CITE

Driving what's next 2.0

Unleashing Possibilities

A Mixed-method Recommendation Study:

Wearable IoT based COVID-19 Device to Monitor

the Condition of Nonhospitalized and Remotely Quarantined Patients

A Research Paper Presented to

The Faculty of College of Information Technology & Engineering

De La Salle Lipa

In Partial Fulfilment of the

Requirements for

Methods of Research

By.

Pangilinan, Patrick

Sajnani, Sanjay

Vergara, Aaron Charles

January 2022

Table of Contents

CHAPTER I

THE BACKGROUND OF THE STUDY

1.1 INTRODUCTION

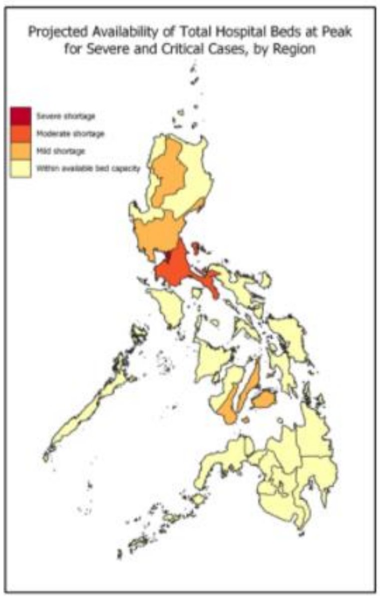
The danger posed by the COVID-19 pandemic has been the most significant global public health hazard since the 1918 pandemic influenza outbreak. As of December 14, 2021, according to the weekly epidemiological update of the World Health Organization (WHO), the weekly incidence of both COVID-19 cases and death have decreased by 5% and 10% respectively in comparison to the previous week, making the new global cumulative COVID-19 confirmed cases and deaths to be nearly 269 million and 5.3 million respectively. Nonetheless, this still corresponds to over 4 million new confirmed cases and around 47,000 new deaths in a week, signifying that the threat of the pandemic is still considerably significant. Alongside statistical reports, new COVID-19 variant developments have occurred, with the rise of the variant B.1.1.529 or more commonly known as variant "Omicron", labeled on November 26, 2021, as a variant of concern by WHO, with the advice of its Technical Advisory Group on Virus Evolution (TAG-VE). The impact of this new variant is most apparent in the African Region, with reports of the largest increase in new cases of 111% percent followed by the Western Pacific Region with a significantly lower increase of 7%.

WHO Region	New cases in last 7 days (%)	Change in new cases in last 7 days *	Cumulative cases (%)	New deaths in last 7 days (%)	Change in new deaths in last 7 days *	Cumulative deaths (%)
Europe	2 593 221 (65%)	-7%	91 631 852 (34%)	28 362 (60%)	-3%	1 598 688 (30%)
Americas	837 345 (21%)	-10%	98 521 311 (37%)	10 562 (22%)	-14%	2 371 246 (45%)
Western Pacific	213 915 (5%)	7%	10 584 344 (4%)	3 335 (7%)	4%	147 539 (3%)
Africa	167 682 (4%)	111%	6 522 517 (2%)	491 (1%)	-1%	153 766 (3%)
South-East Asia	98 021 (2%)	-10%	44 737 006 (17%)	2 643 (6%)	-50%	714 303 (13%)
Eastern Mediterranean	90 633 (2%)	-4%	16 936 781 (6%)	1 568 (3%)	-3%	312 295 (6%)
Global	**4 000 817 (100%)**	**-5%**	**268 934 575 (100%)**	**46 961 (100%)**	**-10%**	**5 297 850 (100%)**

*Table 1. Newly reported and cumulative COVID-19 confirmed cases and deaths, by WHO Region, as of 12 December 2021***

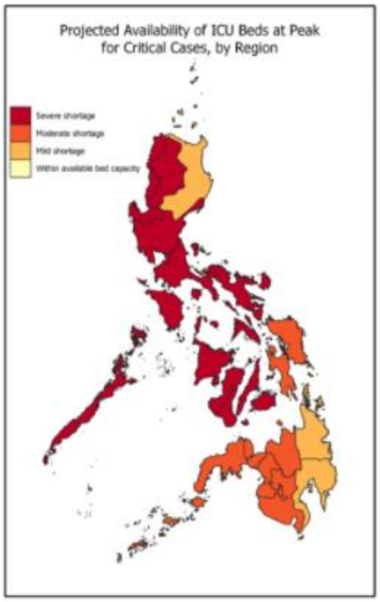
The still ongoing high number of cases coupled with the threat of a new and more infectious variant poses a serious concern to healthcare capacities and resources worldwide. A study conducted by Sen-Crowe et al. (2021), involving a total of 183 countries with a mean of 307.1 Hospital Beds (HBs), 413.9 Acute Care Beds (ACBs), and 8.73 Intensive Care Unit (ICU) bed capacity per a population of 100,000, displayed that there is a weakly positive correlation between the number of ICU beds and COVID-19 deaths, while there is no significant associations exist between the HBs and ACUs bed capacity to COVID-19 mortality. Nonetheless, Sen-Crowe et al. pointed out that the results underestimate the actual impact of the pandemic as it does not consider the significant resource and lifestyle burden experienced by other patient populations. This statement is further supported with Yale University's researchers on their correlation research regarding hospital resource availability and COVID-19 mortality across the United States, where there is a significant association between the availability of hospital resources and patient mortality during the early weeks of the COVID-19 surge (*Janke et al., 2021*). According to their findings in an analysis of 4,453 hospitals in 306 hospital referring regions (HRRs) in the U.S. from March 1 to July 26, 2020, researchers have discovered that geographic regions with fewer resources per COVID-19 patient -- including ICU beds, intensivists or critical care physicians, emergency physicians, nurses, and general hospital beds -- were statistically associated with more deaths in April 2020. From the findings, the number of ICU beds was discovered to have the strongest association to COVID-19 mortality, in which for every additional ICU bed, there would be a one-fifth decrease in the incidence rate of death during the month. Considering that COVID-19 can profoundly exhaust the availability of medical supplies, many hospitals worldwide will experience critical healthcare shortages needed to support COVID and non-COVID patients, making it difficult to consistently accommodate patients with appropriate healthcare and monitoring.

