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PAPER

Remote Heart Rate Monitoring Device Using the Internet of Things

Orlando Iparraguirre-Villanueva(✉), Enrique Surcco-Jacinto, Melanie Balvin-Chávez

Facultad de ingeniería y arquitectura, Universidad Autónoma del Perú, Lima, Perú

oiparraguirre@ieee.org

ABSTRACT

Cardiovascular diseases are the leading cause of death worldwide. Therefore, this study aims to develop a mobile application utilizing the Internet of Things (IoT) to monitor patients' heart rate. The study employed a quantitative approach and a pre-experimental design. The experiment was conducted according to the research plan and involved 20 patients. The Scrum methodology was used for the development of the mobile application. The results reveal a significant improvement in patient and family satisfaction after using the IoT-enabled mobile application. In addition, the average measurement time has decreased to 6.025 minutes, which represents a significant difference compared to the traditional method. The number of measurements has increased from seven to 14 per week, averaging two regular daily measurements. The measurement device has alleviated the concerns of family members who are taking care of loved ones with cardiovascular disease. This tool gives users greater peace of mind, enabling them to take accurate and reliable measurements 24/7.

KEYWORDS

heart patients, proper care, mobile application

1 INTRODUCTION

Cardiovascular diseases are the leading cause of death worldwide [1]. Methods for predicting heart disease are extremely complex [2], and the clinical management of heart failure (HF) in the elderly is not well established. From aggressive treatment to palliative care, decisions must be made on an individualized basis based on each patient's biological deterioration [3]. Many HF patients do not adhere to their treatment regimen, which can lead to worsening symptoms, hospital readmissions, and a reduced quality of life [4].

Monitoring systems for home care are plentiful but are constrained by several limitations [5]. Therefore, the IoT continuous cardiac monitoring system is one of the applications that is available 24/7 [6]. The integrated system includes a synchronized API and a mobile application for predicting and alerting about the situation [7]. In a

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medical setting, heart rate and blood pressure are crucial for evaluating a patient's condition and offering vital information about the current state of their body. Therefore, facilitating the process of using the device to obtain this data is a great advantage [8], [9]. It is crucial to halt the increase in the mortality rate associated with heart failure. This implies implementing specific approaches aimed at preventing and effectively treating the elderly population. In addition, it is essential to effectively manage cardiac patient data to make informed decisions and improve the quality of healthcare. This will be reflected in reduced concern and lower hospital readmission rates [10].

The Internet of Things (IoT) technology helps older people reduce the frequency of hospital visits and enables continuous monitoring of their health status, providing early warnings [11]. This contributes to enhancing medical care for patients and decreasing the mortality rate associated with hospital-treated diseases [12], [13]. The novelty of this study lies in proposing graphical monitoring of patient data to simplify the interpretation and analysis of information gathered by healthcare professionals, thereby enhancing the quality of diagnoses and treatments [14]. The various components and processes comprising this monitoring system are described, along with its characteristics and advantages over other conventional systems. The aim is to make a substantial contribution to advancements in the field of medicine and the care of patients with cardiac issues [15], [16], [17].

This project aims to design an IoT-based system to monitor the health of patients with heart problems. The proposed system aims to provide an accurate and detailed record of the patient's heart rate to identify any irregularities or anomalies that may endanger their health. The article is organized as follows: Section 2 provides a review of the relevant literature; Section 3 presents and develops the methodology; Section 4 discusses the results; Section 5 discusses the results and related studies; and Section 6 provides the conclusions of the research.

2 BIBLIOGRAPHIC REVIEW

Over the last decade, academics and scientists have investigated issues related to heart rate monitoring [18]. For example, in [19], a model was developed to ensure the secure transmission of remote patient health data. They used a two-stage Cryptus IoT lab setup for decoding. The prototype system was tested and proved successful in transferring medical data, opening new possibilities for security on IoT devices. Similarly, autonomous detection and classification of arrhythmias using a learning system was pursued in [20]. Electrocardiogram signals were collected using IoT nodes. A classification model was implemented, and performance functions were analyzed, resulting in a 95% accuracy rate that outperformed existing techniques. Also, in [21], a system was developed with biomedical sensors to provide users with the necessary data for diagnosing and monitoring their condition. In this study, a prototype was developed using sensor-collected data, but it did not yield an accurate diagnosis in all four types of tests. In addition, in [22], they implemented a real-time remote health monitoring system that stores patient parameters to enhance medical communication. They used a functional architecture with data processing on a Raspberry Pi and a Wi-Fi module. Clinical results are accurately collected and support doctors through clinical trials. Also, in [23], they proposed an innovative platform that utilizes blockchain-based smart contracts to monitor patients' vital signs. The system uses Hyperledger Fabric, an enterprise framework for blockchain-based applications. The proposed system overcomes the traditional approach to monitoring patient data in healthcare.

