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Development of a Safe and Smart Sensor for Medical Center Environments

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Annotation: In this study, an IoT-based, smart healthcare monitoring system has been developed to monitor patients' basic health signs and room conditions in real-time. This system can relay information about room temperature, heart rate, and carbon dioxide and monoxide presence in a room. It can simultaneously monitor the vital signs of multiple patients. In case of any abnormalities in either of the sources, the concerned medical team will be alerted continuously until the error is resolved by recalibrating the sensor. The monitoring unit can be implemented either in hospital environments or in-house medical treatment. The whole scheme works properly, with minimal power consumption and negligible error in data gathering when the prototype is experimented with .

The concept of smart buildings has emerged rapidly over the last few decades, and smart buildings are being embraced by developed countries worldwide. However, until recently, developing countries were still stuck with traditional buildings and environments. With the proliferation of various modern devices and the recent trend of global automation, developed countries are advancing towards keeping their environments non-redundant and safe for people. Smart buildings can include homes, offices; shopping malls, hospitals; and other excessive public buildings that can gather information about their environment using various sensors and thereafter take appropriate

actions automatically, with minimal human involvement, which makes such buildings smart when compared to ordinary buildings.

Keywords: IoT, Sensor, Monitoring, Telemedicine, Arduino, RaspberryPi, ZigBee, Smartsensor, Healthcare, Safety, Humidity, Temperature, Gas, Security, Wireless, Algorithm, Microcontroller, Deployment, Privacy, Efficiency.

1. Introduction

Healthcare monitoring system in hospitals and many other health centers has experienced significant growth, and portable healthcare monitoring systems with emerging technologies are becoming of great concern to many countries worldwide [1]. The advent of Internet of Things (IoT) technologies facilitates the progress of healthcare from face-to-face consulting to telemedicine. Sensors with wireless technology and different protocols are being used to monitor patients in real-time, and cloud-based services are used to store and retrieve the data. In many existing systems, only temperature or heartbeat rates are monitored.

In this research work, a smart healthcare system in IoT environment is proposed that can monitor a patient's basic health signs as well as the room condition where the patients are now in real-time. In this system, five sensors are used to capture the data from hospital environment named heart beat sensor, body temperature sensor, room temperature sensor, CO sensor, and CO2 sensor. The data from the hospital environment is automatically sent to a cloud using Wi-Fi feature of the Arduino board. The prior arrangement is supervised using an HTTP web portal which can be used by doctors and other medical staff of the hospital. This proposed system monitors various conditions and provides alerts when any condition goes beyond the threshold value. An alert notification is also sent to the responsible person through email and the HTTP web portal.

Qualitative or binary analysis on the environment is implemented. All the healthcare monitoring and data gathering operations are done using this workstation. A microcontroller, Wi-Fi module, and sensors are used at the remote ends of the system to gather data from the environment. The sensor data can provide several information and hence checks the effect of the parameter on the human body. Arduino UNO is used in this proposed system because it itself is a microcontroller that can interface with a large number of sensors and can communicate with other devices and modules. The error percentage of the developed scheme is within a certain limit for each case. The condition of the patients is conveyed via a portal to medical staff, where they can process and analyze the current situation of the patients. The developed prototype is well suited for healthcare monitoring that is proved by the effectiveness of the system. [2][3][4][5]

2. Background

To ensure the compliance with new health regulations and overall better patient care, many healthcare centers are adopting new designs, improving indoor air quality and upgrading existing structures with high-efficiency, reliable and better construction materials. In addition to improved design, upgrade and new buildings; medication therapy management, usage of different tools and technologies, sensor technology and telemonitoring can also improve adherence to medication. The objective of this work is to create a prototype for sensor monitoring device that could provide smart care in medical environments. First parts of the work discuss existing rules and regulations of healthcare environment monitoring mechanisms and the areas that could utilize sensors, while the latter parts focus on the underlying mechanisms of the prototype system, usage of sensors in place and production of sensor based medical environment monitoring device [1].