The lack of hospital resources is also evident among hospitals in the Philippines. According to the University of the Philippines COVID-19 Pandemic Response Team's April 2020 research on estimating the local health care capacity to deal with COVID-19 case surges, there is a relatively low number of hospital and ICU beds nationwide which could quickly be overwhelmed by the number of patients, considering that the infection curve has not been flattened. The country's hospitals with a level 2 to 3 classification only support a total bed capacity of around 67,119, where it was assumed by the researchers that 80% will be used for treating patients with other illnesses. From such assumption, the country would have a lack of available critical care beds as there are only a little over 2,000 ICU beds to cater a projected 8,800 to 19,800 critical COVID-19 cases. Alongside this, a peak number of cases would require an approximate number of 35,000 additional beds in a scenario wherein the reproductive number of COVID-19 (R0) is 2.



REGION	HOSPITAL BEDS (LEVEL 2&3)	SEVERE AND CRITICAL CASES AT PEAK AS PERCENTAGE OF TOTAL BED CAPACITY		
		R_0=2	R_0=2.5	R_0=3
PHILIPPINES	67,119	77%	93%	103%
National Capital Region (NCR)	18,932	206%	247%	274%
Cordillera Administrative Region (CAR)	1,214	22%	27%	30%
Region I - Ilocos	2,653	19%	22%	25%
Region II - Cagayan Valley	1,926	5%	6%	7%
Region III - Central Luzon	6,121	38%	45%	50%
Region IV-A - CALABARZON	8,309	70%	84%	93%
Region IV-B - MIMAROPA	307	20%	23%	26%
Region V - Bicol	2,124	17%	21%	23%
Region VI - Western VIsayas	4,823	17%	21%	23%
Region VII - Central Visayas	5,286	31%	37%	41%
Region VIII - Eastern Visayas	1,371	11%	13%	14%
Region IX - Zamboanga Peninsula	1,462	9%	10%	11%
Region X - Northern Mindanao	3,270	7%	9%	10%
Region XI - Davao	4,747	5%	6%	6%
Region XII - SOCCSKSARGEN	2,277	10%	11%	13%
Region XIII - Caraga	1,085	6%	7%	8%
Bangsamoro Autonomous Region in Muslim Mindanao (BARMM)	1,212	10%	12%	13%

*Figure 1. Projected availability of hospital beds at the regional level during peak, by UP COVID-19 Pandemic Response Team, as of 20 April 2021***



REGION	HOSPITAL BEDS (LEVEL 2&3)	CRITICAL CASES DURING PEAK AS PERCENTAGE OF ICU BED CAPACITY		
		R0=2	R0=2.5	R0=3
PHILIPPINES	2,081	634%	761%	845%
National Capital Region (NCR)	587	1685%	2022%	2246%
Cordillera Administrative Region (CAR)	38	184%	220%	244%
Region I - Ilocos	82	152%	182%	203%
Region II - Cagayan Valley	60	42%	50%	55%
Region III - Central Luzon	190	308%	370%	411%
Region IV-A - CALABARZON	258	574%	689%	765%
Region IV-B - MIMAROPA	10	161%	192%	213%
Region V - Bicol	66	141%	169%	188%
Region VI - Western VIsayas	150	143%	171%	190%
Region VII - Central Visayas	164	252%	303%	336%
Region VIII - Eastern Visayas	43	88%	105%	116%
Region IX - Zamboanga Peninsula	45	71%	85%	94%
Region X - Northern Mindanao	101	60%	71%	79%
Region XI - Davao	147	39%	47%	52%
Region XII - SOCCSKSARGEN	71	78%	94%	104%
Region XIII - Caraga	34	49%	59%	65%
Bangsamoro Autonomous Region in Muslim Mindanao (BARMM)	38	79%	95%	105%

*Figure 2. Projected availability of Intensive Care Unit (ICU) beds at the regional level during peak of the Covid-19 crisis, by UP COVID-19 Pandemic Response Team, as of 20 April 2021***

Alongside this, the averages of the country's health human resource are evidently understaffed, having only 3.7 doctors and 8.2 nurses per 10,000 population compared to the WHO-prescribed ratio of 1:1000 for both hospital staff. Additionally, there is a wide discrepancy in health human resource statistics across the country. For instance, the ratio of doctors in the National Capital Region meets the WHO-prescribed ratio with 10 doctors per 10,000 of the population, while BARMM has 0.8 per 10,000, showing a clear lack of professional doctors in the region. Considering the number of health human resources, peak-time critical COVID-19 cases alone would also require the attention of approximately 21% of the country's health workers, which is over and above the already heavy regular workload of our medical human resources.

REGION	DOCTORS	NURSES	MEDTECH	HOSPITAL BEDS
PHILIPPINES	**3.7**	**8.2**	**1.2**	**6.1**
National Capital Region (NCR)	10.0	12.0	3.0	13.5
Cordillera Administrative Region (CAR)	6.0	14.8	2.0	6.5
Region I – Ilocos	3.8	10.5	1.3	4.8
Region II - Cagayan Valley	3.2	11.4	1.3	5.1
Region III - Central Luzon	3.4	7.2	1.1	5.0
Region IV-A – CALABARZON	2.7	6.3	0.6	5.3
Region IV-B – MIMAROPA	1.8	5.5	0.5	1.0
Region V – Bicol	2.4	7.3	0.9	3.4
Region VI - Western Visayas	2.9	6.8	1.0	5.9
Region VII - Central Visayas	2.9	9.9	1.2	6.6
Region VIII - Eastern Visayas	2.5	6.6	1.3	2.8
Region IX - Zamboanga Peninsula	2.5	9.0	1.0	3.7
Region X - Northern Mindanao	2.7	8.8	0.9	6.4
Region XI – Davao	2.9	6.7	1.0	8.9
Region XII – SOCCSKSARGEN	2.3	7.8	1.1	4.9
Region XIII – Caraga	2.0	7.4	1.0	3.8
Bangsamoro Autonomous Region in Muslim Mindanao (BARMM)	0.8	3.8	0.3	2.7

*Table 2. Healthcare workers and hospital bed statistics per 10,000 population, by UP COVID-19 Pandemic Response Team, as of 20 April 2021***

