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DEVELOPMENT AND IMPLEMENTATION OF AN IOT DEVICE FOR BODY TEMPERATURE MEASUREMENT USING THE MLX90614 THERMAL SCANNER

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ABSTRACT

During the height of the COVID-19 pandemic, contact tracing is a key point for curbing the transmission of SARS-CoV-2 and reducing associated mortality. In the Philippines, prior entering establishments, individuals are required to have their body temperature measured and log their names in contact tracing forms. The process is tedious and prone to error. An integrated system is envisioned comprising three major components – a database and web server, a web application and an IoT device which automates the measurement and logging of contact information of individuals entering an establishment. In this study, the development and implementation of an IoT device for body temperature measurement using the MLX90614 thermal scanner interfaced to a Raspberry Pi 4B is described.

KEYWORDS: COVID-19, contact tracing, automated temperature scanning, IoT device.

INTRODUCTION

At the onset of the COVID-19 pandemic, the Philippine government enacted new laws to mitigate the spread of the virus. The Inter-Agency Task Force on Emerging Infectious Diseases (IATF-EID) was created under the virtue of the Executive Order No. 168 that was signed by Former President Benigno Aquino III (Executive Order No. 168, 2014). The IATF-EID was formed to to assess, monitor, contain, control and prevent the spread of any potential epidemic in the Philippines (Porcalla, 2014). It was convened last January 2020 to address the spread of COVID-19 (IETF_EID). It is a conglomeration of different agencies under the executive branch of the government. It is headed by the Department of Health, including the

Office of the Cabinet Secretary and the Department of Environment and Natural Resources as its co-chairs.

Republic Act No. 11469 or the “Bayanihan to Heal as One Act,” (RA 11469, 2020) granted President Rodrigo Duterte temporary authority to carry out tasks necessary to implement measures to alleviate, if not contain the transmission of COVID-19 (Bayanihan to Heal as One Act, n.d.). The president also declared a state of calamity throughout the country and imposed an Enhanced Community Quarantine (ECQ) in the entire Luzon (Proclamation No. 929 s. 2020 | Official Gazette of the Republic of the Philippines, 2020).

This paved the way for the IATF to create other quarantine classifications and guidelines therein. These quarantine classifications include the Enhanced Community Quarantine, Modified Enhanced Community Quarantine, General Community Quarantine and General Community Quarantine

During the COVID 19 pandemic where majority of the Philippines is under General Community Quarantine (IATF, 2020), business establishments such as malls were allowed to operate under limited capacities. The minimum health protocol requires individuals entering business establishments to manually fill out contract tracing forms and must submit to mandatory temperature check. Each tenant inside the malls follows a protocol requiring any person who wishes to enter the shop or store to fill up another contact tracing form and undergo another temperature check. This presents inconvenience to business patrons and business owners alike. This process also increases the risk of exposure and spread of the virus. In addition, temperature measurements using hand-held thermal scanners raise doubts on the reliability of the data. The manual nature of contact information presents difficulty in tracing the people who were in close contact with the person who might be developing the symptoms of COVID 19 virus exposure.

Integrating emerging technologies into COVID 19 contact tracing is seen as a viable option that policymakers, health practitioners and IT experts need to seriously consider in mitigating the spread of corona virus (Mbunge, 2020). Currently, there are several contact tracing apps and platforms employed in the country. These include StaySafe.ph (https://www.staysafe.ph/), WeTrace (https://sugbo.ph/2020/wetrace-tracing-app/), CLEAR (Citizen’s Logistics and Early Assessment Report Tool), and ValTrace among others. StaySafe.ph is an online platform and app developed by Multisys Technologies Corporation that lets users report health conditions and generates location-based contact tracing. The app also generates a heatmap that is based on the reported users' data. WeTrace is a contact tracing app that was developed in Cebu. Governor Gwendolyn Garcia required all her constituents to install the app. Another contact tracing solution developed is ValTrace (https://valtrace.appcase.net/). This app uses Quick Response Codes (QR Codes) in lieu of manually inputting personal information from the health declaration form. Registration is made through the app's website (https://valtrace.appcase.net/Register). Both establishments and individuals are required to register as "citizen" (for the individual) and as "merchant" (for the establishment) Citizens are then given a unique code that is used to have it presented upon entering any enclosed indoor establishment within the city for a truly contactless transaction. Merchants are likewise scan the QR codes of the citizens upon entry on their establishments.

