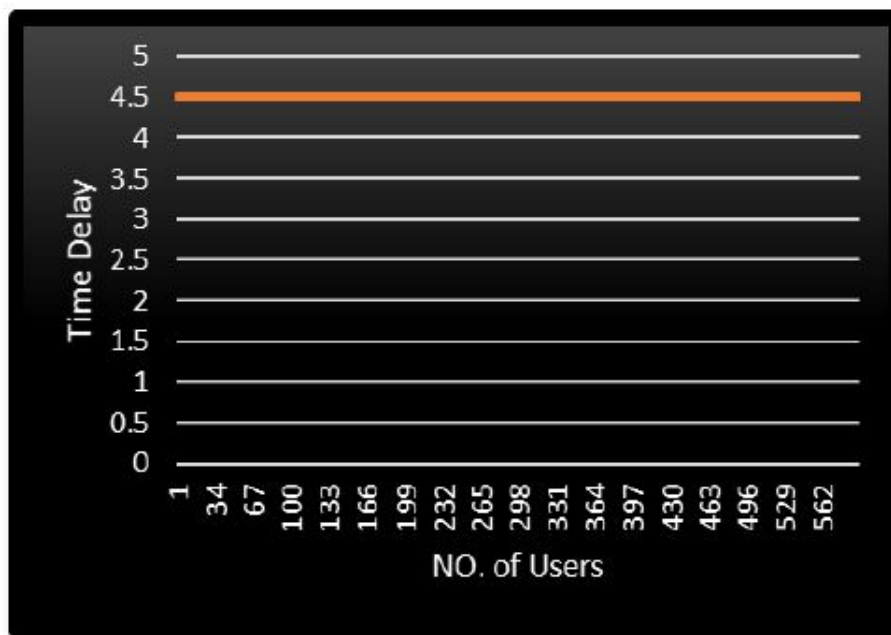


FIGURE 8
Case study 1

Рис. 8 – Изучение конкретного случая 1
Слика 8 – Студија случаја 1

B. Case study Number 2 (Temperature)

In previous research studies, as in (Alenzi & Abdudayem, 2017; Vyawhare et al, 2020), temperature increase or decrease was not taken into account. In this work, we include temperature difference as a factor that can affect the performance of the device. At standard room temperature (25°C or 68 F), the device works very precisely, which means the water pump will be ON for 30 ms. We raised the temperature for around 5 degrees and the device still worked properly with a slight difference -hence the ON mode for the water pump is 45 ms. When we decreased the temperature of the device for 5 degrees, the ON mode lasted for 35 ms, as shown in Figure 9.