The current exhaustion of medical resources leads to patients not getting hospitalized, making them lack the necessary monitoring and care they need from health professionals. Individuals affected by COVID-19 but deemed asymptomatic or with mild symptoms often become outpatients or quarantined individuals who are self-isolated in their homes to accommodate the scarcity of resources among healthcare hospitals. Blair et al (2021) aimed to identify the condition of these quarantined outpatients through a prospective cohort study conducted among 118 SARS-CoV-2-infected outpatients. Results indicated that among individuals in the first week of illness, the most common symptoms included weakness/fatigue (65.7%), cough (58.8%), headache (45.6%), chills (38.2%), and anosmia (27.9%). Participants returned to their usual health between 2 to 6 weeks from symptom onset, 66% of them returning by the 4th week. For individuals who were still sick past the 4th week, 10.9% were presented to the emergency department and 7.6% required hospitalization. Findings from this study concluded that symptoms often persist among affected individuals and there is an uncommon but plausible chance that the individual may need to be hospitalized. From such, proper monitoring of affected individuals while situated in their quarantine areas would be beneficial in providing immediate accommodation in such situations of emergency.

With the advent of Internet of Things (IoT), it has gathered a considerable amount of research traction as a new area of study across a wide range of academic and corporate fields, especially in healthcare. By embracing technological, economic, and social potential, the IoT movement is continually transforming present healthcare systems. It has made its impact in a way that healthcare systems are moving from traditional to more individualized systems, making it easier for patients to be diagnosed, treated, and monitored. It proves to be one of the most disruptive technologies in the field of pervasive and ubiquitous computing, working with limited storage and processing capacity, but is centered around reliability, performance, security, and privacy (*Liu et al., 2015*).

IoT devices consist of a network of wireless, integrated, and linked digital devices that can gather, send and store data without the need for human-to-human or human-to-computer interaction. It offers various benefits for expediting and enhancing health care delivery by proactively identifying health issues and diagnosing, treating, and monitoring patients both in and out of the hospital (*Kelly et al., 2021*). This has its uses, particularly in response to the COVID-19 pandemic through providing healthcare institutions and the general populace with a streamlined way of monitoring their condition in relation to their COVID-19 symptoms.

It is from this perspective in which the research forms around the idea of developing a wearable IoT device for the health monitoring of these nonhospitalized patients. This wearable device will act as the monitoring factor for the patients who are in remote and isolated quarantine to give the means to track their condition minimizing the need for physical contact. For the device to be effective, identifying the necessary variables and parameters to implement and measure would be crucial to create a consistent and effective healthcare experience.

1.2 PROBLEM STATEMENT

The research would be tackling the identification of key factors towards the effective development of the wearable IoT device, considering its specifics and feasibility towards being a solution to the remote health monitoring of nonhospitalized COVID-19 patients. This can further be elaborated or measured upon through these specific questions:

- What patient parameters and details should be considered in the development of a wearable IoT device to monitor non-hospitalized and home quarantined patients, considering the patient's past and current condition history, living conditions as a remotely quarantined patient, and patient activity during remote self-quarantine?
- What would be the perceived effectiveness of the IoT device's concept in its purpose of measuring patient health parameters and conditions of nonhospitalized and remotely quarantined COVID-19 patients?
- What recommendations could be given to ensure that the development of an IoT wearable health device is effective in remotely monitoring the situation and health condition of nonhospitalized and remotely quarantined COVID-19 patients?

1.3 OBJECTIVES

With the Covid-19 pandemic being at large, there is still a considerable amount of people being negatively affected by its influences. From such, it has become imperative that the tools utilized to track and assist patients, especially individuals situated in quarantine locations outside of the normal surveillance and control of medical respondents, be more effective and consistent for use.

The aim of this research is to identify, assess, and apply important medical and technological data and insights to figure out and maximize positive development imperatives of an IoT wearable device and its objective towards monitoring the condition of nonhospitalized and remotely quarantined individuals. The researchers will develop the wearable devices guided by these specific objectives:

- To identify the relevant parameters and factors of the human condition to be utilized and adapted for monitoring patients, based on the patient's past and current condition history, living conditions as a remotely quarantined patient, and patient activity during remote self-quarantine
- To determine the appropriate computer science concepts and algorithms, alongside IoT technologies that would serve as the technical foundation for the project's development stage
- To develop a recommendation framework for the IoT wearable device, taking account of the identified essential patient parameters and symptoms, computer science concepts, and IoT technologies, that will

accurately and consistently function to monitor and assist non-hospitalized and remotely quarantined patients

1.4 SCOPE AND LIMITATIONS

This research mainly focuses on the identification, analysis, interpretation, and validation of facts and ideas that will establish the framework for the development of an IoT wearable device for monitoring nonhospitalized and remotely quarantined COVID-19 patients. It will entail the process of assessing and analyzing important aspects essential in identifying COVID-19 among affected patients, the methodologies and techniques utilized in identifying these symptoms, and the application and integration of these ideas with computer science concepts and IoT technology to develop a proof of concept to demonstrate the practical potential or feasibility of developing an IoT wearable device to accommodate the determined situation.

It is beyond the scope of this research to delve into other significant influences and information regarding the COVID-19 situation, such as its post-conditions and impacts on health, the information regarding vaccines and medications, and government and health department contingency actions, although these topics may be stated to a degree for the purpose of reference and comparison. The scope will mainly focus on the concept of COVID-19 emergency response and monitoring control and how it will be integrated into a wearable IoT device.

CHAPTER II

RELATED LITERATURE, FRAMEWORK, AND DEFINITION OF TERMS

2.1 REVIEW OF RELATED LITERATURE

Patient Physical Condition and History

The importance of identifying patient history is crucial for providing the right care during times of medical crisis. Patient history is significant as with more knowledge known about the patient's medical history, the easier it is to provide the most suitable and effective therapy or support for their condition. Medical history of a patient identifies the genetic conditions an individual was born with, past major health complications experienced, and past administered medical drugs or boosters, which would significantly impact the kind or amount of decisions health professionals would have to take to address an ongoing patient issue. Muhrer (2014) states that the historical data of patients also serves a role of protecting patients from extensive and often unnecessary diagnosis, which would lead to cases of misdiagnosis that can threaten the patient's life significantly.