A development of a non-contact thermometer using MLX90614 was developed by J. Zhang (Zhang, 2018). In this study, the proponent measured the temperature on the armpit, oral, ear and forehead, and compared it to the reading of a traditional mercury thermometer. The results show that the measurements of the infrared thermometer are very close to the measurements of the mercury thermometer on both armpit and oral parts. However, it is impossible to measure the temperature on the ear and forehead using mercury thermometer. Another analysis that can be found is that the measurement on the forehead and ear is lower than the armpit temperature, however the values are close to each other. The study also stated that the distance from the measured body to the measuring device greatly affects the results. The proponent, therefore, recommended that the distance of the body part between 2 to 5 cm to the measuring device before measuring. Another study aimed to compare the accuracy and precision of wrist and forehead temperature with tympanic temperature (Chen et al., n.d.). In this study, it was confirmed that measuring the temperature on the wrists was more stable compared to the forehead measurements. It also concluded that both measurements had significantly great fever screening capabilities for indoors. According to the ASTM E1965-98(2016) standard, the allowable errors of clinical thermometers is 0.1 °C in the temperature range 37–39 °C, 0.2 °C in the temperature range 36–37 °C and 39–41 °C.

In this study, the use of MLX90614 interfaced to a Raspberry Pi Model B (Raspberry Pi Foundation. 2016) is explored. The sensor has been widely used to scan temperatures in a wide variety of applications. The use of the said sensor has also been used in getting human temperature and is comparable to the use of mercury thermometers. The IoT device proposed in this study can be used as the front-end device in an integrated contact tracing system where contact information of individuals where body temperature readings is indicative of possible COVID-19 infections, are logged and forwarded to a central database system.

Figure 1 shows the architecture of the proposed IoT device. The device is composed of the MLX90614 temperature sensor, RPi camera, the touch screen, and the Raspberry Pi Model B. The MLX90614 temperature sensor scans the temperature of the user, the camera reads the QR code provided to the user upon entry, and the touch screen provide the Graphical User Interface. An RPi UPS HAT supplies power to the system.

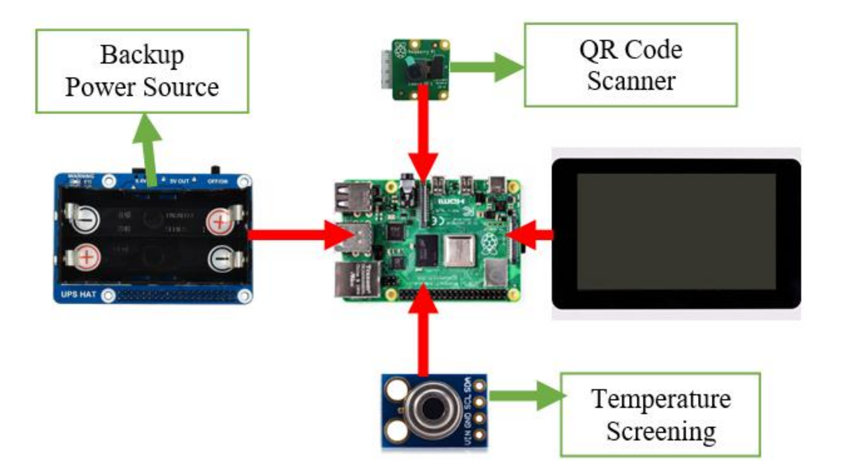

Figure 1: Experimental Set-Up of the System

The hardware component of the system involves a Raspberry Pi 4 as its main hardware component for processing. Other hardware components include the MLX90614 InfraRed Temperature Sensor, Raspberry Pi Camera and LCD Touchscreen. The Raspberry Pi Camera will be used to scan the unique QR codes. The MLX90614 will be used to automatically check The LCD touchscreen will be the main Human Machine Interface (HMI). Database management will likewise be used in this study.