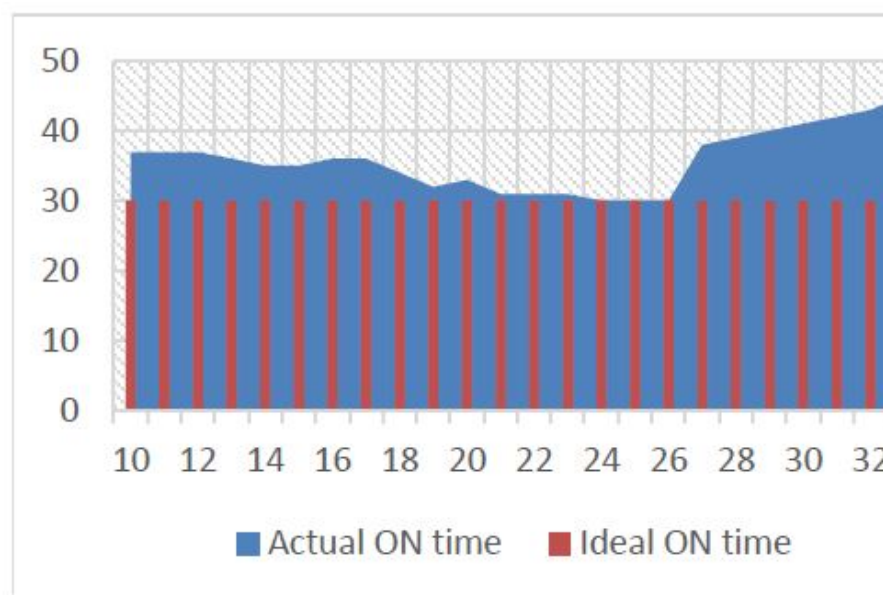


FIGURE 9

Temperature effect on the device performance

Рис. 9 – Влияние температуры на производительность устройства

Слика 9 – Утицај температуре на функционисање уређаја

C. Case study Number 3 (Overlap)

This is an important case study. When the “Motion“ message appears, it means that after 4.5 seconds the water pump will be ON. However, since someone might hold the doorknob for 4.5 seconds, this is called an overlap, and to overcome this problem we added another PIR sensor to the system. The new sensor is located at a point of the door outside the door to detect the next person trying to open the door. In this case, there will be no delay for the water pump and it will start spraying alcohol immediately. Research studies as in (Vyawhare et al, 2020) recommended not using the device during the sanitation, but in this work we found a better solution to that problem. Figure 10 shows a flow chart of the case study 3 process.

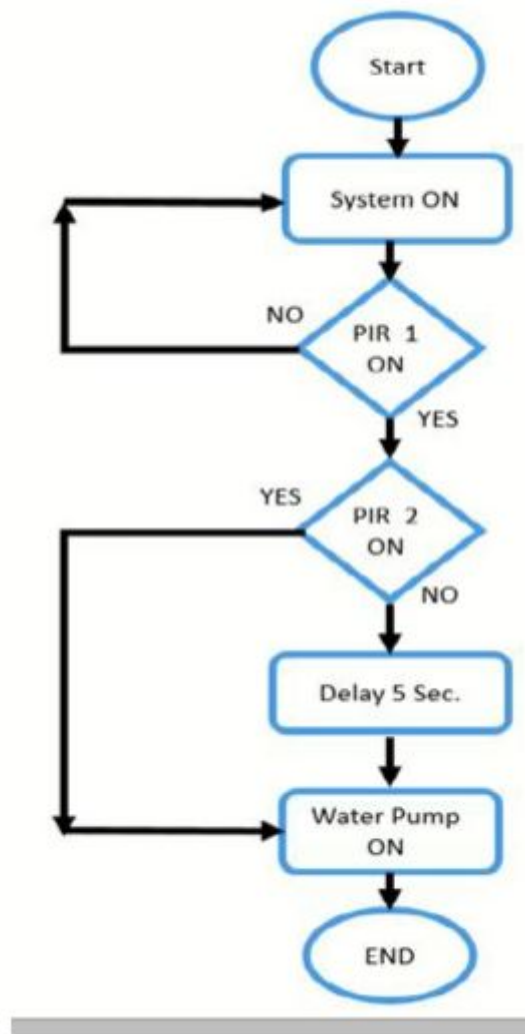


FIGURE 10

Flow chart of case study 3 (Overlap)

Рис. 10 – Блок-схема исследования конкретного случая 3 (перекрытие)

Слика 10 – Дијаграм тока студије случаја 3

Figures 11(a) and 11(b) show the system performance with the overlap before and after adding an extra PIR sensor. Figure 11(a) represents the system without an additional PIR sensor. The result of the system performance appeared to be a retest for the system which means that the system with a new person touching the doorknob added extra delay time to the old one, which means that alcohol was not sprayed by the water pump. After the addition of the PIR sensor Number 2 to the system, the performance status changed to “passed” (Figure 11(b)). Accordingly, the new condition for the system worked accurately.



FIGURE 11

System performance

Рис. 11 – Производительность системы

Слика 11 – Функционисање система

CONCLUSION

This work deals with a problem of doorknobs contaminated due to their everyday use. After a thorough study of the problem, the authors came up with an idea to sterilize the knob and prevent potential infections or diseases. The work in this paper is new and, more importantly, cost-effective with a high accuracy. The major problem encountered at first was the overlapping as mentioned in case study 3 in the Results and Discussions Section but an effective solution was found. The device is accurate, reliable, and useful for both private and public premises and all kinds of doors with knobs. The controller used to operate the device, the Arduino, is simple, easy to program, low in cost and with a very good response speed, providing precise results. For future work, fuzzy logic can be used in order to determine the amount of ethanol needed to be sprayed, which will enable the water pump to be located at any part of the device. A camera can be installed instead of a PIR sensor to solve the overlapping problem.

ACKNOWLEDGMENTS

This work is dedicated to the University of Al-Qalam for Its aid in funding this work.

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