Body Temperature Control Using a Robotic Arm

José Varela-Aldás¹², Andrés Moreira¹, Paul Criollo¹, and Belén Ruales¹

¹ SISAu Research Group, Facultad de Ingeniería y Tecnologías de la Información y la Comunicación, Universidad Tecnológica Indoamérica, Ambato, Ecuador
{josevarela,belenruales}@uti.edu.ec
² Department of Electronic Engineering and Communications, University of Zaragoza, Zaragoza, Spain

Abstract. At the end of 2019, a highly contagious virus appears, changing the form of interaction between humans, this has implied the use of technology as a support tool to counteract the effects of the new disease (COVID-19). Although many technologies have been successfully adapted, applied robotics promises to reduce or even eliminate the need for person-to-person contact. This article presents the control of the body temperature of the clients of a commercial premises through the implementation of a system that includes a robotic arm, two sensors and a mobile device. The robotic arm is constructed using 3D printing and a low-cost electronic circuitry, body temperature is obtained using an infrared sensor, and a mobile device displays, alerts, and stores the information. The developed code allows remote control of the robot positions or a pre-programmed sequence is automatically activated that includes temperature measurement and hand disinfection. The results show the robot in operation and the data acquired by the system, observing adequate temperatures in most of the users and a single alert during the tests carried out. The conclusions establish the importance of the system in the real application and highlight the multiple benefits of this proposal.

Keywords: Body temperature · Arm robotic · Mobile app · COVID-19

1 Introduction

The new coronavirus (SARSS-CoV-2) has produced a health crisis that has most of the world in emergency, this virus apparently is of animal origin and the main effect is a viral pneumonia, although the conditions may vary or not even exist. Studies indicate an incubation period of 0 to 24 days with an average of 5 days, with the first symptoms being fever, cough, nasal congestion, fatigue and other signs of respiratory infections. The virus is considered easy to transmit and can double the number of people infected every seven days, due to the fact that each patient spreads the infection to another 2.2 people on average [1]. The risk of death increases in elderly patients, in critical condition this disease produces high body temperatures (>39 °C) and several associated
disorders [2]. COVID-19 has reformed the customs of society, among the changes adopted are: avoiding contact with objects for public use, personal hygiene measures and social distancing [3]. In addition, governments promote the use of protective equipment to stop the spread of the coronavirus, among the most recommended supplements is the use of protective masks that avoid direct contact between people, and skin infrared thermometers for detection fever [4].

Digital technology has had great influence in the fight against COVID-19, in this way it has been possible to follow the number of cases in different areas in almost real time, this information allows obtaining prediction models and preparation to face outbreaks. Telemedicine enables a patient to receive immediate remote care and reduces physical overcrowding [5]. The bibliographic reviews describe more technologies that have been added to alleviate the impact of the pandemic, thus we have, IoT, drones, artificial intelligence, Blockchain and 5G [6]. Industry 4.0 has also been adapted to provide solutions that mitigate the impact of COVID-19, such as virtual reality applied to teleworking that allows efficient collaborative communication, cloud computing that streamlines digital processes avoiding collapses, and the 3D scanner that avoids contact in body examination [7]. 3D printing has played an important role in the timely manufacture of personal protective equipment [8, 9]. On the other hand, wearables have made available the continuous monitoring of the user’s vital signs, these physiological data allow to alert possible symptoms of the disease or to control the health status of those infected [10]. Of the possible biological variables to be monitored, the temperature allows an early detection of the epicenters of the virus, in this way contagions can be prevented using smart sensor networks [11].

Robotics has also been involved as a combat tool against the current pandemic, since robotic systems have the potential to replace human tasks avoiding contact in disinfection tasks, food delivery and medical assistance. COVID-19 has revealed the need to promote the development of technologies related to robotics to face the risks of infectious diseases [12]. But the new restrictions are limiting the studies that involve human-robot interaction, having to focus efforts on applications that avoid direct contact with the human being. [13]. In this context, the main applications are disinfection of public areas, sophisticated surgical operations, delivery of materials, protecting, comforting or entertaining patients, and measuring body temperature, so that medical personnel prevent contagion [14, 15].

