International Journal of Computing Sciences Research (ISSN print: 2546-0552; ISSN online: 2546-115X)
Vol. 8, pp. 3131-3146
doi: 10.25147/ijcsr.2017.001.1.208
https://stepacademic.net

Short Paper*

Automated Vital Signs Checker: An Alternative Method of Vital Signs Monitoring for Dialysis Patients at Home

Christopher Y. Basmayor
Department of Computer Engineering, University of San Jose-Recoletos, Philippines

Lourd Dhinber G. Tangaran
Department of Computer Engineering, University of San Jose-Recoletos, Philippines

Hyacynth Vianka V. Baylosis
Department of Computer Engineering, University of San Jose-Recoletos, Philippines

Pearl Joy N. Ornopia
Department of Computer Engineering, University of San Jose-Recoletos, Philippines

Jerome B. Amor
Department of Computer Engineering, University of San Jose-Recoletos, Philippines
Jerome.amor@usjr.edu.ph
0009-0003-9759-5417
(corresponding author)

Rey S. Mabatid
Department of Computer Engineering, University of San Jose-Recoletos, Philippines

Date received: May 7, 2024
Date received in revised form: July 14, 2024; July 15, 2024; July 24, 2024
Date accepted: July 24, 2024

Recommended citation:

Basmayor, C., Tangaran, L.D., Baylosis, H.V., Ornopia, P.J. Mabatid, R., Amor, J., (2024). Automated vital signs checker: An alternative method of vital signs monitoring for dialysis patients at home. *International Journal of Computing Sciences Research*, *8*, 3131-3146. https://doi.org/10.25147/ijcsr.2017.001.1.208

**Special Issue on International Research Conference on Computer Engineering and Technology Education (IRCCETE). Guest Associate Editors: Dr. Roben A. Juanatas (National University-Manila) and Dr. Nelson C. Rodelas (University of East).*

Abstract

Purpose – This study emphasizes the need to monitor vital signs in dialysis patients and how vital signs can offer crucial information about maintaining blood pressure, assessing heart rate, tracking the body's temperature, and measuring oxygen saturation especially when the dialysis patients are at home.

Method – An alternative vital signs checker system was developed to monitor their health at home conveniently. To obtain precise essential sign measurements, the system utilizes the MLX90614 sensor for body temperature, the MAX30100 sensor for heart rate and oxygen level, and the Sunrom blood pressure module for systolic and diastolic blood pressure readings.

Results – The proposed system exhibits a promising result compared to conventional devices. After conducting 20 tests from 10 different subjects, it demonstrated a temperature sensor accuracy of a percentage error of 2.99% at 1cm, 5.55% at 2 cm, and 6.98% at 3 cm. Moreover, the system achieves a 5.72% percentage error in heart rate measurement, a 1.01% percentage error in measuring oxygen levels, a 5.36% error rate for systolic blood pressure measurement, and a 5.51% error rate for diastolic blood pressure measurement.

Conclusion – With low percentage errors in multiple vital sign measurements, including body temperature, heart rate, oxygen levels, and blood pressure, the system offers reliable and convenient monitoring capabilities.

Recommendations – Several suggestions for future research to ensure the successful design and implementation such as improvement of the user design interface, explore potential machine learning applications, and a language-adaptive user manual.

Research Implications – the successful integration of sensors presents significant implications for continuous and comprehensive monitoring of vital signs, the systems automation reduces the burden of healthcare professionals, improves patient outcomes through early intervention, and enhances healthcare efficiency by providing real-time data for more informed decision-making for healthcare professionals.

Keywords – home dialysis monitoring, health monitoring, remote vital signs, alternative health checking

INTRODUCTION

End-stage renal disease (ESRD) is a concern when it comes to global health. End-stage renal disease (ESRD) is a progressive, irreversible loss of kidney function that is deadly (Abbasi et al., 2010). Dialysis is necessary when a patient's kidneys cannot meet their body's needs. The doctor must create an entry or entrance into the patient's blood vessels to get their blood into the dialyzer. Minor surgery is used to accomplish this, typically on the patient's arm (National Kidney Foundation, 2015).

According to the annual report of the Philippine Renal Disease Registry in 2017, there was an increase in numbers in terms of new dialysis patients from 9,716 in 2010 to 21,535 in 2016. Moreover, according to Cinchez (2022), a little over 2,000 chronic kidney disease (CKD) patients from Central Visayas are listed in the PhilHealth Dialysis Database from August 2021 to August 2022. Traditionally, patients who still have some renal function undergo hemodialysis three times per week or sometimes twice each week (Kalantar-Zadeh et al., 2014).