In another study [24], the researchers aimed to reduce stress and agitation during blood pressure measurements. Their prototype consisted of six design steps, including the electronics required to capture and condition the analog signal, device connectivity, and data transfer to the cloud, following the IoT model. Testing and validation indicated that the prototype could serve as a solution for home blood pressure monitoring, eliminating the need for patients to travel to hospitals. Similarly, in [25], they analyzed the benefits of IoT for epidemiology and public health. The author reviewed texts and databases and found that IoT presents significant opportunities due to big data and the technologies of the fourth industrial revolution. However, there are security and privacy concerns. Ultimately, the study concluded that IoT provides multiple sources of real-time data, which enhances the understanding of health events and enables proactive and predictive care for the general population, particularly in epidemiology and public health.

Similarly, in reference [26], the remote monitoring of a patient's health status over the Internet was proposed. This system ensures data security by implementing an IoT-RRHM system that is resilient to known attacks, allowing fast and secure access over the Internet and WBAN. An experimental real-time configuration of the IoT-RRHM framework in a WBAN environment is presented, testing intra-BAN and inter-BAN communication. The robustness of the system was verified by simulation using AVIVASPA. Finally, in reference [27], an application was developed that utilizes the mobile phone camera to measure vital signs. Using an algorithm and a neural network, the system analyzed high-resolution videos and compared them with a database of over 206 videos, offering precise details and accurate data. When the camera was turned on, it captured, processed, and classified the image to send relevant data.

3 METHODOLOGY

This section presents the research method and the development of the monitoring system. This is an applied study with a quantitative approach and a pre-experimental design in which the experiment was conducted according to the research plan. The pre-test and post-test designs are represented in Equation (1).

$$GE: O_1 \times O_2 \tag{1}$$

Where:
GE: Experimental group
O_1: Pre-test
O_2: Post-test
$\times$: Variable manipulation

A purposive sampling of 20 patients with heart disease was used in this study. The data was then subjected to statistical analysis to conclude from the results.

The Scrum software development methodology was used for developing the monitoring system. Scrum is considered a lightweight methodology because it emphasizes collaboration, communication, and teamwork, making it ideal for projects that necessitate rapid responses to changing situations. In addition, it promotes continuous improvement and adaptive learning during the project [28]. Scrum is composed of the following phases: sprint planning, sprint development, sprint review, and sprint retrospective.

3.1 Development of the case study

In this section, the prototyping process for the monitoring system is developed using the Scrum lifecycle methods mentioned above. Scrum is a popular agile methodology used in software development projects to enhance collaboration, adaptability, and productivity. The Scrum framework includes a series of sprints or iterations, where each sprint involves planning, designing, developing, testing, and delivering a piece of functionality. The architecture of the monitoring system is presented in Figure 1.

The acquisition of a node and/or esp8266 with the KY-039 pulse sensor has been completed. This setup provides the necessary support to collect patient data and transmit it to the cloud, facilitated by the integrated Wi-Fi module on the board. This part is essential for the development of the application, as it marks the initial step in facilitating communication among the patient, the family, and the doctor. Figure 2 shows the device used for this research.

