LabVIEW-based Remote Patient Monitoring System in Hospital Using Arduino Mega

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تصميم نظام مراقبة المرضى داخل المستشفى يعتمد على برمجة لابفيو باستخدام الأردوينو ميجا

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Abstract:
The recovery of the patient is not limited to providing treatment, but it also requires continuous follow-up and monitoring to ensure his safety and avoid any serious changes that may occur in the patient. There is no doubt that traditional methods of monitoring the health condition in which the doctor is forced to visit the patient in his place are often expensive and require a lot of time, in addition to the doctor making a lot of effort due to his frequent visits to patients. Many studies have been presented to develop methods of monitoring the health of patients, through the use of various technologies, the most important of which is the Internet of Things (IoT) technology, which provides the possibility of remote monitoring using platforms on the Internet that are accessed via mobile devices, so that the patient's health condition is displayed on these platforms, and then the doctor can view it wherever he is. The idea of this research came to design a remote health monitoring system that does not require an Internet connection to use, unlike what is found in monitoring systems that rely on IoT technology that require an Internet connection. In this research, the Arduino Mega board and LabVIEW program were used to program the monitoring system and design the graphical user interface (GUI). This interface displays the changes in the vital parameters of six patients: temperature, heart rate, and blood oxygen level, so that the doctor inside the hospital can monitor the condition of the six patients in real time while they are in their rooms without having to be next to them, with the possibility of setting the maximum and minimum permissible value for these parameters, so that if one of these parameters is outside the specified range, the system alerts the doctor by turning on an indicator light to alert him of the presence of a danger to one of these six patients. The health monitoring system for the patients' condition was designed and tested on six people and the results were good, as the vital parameters of these people were displayed on the user interface in real time, and an indicator light was turned on for one of the patients to alert the doctor because one of the parameters was outside the specified range.

Keywords: Remote Patient Monitoring, Arduino, LabVIEW.

الملخص:
إن شفاء المريض لا يقتصر فقط على تقديم العلاج له، بل يحتاج إلى المتابعة والمراقبة باستمرار، وذلك لضمان سلامته وتدارك أي تغيرات خطيرة تطرأ على المريض، و لا شك في أن الطرق التقليدية لمراقبة الحالة الصحية التي يكون فيها الطبيب مضطرا إلى زيارة المريض في مكانه تكون في أغلب الأحيان مكلفة و تحتاج الكثير من الوقت، علاوة على بذل الطبيب لكثير من الجهد بسبب زيارته المتكررة للمرضى. الكثير من الدراسات قُدمت لتطوير طرق المراقبة الصحية للمرضى، وذلك من خلال استخدام مختلف التقنيات أهمها تقنية انترنت الأشياء IoT التي وفر إمكانية المراقبة عن بعد باستخدام منصات على الانترنت يتم الوصول لها عن طريق الأجهزة المحمولة، بحيث يتم عرض الحالة الصحية للمريض على هذه المنصات، ومن تم يمكن للطبيب من الاطلاع عليها أينما كان. لقد جاءت فكرة هذا البحث لتصميم نظام مراقبة صحية عن بعد لا يتطلب استخدامه اتصالا بالأنترنت، على غير ما هو موجود في أنظمة المراقبة التي تعتمد على تكنولوجيا IoT التي تتطلب اتصالا بالإنترنت. لقد تم في هذا البحث استخدام لوحة الأردوينو ميجا، و برنامج LabVIEW لبرمجة نظام المراقبة وتصميم واجهة المستخدم الرسومية GUI ، هذه الواجهة يتم فيها عرض التغيرات في المعلمات الحيوية لعدد ستة من المرضى وهي: درجة الحرارة و عدد نبضات القلب و نسبة الاكسيجين في الدم، بحيث يتسنى للطبيب داخل المستشفى من المراقبة الحظية لحالة المرضى الستة وهم موجودون في غرفهم في الوقت الفعلي دون الحاجة لأن يكون بجانبهم، مع وجود إمكانية ضبط أقصى و أقل قيمة مسموح بها لهذه المعلمات، بحيث إذا كانت إحدى هذه المعلمات خارج المدى المحدد لها فإن النظام يقوم بتنبيه الطبيب من خلال تشغيل مصباح بيان لتنبيهه بوجود خطر على أحد هؤلاء المرضى الستة. تم تصميم واختبار نظام المراقبة الصحية لحالة المرضى على ستة أشخاص وكانت النتائج جيدة، حيث تم عرض المعلمات الحيوية لهؤلاء الأشخاص على واجهة المستخدم في الوقت الفعلي، كمتا تم تشغيل مصباح بيان لأحد المرضى لتنبيه الطبيب بسبب خروج إحدى المعلمات عن المدى المحدد لها.