The problem arises when patients are in the comfort of their homes taking SIDI or LIDI and cannot excrete potassium buildup and other electrolytes, which could cause cardiovascular diseases (Foley et al., 2011). Numerous studies on vital sign analysis assume that a disruption in the vital signs often precedes profound implications (Brekke et al., 2019; Kause et al., 2004; Buist et al., 2004; Hillman et al., 2001). Each dialysis session could result in various hemodynamic alterations and variations in vital signs that could impact a patient's quality of life (Shoji et al., 2004).

Regular checking of vital signs is essential because dialysis patients have a higher risk of developing cardiovascular and metabolic diseases and are at risk when not in dialysis centers. After gathering data, the proponents aim to develop an aid to help dialysis patients with SIDI or LIDI monitor their vital signs when they are in the comfort of their homes.

LITERATURE REVIEW

Due to failure in excretion function, dialysis patients have difficulty managing food and fluid intake. As a result, patients experienced increased weight between two dialysis sessions. Increased IDWG is linked to a higher risk of heart disease, mortality, and hospitalization. Additionally, the rise in blood pressure issues and variations in blood pressure during hemodialysis is related to an increase in IDWG percentage. (Cabrera et al., 2015).

Body Temperature

The normal range for body temperature is 36.4°C to 37.2°C, or 97.5°F to 98.9°F. In the morning, it is often lower, and in the evening, it is higher. Most medical practitioners classify fever as when the body temperature is above 38°C or 100.4°F (Johns Hopkins

Medicine, n.d.).

Heart Rate or Pulse Rate

According to Guichard (2018), there are three general ways to determine heart rate: (1) normal, (2) fast, and (3) slow. Normal resting heart rates range from 60 to 100 beats per minute. A resting heart rate over 100 beats per minute is called tachycardia, while a resting heart rate of less than 60 beats per minute is called bradycardia.

Blood Pressure

A blood pressure check measures the pressure in the arteries as the heart beats. A blood pressure exam might include both a standard physical and a screening for high blood pressure (hypertension) (Mayo Clinic, 2021).

Blood Oxygen Saturation

A person's blood oxygen level gauges the oxygen red blood cells carry. A person's body strictly regulates the oxygen level in his/her blood. Maintaining a proper oxygen-saturated blood balance is crucial for a person's health. An oxygen saturation of 95% or more is considered normal. Normal levels might range from 90% in some sufferers of chronic lung disease or sleep apnea (Holland, 2022).

Portable Technologies

AMON, a fixed and miniature wrist-type device, is one of the experiments involving numerous health monitoring devices (Anliker et al., 2004). AMON can continually measure the temperature, activity, and blood oxygen saturation (SPO2). Kaputa et al. (2010) also created a device that patients can use to gather physiological data away from a medical facility. The device employs biosensors to gather data on the user's weight, electrocardiogram (ECG), non-invasive blood pressure (NIBP), heart rate, and pulse oximetry (SpO2). Priya et al. (2014) designed a wireless ECG portable system for remote cardiac activity monitoring. All patients' ECG data and heartbeats are collected on a single computer and analyzed using a microcontroller (Arduino Uno).

Swaroop et al. (2019) designed a real-time health monitoring system to store a patient's primary health parameters. They used Sunrom blood pressure and heart rate sensors that were interfaced with the microcontroller, specifically the Raspberry Pi 3 (RPi3). However, the target patients of this study are not dialysis patients but all patients in general. Oxygen saturation is an essential parameter for dialysis patients and should be considered.

METHODOLOGY

Figure 1 shows how the proponents planned to gather vital signs from the dialysis patient, including blood pressure, heart rate, oxygen saturation, and body temperature.