Current experiences with COVID-19 results in affected individuals experiencing numerous health complications that threaten their life. A 2021 study from Elliot et al. identified seven (7) predicative signs of COVID-19 exposure and infection among individuals, which include: (1) loss or change of sense of smell, (2) loss or change of sense of taste, (3) fever, (4) new persistent cough, (5) chills, (6) appetite loss, and (7) muscle aches. The symptoms are found to be also present and perform similarly with infected individuals across age groups, making it practically a universal predictor of COVID-19 infection. According to an article by the CDC (2021), the patient's COVID-19 disease course, degree of sickness, and therapies received should all be included in the history of current illness, as COVID-19 can induce post-COVID conditions to affected individuals. Previously affected individuals can be affected by ongoing symptoms four or more weeks after the first being infected, up to multi organ damage, especially the lungs, and autoimmune conditions, which are cases that can be experienced after a severe COVID-19 infection (*CDC, 2021*).

The CDC (2021) also indicated that the prior conditions that could impact the severity of COVID-19 disease are, including but not limited to, asthma, allergies, chronic obstructive pulmonary disease, interstitial lung disease, chronic kidney disease, diabetes mellitus, obesity, sleep disorders, prior autoimmune disease, mood disorders (e.g., anxiety or depression), trauma and stressor-related disorders (e.g., adjustment disorder or PTSD), hypertension, and migraines, which should be assessed in the past medical history. The social history should include an evaluation of the patient's degree of material and social support and resources (e.g., finances, employment, housing, food access) and their possible influence on the patient's ability to access health and recuperation services. Healthcare providers should assess the patient's present and pre-infection level of activity (e.g., type of job or school activities, activities of daily life) and screen for a potential or known drug use issue.

<u>Living Conditions of the Patient</u>

When the pandemic hit, it brought along a wave of quarantine restrictions that prevented much action for the people under it. In a particular study (*Tee et al., 2020*), it was compared that the Philippines' own quarantine situation has led to a higher amount of mental health distress compared to China. Either way, the presence of the pandemic had greatly affected the mental and physical state of individuals from both locales. In another study by Mattioli et al. 2020, the effects of quarantine took its place on the result of increased deficits of necessary nutrients due to diet changes brought about by the situation and has also brought an increase of risk in cardiovascular diseases due to the advent of the increase of unhealthy lifestyles becoming more apparent within the pandemic restrictions. These characteristics could become more apparent in the situations of remote quarantine where even more restrictions will probably be in place.

Living conditions of Covid-19 patients that are currently in remote quarantine could be subject to reduced availability of a balanced diet, lessened interaction, and communication with health personnel, and ultimately could result in a negative effect on their mental health and on their perception of it. This is supported through delving into more of the study of Mattioli et al. (2020), that showed the prevalence of a more Vitamin deficient diet being undertaken, leading to a lower chance of securing healthy eating during quarantine. These factors could bring more distress to the patient's condition if their effects were to surface at a quick pace on the patient's living condition. This brings in a more risk-prone condition for the patients due to these factors that could overall impact the health monitoring that would be needed to suffice in these situations. UP (2020) had presented in a study that within the country, there are significant low numbers of medical supplies, medical staff, and hospital and ICU rooms that could not suffice for every need of COVID-19 patients should the infection rate rise to and stay at a high pace. Such a situation implies that even the procurement of needs for the remotely quarantined patients are on a significant halt or slowdown, as sources of important health care and supplies they need to supplement their self-quarantine lifestyle are limited or unavailable. This could eventually lead towards higher risk for patients' living conditions, especially for their worsening health conditions due to COVID-19.

Patient Activity during remote self-quarantine

It is a commonly accepted truth that fitness improves people's immune system and helps regulate individuals' weight to stay fit, making clear that the COVID-19 pandemic has altered the lives of all individuals. This pandemic crisis demonstrated that fitness is crucial for people of all ages, and that physical activities and nutrition play a significant part in our lives. According to a study by Castañeda-Babarro, et al. (2020), the confinement and social isolation of COVID-19 may influence usual health behavior. The unprecedented worldwide confinement, of which Spain has been one of the most affected—with severe controls on confinement—may have altered physical activity and sedentary habits because of prolonged stays at home.

Patients who are remotely quarantined are subjected to performing less physical and social activities during their condition, due to the restrictions imposed by being infected by the disease. WHO (2020) on home care indicated that patients with suspected or confirmed COVID-19 cases are to be managed with strict home isolation with the proper home setting, alongside limiting the communications from the outside world, with only the appropriate caregivers being around for the patient. Such limitations may lead to physical and social complications with the COVID-19 patient, due to the disconnect or incapability of performing more of their old usual activities.

IoT Technologies as Health Innovations during the Pandemic

The usage of technology in modern-day solutions increases and becomes more crucial to various sectors including that of health. Wearable technologies have had a huge rise in their usage and benefits towards health-related solutions for Covid-19 together with its capabilities of enforcing health monitoring and social distancing as well as using the machine and AI algorithms in efficient ways but it must always be taken note of that there will be certain socioeconomic factors that will play into making the process of using wearable technology or more specifically its system into accuracy through possible bias or difficulty of measuring said socioeconomic factor (*Amin et al. 2021*). The IoMT (Internet of Medical Things) is a term used to describe the use of IoT in the field of medical treatment. During the COVID-19 pandemic, the IoMT deployed medical devices and applications to give healthcare services to patients in hospitals or at home, as well as important big data to healthcare systems and key governmental sectors (*Abdel-Basset et al., 2021*), and it's the technology surrounding this paradigm that the wearable sensor is going to be based around on. Technology adoption itself has seen a quick and effective transition for health solutions as well as the algorithms behind its systems but because of the focus on major areas for solutions, some specific areas are not much covered yet (*Golinelli et al. 2020*). This means that although the technology for the wearable IoT device has seen its rise, it is not completely effective or known in all areas and must be further studied upon.

The use of health tracking technologies can prove beneficial to the data and overall health monitoring of Covid patients. In a study by Yordanov et al. (2020), they have made a health monitoring system named "Covidom" which provides the users with self-check-up, condition monitoring, and alarms for the health authorities to support in their monitoring and management of the patient's health. Through this, it can be inferred that wearable devices could be able to give a beneficial result as well. The use of sensor data can be paired with symptom data from patients to give a more accurate prediction of any possible Covid case and it could also be indicative for tests (*Quer et al. 2021*).