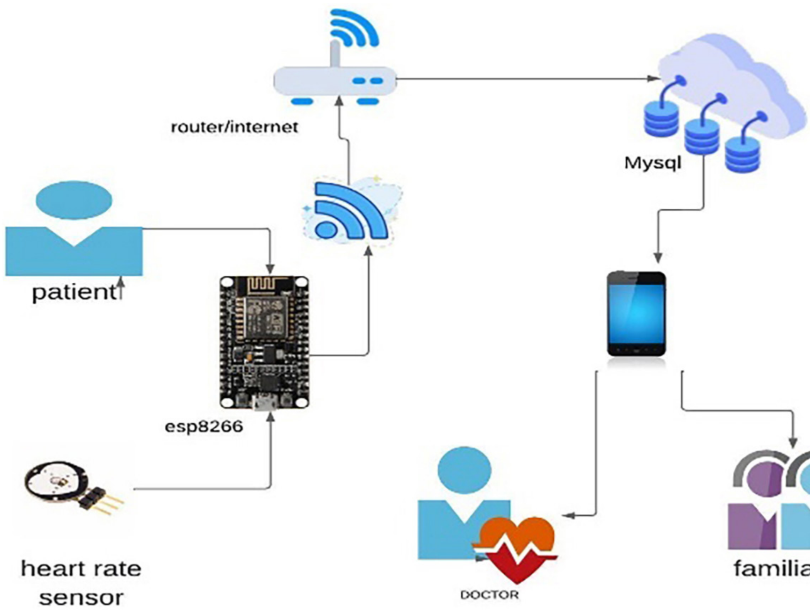

Fig. 1. The architecture of the monitoring system

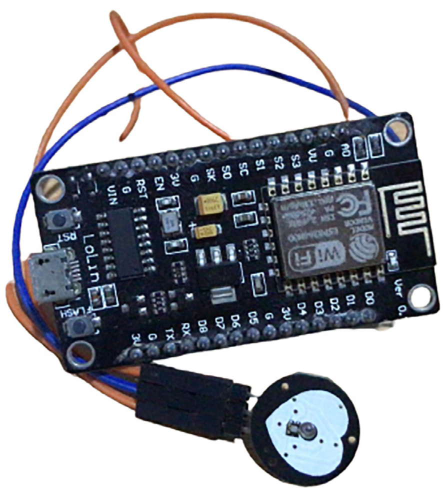

Fig. 2. esp8266 with heart rate sensor

Sprint planning. This sprint was planned to use a Scrum-based process. Meetings were conducted to prioritize tasks and estimate the time required to complete them. The tasks ranged from developing a prototype with the ESP8266 connected to the cloud to enabling users to log in with the relevant role and submit queries to the doctor. This is shown in Table 1, which summarizes the desired requirements for implementing and developing the case study.

Table 1. Epics of the monitoring system

Code	Description
RF01	The device will record the patient's heart rate.
RF02	The system will display a screen where the username and password will be entered.
RF03	The mobile application will display the patient's heart rate in real time.
RF04	The mobile application shall display the company logo on the home screen.
RF05	The mobile application shall allow the family member to ask questions to the doctor.
RF06	The mobile application shall display prescriptions to family members.
RF07	The mobile application shall allow the physician to review the queries made by the family member.
RF08	The mobile application shall allow the physician to record prescriptions to the patient's family member.
RF09	The mobile application shall allow a chat where the patient's family member and the physician can converse.
RF10	The application shall display the number of registered users.
RF11	The system shall send an alert if the heart rate is too high or too low.
RF12	The mobile application shall allow a chat in which the patient's family member and the physician can converse.

This project was planned collaboratively with each team member who participated in it. We used planning poker to assess the difficulty of each part of the system. For instance, real-time registration was considered the easiest task with a weight of 1, while allowing family members to view their patient's information was rated with a weight of 5. As shown in Table 2.

Table 2. Prioritization

ID	Characteristic/Functionality	Priority	Risk	Weight	Interaction
H-01	I need a measuring device to record the patient's vital signs in real time.	high	under	1	1
H-02	I need an access login.	high	high	3	1
H-03	I need to be able to view patient information in real time.	high	half	5	1
H-04	I need to have a record of the patient's vital signs.	high	high	3	2
H-05	I need to be able to consult a doctor.	half	low	1	2
H-06	I need to be able to view my doctor's prescriptions.	low	low	2	2
H-07	I need to review the consultations made to me by patients' relatives.	half	low	2	2
H-08	I need to register indications for family members.	half	low	2	2
H-09	I need to consult to monitor the number of equipment that are running.	low	high	4	3
H-10	I need to have a record of all users and roles.	half	low	2	3
H-11	I need to display disconnected equipment.	low	high	4	3

Sprint development. Sprint 1: The main objective of the first sprint is to develop three user stories with a total weight of 9 points. This means that these tasks must be completed within a specified period, which may vary according to the development team's specifications. Among these tasks are the development of the access component and the measurement of heart rate in elderly patients, as shown in Table 3.