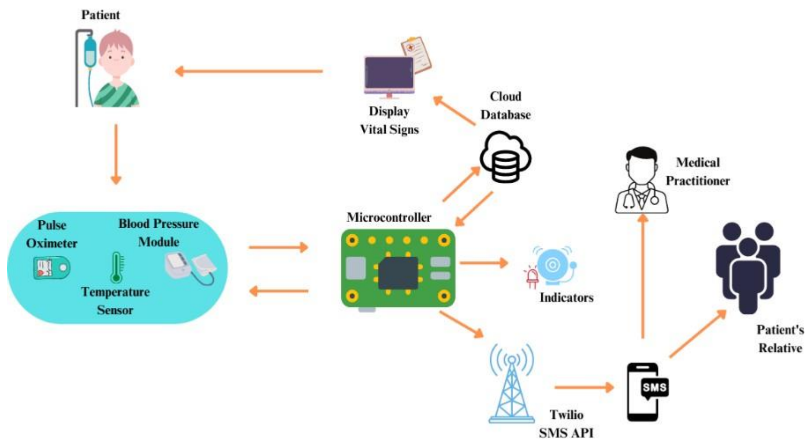

Figure 1. Methodology Design

The researchers used Raspberry Pi 4 Model B as the main controller of the system. Next, the output will be displayed on the monitor showing the vital signs readings, and the indicators will act depending on the value of the vital signs. Lastly, the dialysis patient's medical practitioners and relatives will receive the data through a short messaging service (SMS).

Software Requirements

The proponents used Raspberry Pi OS as the operating system for the Raspberry Pi device, and Thonny as an Integrated Development Environment (IDE) for programming and testing the code that controls the sensors and the overall system, the researchers chose to utilize PostgreSQL as the primary database management system tool for the prototype. Twilio API is crucial in enabling the smooth transfer of the patient's vital signs to their healthcare professional and any specified family members or relatives providing the platform for running the vital signs monitoring software and enabling communication with sensors and modules used in the system.

Hardware Used

In Figure 2, the Raspberry Pi has been used as the main controller of the system. Raspberry Pi 4 Model B acts as a minicomputer, it is where the desktop application will be loaded as well as the sensors used for acquiring vital signs. MLX90614 temperature sensor is an infrared thermometer used for measuring temperatures without making contact. The heart rate and blood oxygen saturation levels can both be determined using the MAX30100 pulse oximeter. Two LEDs are present on the device, one of which emits red light and the other infrared light.

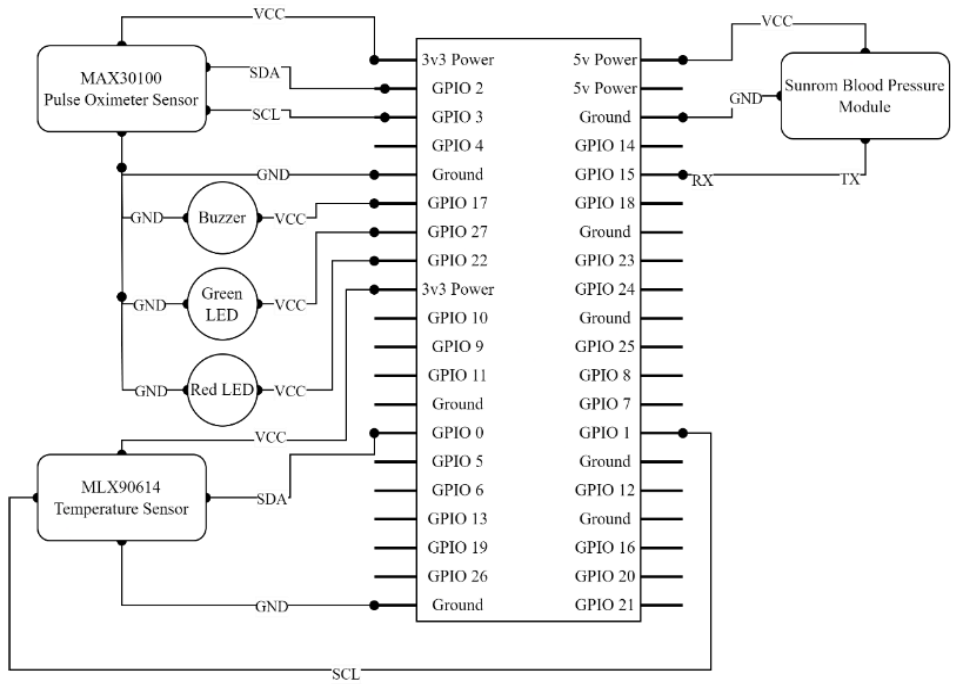

Figure 2. Schematic Diagram of the Proposed System

Only infrared light is required to determine heart rate. Oxygen levels in the blood are determined using both red and infrared light The researchers used a Sunrom blood pressure module to measure the systolic and diastolic blood pressure of the patient. This blood pressure module will generate an output in the form of serial data which can be easily interfaced with the Raspberry Pi through the serial interface board. Just like the regular digital blood pressure monitor, the Sunrom blood pressure module comes with a cuff for air compression and a display monitor for viewing the acquired results.