Cheap and efficient wireless communication module that would easily embed in patient environment and provide real time monitoring has become one of the most demanding and challenging platform for researchers related to innovative healthcare monitoring. Wireless sensor networks are playing a more dominant role such as ECG, temperature, pulse and sound processing nodes, and recent developments of miniaturized low power sensors improve operational longevity across conventional wired systems. In this work a novel wireless e-Health monitoring based on bio sensor architecture in 802.15.4 communication range is presented. All the processed data can be viewed by either an internet network camera or an internet camera phone. The experimental results have been seen good coverage of the proposed nodes and operating distance could cover significantly larger area than with Wi-Fi. Work is needed in optimizing the power consumption and detecting more target living species to the systems or adopting alternative eco-friendly bio-sensors [6].

3. Literature Review

This Smart Home technology is meant for smart healthcare monitoring for aging. The design, requirements, and architecture of the system are described. Users can access the call-centre in a variety of ways. The patient management module is a web-based application running on a Windows Internet Information Server. It interfaces to the CCMC's central database server using Active Server Pages (ASP) technology. Besides hand-held devices, health professionals can access the call-centre through the Internet from other computers anywhere in the world. It handles the patient's clinical information. Moreover, it is a tool for cooperation among healthcare professionals, in which they can write their notes. Accessing the window will show the clinical data with right to write by authorized health professionals only.

The home visit unit is a laptop computer linked to the CCMC by mobile phone technology, which supports the home visit activities by health professionals. A normal laptop computer with Windows software, laser eye disk, and Internet connection can be used as this unit. For the patients requiring closer follow-up, the Patient Units become the preferred option. These are initially stationary units needed for the five wired sensors: blood pressure, pulse oximeter, weight, blood glucose, and cardiogram and those collected using a portable laptop computer with Bluetooth tags that are needed for the fall detector Zigbee node and Health Buddy transceiver. The Patient Unit receives information from the sensors, running the sensor specific Data Acquisition Module and then sends processed data to the CCMC.

This will be a smart home where a smart home medical monitoring system collects critical measurements of electrocardiogram (ECG), blood pressure (BP), pulse, glucose, and weight. The architecture of the system is based on the integration of smart state-of-the-art sensors, Bluetooth transceivers, mobile phones, and networks. A Smart Home medical monitoring system can help elderly residents avoid or delay institutional care. The goal is to increase such residents' independence and quality of life, allowing in-home and out-of-home monitoring for abnormalities and emergencies [7].

3.1. Existing Sensor Technologies

Sensors are electronic devices that detect a physical quantity such as temperature, pressure, or loudness and convert it into an electronic signal. A sensor is a device that mimics the natural senses and collects data about the property or quality of sensed objects, converting collected data into physical values for further processing by the control system, sending these processed data to the actuators to improve system performance. On the contrary, sensors are devices that deliver information about the output of a physical process. Smart sensors are more advanced; they go beyond measuring physical quantities. They comprise basic sensor functions and built-in algorithmic capabilities, including filtering, compensation, self-checking, and diagnostics algorithms. They achieve data processing and measurement functions previously reserved for other devices, simplifying system architecture and increasing reliability. Sensors measure the property of sensed objects, both actively and passively. They can be classified according to their bearing or the nature of their measurement. Based on how they interact with the measured source, sensors can be intrusive, non-intrusive, minimally invasive, or invasive. Non-invasive sensors are desirable; they are less costly, require less maintenance, are accessible and user-friendly, and allow for more repeated measurements with less distress for the patient [7].