Another smart system that was developed in a research by El-Din et al., (2020) monitors persons suffering from this condition by implementing several sensors that capture numerous aspects of their patients every second. The patient's temperature, respiration rate, pulse rate, blood pressure, and time are among the data measured. The suggested approach saves lives and enhances decision-making in critical situations. It suggests combining artificial intelligence and IoT to quarantine and create judgments in a variety of circumstances. It allows for remote patient monitoring and ensures that patients receive medications and comprehensive health care without anyone becoming ill with this disease.

The assessment of the factors to be measured by the wearable IoT device for health monitoring that specifically addresses COVID-19 patients for accurate results is essential. Hasty et al. (2021), conducted a study that proved that Heart Rate Variability (HRV) values measured through a wearable device would be able to serve as a factor for the identification of COVID-19 development within the patient through an acute inflammatory response. In another study (*Hirten et al., 2021*), longitudinal HRV values were found to be accurate predictors of Covid-19 in both symptomatic and asymptomatic patients. A study by Xu et al. (2020), takes an approach to continually monitor the development of COVID-19 patients who were isolated at home through a telemedicine system. The technology assisted patients in self-assessing their symptoms and updating the multidisciplinary team via a telemedicine form kept on a cloud service, which the multidisciplinary team used to make treatment decisions. Its system is based on three flags (red, yellow, and green), and if a patient's condition worsened (e.g., repeated and persistent fever >38.5 degrees Celsius, cyanosis or CT image deterioration >50 percent within 48 hours), or if their mental state scores continued to decline, the patient was flagged as "red," and the multidisciplinary team decided that the patient should be admitted to the hospital for treatment. This gives insight as to what actions to take depending on the patient's concurrent condition.

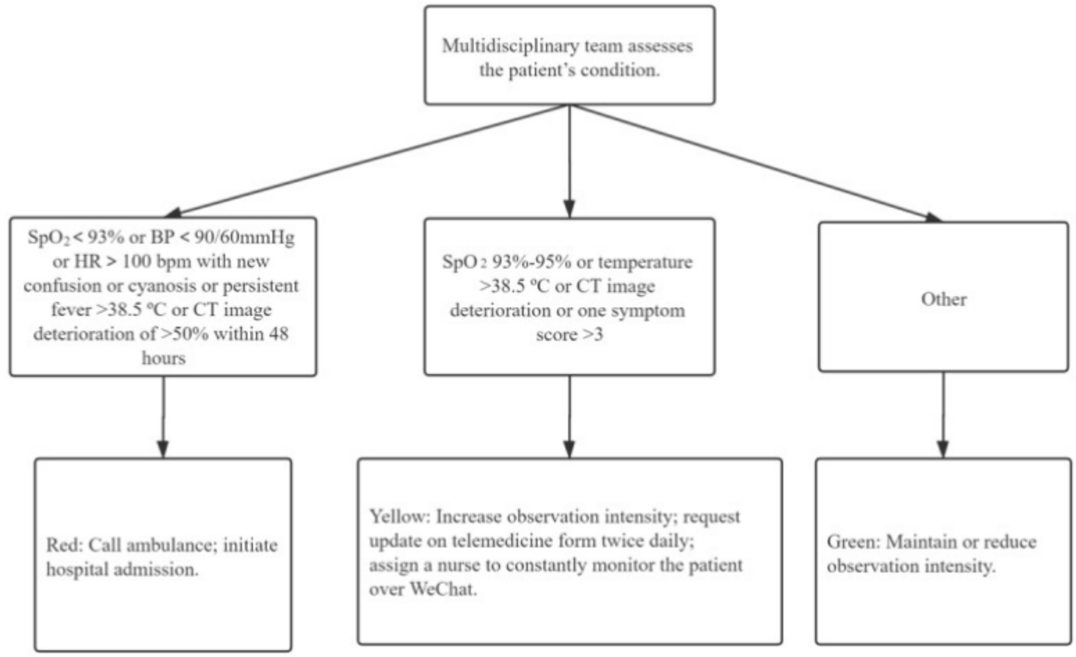


Figure 3. Decision tree of patient treatment for MDT based on patients' condition updates via the eCounseling system by Xu et al. (2020)

In determining the use of the wearable sensor, the framework and functionalities must also be thought of. Ullah et al. (2021), in their study shows the use of a geofencing framework together with a wearable health sensor for Covid patients which not only tracks the health of the patient but also has implications on social distancing and monitoring due to the geofencing use. A study by Singh et al., (2020) proposes a wearable IoT device that considers cost, namely the IoT-Q-Band, with a bundled mobile application and cloud-based monitoring system, provides a scalable way to detect the absconding COVID-19 quarantine subjects and track them in real-time. The wearable band is worn by a quarantine subject either on the hand, arm, or leg and wirelessly connected to the mobile application via a Bluetooth link. The processing unit (ESP32 [26]) of the band repeatedly senses at specific time intervals whether the band has been tampered. After sensing, the band transmits the status (a byte of data) to the mobile application at every 2 minutes interval. The subject will be registered to the IoT-Q-Band system only by concerned medical authority and responsible for setting the duration of the quarantine and authenticating the details.

However, it is not wearable sensors in these forms that are only beneficial, other technological solutions for COVID-related problems have surfaced. An example of which was when a study showed that Robotic Process Automation (RPA) robots were able to assist various sectors allowing automation of tasks and data gathering to improve upon the services during the COVID lockdown (*Doğuç, 2021*). A study published in 2021 proposed a three-layered architecture in developing an IoT based wearable device to monitor remote-quarantined patients of COVID-19 and the wearable IoT layer is responsible for managing the gathering of two types of data: location-based GPS sensor data and health care data for COVID-19 symptoms such as temperature, heart rate, oxygen saturation (SpO2), and cough count. Depending on the application design, this layer consists of a microcontroller that receives data from associated sensor modules and is controlled by an IoT core. Using a GPS sensor, the IoT-designed application collects all the geographical data of various patients, identifies the patient's position in real time, and saves the information in the cloud (*Al Bassam et al., 2021*).