The actual prototype is shown in Figure 3. It is composed of an LCD touchscreen, wrist blood pressure module, temperature sensor, pulse oximeter sensor (heart rate and oxygen level sensor), and a graphical user interface. The LCD touchscreen supports touch input, enabling users to interact with the graphical user interface effortlessly by tapping, swiping, or scrolling on the screen. The wrist blood pressure module measures blood pressure properly by utilizing modern technology. The device uses an inflatable cuff to apply regulated pressure on the wrist, detect artery pulsations, and compute blood pressure values based on the data gathered. The MLX90614 temperature sensor uses infrared technology to enable non-contact temperature measuring. Without needing to make direct touch, it can measure the skin's surface temperature accurately, without any pain or chance for contamination that comes with conventional thermometers. The pulse oximeter sensor is a highly integrated module created for applications that monitor oxygen levels and heart rate. It comes in a single package with red and infrared LEDs, a photodetector, and ambient light cancellation circuitry. The sensor works by shining light onto the skin, where it is then able to recognize changes in light absorption brought on by blood flow.

Figure 3. Actual Prototype

Algorithm 1 Temperature Reading Acquisition

1: Connect the temperature sensor to the Raspberry Pi
2: Initialize the I^2C communication protocol
3: Set the device address of the temperature sensor
4: Read the object temperature from the temperature sensor
5: The object temperature is calculated using the formula provided in the datasheet.
   To[°K] = Toreg x 0.02 (Melexis, 2019)
   To - Object Temperature
   °K - degrees Kelvin
   Toreg - temperature register value
6 Output the temperature value

Figure 4. Data Acquisition Algorithm for Temperature Sensor

The data acquisition algorithm for the temperature sensor is found in Figure 4 as shown in the table, the temperature sensor uses an I2C communication protocol. The sensor acquires both the ambient temperature, which refers to the temperature of the surrounding environment, and the object temperature, which refers to the temperature of the target object being measured by the sensor. But to acquire body temperature, the researcher only acquires the object temperature. The temperature sensor uses Stefan-Boltzmann law as the basis for calculating the object temperature.

Algorithm 2 Pulse Rate Reading Acquisition

1: Connect the Pulse Oximeter Sensor to the Raspberry Pi
2: Initialize the I^2C communication protocol
3: Set the device address of the MAX30100
4: Set the sampling rate and LED power
5: Enable the pulse oximeter sensor and wait for it to stabilize
6: Read the red and infrared LED values
7: Calculate the ratio of the red to infrared LED values.
ratio = red LED value/infrared LED value
8: Output the oxygen level and heart rate value

Figure 5. Data Acquisition Algorithm for Pulse Oximeter Sensor

Figure 5 presents the data acquisition algorithm for the Pulse Oximeter Sensor. The sensor utilizes the I2C communication protocol to communicate with the Raspberry Pi. To ensure the accuracy and reliability of the data, a 30-second stabilization period is set after enabling the pulse oximeter sensor (Tham et al., 2020). After the 30-second duration, the Pulse Oximeter Sensor sensor will output the oxygen level and heart rate.

Algorithm 3 Blood Pressure Reading Acquisition

1: Connect the Sunrom Blood Pressure Module to the Raspberry Pi
2: Configure the Raspberry Pi GPIO pins for communication
3: Initialize the UART communication protocol
4: Establish a connection with the sensor
5: Start reading data from the sensor
6: Continuously monitor the sensor for new measurements
7: Output the systolic and diastolic pressure values

Figure 6. Data Acquisition Algorithm for Sunrom Blood Pressure Module

The data acquisition algorithm for the Sunrom blood pressure module is presented in Figure 6. The Sunrom blood pressure module utilizes the UART communication protocol to establish communication with the Raspberry Pi. Similar to a typical digital blood pressure monitor, the Sunrom blood pressure module provides readings for both systolic and diastolic blood pressure as its output.

RESULTS

Each sensor used in the proposed prototype underwent 20 tests from 10 different users. In determining the accuracy of the proposed system, the researchers employed the use of the percentage error. The percentage error formula is commonly used to measure the discrepancy between the predicted and measured values. By comparing the predicted values of the system with the measured values, the researchers were able to calculate the percentage error and assess the level of accuracy achieved (Equation 1, Johnston et al., 1990).

$$Percentage error = \frac{\text{predicted value - measured value}}{\text{measured value}} \times 100 \qquad \textit{Equation 1}$$

Additionally, the margin of error formula was applied to evaluate the range of accepted values to be considered as accurate. This formula considers both the true positive and true negative rates, providing a comprehensive measure of accuracy. In calculating the margin of error, the researchers calculated the accuracy with a 95% confidence level (Equation 2; Harper, 2018).