الكلمات المفتاحية: مراقبة المرضى عن بعد، أردوينو، لابفيو.

Introduction

To avoid any complications or deterioration in the patients' condition, the continuity and regularity of health care and patient monitoring have become a matter that must be taken into consideration [1]. This is because not being informed of any change that occurs in the patient's health condition early, especially if this change is for the worse, this will cause bad results for the patient's health [2]. Health monitoring is the process of following up on patients

and collecting their data to diagnose their conditions. This monitoring may be done traditionally by collecting data for patients by visiting the patient repeatedly and recording his data and then diagnosing his condition, or it may be done remotely by using smart systems and various communication networks so that different parameters in the human body are sensed and then these readings are sent remotely to doctors and specialists who supervise the patient's condition. This method is known as remote health monitoring (RPM)[3]. For the patient's health monitoring to be permanent and continuous, traditional healthcare methods will not meet this purpose. Still, they may cause many problems due to the time taken to measure the patients' vital information, as well as the effort exerted by the nurse to obtain this information [4]. This is because diagnosing the patient's condition in traditional methods depends on the doctor visiting the patient and examining his health condition directly. However, this method has negatives, including not adhering to appointments, as well as the effort exerted by the doctor and the time taken to reach the patient and diagnose him, which causes the patient not to be provided with appropriate treatment at the appropriate time [5]. The process of monitoring and detecting the health status of patients was and still is based mainly on the doctor visiting the patients, whether they are in the hospital or at their homes [3]. Therefore, finding an alternative to the traditional patient monitoring process has become a must, due to the time and effort it consumes from the doctor, which results in delays in diagnosing patients and delays in their recovery [3]. Modern methods based on digital technology will be able to provide continuous and permanent communication between the nurse and the patient [6]. Modern methods are distinguished by their ability to share patient data with the doctor in real time, which helps diagnose the patient's condition and know the changes that occur in his health condition [7]. Patient health monitoring systems have been developed using technologies that operate through sensors and remote communication devices, which have the ability to provide continuous patient monitoring [8]. The RPM remote patient monitoring system has been implemented by sensing specific parameters in the patient's body such as temperature, heart rate, etc. using a set of sensors installed on the patient's body, so that the sensor readings are transferred to microcontrollers that process these readings and display them on graphical interfaces that are available to the doctor [9]. Remote patient monitoring (RPM) can be defined as the procedures that allow the nurse to monitor the patient's condition remotely through modern communication methods that share the patient's vital parameters so that the nurse can view them and then diagnose the patient's condition [10]. On the other hand, remote patient monitoring (RPM) is about monitoring the condition of patients wherever they are, whether in the hospital, at home, or even while they are on the move. RPM systems allow the doctor to continuously monitor the patient's condition and thus diagnose his condition [9]. Lack of discipline in measuring the patient's vital parameters may lead to a deterioration in the patient's health condition, and may even lead to death [11]. RPM systems contribute significantly to improving the quality of diagnosis and quickly detecting any deterioration in the patient's health, and thus addressing any danger that may occur to the patient before it is too late [12]. The patient monitoring process is done remotely by deploying various sensors on the patient's body. These sensors read the patient's conditions and transfer them to the control units (microcontrollers), and then display these readings on a user interface on the phone or computer [9]. IoT technology is the core element of RPM remote patient monitoring systems, as IoT technology provides the doctor with the ability to continuously monitor patients from anywhere in the world [3]. IoT is based on connecting and integrating electronic devices with each other via the Internet, to form a wide network of devices, through which data is shared, in addition to the ability to monitor and control these devices remotely [9]. An IoT-based patient health monitoring system RPM was designed using ESP32 board, which reads the patient's vital parameters (temperature, blood oxygen, heart rate), and displays these parameters on a user interface that the doctor can view on his phone from anywhere in the world [3]. However, IoT technology requires RPM systems to be permanently connected to the Internet to share with doctors [9]. The use of Internet of Things technology in healthcare systems also requires the process of storing and sharing data over the Internet [8]. Which may not be available in some areas, especially remote ones. Monitoring patients in hospitals depends on the nurse visiting patients at regular intervals, which vary from one region to another. Until now, there are no fixed standards for the periods required to monitor and examine patients in hospitals. The period of monitoring patients ranges from 4 to 6 hours, and the time of these periods decreases depending on the patient's condition, which may require a nurse's visit in a shorter time. The time taken to measure the vital parameters of a single patient in the hospital and diagnose his health condition was measured, and it was approximately five minutes if the lost time resulting from some interruptions during the time allocated for the nurse's visit to the patient is excluded, as the total time sometimes required to visit and examine the patient reaches approximately seven minutes. Also, the time required only for the process of measuring the patient's vital parameters itself takes approximately four minutes, which is not a small amount of time if the total number of patients in the hospital is taken into account, which has a negative result on the work efficiency of the nurses responsible for measuring the vital parameters of patients, in addition to the delay in completing the work [11].