In similar works we have the construction of a biomedical signal extraction device using IoT, this easy-to-develop system uses Arduino and allows obtaining heart rate, blood pressure, blood oxygen, respiratory rate, vital capacity and psychological index for storage and subsequent analysis of information. In addition, body temperature is recorded using a GY-906 module [16]. Regarding exclusive temperature measurement, in [17] a high precision system is implemented using various infrared sensors for domestic and medical purposes. In the context of COVID-19, a smart helmet has been proposed that incorporates a thermal imaging system to measure temperature and detect fever, obtaining a high demand from the health system [18]. In relation to robotics, [19] implemented a Tele-Echography system to avoid contact with patients, using a robotic arm and a 5G communication network to guarantee stability. Finally, a humanoid robot
is developed to alert and measure the temperature of people using a thermal scanner, the processes are activated with the signal of a presence sensor [20].

This work describes the design and construction of a robotic arm with 3° of freedom to control the body temperature of those attending a commercial premise. The document has been organized as follows: INTRODUCTION presents the generalities and some related works; FORMULATION details the characteristics and components of the system; the HARDWARE and SOFTWARE of the proposal is described; RESULTS present the robot in operation and the acquired data; and finally, the CONCLUSIONS and DISCUSSIONS are established.

2 Formulation

The reviewed literature demonstrates the needs of the global health crisis caused by COVID-19, as well as the application of technology on various fronts to counteract the effects on health and the collective economy. Nowadays it is common to use infrared thermometers at the entrance of commercial premises, followed by the application of hand sanitizer gel, these activities are of vital importance to alert and prevent contagions, for which it is necessary to develop proposals that automate this process. This system can be implemented using various mobile mechanisms, but a robotic system offers a feasible and flexible solution, so that the robot can perform several tasks such as: positioning to take the temperature and the autonomous application of the disinfectant. In addition, it is important to consider that the temperature sensor must perform the measurement without any contact with the user, this is solvable through an infrared sensor, similar to the devices used when executing the activity manually.

In relation to the electronic control card, there are currently several hardware development options, but cost reduction and accessibility to materials should be considered to facilitate the reproduction of the proposal. Based on this, Arduino is a widely used tool in prototyping that includes free access software with online support. In addition, it has compatibility with several sensors and modules of conditioning and wireless communication, useful to improve the interactive characteristics of the proposal. On the other hand, mobile devices are widely used as information output elements, as well as to remotely operate the electronic system.

Figure 1 presents the components of this proposal, starting from the user who interacts with the manipulator robot with the different pre-programmed processes. The person approaches the robot and the proximity sensor detects this presence to enable the automated sequence; the robotic arm changes the position of the end to take the temperature reading, at this stage the user must place the wrist near the sensor; The next step is the application of the disinfectant gel on the user’s hands, this by pressing the container through the robot’s claw; Finally, the controller maintains bidirectional communication with a mobile device, sending data and alerts from the user, and receiving movement orders for the robotic arm, these orders change the location of the end to any of the positions set in the control sequence.
To implement the proposal, the synthesis of each of the system components is required, including the physical structure of the robot, the mathematical model, the electronic circuit, the programming of the control actions and the development of the mobile application. The design of the proposal has been divided into two sections: Hardware and Software.

3 Hardware

3.1 3D Design

The physical structure of the manipulator robot in this proposal is designed using CAD software for subsequent 3D printing. Considering that the robot has a three-dimensional environment as its workspace, due to the need for movements in the plane and also elevation (up-down), an anthropomorphic robot with 3° of freedom is proposed. The proposed mechanism appears to be the shape of a human arm through angular movements in each joint, in this case 3 joints are needed, each with a respective actuator, this number of motors allow the end to move freely in space, obtaining a holonomic robot. In addition, an extra actuator is required to give action to the end effector, by means of a movement transformation mechanism the opening and closing of the claw is generated.

Figure 2 shows the 3D design of the proposed robot manipulator, the main controller is installed in the rectangular base located in the lower part and the proximity sensor is installed through 2 holes in the front cover. Above, a cylindrical component is located that contains the first servomotor and supports the kinematic chain, this element rotates with the entire upper mechanism activating the first degree of freedom. The second servomotor coupled with a U-shaped support is placed on the cylinder, the first link of the robot is installed on the motor shaft. The links of the manipulator are designed using parallel bars connected through guide shafts to copy the movement, at
the end of each link a servomotor is incorporated, the third actuator to actuate the second link and the fourth actuator to actuate the end effector. The claw is built based on the classic mechanism of gears that move two fasteners at the same time.

![3D design of the anthropomorphic manipulator robot.](image)

Each of the design components are manufactured using 3D printing, importing the elements in STL extension to upload the files to the printer server and set the print settings.