Synthesis:

The researchers and authors of the following related literature and studies present the significant impact that the pandemic issue of COVID-19 has brought to current modern society. Social, physical, psychological, mental, and economic influences have proved to greatly influence the dynamics of the situation, making the creation of intelligent and technological solutions essential to address the ever-expanding and complicated COVID-19 situation. The gathered literature and studies provide strong implications for the use of IoT-related devices or related concepts to sensor data usage in supporting health management functionalities related to COVID-19 and remote health monitoring. From such, this paper will delve into incorporating the valuable information and findings covered and concluded on by these studies to assess and develop recommendations for the development of an IoT wearable device aimed to provide a smart solution to provide assistance on COVID-19 regarding nonhospitalized and remotely quarantined patients.

1.2 CONCEPTUAL FRAMEWORK

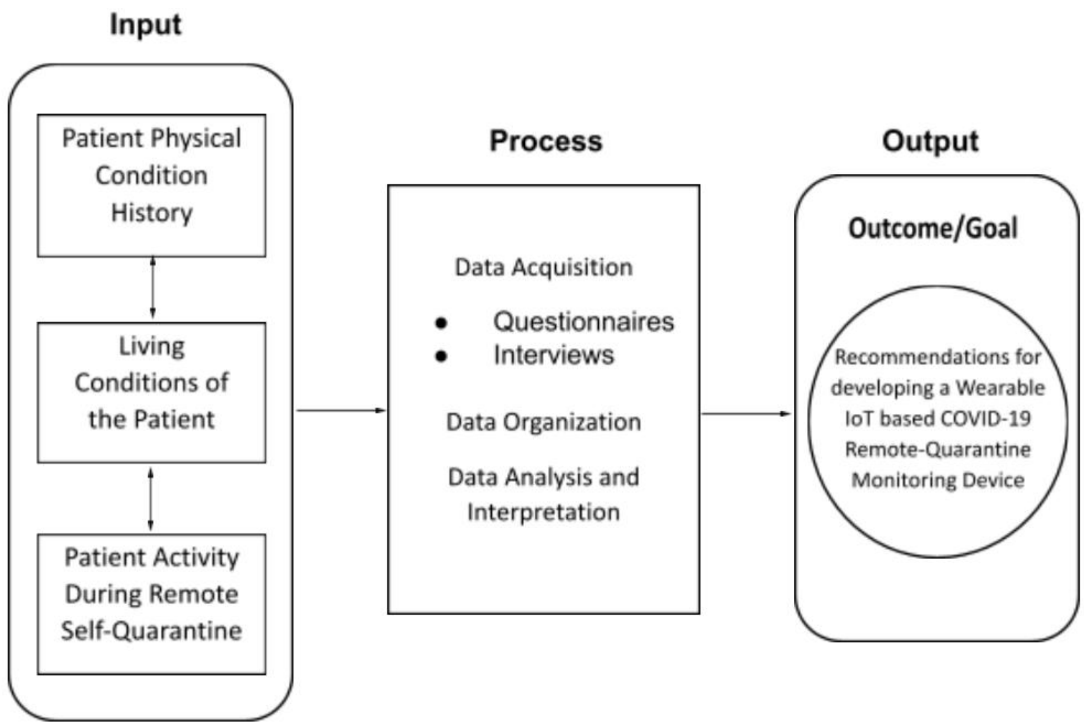


Figure 4. The Conceptual Framework for Wearable IoT based COVID-19 Device to Monitor the Condition of Nonhospitalized and Remotely Quarantined Patients

Figure 4 depicts the different variables that will be considered in creating the recommendations for developing a viable wearable IoT device to monitor nonhospitalized COVID-19 patients, leading to determine what parameters, technology to use, and computer science concepts to apply in the development of such device. This model depicts three layers ordered from left to right to reflect the flow of the process, as shown by an input-process-output diagram, and the connection of each of the processes. According to the model, three factors would be necessary for deciding what variables to take into consideration for accurately monitoring a remotely quarantined patient's condition regarding their COVID-19 symptoms.

The first variable, patient physical condition history, is necessary to determine the symptoms that would leave the patient more vulnerable to COVID-19's symptoms which may aid in monitoring them. The history of present illness should include the patient's COVID-19 disease course, degree of sickness, and treatments received. This also includes the factors which determine the patient's susceptibility to COVID-19 symptoms such as age, past medical history, etc. The large range of signs and symptoms identified in patients with COVID-19 thus far necessitates a comprehensive approach to evaluate the patient's condition history. This is an important part of the development of the device to find which patients may require more intense monitoring.

One other important variable to consider is the living conditions of the patient. There are many factors at play in determining one's susceptibility to disease, overall health, and quality of life. These factors may be a contributor to exacerbating illness, but also conversely, strengthen one's health. Such examples of these are housing conditions, the disposition to drink alcohol or smoke, level of physical activity, etc. These considerations assist the device in accounting for these factors.

And lastly, patient activity during remote self-quarantine. The general populace's way of life has been significantly altered by COVID-19. And this break from regular life may cause some complications with oneself either mentally or physically. Many healthcare specialists stress the need of keeping connected during the pandemic and recommend making time for social relationships, whether online or in person. It is thus important to consider this factor when developing the device for knowing the patient's mental or physical activity to provide them with the appropriate tools to monitor this facet of their health.

1.3 DEFINITION OF TERMS

This section presents the technical terms that were used in this research, showing the conceptual and operational definitions of each term.

- Algorithm - a set of steps that are followed to solve a mathematical problem or to complete a computer process.
- Centralized Digital Platform - refers to the platform that the device will use that contains all the relevant functionalities for monitoring remotely quarantined patients.
- Epidemiological - relating to a branch of medical science that deals with the incidence, distribution, and control of disease in a population
- Geofencing - the use of GPS or RFID to create a virtual boundary for geographic use.
- Heart Rate Variability - the variation of time intervals between heartbeats.
- IoT - an acronym for Internet of Things; the networking capability that allows information to be sent to and received from objects and devices using the Internet.
- Pandemic - occurring over a wide geographic area, such as multiple countries or continents, and typically affecting a significant proportion of the population, which in this paper's context, refers to the COVID-19 pandemic.