Proposed model

The patient monitoring system presented in this paper was designed based on two main parts: hardware and software. The hardware part of this system can be seen in the block diagram shown in Figure (1), where data is collected through a set of sensors, processed inside the microcontroller, and then dealt with in the system environment based on this data.

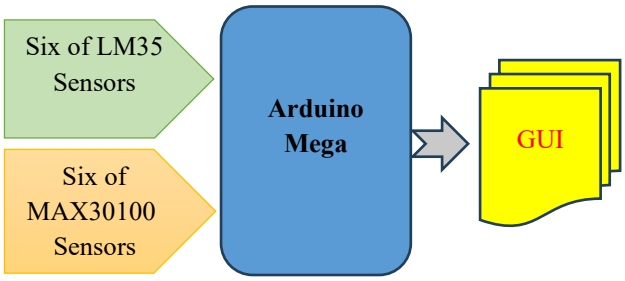

Figure 1: The block diagram of the presented system.

A. hardware

The presented system has been designed by using the following components:

1. LM35 temperature sensor

LM35 sensor shown in Figure 2, is characterized by its low cost, in addition to its accurate reading and ease of connection and use. This sensor also has a good reading range, which ranges from 0^0C to 100^0C degrees Celsius, and is also characterized by a high reading accuracy of up to +/- 0.4^0C, and an operating voltage of 4V to 20V. [13]

Figure 2: LM35 sensors.

2. **MAX30102 *sensor***

number of heart beats per minute, and the percentage of oxygen in the blood both of them can be sensed by **MAX30102 *sensor***, by placing the patient's finger on this sensor. **MAX30102 *sensor*** shown in Figure 3, is characterized by a very high measurement accuracy of up to 95%, in addition to its need for a simple operating voltage not exceeding 3V [13].

Figure 3: MAX30102 sensor.

3. Arduino Mega

The Arduino Mega board illustrated in Figure 4, is the heart of the monitoring system circuit presented in this research. It contains 54 pins that are used as digital inputs or outputs, in addition to containing 15 analog pins to which the sensors are connected.