MATERIALS AND METHODS

The Raspberry Pi 4 is a small single-board computer that is used in a wide variety of applications (Raspberry Pi Foundation, 2016). The Raspberry Pi Camera V2.1 features a Sony IMX219 image sensor. It is a high quality 8-megapixel sensor that is designed in custom for RPi. It features a fixed focus lens. Such applications include image processing and robotics. The use of the Raspbian Stretch OS provided better scalability and adequate support since this is open source and is based on Linux. MLX90614 from Melexis is incorporated to acquire body temperature. The MLX90614 consists of infrared-sensitive thermopile detector, signal conditioning chip, 17-bit analog to digital converter, and powerful digital signal processor in single unit. The standard version has accuracy of ±0.5 °C and resolution of 0.02 °C for object temperature of 0 to 60 °C and ambient temperature of 0 to 50 °C. This version has an FOV of 90° to measure temperature of the target with spot size of 5 cm in diameter. The distance between thermometer and forehead/wrist should be between 2.5 to 5 cm for best accuracy. The device can operate normally using power supply voltage of 2.6 to 3.6 V with current consumption up to 2.5 mA. The UPS HAT can power the Raspberry Pi seamlessly from power connection or backup batteries. It has the standard Raspberry Pi 40PIN GPIO extension header. It also has the I2C bus communication that could monitor the voltage, current, power, and remaining capacity of the battery in real time.

Software Development Tools

Rasbian OS is used in the Raspberry Pi with Python programming language used to develop the application program. ZBar and OpenCV libraries were used to read the barcode. The application software that control the hardware and processes measure data will be developed using Python. Python is a high-level, multipurpose programming language created in late 1980's. It is a known programming language widely used by the research community because of its simple syntax and specialized packages. Python is a free and simple object-oriented programming language that offers dictionary (hashes) support and provides more choices in graphics packages and tools. With this, Python is a good language choice for object detection application. Open Source Computer Vision or OpenCV is mainly designed for real-time computer vision applications. OpenCV library has around 300 embedded algorithms which are composed of algorithms for computer vision and machine learning.

ZBar is an open-source software suite for reading bar codes and QR codes from various sources ("ZBar Bar Code Reader Library: Main Page," n.d.). The flexible, layered implementation facilitates code scanning and decoding for any application. Tkinter ("Tk Interface") is python's standard cross-platform package for creating graphical user interfaces (GUIs). It provides access to an underlying Tcl interpreter with the Tk toolkit, which itself is a cross-platform, multilanguage graphical user interface library.

System Evaluation and Validation

Ten participants were asked to participate by getting their temperature using the IoT infrared thermometer and the digital thermometer as validation. Ten trials were done. In each trial, the participants were asked to get their armpit temperature using the digital thermometer. Using the device, the participants were also asked to get their temperature of their forehead, palms, dorsum and wrists. These are the most common areas that are utilized in temperature scanning. The proponent also informed the participants to scan their temperature at approximately 2cm from the scanner to get accurate results. The timeframe of each trial were roughly 10-15 minutes each. Moreover, the participants were asked not to conduct strenuous activities during the trials. Moreover, the NCIT has been programmed to scan a minimum temperature of 33 degree Celsius. This is the least value of temperature when a participant moves a certain measurement area approximately 2 to 5 cm to the measuring device.

Figure 2 shows the prototype measuring the temperature (right) and temperature measured using a standard thermometer. The device will be validated using a Medica Digital Thermometer. Here, the participants will have their temperatures checked using the prototype and the Medica Digital Thermometer.

Figure 2: The prototype measuring the temperature (right) and temperature measured using a standard thermometer

Temperatures on the forehead, palm, dorsum, and wrists will be measured using the novel device and the armpit temperature will be measured by the digital thermometer. This armpit temperature will serve as the reference temperature to be used in the tests. Statistical analyses will be done to determine which part will yield better results as compared to the reference temperatures. Moreover, since it is expected that there are differences in the temperature readings, the device will be calibrated, and an offset temperature will be introduced. This will give us a calibration offset to get more accurate results. The offset temperature will be defined as the summation of the differences of the readings of the device and the reading of the digital thermometer.