Margin of Error = Critical Value (1.960) x Standard Error Deviation *Equation 2*

Table 1. Test Results of Blood Pressure Readings

Test Subjects	**System Reading**		**Ground Truth Reading**		**Percentage Error**	
	Sunrom Blood Pressure Module		**Omron HEM-7120**			
	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)	Systolic Pressure (%)	Diastolic Pressure (%)
1	137	110	144	111	4.86	0.90
	121	72	127	86	4.72	16.28
2	104	73	109	75	4.59	2.67
	147	97	144	99	2.08	2.02
3	117	71	121	76	3.31	6.58
	97	68	104	70	6.73	2.86
4	138	100	146	108	5.48	7.41
	146	98	137	92	6.57	6.52
5	117	89	123	94	4.88	5.32
	137	86	123	94	11.38	8.51
6	152	116	146	112	4.11	3.57
	92	65	89	71	3.37	8.45
7	134	86	128	82	4.69	4.88
	115	78	121	86	4.96	9.30
8	144	91	136	88	5.88	3.41
	134	83	140	86	4.29	3.49
9	121	86	117	81	3.42	6.17
	137	91	141	89	2.84	2.25
10	161	103	147	96	9.52	7.29
	138	88	126	86	9.52	2.33
Mean	**129.45**	**87.55**	**128.45**	**89.10**	**5.36%**	**5.51%**
STD (±)	**17.92**	**13.54**	**15.34**	**11.79**	**2.33**	**3.46**

During the testing phase, Table 1 presents the verification results of the Sunrom blood pressure module and the Omron HEM-7120. The Sunrom blood pressure module demonstrates a satisfactory level of accuracy for both systolic and diastolic blood pressure.

Table 2 presents the results of comparing the MLX90614 sensor and IR Digital Thermometers at various distances (1 cm, 2 cm, and 3 cm).

Table 2. Test Results of Body Temperature Readings

Distance	1 cm (°C)		1E(%)	2 cm (°C)		2E(%)	3 cm (°C)		3(E%)
Subject	**SR**	**GR**		**SR**	**GR**		**SR**	**GR**	
1	35.61	36.5	2.44	34.33	36.4	5.69	33.93	36.4	6.79
	34.73	36.3	4.33	34.39	36.3	5.26	33.76	36.2	6.74
2	34.49	36.4	5.25	34.17	36.5	6.38	33.87	36.5	7.21
	36.05	36.5	1.23	34.19	36.4	6.07	33.79	36.4	7.17
3	34.77	36.3	4.21	34.29	36.4	5.80	33.83	36.4	7.06
	35.21	36.4	3.27	34.37	36.3	5.32	33.73	36.3	7.08
4	34.86	36.6	4.75	34.45	36.2	4.83	34.01	36.5	6.82
	34.92	36.1	3.27	34.31	36.4	5.74	33.93	36.3	6.53
5	35.41	36.5	2.99	34.17	36.3	5.87	33.87	36.4	6.95
	35.23	36.3	2.95	34.33	36.4	5.69	33.71	36.4	7.39
6	36.09	36.2	0.30	34.23	36.5	6.22	33.21	36.2	8.26
	35.37	36.4	2.83	34.29	36.2	5.28	33.43	36.3	7.91
7	35.67	36.6	2.54	34.43	36.3	5.15	33.87	36.4	6.95
	35.81	36.1	0.80	34.45	36.4	5.36	33.91	36.5	7.10
8	35.75	36.5	2.05	34.37	36.4	5.58	34.17	36.4	6.13
	36.01	36.1	0.25	34.43	36.5	5.67	34.01	36.2	6.05
9	34.91	36.3	3.83	34.47	36.4	5.30	33.87	36.4	6.95
	34.85	36.6	4.78	34.39	36.4	5.52	33.77	36.0	6.19
10	34.99	36.5	4.14	34.41	36.2	4.94	33.65	36.3	7.30
	34.93	36.2	3.51	34.43	36.4	5.41	33.93	36.5	7.04
Mean	**35.28**	**36.37**	**2.99**	**34.35**	**36.37**	**5.55**	**33.81**	**36.35**	**6.98**
STD (±)	**0.48**	**0.16**	**1.44**	**0.09**	**0.09**	**0.39**	**0.20**	**0.12**	**0.52**

Legend: SR-System Result, GR-Ground Truth Result, 1E-1cm percentage error, 2E-2cm percentage error, 3E-3cm percentage error

Table 3 shows that, when verified with a RHOS Fingertip Pulse Rate Oximeter, the MAX30100 achieved a percentage error of 5.72% for heart rate measurements, demonstrating a decent level of reliability. Furthermore, when compared to the RHOS Fingertip Pulse Rate Oximeter, the MAX30100 displayed an accuracy percentage of 1.01% for oxygen level measurements, indicating its competence in reliably monitoring oxygen levels.