### 3.2 Kinematic Model

Based on the characteristics of the designed robot, the kinematic behavior is analyzed using the geometry of the robot that positions the operating end. The purpose is to find the mathematical equations that locate the X, Y and Z coordinates of the point of interest, in this case the claw, for this the vector decomposition of the links (projections) is used according to the established reference system.

To find the kinematic model, the reference system is fixed at the beginning of the first link, with the Z axis as the robot height, where \( l_1 \) and \( l_2 \) are the lengths of the links, in the case of the second link, the length includes the claw. \( \beta \) is the angle of rotation around Z that the entire manipulator rotates, \( q_1 \) is the rotation of the first link, \( q_2 \) is the rotation of the second link, and \( P_i \) is the end effector position on each reference axis. The equations obtained are presented below.

\[
\begin{align*}
P_x &= l_1 \cos(q_1) \cos(\beta) + l_2 \cos(q_1 + q_2) \cos(\beta) \\
P_y &= l_1 \cos(q_1) \sin(\beta) + l_2 \cos(q_1 + q_2) \sin(\beta) \\
P_z &= l_1 \sin(q_1) + l_2 \sin(q_1 + q_2)
\end{align*}
\]
The mathematical model obtained is used to find the angles in each of the positions of the automated sequence to measure the temperature and apply the disinfectant. For this case is not necessary to define the kinematics differential equations of the robot.

### 3.3 Electronic Circuit

The electronic circuit is designed based on the Arduino board, which has digital inputs and outputs, as well as synchronous and asynchronous serial communication, it also has voltage regulators that allow the circuit to be powered with up to 12 V direct current and have an internal source of 5 V. These features allow incorporating the sensors, actuators and communicators of the proposed system, using low-cost devices and open-source software (Arduino IDE).

Figure 3 presents the electronic circuit diagram, the external supply source supplies 6 V to the input of the Arduino (VIN) and to the power pins of the servo motors. The actuators are MG995 servomotors that reach a maximum torque of 11 Kg-cm, the pins used in the control of movements by set width are 7, 8, 9 and 10, which are configured as digital outputs of Arduino. The sensors and the wireless communication module are powered by 5 V provided by the internal source. To detect the presence of the user, an HC-SR04 ultrasonic sensor is used that allows to measure proximity up to 2 m away, Trigger is connected to pin 3 as digital output, and Echo to pin 2 as digital input. Body temperature is measured by a GY-906 sensor that allows non-contact measurement of ambient temperature and target temperature in a range from $-70 \degree C$ to $+380 \degree C$, this device works through asynchronous communication I2C; SCL and SDA are connect to pins A5 and A4, respectively.

![Electronic Circuit Diagram](image)

**Fig. 3.** Electronic circuit for temperature control using a robotic arm.

The wireless communication means is carried out through the HC-06 Bluetooth module that transmits serial communication, from the module the TXD and RXD pins are connected to digital pins 0 and 1 of the Arduino that are enabled by default for communication.
4 Software

4.1 Programming

The programming code in the robot has two objectives to meet, automate the sequence of temperature measurement and disinfectant application, and exchange information with the mobile application, so there may be interruptions between the two. In this sense, it is chosen to prioritize the remote control of the robot’s actions, that is, the automated sequence is executed only if there are no external orders. In addition, the sequence starts only if a presence is detected in front of the robot, presenting the data on the screen and storing the relevant information for the results.

The flow diagram of the main program for the manipulator is presented in Fig. 4, starting with the configuration of the Arduino’s digital inputs and outputs, and setting the data for 3 positions in the sequence. The repetitive loop starts with the reading of the serial port, if there is any positioning order from the mobile device, the robot must execute it immediately. Otherwise the proximity sensor checks the distance of the objects and if it is less than 50 cm it activates the automatic sequence, placing itself in the second position to read the body temperature, then it is located in position 3 to discharge the disinfectant, and return to the starting position. Distance and temperature data are sent and displayed on the screen of the mobile device, as well as alerts of high temperatures that can mean infection (COVID-19), this when the temperature exceeds 37.5 °C, and all body temperature data are stored on mobile device.