Figure 4: Arduino mega.

B. Software

LabVIEW software was used in this paper to program the system, this software has the ability to design a graphical user interface (GUI) through which changes in the system environment can be monitored. A graphical interface has been designed in this research through which changes in the readings of the sensors connected to the patients can be monitored and then displayed on the user interface in real-time.

The idea of the monitoring system presented in this research

The patient monitoring system presented in this research senses the vital parameters in the human body, which are: body temperature, heart rate per minute, and blood oxygen level, then transfers these readings to the Arduino board to process them and then display them on the GUI shown in Figure 5. This system monitors many patients at the same time in real-time, as this system includes six LM35 sensors to be connected to the bodies of six patients, in addition to six MAX30100 sensors that are also connected to the bodies of the six patients, so that the temperatures, heart rate, and blood oxygen level are sensed for all of these patients at the same time, then transferring these readings to the Arduino board to display them to the doctor in his room without the need for him to be next to the patients so that the doctor can monitor the patients' condition remotely without the need to move around the patients' rooms. This system is also distinguished by not needing the Internet, as the LabVIEW program was used to program it and then the graphical user interface was designed to display the sensor readings on it.

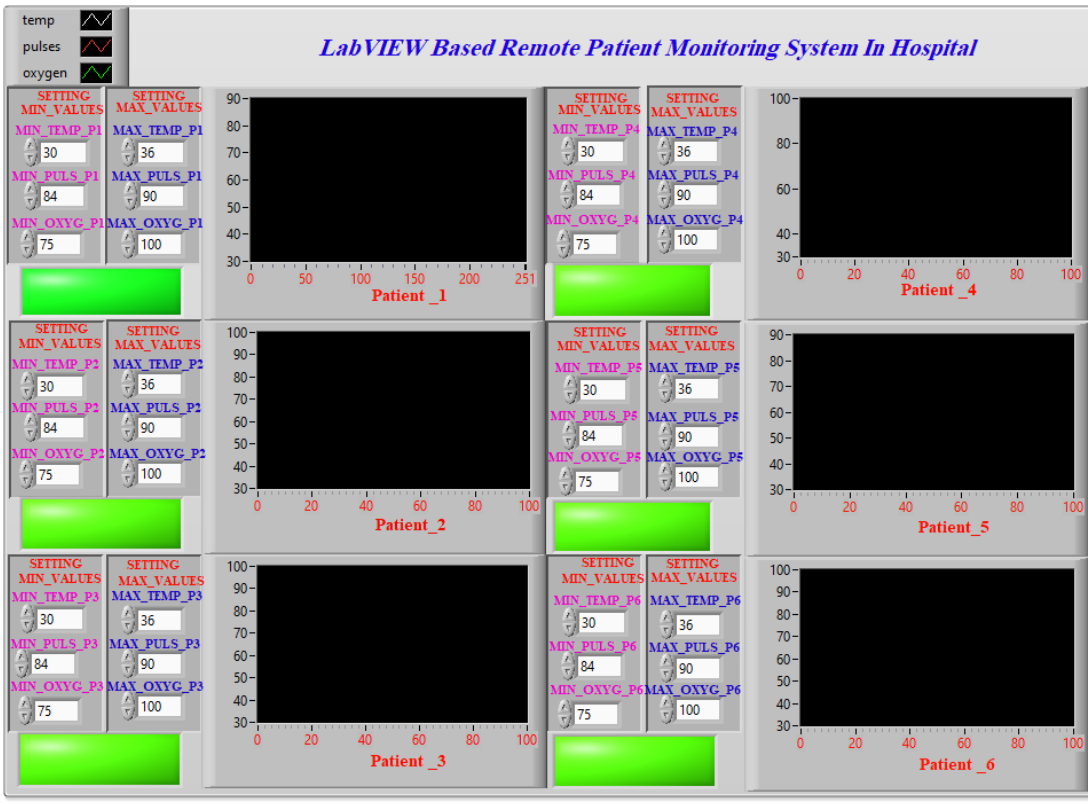

Figure 5: GUI of the presented system.