Table 3. Test Results of Heart Rate and Oxygen Level Readings

Subject	Heart Rate (BPM)			Oxygen Level (%)		
	MAX30100	RHOS Fingertip Pulse Rate Oximeter	Percentage Error (%)	MAX30100	RHOS Fingertip Pulse Rate Oximeter	Percentage Error (%)
1	89	81	9.88	100	99	1.01
	90	80	12.50	99	99	0.00
2	86	87	1.15	100	98	2.04
	88	84	4.76	100	99	1.01
3	90	92	2.17	100	99	1.01
	84	89	5.62	100	99	1.01
4	89	81	9.88	100	99	1.01
	86	89	3.37	100	99	1.01
5	90	78	15.38	97	99	2.02
	79	73	8.22	100	99	1.01
6	81	76	6.58	100	99	1.01
	88	91	3.30	100	99	1.01
7	83	86	3.49	98	98	0.00
	79	82	3.66	100	99	1.01
8	85	88	3.41	100	99	1.01
	87	83	4.82	100	99	1.01
9	91	88	3.41	99	99	0.00
	86	90	4.44	100	98	2.04
10	87	82	6.10	100	99	1.01
	91	89	2.25	100	99	1.01
Mean	**86.45**	**84.45**	**5.72**	**99.65**	**98.85**	**1.01**
STD (±)	**3.69**	**5.28**	**3.61**	**0.81**	**0.37**	**0.56**

Table 4 shows the margin of error for each vital signs measurement. The margin of error provides an estimate of the range that can be considered accurate for vital signs measurements.

Table 4. Vital Signs Measurements: Margin of Error Summary

Vital Signs		**System Readings**	**Ground Truth Readings**	**Margin Error (95% confidence level)**
Body Temperature (°C)	1 cm	35.28°C	36.37°C	± 0.22
	2 cm	34.35°C	36.37°C	± 0.04
	3 cm	33.81°C	36.35°C	± 0.09
Heart Rate (BPM)		86.45 BPM	84.45 BPM	± 1.62
Oxygen Level (%)		99.65%	98.85	± 0.36
Blood Pressure (mmHg)	systolic	129.45	128.45	± 8.06
	diastolic	87.55	89.10	± 6.09

DISCUSSION

Table 1 shows the percentage error of 5.36% for systolic measurements and 5.51% for diastolic measurements. Additionally, values falling within the ranges of 129 ± 8.06 (systolic) and 87.53 ± 6.09 (diastolic) are considered accurate values with a 95% confidence level. These results indicate that the Sunrom blood pressure module provides reliable measurements within an acceptable range of accuracy for both systolic and diastolic blood pressure readings.

In Table 2, the data reveals that as the distance between the temperature sensor and the user's wrist increases, the percentage error also increases (2.99% at 1 cm, 5.55% at 2 cm, and 6.98% at 3 cm). These findings strongly suggest that the accuracy of the MLX90614 sensor's measurements diminishes as the patient's wrist moves farther away from the sensor.

In Table 3, the MAX30100 sensor demonstrates reasonable accuracy for heart rate measurements, with a 5.72% error, and excellent accuracy for oxygen level measurements, with a 1.01% error, when compared to the RHOS Fingertip Pulse Rate Oximeter.

In Table 4, for blood pressure measurements, values falling within the ranges of 129.45 ± 8.06 (systolic) and 87.55 ± 6.09 (diastolic) are considered accurate values with a 95% confidence level. Values falling within the ranges of 35.28°C ± 0.22 at 1cm, 34.35°C ± 0.04 at 2cm, and 33.81°C ± 0.09 at 3 cm are considered accurate values for temperature readings at a 95% confidence level. In addition, for heart rate measurements, values falling within the range of 86.45 ± 1.62 beats per minute are considered accurate with a 95% confidence level. For oxygen level measurements, values falling within the range of 99.65% ± 0.36% are considered accurate with a 95% confidence level. These findings indicate that the system reliably measures vital signs within acceptable margins of error, supporting its potential use in clinical settings for continuous and accurate patient monitoring.

CONCLUSIONS

The integration of the MLX90614 temperature sensor, MAX30100 heart rate and oxygen level sensor, and Sunrom blood pressure module into a single automated vital signs checker system was successfully achieved. The system features a graphical user interface developed using Tkinter, a Python framework.