![Flow chart the main robot program.](image-url)

Fig. 4. Flow chart the main robot program.
4.2 Inverse Kinematics

In relation to the 3 positions of the sequence (Rest, temperature measurement and application of disinfectant), they are designed by inverse kinematics, that is, using the kinematic model, the required angles are determined to reach the desired positions. Inverting the equations of direct kinematics is usually inconvenient due to results with double solutions and complex operations. In this case the unknown variables \( (\beta, q_1, q_2) \) have nonlinear analytical solutions due to the trigonometric functions and the product between functions. On the other hand, the optimization solution uses pre-programmed search algorithms that find feasible solutions for this proposal.

To propose the system of equations to be minimized (based in [22]), the desired positions \( P_{id} \) are inserted into the problem as known values, using the position error \( P_{id} - P_i \) for each component of the reference system. The optimization problem consists of finding the values so that each of the equations is equal to zero or very close to zero. The system of equations to be solved by software is presented below:

\[
0 = P_{xd} - l_1 \cos(q_1) \cos(\beta) + l_2 \cos(q_1 + q_2) \cos(\beta) \\
0 = P_{yd} - l_1 \cos(q_1) \sin(\beta) + l_2 \cos(q_1 + q_2) \sin(\beta) \\
0 = P_{zd} - l_1 \sin(q_1) + l_2 \sin(q_1 + q_2)
\]  

4.3 Mobile Application

The administrator interface is implemented in the mobile application, it is developed in Ionic, an open source multiplatform software. The most important component of the app is communication with the robot manipulator via Bluetooth, which allows sending and receiving bidirectional interaction data.

Figure 5 shows the two screens developed in Eclipse, the interface starts presenting the image of the robotic arm and the option to connect to the system. Next, the main screen appears, divided into 4 parts: the connection, which lists the Bluetooth devices and allows you to refresh the connection; the data, which shows the information of the sensors through labels that are constantly updated; the control, which contains 3 buttons listed in the order of the sequence (1.–Rest, 2.– Measure Temperature, 3.– Gel Application) to place the robot in the desired position; and the alert, which presents a warning image with sound in case of exceeding the body temperature limit value, by default the robot image is presented.
The mobile application also stores the biometric data taken during all measurements performed, recording the body temperature of each user. For ease, the information is saved in a plain text file that is constantly updated as the data is generated.

5 Results

For the results, the robotic arm is manufactured using 3D printing in polylactide (PLA) as consumable material. Proceeding to assemble the robot and obtaining an approximate weight of 580 grams without considering the disinfectant gel container. Figure 6 shows images of the assembled manipulator, observing all the components attached to the robot, the distance sensor installed on the base and the temperature sensor attached to one side of the tweezers, the gel container has been fixed inside the claw for apply the disinfectant. Furthermore, the proposed system thermometer is calibrated using a commercial infrared thermometer. Tests are carried out with different movements in the 3° of freedom and the claw, validating the operation of the constructed manipulator.
To implement the robot at the entrance of the commercial establishment, the angles are required for each servomotor and in each of the positions of the sequence. The approach to solve the inverse kinematics is implemented in the MALTBAB software, using the \textit{fsolve} function that allows finding the solution using numerical methods. Table 1 presents the input parameters (dimensions and desired positions) and the solutions found, these values are included in the main programming code and the system is implemented.

\begin{table}[h]
\centering
\caption{Robot arm positioning values}
\begin{tabular}{|c|c|c|c|}
\hline
Parameter & Value [m] & Solutions & Value [°] \\
\hline
L_1 & 0.2 & & \\
L_2 & 0.3 & & \\
P_{xd} & 0.1 & \beta & 0 \\
& 0 & & 90 \\
& 0 & & 90 \\
P_{yd} & 0 & q_1 & 153 \\
& 0.1 & & 153 \\
& 0.15 & & 138 \\
P_{zd} & 0.2 & q_2 & -132 \\
& 0.2 & & -132 \\
& 0.15 & & -135 \\
\hline
\end{tabular}
\end{table}

Fig. 6. Robot manipulator in operation.
The system is used by a grocery store for a week, collecting body temperature 265 times, the data is downloaded and presented in Fig. 7. A mean temperature of 36.6 °C is obtained, a minimum of 35.8 °C and a maximum of 37.3 °C (without alerts). Of all the users evaluated in this period, a single alarm is generated, with a temperature of 37.7 °C.