Table 3. Prioritization of Sprint 1

ID	Role	Characteristic/Functionality	Priority	Risk	Weight	Interaction
H-01	As a doctor	I need a measuring device to record the patient's heart rate in real time.	high	low	1	1
H-02	As a doctor/family member/administrator	I need an access login.	high	high	3	1
H-03	As a family member/doctor	I need to be able to view patient information in real time.	high	half	5	1

Figure 3 displays the outcome of sprint 1, where the login screen was developed to provide access based on the user's role, whether they are a doctor, family member, or administrator, with distinct sections for each role.

This development process is followed for each of the sprints. For example, in Figure 4, the interface for real-time recording of the patient's heart rate, transmitted through the Arduino sensor connected to a cloud database, is presented.

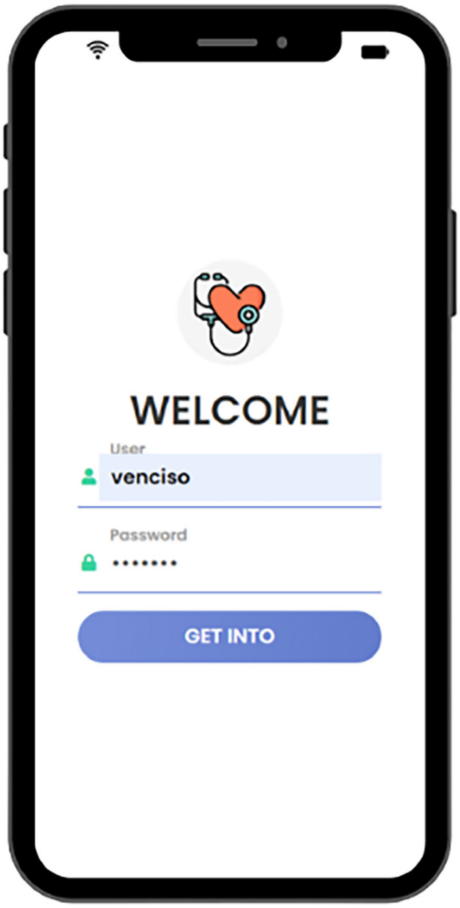

Fig. 3. System login screen

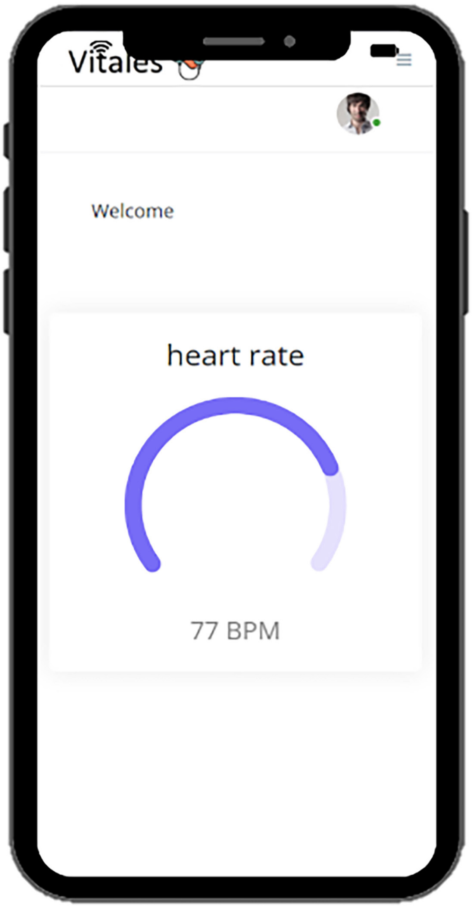

Fig. 4. Heart rate recording

Sprint review. During this phase, a follow-up meeting is conducted to assess each deliverable with the entire team. This meeting highlights the development progress of various aspects of the sprints, particularly focusing on functionality such as the database, remote connections, and the heart rate graph. We reached in a agreement consensus on each deliverable after its development.