- Parameters - any of a set of physical properties whose values determine the characteristics or behavior of something e.g., health criterias of the patient relating to their condition in regards with their COVID-19 infection.
- Remotely Quarantined - pertains to patients who are conducting quarantine in their homes or are not currently quarantined in a hospital setting.
- Robotic Process Automation - software designed and aimed for automating business processes and digital tasks.
- Smart systems - systems that use the functions of sensing and smart technologies for decision making.
- Telemedicine - the use of electronic channels and telecommunications in providing health services.

CHAPTER III

METHODOLOGY

3.1 RESEARCH METHODOLOGY

This chapter presents a description of the research design selection and description of respondents, research instruments, data collection procedure and statistical treatments used.

Research Design

Assessing the patient parameters that the device uses and determining the right recommendations for an effective IoT wearable health device requires the use of a mixed-method research. Such a research design provides a comprehensive view rather than solely a quantitative or qualitative research since it incorporates the benefits of both methods. It is a novel approach that is quickly gaining traction among health researchers, particularly in health services research (Tariq & Woodman, 2013), and it may prove to be useful in this research paper.

The mixed method approach utilizes a convergent parallel design to grasp an in-depth understanding of the topic, by administering the use of quantitative and qualitative elements concurrently in the same phase of the research process. In this research process, both methods are considered equally through performing initial independent analyses, in which results would undergo joint interpretation. This design enables better understanding of the research topic through the analysis of data between two different method perspectives that provides complementary results, reinforcing the validity of the study (Creswell & Pablo-Clark, 2011).

Triangulation of methods will be performed to further the validity and corroboration of the research study, encouraging a direct, comparative approach with both quantitative and qualitative results. Each data will be analyzed independently from each other, which would then be integrated and re-analyzed at a single phase with equal use and comparison of both methods.

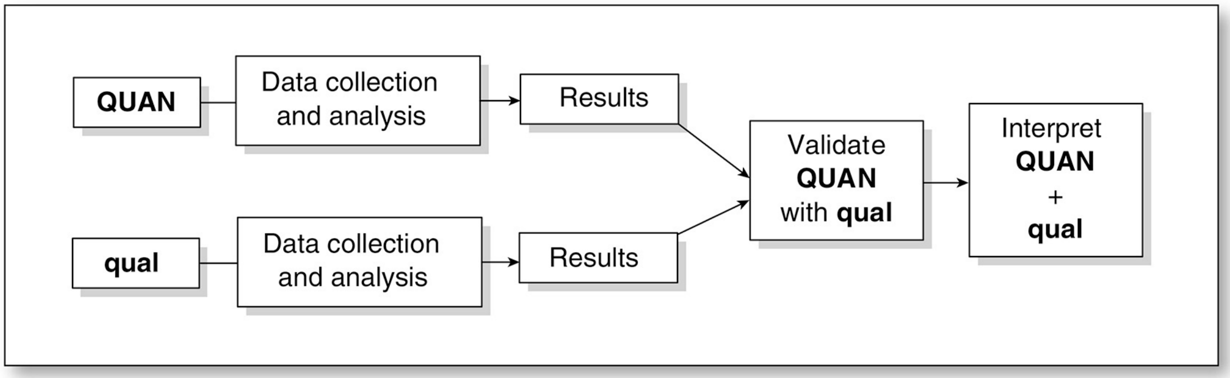


Figure. 5 Convergent Parallel Design

Respondents of the Study

The research applied a non-probability, purposive, convenience sampling technique, in which the samples chosen through this design were selected by their availability, proximity, and accessibility from the researchers. Non-probability sampling utilizes non-randomized methods to get the sample, in which instead of being randomized, participants are selected because they are easy to access. Purposive sampling is a type of non-probability sampling in which participants are chosen with a specific purpose relating to the study. Convenience sampling is another type of non-probability sampling is another non-probability sampling in which participants are chosen as per the researchers' own convenience (*Showkat and Parveen, 2017*).

With this sampling method, a minimum of one hundred (100) individuals with recent or past COVID-19 history that were nonhospitalized or remotely quarantined at some point of their condition would be conveniently selected to participate in quantitative data research, conveniently selecting 50% female and male respondents each. Having one hundred (100) respondents allows for a 10% margin of error with a level of confidence of 95%, which is considered to be a minimum for a survey research with limited resources (*Delice, 2010*). Furthermore, six (6) to twelve (12) respondents who are specifically working in the medical field would be conveniently selected to participate in short qualitative data gathering. This number of respondents for a qualitative study is recommended to achieve the maximum thematic saturation out of a minimal number of respondents (*Guest et al, 2006; Fugard and Potts, 2015*). The stepwise inductive thematic analysis of 60 in-depth interviews among female sex workers in West Africa from Guest et al (2006) research concluded that 70% of all 114 identified themes were already stated within the first six (6) interviews, and 92% were identified within the first twelve (12) interviews, concluding that 12 interviews is already enough for gathering most of the qualitative themes from respondents.

Research Locale

The locale in which the quantitative and qualitative collection for the study will be conducted mostly within Lipa City, Batangas, but the respondents can also be taken within different places within the country, assuming they could be conveniently interacted with, to increase the population choices on choosing samples, for the convenience of data collection when needed. All the respondents will be interacted through online means.

Research Tools and Instruments

To quantitatively measure the patient's physical condition, living conditions, and patient activity during remote self-quarantine, the study will adapt a questionnaire specifically made for the study, following multiple choice and Likert Scale type questions with four subtopics: (1) patient's physical condition history, involving past illnesses history and COVID-19 symptom experiences, (2) living conditions of the patient during the remote self-quarantine, (3) patient activity during remote self-quarantine, and (4) perceptions of an IoT wearable COVID-19 health device for nonhospitalized individuals. The Likert Scale questions are structured with the following measures: 1 - strongly disagree, 2 - disagree, 3 - agree, 4 - strongly agree.

For the quantitative result analysis, each subtopic and its respective items will be described through the usage of frequency distribution statistics. Items per subtopic will also be ranked according to their frequency, to highlight significance in item responses relating to the respondents. The weighted mean of the Likert Scale results will be calculated and will be given appropriate verbal interpretations according to the value. The Likert Scale's weighted mean values will use the following basis for research analysis results: the range of 1.00 – 1.49 for strongly disagree; 1.50 – 2.49 for disagree; 2.50 – 3.49 for agree; and 3.50 – 4.00 for strongly agree.