The researchers discovered that the automated vital signs checker can consistently track the vital signs of dialysis patients outside of the facility, providing highly satisfactory results. With the verification from commercially available medical devices, the proposed system exhibits remarkable accuracy levels in vital sign measurements. For body temperature, the system achieves a percentage error of 2.99% at a 1cm distance, 5.55% at a 2cm distance, and 6.98% at a 3cm distance. The system demonstrates a 5.72% percentage error in heart rate measurement, ensuring reliable monitoring of cardiovascular activity. Moreover, it achieves an impressive 1.01% percentage error in measuring oxygen levels, essential for assessing respiratory health. In terms of blood pressure, the system achieves a 5.36% percentage error for systolic measurements and a 5.51% percentage error for diastolic measurements.

Overall, the proposed automated vital signs checker presents a valuable solution for the routine monitoring of dialysis patients' vital signs outside of the healthcare facility. With consistently high accuracy rates across various vital sign measurements, including body temperature, heart rate, oxygen levels, and blood pressure, the system offers reliable and convenient monitoring capabilities.

RECOMMENDATIONS

Several suggestions should be considered for future research to ensure the successful design and implementation of an automated system for monitoring the vital signs of dialysis patients away from the dialysis center. To improve the usability of the automated vital signs checker system, the user interface design should be enhanced for maximum patient comfort. Additionally, exploring the potential for implementing machine learning algorithms could increase the precision of vital sign measurements and offer patient-specific insights and suggestions. Providing a language-adaptive user manual with instructions in different dialects will ensure accessibility for the diverse patient population. Future researchers can expand the system's capabilities by adding vital sign measurements.

IMPLICATIONS

The successful integration of the MLX90614 temperature sensor, MAX30100 for heart rate and oxygen level sensor, and Sunrom blood pressure module into a single automated vital signs checker system presents significant implications for healthcare monitoring particularly dialysis patients especially when they are at their homes to check for their vital signs before and after undergoing dialysis treatment.

ACKNOWLEDGEMENT

The researchers would like to express our greatest gratitude to the following persons who made the development of this project successful. Project Adviser, Engr. Rey Mabatid, Engr. Eutequio III Zante L. Palermo, Engr. Jerome Amor, to our family and the Almighty God.

FUNDING

The study did not receive funding from any institution.

DECLARATIONS

Conflict of Interest

The researcher declares no conflict of interest in this study.

Informed Consent

Full consent to all participants was agreed upon before taking part in this study.

Ethics Approval

Not applicable.

REFERENCES

Abbasi, M. A., Chertow, G. M., & Hall, Y. N. (2010). End-stage renal disease. *BMJ Clinical Evidence*, *2010*, 2002. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3217820/

Anliker, U., Ward, J. A., Lukowicz, P., Troster, G., Dolveck, F., Baer, M., Keita, F., Schenker, E. B., Catarsi, F., Coluccini, L., Belardinelli, A., Shklarski, D., Alon, M., Hirt, E., Schmid, R., & Vuskovic, M. (2004). AMON: A wearable multiparameter medical monitoring and alert system. *IEEE Transactions on Information Technology in Biomedicine*, *8*(4), 415-427. https://doi.org/10.1109/TITB.2004.837888

Brekke, I. J., Puntervoll, L. H., Pedersen, P. B., Kellett, J., & Brabrand, M. (2019). The value of vital sign trends in predicting and monitoring clinical deterioration: A systematic review. *PloS One*, *14*(1), e0210875. https://doi.org/10.1371/journal.pone.0210875

Buist, M., Bernard, S., Nguyen, T. V., Moore, G., & Anderson, J. (2004). Association between clinically abnormal observations and subsequent in-hospital mortality: a prospective study. *Resuscitation*, 62(2), 137-141. https://doi.org/10.1016/j.resuscitation.2004.03.005

Cabrera, C., Brunelli, S. M., Rosenbaum, D., Anum, E., Ramakrishnan, K., Jensen, D. E., ... & Stefánsson, B. V. (2015). A retrospective, longitudinal study estimating the association between interdialytic weight gain and cardiovascular events and death in hemodialysis patients. *BMC Nephrology*, *16*(1), 1-9.

Cinchez, D. (2022). *Cebu Provincial Board commends PhilHealth's extension of dialysis coverage*. Retrieved from https://www.philhealth.gov.ph/news/2022/commends_extension.pdf

Foley, R. N., Gilbertson, D. T., Murray, T., & Collins, A. J. (2011). Long interdialytic interval and mortality among patients receiving hemodialysis. *New England Journal of Medicine*, *365*(12), 1099-1107.