The probe sensor can detect the temperature, humidity, and air quality of the patient's room and also monitor the heart rate, body temperature, and motion of the patients. Its function is to monitor the room condition as well as the patient's basic conditions and if any critical changes occur; it is sent to a central hub with the help of a wireless network. A smart healthcare monitoring system in hospitals and healthcare centers has witnessed considerable volumetric growth [1]. Also, portable health monitoring systems have gained importance among the world's people. An IoT system is proposed to monitor a patient's identification, basic health signs, temperature, humidity, and CO and CO2 level of his/her room in real time using heartbeat, body temperature, temperature, humidity, CO, and CO2 sensors. The systems are being run on the portable Raspberry Pi 3B module. The condition of the patients is conveyed through a web portal to the medical staff for further processing and analysis. The prototype seems to be effectively suited for healthcare monitoring in hospitals and healthcare centers.

3.2. Applications in Healthcare

This paper presents a safe and smart human motion and physiological signal detection sensor that can be used in medical centers and healthcare environments. A sensor node, consisting of a 6-axis motion MEMS sensor and a heart rate sensor, detects the human action and enables transmission of this activity to the cloud server via the LoRaWAN infrastructure. A remote server manages the cloud server and connected devices such as sensor nodes and gateways and analyses the received signal. The sensor node can detect a total of eight different key actions, with three states for heart rate sensor detection. The usable distance of the sensor node is more than 100 m in an open area. The ability to wirelessly monitor human motion anywhere has benefits in various industries like wearable devices and telemedicine.

Telemedicine is a significant technological trend that provides efficient, quality healthcare to patients and assists them within and outside hospital walls. Many hospitals have already adopted telemedicine services, which deliver hospital services like e-notice, e-prescription, e-receiving, and e-lab reports [1]. Health monitoring systems are being developed with low-cost, portable devices that can monitor human health by detecting vital signs and sending them to a remote server for analysis. Hospitals and medical centers also need to maintain the health and safety of the places where patients, doctors, nurses, and visitors stay, especially after the COVID-19 pandemic. Designing and implementing a system that can wirelessly monitor vital signs and environmental conditions of healthcare centers is more challenging and demanding.

The healthcare monitoring systems have attracted burgeoning research interest in recent years. With the advancement of emerging technologies, a significant growth of potability and portable healthcare monitoring systems can be observed worldwide [6]. With the emergence of electronic health record (EHR), health monitoring systems are more likely to shift from face-to-face consulting to telemedicine, which can provide healthcare services to a broader patient population with a decrease in area restrictions. As telemedicine systems evolve, patients can avoid overcrowded hospitals and contact doctors at home. The development of the Internet of Things (IoT) has proven to be very effective for telemedicine and health monitoring systems. Sensors in the telemedicine system can be used to collect vital signs from patients, which can send them to distant hospitals for analysis and context aware actions.

3.3. Safety Standards and Regulations

This section provides an overview of the safety standards applicable to the smart sensor defined in previous sections, divided into hardware and software safety.

Treatment of Hardware Safety. Hardware safety covers regulations from mechanical, electrical and electromagnetic, environmental, and usability safety perspectives, as well as data transfer reliability.

Mechanical Safety. The smart sensor must ensure that its mechanical components do not expose the user to exogenous forces, either during normal and acceptable operating conditions or in foreseeable fault conditions and when subject to abnormal conditions.

Besides providing test results demonstrating compliance with mechanical safety, design considerations must also demonstrate that: mounting and packaging do not provide any risk of injuries when manipulated; exposure to exogenous forces does not affect the overall function of the smart sensor; the smart sensor will not generate any dangerous events or excessive durability defects during transportation.

Electrical Safety. The smart sensor must ensure that its electrical components do not expose the user to electrical hazards, either during normal and acceptable operating conditions or in foreseeable fault conditions and when subject to abnormal conditions.

Besides providing test results demonstrating compliance with electrical safety, design considerations must also demonstrate that: electrical floating is guaranteed; measures to avoid degradation of electrical safety in case of partial functional faults are defined; and at least some potential electrical hazards are removed through both hardware and software redundancies.

Electromagnetic Compatibility Safety. The smart sensor must comply with electromagnetic compatibility constraints to ensure that: the presence of electric, magnetic, and electromagnetic signals does not impair safety functions; electromagnetic signals from the smart sensor and from ancillary electrical/ electronic components do not impair the overall function of such devices; proper concentrated and radiated noise filtering measures are adopted based on target markets.