RESULTS AND DISCUSSION

The mean and standard deviation of each temperature-taking area are shown in Table 1. The mean Armpit Temperature measured with a Digital Thermometer is 36.552, with a standard deviation of 0.2572. The mean Forehead Temperature using NCIT is 35.077 with a standard deviation of 0.3931. The mean Palmar Temperature using NCIT is 35.02, with a standard deviation of 0.0222. The mean Dorsal Temperature calculated with NCIT is 33.541 with a standard deviation of 0.0675. Finally, the mean Wrist Temperature using NCIT is 33.797 with 0.5506. The mean represents the average temperature, whereas the standard deviation measures how close the data is to the mean. The table shows the comparison between each area where the temperature is taken. The Pearson R Correlation between the armpit temperature using digital thermometer & forehead temperature using NCIT is 0.197, which indicates a very low positive relationship. Since the p-value (0.05) is equal to the level of significance (0.05), the proponent rejects the null hypothesis. Concluding that there is a significant relationship between the variables indicated.

Table 1: The mean and standard deviation of each temperature-taking area.

Paired Samples Statistics		**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Armpit Temperature using Digital Thermometer	36.552	100	0.2572	0.0257
	Forehead Temperature using NCIT	35.077	100	0.3931	0.0393
Pair 2	Armpit Temperature using Digital Thermometer	36.552	100	0.2572	0.0257
	Palmar Temperature using NCIT	35.02	100	0.2225	0.0222
Pair 3	Armpit Temperature using Digital Thermometer	36.552	100	0.2572	0.0257
	Dorsal Temperature using NCIT	33.541	100	0.6748	0.0675
Pair 4	Armpit Temperature using Digital Thermometer	36.552	100	0.2572	0.0257
	Wrist Temperature using NCIT	33.797	100	0.5506	0.0551

Table 2: Taking the difference between armpit measurements and taken by the NICT in each part and taking the correlation to determine which pair will be used for taking the measurements.

Paired Samples Correlation		Pearson R Correlation	Relationship	P-value	Decision	Remarks
Pair 1	Armpit Temperature using Digital Thermometer & Forehead Temperature using NCIT	0.197	Very Low Positive Relationship	0.05	Reject the Null Hypothesis	Significant
Pair 2	Armpit Temperature using Digital Thermometer & Palmar Temperature using NCIT	0.321	Low Positive Relationship	0.001	Reject the Null Hypothesis	Significant
Pair 3	Armpit Temperature using Digital Thermometer & Dorsal Temperature using NCIT	0.24	Low Positive Relationship	0.016	Reject the Null Hypothesis	Significant
Pair 4	Armpit Temperature using Digital Thermometer & Wrist Temperature using NCIT	0.122	Very Low Positive Relationship	0.228	Failed to Reject the Null Hypothesis	Not Significant

Table 3: The mean differences of each area where the temperature is taken.

Paired Differences	Mean	Std. Dev	Std. Error Mean	95% Confidence Interval of the Difference		P-value	Decision	Remarks
				Lower	Upper			
Armpit Temperature - Forehead Temperature	1.475	0.4253	0.0425	1.3906	1.5594	0	Reject the Null Hypothesis	Significant
Armpit Temperature - Palmar Temperature	1.532	0.281	0.0281	1.4762	1.5878	0	Reject the Null Hypothesis	Significant
Armpit Temperature - Dorsal Temperature	3.011	0.6621	0.0662	2.8796	3.1424	0	Reject the Null Hypothesis	Significant
Armpit Temperature - Wrist Temperature	2.755	0.5786	0.0579	2.6402	2.8698	0	Reject the Null Hypothesis	Significant

Table 4: System test using random participants.