![Fig. 7. Body temperature acquired by the implemented system.](image)

Regarding the user experience, the participants expressed satisfaction with the service provided by the manipulator robot, highlighting the speed of the process, with a pre-programmed task execution time of approximately 11 s. On the other hand, older users do not feel safe using the system. Although this proposal is interesting and attractive for users, there are simpler ways to solve the same problem, Table 2 presents some advantages and disadvantages of this proposal compared to other solutions, such as pedal mechanisms to apply gel, dispensers automatic and static temperature sensors.

| Advantages                                      | Disadvantages                                      |
|------------------------------------------------|---------------------------------------------------|
| Remote monitoring of the process from the mobile application | Requires affinity with mobile technology           |
| Minimal waste of hand disinfectant gel          | Limited volume of hand disinfectant gel            |
| Sensation of vigilance in the user by the robotic system | Distrust and insecurity on the part of the user     |
| Robot manipulator installation flexibility      | Some resources are required to implement the proposal |
6 Conclusions and Discussions

The new measures adopted by society in the time of COVID-19 have forced the generation of technological solutions that contribute to the management of the global health crisis, robotics being a tool to avoid contact between people. This proposal designs, builds and implements a robotic arm as a substitute tool in the temperature control process when accessing commercial premises, in this way customers do not have contact with another person at the time of entering to make purchases. The system has been designed in hardware and software; the 3D design of the manipulator robot is carried out, obtaining the mathematical equations that describe the position of the final effect, and designing the electronic circuit that includes sensors, actuators and communication on the Arduino board; the programming code prioritizes the orders from the mobile device, the automated sequence is designed using angles of the inverse kinematics of the robot, and the mobile application allows data and alerts to be viewed, storing the registered temperatures.

The manipulator is built using additive manufacturing through a 3D printer, assembling all the elements and verifying the correct operation. The tests carried out in a place groceries supplier demonstrate the importance of this proposal, managing to control the access of 265 people to the establishment in a period of 7 days. The recorded temperatures show temperature ranges consistent with the human body, with an average of 36.6 °C. In addition, an alert threshold of 37.5° is established to warn customers of a possible fever symptom and to take action at the time of alert. Early detection of fever not only takes care of the workers on the premises, it also anticipates the user of symptoms related to the infection.

Regarding the use of the GY-906 sensor for body temperature measurement, [17] it uses this and other low-cost devices to monitor biometric data, and infrared technology has been used for precise systems in temperature measurement [18]. On the other hand, there are proposals that allow monitoring the temperature of individuals using portable thermal cameras [19], but they still require a human present for operation, unlike the proposal presented in this document. Regarding robotics applied in similar cases, few studies have been found in the bibliography, highlighting the proposal of [20], which uses a humanoid robot to measure body temperature. Compared to the last, this work incorporates a mobile device as a remote control and visualization tool, increasing performance and improving interaction with the system. Finally, although there are simpler solutions to this problem, the implementation of robotic systems in common tasks allows us to analyze robots in new environments.