The GUI was designed to contain six parts, each part of which parts as shown in figure 6 is specific to one of the patients and contains several elements, which are:

A. ***Signal plotter:*** It displays a curve that shows the change in the vital parameters of the patients.
B. ***Control elements:*** Through which the maximum and minimum values of each vital information are set for each patient separately, so that if this information increases or decreases from these values, the system alerts the doctor.
C. ***Indicator lamp:*** Through this lamp, the doctor is alerted to the critical condition of the patients, as it is green when the patient's condition is good, while it changes to red when one of the parameters is greater than or less than the values set in the system's control elements.
D. ***Parameter display unit:*** In these units, the current readings of the parameters are displayed.

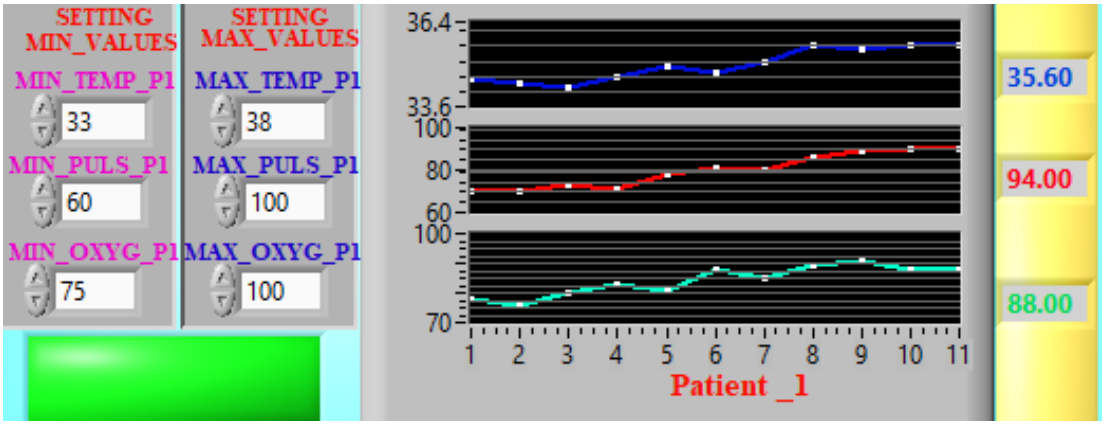

Figure 6: The elements contained in each part of the GUI.

Results

The remote patient monitoring system presented in this research was designed and programmed using LabVIEW software, where all the results obtained in real-time for the patients' health conditions were displayed on the GUI and are shown in Figure 7. The maximum and minimum permissible information values were set as follows:

A. Maximum temperature = 38 C^0, Minimum temperature = 33 C^0.
B. Maximum rate of oxygen = 75, Minimum rate of oxygen = 100.
C. Maximum pulse per minute = 70, Minimum pulse per minute = 100.

It can be noted from the figure 7 that the vital parameters of the first, second, third and fourth patients were within the permissible range, which indicates that their health condition is good, while the vital parameters of the fifth patient were outside the permissible range, which led to the indicator light turning on and changing its color to red, announcing the presence of an abnormal condition for the fifth patient, which requires the doctor's intervention and transfer to this patient's room.