Referenc Temp	Logged Temp	Difference	Accuracy
36.2	36.2	0	1
36.3	36.2	0.1	0.997245179
36.3	36.1	0.2	0.994490358
36.4	36.5	-0.1	0.997252747
36.1	36.2	-0.1	0.997229917
36.7	36.5	0.2	0.994550409
36.4	36.5	-0.1	0.997252747
36.6	36.7	-0.1	0.99726776
36.7	36.5	0.2	0.994550409
36.5	36.5	0	1
36.3	36.3	0	1
36.4	36.3	0.1	0.997252747
36	36.2	-0.2	0.994444444
36.1	36.1	0	1
36.6	36.7	-0.1	0.99726776
36.4	36.6	-0.2	0.994505495
36.4	36.5	-0.1	0.997252747
36.5	36.4	0.1	0.997260274
36.5	36.4	0.1	0.997260274
36.7	36.9	-0.2	0.994550409
36.7	36.6	0.1	0.997275204
36.7	36.8	-0.1	0.997275204
36.6	36.6	0	1
36.6	36.5	0.1	0.99726776
36.5	36.4	0.1	0.997260274
36.4	36.4	0	1
36.3	36.4	-0.1	0.997245179
36.5	36.3	0.2	0.994520548
36.5	36.4	0.1	0.997260274
36.2	36.3	-0.1	0.997237569
36	36.3	-0.3	0.991666667
36.1	36	0.1	0.997229917
36	36	0	1
36.3	36.5	-0.2	0.994490358
36.3	36.4	-0.1	0.997245179
36.6	36.3	0.3	0.991803279
36.5	36.3	0.2	0.994520548
36.4	36.4	0	1
36.3	36.5	-0.2	0.994490358
36.5	36.7	-0.2	0.994520548
36.8	36.8	0	1
36.9	37	-0.1	0.997289973

37	37	0	1
36.9	36.8	0.1	0.997289973
37	37.1	-0.1	0.997297297
36.5	36.6	-0.1	1.002739726
36.6	36.6	0	1
36.6	36.2	0.4	0.989071038
36.7	36.4	0.3	0.991825613
36.6	36.4	0.2	0.994535519
AVERAGE		**0.008**	**0.99681983**

To determine which part among the four is the most suitable part to have the temperature taken, the proponent took the difference between armpit temperature taken by the digital thermometer and the temperature taken by the NICT in each part. The calculation is summarized in Table 2. The table shows the comparison between each area where the temperature is taken. The Pearson R Correlation between the armpit temperature using digital thermometer & forehead temperature using NCIT is 0.197, which indicates a very low positive relationship. Since the p-value (0.05) is equal to the level of significance (0.05), the proponent rejects the null hypothesis. Concluding that there is a significant relationship between the variables indicated. For the Armpit Temperature using Digital Thermometer & Palmar Temperature using NCIT, the Pearson R Correlation is 0.321, which indicates a low positive relationship. Since the p-value (0.001) is less than the level of significance (0.05), the proponent rejects the null hypothesis. Having concluded that there is a significant relationship between the variables mentioned. The Pearson R Correlation between the Armpit Temperature using Digital Thermometer & Dorsal Temperature using NCIT is 0.24, which indicates a low positive relationship. Since the p-value (0.016) is less than the level of significance (0.05), the proponent rejects the null hypothesis. Concluding that there is a significant relationship between the variables indicated. Lastly, the Pearson R Correlation between the armpit temperature using Digital Thermometer & Wrist Temperature using NCIT is 0.122, which indicates a low positive relationship. Since the p-value (0.228) is less than the level of significance (0.05), the proponent failed to reject the null hypothesis. This means that there is no significant relationship between the variables indicated.