Sprint retrospective. At the end of the sprints, we were able to showcase the work completed by implementing the tracking system, and we assessed potential enhancements for the application's future. Furthermore, when presented to the final customers (patients and their families) and other physicians, satisfaction with the results obtained through the application was evident. The monitoring system was applied to 20 patients for a short time under the supervision of a physician to validate its effectiveness.

4 RESULTS

This section presents the results related to the development of the research within the use case. The first KPI indicates that a patient satisfaction assessment was conducted to evaluate if the monitoring system met the expectations of both patients and their relatives. This was achieved by conducting a satisfaction survey while using the application. For the second KPI, we were able to verify, through time tracking, the variation in the time individuals needed to measure their heart rate before and after using our application. This was achieved by measuring the time delay before and after using the monitoring system. Along the same lines, the third KPI analyzed the frequency with which individuals could traditionally measure their heart rate, compared to the current accessibility provided by our unique remote and unlimited system, allowing for multiple heart rate measurements as required, as demonstrated in Table 4.

Table 4. Pre-test and post-test results

No	KPI-1		KPI-2		KPI-3	
	User Satisfaction (%)		Monitoring Time (min)		Amount of Monitoring Pereek	
1	12	17	20	3	1	14
2	12	18	15	5	1	7
3	11	18	30	4	3	7
4	12	18	25	3	2	14
5	11	19	20	3	3	7
6	12	19	15	4	2	14
7	13	19	10	3	1	7
8	11	19	25	3	1	14
9	12	18	20	4	3	7
10	11	19	20	4	2	14
11	11	19	30	4	1	14
12	11	19	40	6	2	7
13	11	18	35	3	3	7
14	11	18	45	3	2	14
15	11	18	50	4	1	14
16	11	18	55	6	3	7
17	11	18	35	6	1	7
18	11	19	40	3	3	14
19	10	18	30	4	2	14
20	10	18	15	3	2	7

Outcome data were collected by implementing a pre- and post-test, using the same approach to assess the above indicators. The summarized results are derived from a sample group consisting of 20 patients from a medical center. Table 5 shows a summary of the normality test.

We observe that the "p" variable offers insights into the normality of the data, enabling us to ascertain whether it adheres to an anticipated pattern or exhibits anomalous behavior. The utilization of these values aids us in evaluating the distribution of the data and its deviation from normality, which is crucial in statistical analysis.

Table 5. Summary of the normality test

Indicators	Sample	Statistician	gl	p
User satisfaction	PRE KPI-1	1.77	31	0.01
	POST KPI-1	1.64	31	0.01
Monitoring time	PRE KPI-2	0.19	16	0.10
	POST KPI-2	0.66	16	0.10
Amount of monitoring	PRE KPI-3	0.93	31	0.10
	POST KPI-3	0.82	31	0.10

4.1 Results of the first indicator (KPI-1)

The results shown in Figure 5 reveal the positive impact of implementing the heart rate monitoring system. When assessing user/patient satisfaction, the responses were overwhelmingly positive. 50% of respondents expressed satisfaction with the solution, while the other 50% were very satisfied with the application. These results suggest that the application has not only met but also exceeded user expectations in terms of functionality and usability, indicating widespread acceptance of the solution. Overall, the results demonstrate the effectiveness of the heart rate monitoring application and its potential to improve the health and well-being of its users.