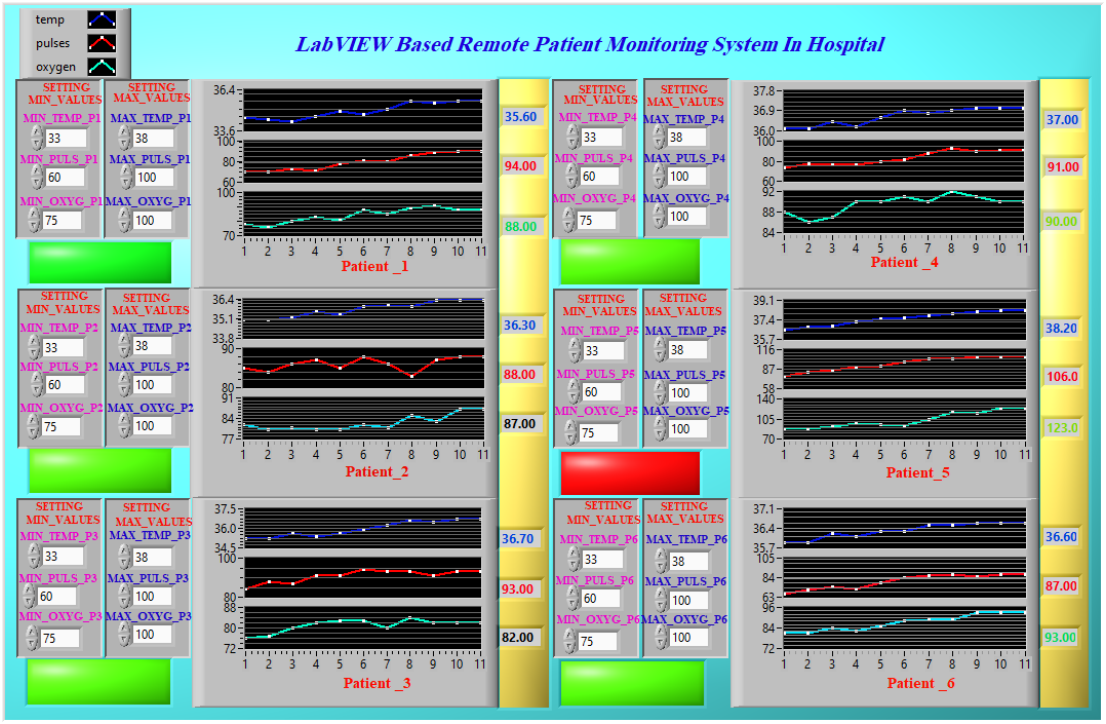

Figure 7: The vital parameters of the six patients in the real time.

The last values of the vital parameters of the six patients can be seen in Table 1.

Table 1 The last parameter reading of the six patients

Patient	parameters		
	Temperature C^0	Pulse rate (PBM)	Oxygen in blood %
1	35.6	94	88
2	36.3	88	87
3	36.7	93	82
4	37.0	91	90
5	38.2	106	123
6	36.6	87	93

Conclusions

Monitoring the health status of patients is considered one of the most important reasons for the success of the treatments provided by doctors to patients, and since monitoring the health of patients using traditional methods costs a lot of time and effort in addition to the lack of instant follow-up of patients in traditional methods, these methods have been developed by using several technologies that provide the possibility of remote follow-up, so that the doctor can monitor the patient remotely and diagnose his health condition without the need to be next to him. In this research, a system for monitoring several patients remotely was designed using the LabVIEW program, so that the system environment is monitored and the changes that occur in it are displayed on the GUI user interface for all patients at the same time.

Reference

1- Gabriella Facchinetti, Daniela D'Angelo, Michela Piredda, Tommasangelo Petitti, Maria Matarese, Alice Oliveti, Maria Grazia De Marinis, ***"Continuity of care interventions for preventing hospital readmission of older people with chronic diseases: A meta-analysis, International Journal of Nursing Studies***", Volume 101, 2020.

2- Brianna, Lee, S.H***, "Chemotherapy: how to reduce its adverse effects while maintaining the potency?"***. *Med Oncol* **40**, 88 (2023).

3- Ahmed S.D.A, Elhadi E.A, Nuria M.H, Abdussalam A.A, "***An Affordable Internet of Things Solution for Health Monitoring Utilizing ESP32 Technology***", *AJAPAS*, vol. 3, no. 4, pp. 356–364, Nov. 2024.