Guichard, J. L. (2018). *What is a normal heart rate?* Retrieved from https://myheart.net/articles/what-is-a-normal-heart-rate/

Harper, B. W. (2018). *Attributing accelerated increases in salinity in the Mediterranean coastal zone to climate change and seawater desalination brine and the resultant unsustainability of modern desalination technology* (unpublished manuscript). Nova Southeastern University, Florida, United States. Retrieved from https://nsuworks.nova.edu/cnso_stucap/340/

Holland, K. (2022). *Is my blood oxygen level normal?*. Retrieved from https://www.healthline.com/health/normal-blood-oxygen-level#oxygen-levels

Hillman, K. M., Bristow, P. J., Chey, T., Daffurn, K., Jacques, T., Norman, S. L., Bishop, G. F., & Simmons, G. (2001). Antecedents to hospital deaths. *Internal Medicine Journal, 31*(6), 343-348. https://doi.org/10.1046/j.1445-5994.2001.00077.x

Johnston, A., Sketris, I., Marsden, J. T., Galustian, C. G., Fashola, T., Taube, D., Pepper, J., & Holt, D. W. (1990). A limited sampling strategy for the measurement of cyclosporine AUC. *Transplantation Proceedings, 23*(3), 1345-1346. Retrieved from https://pubmed.ncbi.nlm.nih.gov/2349694/

Kalantar-Zadeh, K., Unruh, M., Zager, P. G., Kovesdy, C. P., Bargman, J. M., Chen, J., Sankarasubbaiyan, S., Shah, G., Golper, T., Sherman, R., & Goldfarb, D. S. (2014). Twice-weekly and incremental hemodialysis treatment for initiation of kidney replacement therapy. *American Journal of Kidney Diseases*, *64*(2), 181-186. https://doi.org/10.1053/j.ajkd.2014.04.019

Kaputa, D., Price, D., & Enderle, J. D. (2010). A portable, inexpensive, wireless vital signs monitoring system. *Biomedical Instrumentation & Technology*, *44*(4), 350-353.

Kause, J., Smith, G., Prytherch, D., Parr, M., Flabouris, A., & Hillman, K. (2004). A comparison of antecedents to cardiac arrests, deaths, and emergency intensive care admissions in Australia, New Zealand, and the United Kingdom—the ACADEMIA study. *Resuscitation*, 62(3), 275-282. https://doi.org/10.1016/j.resuscitation.2004.05.016

Mayo Clinic Health System. (2021). *Know your numbers: Blood pressure*. Retrieved from https://www.mayoclinichealthsystem.org/hometown-health/speaking-of-health/know-your-numbers-blood-pressure

Melexis. (2019). *MLX90614 family*. Retrieved from https://www.melexis.com/en/documents/documentation/datasheets/datasheet-mlx90614

National Kidney Foundation. (2015). *Hemodialysis: How does hemodialysis work?.* Retrieved from https://www.kidney.org/atoz/content/hemodialysis

Priya, L., Hariprasad, R., & Raghul, R. (2014, March). Real-time monitoring of vital signs using wireless technique. In *2014 International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE)* (pp. 1-7). IEEE.

Shoji, T., Tsubakihara, Y., Fujii, M., & Imai, E. (2004). Hemodialysis-associated hypotension as an independent risk factor for two-year mortality in hemodialysis patients. *Kidney International, 66*(3), 1212-1220. https://doi.org/10.1111/j.1523-1755.2004.00812.x

Swaroop, K. N., Chandu, K., Gorrepotu, R., & Deb, S. (2019). A health monitoring system for vital signs using IoT. *Internet of Things*, 5, 116-129.

Tham, O. Y., Markom, M. A., Bakar, A. A., Tan, E. M. M., & Markom, A. M. (2020, October). IoT health monitoring device of oxygen saturation (SpO2) and heart rate level. In *2020 1st International Conference on Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE)* (pp. 128-133). IEEE. https://doi.org/10.1109/ICITAMEE50454.2020.9398455

Author's Biography

Christopher Y. Basmayor, Hyacinth Vianka V. Baylosis, Lourd Dhinber G. Tangaran, and Pearl Joy N. Ornopia are all fourth-year Computer Engineering students at the University of San Jose-Recoletos upon the completion of this thesis.

Engr. Jerome B. Amor and Engr. Rey S. Mabatid are instructors at the University of San Jose-Recoletos Computer Engineering Department.