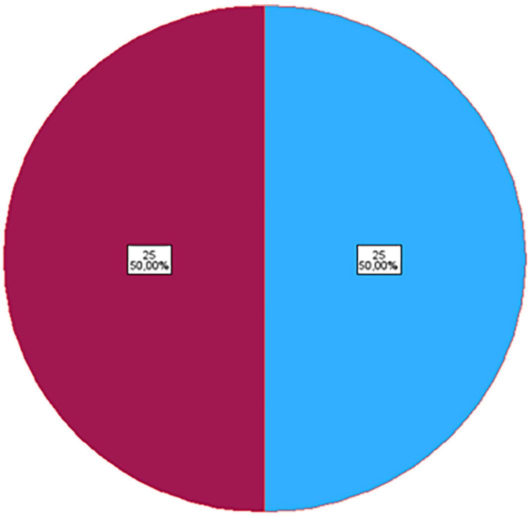

Fig. 5. PKI-1 satisfaction level

4.2 Results of the second indicator (KPI-2)

The results of KPI-2, related to heart rate monitoring, are quite promising. The analysis shows that the data follow an expected pattern and are within the limits of a normal distribution. In addition, there is a significant difference in the mean between pre- and post-assessments. Before, patients had to wait an average of 25 minutes to reach the health center, but with the IoT monitoring system, the average wait time has been reduced to a maximum of six minutes. This is very beneficial for families, as it significantly reduces both the time and cost associated with transportation to the medical center. Furthermore, this solution also helps prevent other complications, such as challenges associated with patient mobilization. Overall, the results suggest that the IoT monitoring system is an effective solution that can help enhance healthcare services, particularly in regions with limited access to healthcare facilities.

4.3 Results of the third indicator (KPI-3)

These results demonstrate the empowering capability of the monitoring system, as patients can now perform their measurements. This new capability allows individuals to take measurements autonomously at home or with the assistance of a loved one, eliminating the need to visit a medical center. From a technical standpoint, the maximum number of measurements that can be taken is 14 per week. This implies that patients can take an average of two measurements per day over the course of a week. These results underscore the practicality and convenience of the solution, enabling patients to monitor their health status regularly and accurately.

5 DISCUSSIONS

In this study, a mobile application was developed to assist in measuring the heart rate of older adults. Scrum methodology was used for the development, along with devices such as Arduino and a sensor. This innovative application provides an effective and practical tool to measure heart rate from home, avoiding complications associated with traveling to a medical facility. This aligns with the findings in article [21], which highlight the crucial role of biomedical sensors in providing essential data for collecting accurate and real-time information. This streamlines the patient assessment process, especially in monitoring heart rate remotely, as discussed in [23]. We agree with the concept of developing an innovative Android platform that enables remote heart rate monitoring by patients or their caregivers. It is designed to offer an enhanced experience and provide peace of mind to users by allowing them to easily access heart rate data remotely. The reference article [24] emphasizes the significance of reducing measurement time and facilitating remote monitoring in the medical field, a concern closely related to our work. During testing, our application received positive feedback from users. The results indicated that reducing measurement time and enabling remote monitoring were highly beneficial for both patients and their families. This achievement was made possible by the implementation of IoT technology, which played a crucial role in enabling efficient communication among the sensor, database, and internet connectivity. As highlighted in the reference article [25], this integration is a key component for ensuring the proper functioning of our project. The use of IoT technology has proven to be very beneficial in the medical field. In our specific case, it has been essential for facilitating communication between the sensor, the database, and internet connectivity. This integration has been a crucial part of ensuring the success of our work.

6 CONCLUSIONS

After developing the mobile heart rate monitoring application using Arduino sensors, it was concluded that the scientific importance of this study is crucial for the advancement of future research related to remote heart rate measurement. The data collected through the mobile application provides precise measurements, facilitating the development of strategies to promote the utilization of this heart rate monitoring implementation by both doctors and patients. These contributions enable the development of more effective and efficient initiatives for the use of heart rate measurement in older adults, independent of the medical center. Finally, this application has been found to greatly assist users by significantly reducing both the time and costs associated with measurements. By doing so, the time-consuming process of visiting a medical center in person for measurements in the traditional way is avoided. Furthermore, there has been a notable increase in patient satisfaction due to the availability of a quicker, more convenient, and remote method of taking measurements. This has significantly alleviated the concerns of family members, who now have greater peace of mind.

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8 AUTHORS

Orlando Iparraguirre-Villanueva is a Systems Engineer with a master's degree in information technology management, PhD in Systems Engineering from Universidad Nacional Federico Villarreal-Peru. ITIL® Foundation Certificate in IT Service, Specialization in Business Continuity Management, Scrum Fundamentals Certification (SFC) (E-mail: oiparraguirre@ieee.org).

Enrique Surcco-Jacinto is a student at Universidad Autónoma del Perú, with knowledge in electronics, electricity, programming languages such as HTML, PHP, JS and SQL. In addition, he has knowledge and certification in Scrum (E-mail: esurcco@autonoma.edu.pe).

Melanie Balvin-Chávez is a student at Universidad Autónoma del Perú, with knowledge in IoT, Electricity, programming languages such as Python, PHP, JS and SQL. and has knowledge and certification in Scrum (E-mail: mbalvin@autonoma.edu.pe).