Testing is usually performed by manufacturers on test scenarios based on standards. Before testing, two documents must be accompanied: a description of the smart sensor's grounds, including the basic configuration of the sensor; and a description of all ancillary electrical/electronic components and interfaces at signal and power supply levels. [8][9][10]

4. Design Requirements

Environmental monitoring in medical centers is essential for efficient management, maintenance, and hazard mitigation, where safety, quality, and regularity are crucial. This technology has been considered as close as possible in patient surroundings. Currently, temperature and humidity measuring instruments are used for environmental monitoring in patient circumstances. Besides, a healthcare management system has been developed for communicating with various sensors and measuring new vital signs that are scarcely available in a hospital setting. The main aims of the system are to get significant and safe vital parameter data and to provide precise environmental parameter data.

To accurately measure environmental parameters, a temperature and humidity sensor should be constructed using a digital signal for reducing distortion errors. Because the discharge of gas, liquid, and dust can occur depending on the equipment type in the medical center, they should be detected for remoteness management, where its visibility and flexibility are important for broadband managing criteria. The designed device had better have an adequate number of sensors installed to obtain a number of objective data of measuring vital environmental information.

For flexibility, wireless communication was applied to get rid of the hazards of littering wires. To ensure safety, the designed device must meet a mandatory industrial network and security standards. Visual latency and handling power consumption should be kept as low as possible for fast management of hazardous situations while the sensor counts increase, which can be the result of the design difference described in earlier.

The designed sensor provides the needed safety, flexibility, and efficiency, delivering streams of data from a medical center environment to decision makers. These data can be visualized in several ways that can improve decision making. The proposed tool promises to solve better environmental management problems for medical centers compared with existing solutions. There are different sensors in a medical center environment, with each sensor type contributing its own value. The early stage of the analysis process is the gathering of data from our sensors that is not easily accessible. This is precondition for efficacy and secure management. [11] [12]

4.1. Functional Requirements

Smart devices based on the IoT paradigm have received considerable academic and industrial attention in recent years. Research showed that many smart devices based on the IoT are emerging for consumer needs, such as smart homes, smart vehicles, smart boxes, smart energy, and smart cities. Sensors are critical components of smart devices and appliances. Modern smart devices usually require multimodal sensors to monitor various physical, chemical, and biological parameters. Due to the increased demand for multi-sensor-based smart devices, researchers and engineers are developing integrated multi-sensor solutions to significantly reduce the size, weight, and power consumption of the smart device. In this regard, many electronic systems-on-chips (SoCs) with integrated multi-sensor functionalities have been introduced for consumer needs. Likewise, cloud- and mobile-based computation, communication, storage, and analysis technologies have gained noteworthy attention for consumer electronics and healthcare devices based on the IoT [11]. However, a smart medical sensor device that simultaneously provides various health parameters without compromising safety, convenience, and timeliness has not yet been developed.

The proposed smart sensor is envisioned to make it safe, secure, non-invasive and easy to use. The wearable device will be designed to monitor health parameters of ambulatory patients and send the parameters to the monitoring device wirelessly. The proposed wearable device identifies the potential problems with the health parameters and generates alarms for the problems. An application will be designed for mobile portable devices such as smartphones, tablets and laptops that can communicate with the wearable device and display the health parameters. The mobile application maintains a patient database for follow up purpose and displays the graphical representations of the health parameters to the physicians for analysis. Alerts will be generated for the patients’ health upon data mining techniques performed on the server using machine learning algorithms. Laboratory environment monitoring and analysis of the laboratory environment is proposed to support the IoT basis of this project [12]. The design of innovate ideas will include the development of cloud-based devices which is user friendly GUI with user access controls for data storage and retrieval of laboratory environment analysis. Building a 50-foot-long conference bridge for meeting with the clients and stakeholders on several occasions could also be part of engineering effort.