References

1. Velavan, T.P., Meyer, C.G.: The COVID-19 epidemic. Trop. Med. Int. Heal. 25, 278 (2020). https://doi.org/10.1111/tmi.13383
2. Lian, J., Jin, X., Hao, S., Cai, H., Zhang, S., Zheng, L., Jia, H., Hu, J., Gao, J., Zhang, Y., et al.: Analysis of epidemiological and clinical features in older patients with coronavirus disease 2019 (COVID-19) outside Wuhan. Clin. Infect. Dis. 71, 740–747 (2020). https://doi.org/10.1093/cid/ciaa242
3. Cascella, M., Rajnik, M., Cuomo, A., Dulebohn, S.C., Di Napoli, R.: Features, evaluation and treatment coronavirus (COVID-19). In: Statpearls [internet]. StatPearls Publishing (2020)
4. Wu, E., Qi, D.: Masks and thermometers: paramount measures to stop the rapid spread of SARS-CoV-2 in the United States. Genes Dis. (2020). https://doi.org/10.1016/j.gendis.2020.04.011
5. Ting, D.S.W., Carin, L., Dzau, V., Wong, T.Y.: Digital technology and COVID-19. Nat. Med. 26, 459–461 (2020). https://doi.org/10.10138/s41591-020-0824-5
6. Chamola, V., Hassija, V., Gupta, V., Guizani, M.: A comprehensive review of the COVID-19 pandemic and the role of IoT, drones, AI, blockchain, and 5G in managing its impact. IEEE Access 8, 90225–90265 (2020). https://doi.org/10.1109/ACCESS.2020.2992341
7. Javaid, M., Haleem, A., Vaishya, R., Bahl, S., Suman, R., Vaish, A.: Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. Diabetes Metab. Syndr. Clin. Res. Rev. 14(4), 419–422 (2020). https://doi.org/10.1016/j.dsx.2020.04.032
8. Tino, R., Moore, R., Antoline, S., Ravi, P., Wake, N., Ionita, C.N., Morris, J.M., Decker, S. J., Sheikh, A., Rybicki, F.J., et al.: COVID-19 and the role of 3D printing in medicine (2020). https://doi.org/10.1186/s41205-020-00064-7
9. Varela-Aldás, J.L.: Impresión 3D y COVID-19. CienciAmérica 9, 51–57 (2020). https://doi.org/10.33210/ca.v9i2.292
10. Jeong, H., Rogers, J.A., Xu, S.: Continuous on-body sensing for the COVID-19 pandemic: Gaps and opportunities (2020). https://doi.org/10.1126/sciadv.abd4794
11. Chamberlain, S.D., Singh, I., Ariza, C.A., Daitch, A.L., Philips, P.B., Dalziel, B.D.: Real-time detection of COVID-19 epicenters within the United States using a network of smart thermometers. medRxiv (2020). https://doi.org/10.1101/2020.04.06.20039909
12. Yang, G.-Z., Nelson, B.J., Murphy, R.R., Choset, H., Christensen, H., Collins, S.H., Dario, P., Goldberg, K., Ikuta, K., Jacobstein, N., et al.: Combating COVID-19—The role of robotics in managing public health and infectious diseases (2020). https://doi.org/10.1126/scirobotics.abb5589
13. Feil-Seifer, D., Haring, K.S., Rossi, S., Wagner, A.R., Williams, T.: Where to next? the impact of COVID-19 on human-robot interaction research. ACM Trans. Hum. Robot Interact. 10, 1–7 (2020). https://doi.org/10.1145/3405450
14. Khan, Z.H., Siddique, A., Lee, C.W.: Robotics utilization for healthcare digitization in global COVID-19 management. Int. J. Environ. Res. Public Health. 17, 3819 (2020). https://doi.org/10.3390/ijerph17113819
15. Zeng, Z., Chen, P.-J., Lew, A.A.: From high-touch to high-tech: COVID-19 drives robotics adoption. Tour. Geogr. 1–11 (2020). https://doi.org/10.1080/14616688.2020.1762118
16. Samalavicius, N.E., Siaulys, R., Janusonis, V., Klimasauksiene, V., Dulskas, A.: Use of 4 robotic arms performing Senhance®robotic surgery may reduce the risk of coronavirus infection to medical professionals during COVID-19. Eur. J. Obstet. Gynecol. Reprod. Biol. (2020). https://doi.org/10.1016/j.ejogrb.2020.06.014
17. Cheng, Y.-H., Kuo, C.-N.: Development of IoT-based simply constructed mobile biomedical signals extraction device. In: Asian Conference on Intelligent Information and Database Systems, pp. 391–401 (2020). https://doi.org/10.1007/978-981-15-3380-8_34
18. Guo, Z., Chu, J.: Design and implementation of infrared temperature measurement system. In: 2017 5th International Conference on Machinery, Materials and Computing Technology (ICMCT 2017) (2017). https://doi.org/10.2991/icmctmct-17.2017.115
19. Mohammed, M.N., Syamsudin, H., Al-Zubaidi, S., AKS, R.R., Yusuf, E.: Novel COVID-19 detection and diagnosis system using IOT based smart helmet. Int. J. Psychosoc. Rehabil. 24, 2296–2303 (2020). https://doi.org/10.37200/IJPR/V24I7/PR270221
20. Wang, J., Peng, C., Zhao, Y., Ye, R., Hong, J., Huang, H., Chen, L.: Application of a robotic tele-echography system for COVID-19 pneumonia. J. Ultrasound Med. (2020). https://doi.org/10.1002/jum.15406

21. Rane, K.P.: Design and development of low cost humanoid robot with thermal temperature scanner for COVID-19 virus preliminary identification. Int. J. Adv. Trends Comput. Sci. Eng. 9, 3485–3493 (2020). https://doi.org/10.30534/ijatcse/2020/153932020

22. Varela-Aldás, J., Ayala, M., Andaluz, V.H., Santamaría, M.: Inverse kinematics of a redundant manipulator robot using constrained optimization. Adv. Intell. Syst. Comput. 1137 AISC, 233–242 (2020). https://doi.org/10.1007/978-3-030-40690-5_23