To determine and attain insights relating to the COVID-19 situation and its influence toward the patient's physical condition, living conditions, and patient activity during remote self-quarantine, online interviews will be performed by the researchers with six (6) to twelve (12) respondents who work in the medical field. The session will be facilitated by the researchers, who will interview one individual each per session while performing the necessary documentation of the whole interview session. Most questions given will tackle insights regarding patient's physical condition, living conditions, and patient activity during remote self-quarantine, with one question involving their expert opinion or perception regarding the concept of an IoT wearable COVID-19 health device for monitoring nonhospitalized individuals and its practicality.

For the qualitative results analysis, a transcription grid will be formed for each question, which will undergo objective coding and analysis. Thematic analysis will be performed to pinpoint and examine the key points and patterns within the data, which will be studied and grouped accordingly to form a general theme.

Triangulation of data will be utilized for further validation as results accomplished independent analysis and interpretation. The qualitative and quantitative results will be integrated to reinforce the data gathered from two separate methods. Related literature and studies will be utilized to establish soundness of data results, and to find connections, conformity, or contradictions among findings.

Data Gathering Procedure

The researchers will personally organize and administer the distribution of the research instruments to the respondents through online mediums, with social media platforms for quantitative research respondents, and through social media, email, and google meet for qualitative research respondents. The quantitative questionnaires will be given through Google Forms, while the qualitative questions will be asked through the interview medium preferred by the selected respondents. The respondents will be given prior knowledge about the study and its significance, as well as the appropriate letter of consent, before making them participate in the data gathering process.

Ethical Consideration

Ethical considerations will be observed in the research paper. Respondents from the locale will be first asked for permission through letters of consent before the data gathering process. The letter of consent will provide the respondents with information regarding the nature and purpose of the study and ensure that anonymity will be assured and kept. All information incorporated in the study will be maintained and kept true, devoid of any kind of deception and falsification. Any forms of affiliation, as well as possible conflicts of interests, are declared in this study, with no exceptions.

References:

Blair, P. W., Brown, D. M., Jang, M., Antar, A. A., Keruly, J. C., Bachu, V. S., ... & Manabe, Y. C. (2021, February). The clinical course of COVID-19 in the outpatient setting: a prospective cohort study. In *Open forum infectious diseases* (Vol. 8, No. 2, p. ofab007). US: Oxford University Press. https://doi.org/10.1093/ofid/ofab007

Castañeda-Babarro, A., Arbillaga-Etxarri, A., Gutiérrez-Santamaría, B. & Coca, A. (2020). Physical Activity Change during COVID-19 Confinement. *Int J Environ Res Public Health*. 17(18) doi: 10.3390/ijerph17186878. PMID: 32967091; PMCID: PMC7558959.

Centers for Disease Control and Prevention. (2021). Patient History and Physical Exam. Retrieved January 10, 2022, from https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-care/post-covid-workup.html

Centers for Disease Control and Prevention. (2021). Post-COVID Conditions. Retrieved January 10, 2022, from https://www.cdc.gov/coronavirus/2019-ncov/long-term-effects/index.html

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Delice, A. (2010). The Sampling Issues in Quantitative Research. *Educational Sciences: Theory and Practice*, *10*(4), 2001-2018.

Fugard, A. J., & Potts, H. W. (2015). Supporting thinking on sample sizes for thematic analyses: a quantitative tool. *International Journal of Social Research Methodology*, *18*(6), 669-684.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field methods*, *18*(1), 59-82.

Janke, A. T., Mei, H., Rothenberg, C., Becher, R. D., Lin, Z., & Venkatesh, A. K. (2021). Analysis of hospital resource availability and COVID-19 mortality across the United States. *Journal of Hospital Medicine*, *16*(4), 211-214. https://doi.org/10.12788/jhm.3539

Kelly, J. T., Campbell, K. L., Gong, E., & Scuffham, P. (2020). The Internet of Things: Impact and Implications for Health Care Delivery. Journal of medical Internet research, 22(11), e20135. https://doi.org/10.2196/20135

Liu, Y., Dong, B., Guo, B., Yang, J., & Peng, W. (2015). Combination of cloud computing and internet of things (IOT) in medical monitoring systems. *International Journal of Hybrid Information Technology*, *8*(12), 367-376.

Muhrer, J. C. (2014). The importance of the history and physical in diagnosis. *The Nurse Practitioner*, *39*(4), 30-35.

Sen-Crowe, B., Sutherland, M., McKenney, M., & Elkbuli, A. (2021). A closer look into global hospital beds capacity and resource shortages during the COVID-19 pandemic. *journal of surgical research*, *260*, 56-63.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7685049/

Showkat, N., & Parveen, H. (2017). Non-probability and probability sampling. *Media and Communications Study*, 1-9.

Tariq, S., & Woodman, J. (2013). Using mixed methods in health research. *JRSM short reports*, *4*(6), 2042533313479197. https://doi.org/10.1177/2042533313479197

UP COVID-19 Pandemic Response Team. (2020). Estimating Local Healthcare Capacity to Deal with COVID-19 Case Surge: Analysis and Recommendations. Retrieved from: https://up.edu.ph/estimating-local-healthcare-capacity-to-deal-with-covid-19-case-surge-analysis-and-recommendations/

World Health Organization. (2021). Classification of Omicron (B. 1.1. 529): SARS-CoV-2 Variant of Concern. Retrieved from: https://www.who.int/news/item/26-11-2021-classification-of-omicron-(b.1.1.529)-sars-cov-2-variant-of-concern

World Health Organization. (2020). *Home care for patients with suspected or confirmed COVID-19 and management of their contacts: interim guidance, 12 August 2020* (No. WHO/2019-nCoV/IPC/HomeCare/2020.4). World Health Organization.

World Health Organization. (2021). COVID-19 weekly epidemiological update, 14 December 2021. Retrieved from: https://www.who.int/publications/m/item/weekly-epidemiological-update-on-covid-19---14-december-2021

Xu, T., Pujara, S., Sutton, S., & Rhee, M. (2018). Peer reviewed: Telemedicine in the management of type 1 diabetes. *Preventing chronic disease*, *15*.