As to which measurement method to use, Table 3 shows the mean differences of each area where the temperature is taken. The area which has the lowest mean difference is Armpit Temperature using Digital Thermometer and Forehead Temperature using NCIT which is 1.475 and since the p-value is 0.000, the proponent rejects the null hypothesis which also indicates that there is a significant difference between the pair. For the Armpit Temperature using Digital Thermometer and Palmar Temperature using NCIT the mean difference is 1.532 and since the p-value is 0.000, the researcher rejects the null hypothesis which also indicates that there is a significant difference between the pair. The mean difference of Armpit Temperature using Digital Thermometer and Dorsal Temperature using NCIT is the highest among the pairs which are 3.011 and since the p-value is 0.000, the researcher rejects the null hypothesis which also indicates that there is a significant difference between the pair. Lastly, the mean difference of Armpit Temperature using Digital Thermometer and Wrist Temperature using NCIT is 2.755, and since the p-value is 0.000, the researcher rejects the null hypothesis which also indicates that there is a significant difference between the pair. Based on the above data, the difference between Templar Temperature and Armpit Temperatures were the ones who are nearest to each other. with a mean difference of 1.475 there is a standard deviation of 0.4253. However, there are trade-offs to be considered. These trade-offs are the standard deviation and the Pearson-R Correlation coefficient. Since the palmar temperature has the least standard deviation and has the highest Pearson R correlation coefficient. Thus, it is recommended to use the Palmar Temperature based on the data gathered. Consequently, the participants were also asked which of the methods they most prefer. Majority of them preferred the Palmar and the Dorsal route as these are easier parts to get their temperature. Based on the data gathered, it is therefore recommended to use the palmar method.

Table 4 shows the systems test conducted to random participant who are were asked to have their temperatures checked and have their respective QR code scanned. of random customers. Based on the data above, 90% (45 of 50) of the mean difference between the reference temperature (armpit temperature) and the experimental temperature (palmar temperature) are within the target difference of ±0.2 degrees. Moreover, the mean accuracy is 99.68% which passed the target accuracy of 95%.

CONCLUSIONS

In this study, an IoT device that measures body temperature was developed and implemented. The device utilized MLX90614 to get the temperature measurements and a Raspberry Pi Camera to scan the QR Codes. Correlation studies conducted indicated that highest accuracy is achieved when making palmar temperature measurements. Using the system test data, the prototype can achieve mean accuracy of 99.68%.

REFERENCES

1. Republic Act No. 11469 or the "Bayanihan to Heal as One Act," RA 11469, https://www.officialgazette.gov.ph/2020/03/24/republic-act-no-11469/
2. Chen, G., Xie, J., Dai, G., Zheng, P., Hu, X., Lu, H., Chen, X., & Chen, X. (n.d.). Validity of Wrist and Forehead Temperature in Temperature Screening in the General 1 Population During the Outbreak of Novel Coronavirus: a prospective real-world 2 study 3 4 (Validity of Wrist and Forehead Temperature in Temperature Screening in the. https://doi.org/10.1101/2020.03.02.20030148, 2019.
3. IATF, EID. Inter-Agency Task Force for Emerging Infectious Diseases- Resolution No. 1 - RECOMMENDATIONS FOR THE MANAGEMENT FOR THE MANAGEMENT OF THE NOVEL CORONAVIRUS SITUATION. (n.d.). Retrieved August 22, from https://www.doh.gov.ph/sites/default/files/basic-page/IATF Resolution.pdf, 2020.
4. Mbunge, E. Integrating emerging technologies into COVID-19 contact tracing: Opportunities, challenges and pitfalls. https://doi.org/10.1016/j.dsx.2020.08.029, 2020.
5. Porcalla, D. Task force on emerging infectious diseases formed | Philstar.com. The Philippine Star, 2014.
6. Proclamation No. 929 s. 2020 | Official Gazette of the Republic of the Philippines, (2020). Q&A on coronaviruses (COVID-19). https://www.who.int/emergencies /diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-coronaviruses, 2020.
7. TK Interface, https://docs.python.org/3/library/tkinter.html
8. Raspberry Pi Foundation Raspberry Pi Foundation Strategy, 2016-2018. 13.
9. ZBar Bar Code Reader Library: Main Page. (n.d.). Retrieved December 9, 2020. from http://zbar.sourceforge.net/api/
10. Zhang, J. Development of a Non-contact Infrared Thermometer, 2018; 153(Aetr 2017): 308–312. https://doi.org/10.2991/aetr-17.2018.59.