4- Hege Wathne, Carl May, Ingvild Margreta Morken, Marianne Storm, Anne Marie Lunde Husebø, ***"Acceptability and usability of a nurse-assisted remote patient monitoring intervention for the post-hospital follow-up of patients with long-term illness: A qualitative study",*** International Journal of Nursing Studies Advances, Volume 7, 2024.

5- Bradley A McGregor, Gregory A Vidal, Sumit A Shah, James D Mitchell, Andrew E Hendifar. ***"Remote Oncology Care: Review of Current Technology and Future Directions".*** Cureus. 2020 Aug 31;12(8):e10156. doi: 10.7759/cureus.10156. PMID: 33014652; PMCID: PMC7526951.

6- Hardeep Singh, Terence Tang, Carolyn Steele Gray, Kristina Kokorelias, Rachel Thombs, Donna Plett, Matthew Heffernan, Carlotta M Jarach, Alana Armas, Susan Law, Heather V Cunningham, Jason Xin Nie, Moriah E Ellen, Kednapa Thavorn, Michelle LA Nelson, ***"Recommendations for the Design and Delivery of Transitions-Focused Digital Health Interventions: Rapid Review***", JMIR Aging, Volume 5, Issue 2,2022.

7- Girgis A, Bamgboje-Ayodele A, Rincones O, Vinod SK, Avery S, Descallar J, Smith A', Arnold B, Arnold A, Bray V, Durcinoska I, Rankin NM; PROMPT-Care Implementation Authorship Group; Delaney GP. ***"Stepping into the real world: a mixed-methods evaluation of the implementation of electronic patient-reported outcomes in routine lung cancer care".*** J Patient Rep Outcomes. 2022 Jun 20;6(1):70. doi: 10.1186/s41687-022-00475-6. PMID: 35723827; PMCID: PMC9207870.

8- Itamir De Morais Barroca Filho, Gibeon Aquino, Ramon Malaquias, Gustavo Girão, And Sávio Rennan Menêzes Melo, "***An Iot-Based Healthcare Platform For Patients In Icu Beds During The Covid-19 Outbreak***," In IEEE Access, Vol. 9, Pp. 27262-27277, 2021, Doi: 10.1109/Access.2021.3058448.

9- Palanivel Rajan, S., Dineshkumar, T. (2022). "***In Hospital and in Home Remote Patient Monitoring"***. In: Mishra, S., González-Briones, A., Bhoi, A.K., Mallick, P.K., Corchado, J.M. (eds) Connected e-

Health. Studies in Computational Intelligence, vol 1021. Springer, Cham. https://doi.org/10.1007/978-3-030-97929-4_15

10- Frederico Arriaga Criscuoli de Farias facfarias@ucs.br, Carolina Matté Dagostini, Yan de Assunção Bicca, Vincenzo Fin Falavigna, and Asdrubal Falavigna***, "Remote Patient Monitoring: A Systematic Review",*** Telemedicine and e-HealthVol. 26, No. 5, 2020.

11- Chiara Dall'Ora, Peter Griffiths, Joanna Hope, Jim Briggs, Jones Jeremy, Stephen Gerry, Oliver C Redfern, ***"How long do nursing stafftake to measure and record patients' vital signs observations in hospital? A time-and-motion study***", International Journal of Nursing Studies, 2021.

12- Lynne Warner Stevenson, Heather J. Ross, Lisa D. Rathman, John P. Boehmer, ***"Remote Monitoring for Heart Failure Management at Home: JACC Scientific Statement***", Journal of the American College of Cardiology, Volume 81, Issue 23, 2023.

13- P. Verma and R. Mishra, "***IoT based Smart Remote Health Monitoring System***", 2020 International Conference on Electrical and Electronics Engineering (ICE3), Gorakhpur, India, 2020, pp. 467-470, doi: 10.1109/ICE348803.2020.9122864.