4.2. Safety Requirements

As healthcare systems are becoming more integrated, sensing control systems that monitor various parameters (e.g., health, environmental, and usage) and act accordingly for surveillance and prompting the focus of smart healthcare [13]. Low-cost, low-power, and versatile sensor nodes that can be mounted on every equipment/area to collect and control data are needed for this applications. Closed and robust electronic design concepts, automatic and adaptable initial firmware configurations, smart reasoning algorithms, and user-friendly cloud interface/platform architectures with features that can be extended later are the main important aspects of this category of applications. Integrated design multi-functional sensor nodes (sensing, control, processing, wireless communication, storage) with an advanced real-time on-cloud integrated architecture that displays them at ausrp platform API like web-based application have been proposed. The proposed architecture is capable of supporting a greater number of nodes, databases, and future artificial-intelligence-supported advanced reasoning algorithms. Each sensor node can determine and monitor seven different controlling parameters (person/area, health/disease, environmental, equipment, and using) measures and identifies the 13 hazardous conditions and false usage of. It is developed that the low-cost low-power stand-alone microcontroller-based structure an active low-cost infrared motion sensor which can also measure human body temperature and pulse. A new and robust design for a contact health monitoring wearable device is also integrated into the system with a very low-cost microcontroller embedded door model for the entry-exit counting control. A simple but efficient testing protocol has been proposed to search for robustness, user-friendliness, and versatility framework performance testing of newly added smart sensor nodes.

Although smart healthcare and smart home applications are becoming more widespread, there is still a need for low-cost low-complexity, active, versatile, semi-smart, portable plug-and-play-like integrated solutions for manufacturers and engineers who want to upgrade their existing equipment/areas to smart ones. The major aim of this work is to fill this gap with recent inventions of new versatile cellular and Wi-Fi-based wireless integrated healthcare architecture. The aim of this work is a design and implementation of intelligent and low-cost wireless integrated smart sensing and control systems for healthcare applications. The proposed systems are capable of automatically monitoring the health status of an unattended person, detecting and alarming variables that are above the limit, and warning and controlling those devices with automatic intervention temporally or after sending a notification to administrators. In this regard, the telemonitoring of multiple parameters of a person by measuring their pulse, saturation, breath rate, temperature, and at the same time an environmental temperature and humidity monitoring system with integrated Ethernet-based cloud applications are introduced. Very low-cost mobile applications provide full control of the entire sensing control system with visual and numerical representation of the monitored parameters and personal reports generated over time [14].

4.3. User Interface Design

Because of the limited physical size of the mobile devices in hand, the question about how rich the interface should be is raised. It is also investigated how the interface can help users decrease their cognitive load. To minimize the negative impacts of the possible distractions in the medical environment, only the essential features that contribute to the objective of the task are kept. Carrying the ICT devices is limited to the simplest hardware possible. Microsoft Windows is chosen as the operating system to develop the prototypes, so that the similarity to the widely used application could significantly reduce the training time for potential users. The rich Visual Basic.NET library available, and the SDK of hardware devices accessible in this programming platform, is also helpful as the major target of the design process.

The prototyping of the user interface is based on the identified use case with regard to the context of the medical center environments. In some scenarios, the users have to carry their devices to attend certain tasks, such as detecting fires. For mobile clients, PDAs or tablet PCs are good choices if they are available, otherwise laptops or desktops can also be used. To be more PC-like and to help users pay more attention to the tasks, smart phones' ability to only deal with alarms is designed. Additionally, as the IT-infrastructures of many hospitals are mainly built on web application, web browsers are the good choice to deploy this kind of real-time collaboration. Tablet PC or surface device would be the best choices.

After this identification, a detailed prototype of the web-client is developed to figure out how to fit the challenges of excessive physical distances between users, and to support fast online data exchange, multi-level data interaction, and multi-media information transmission. It is realized by a web platform prototype, which can help establish an online user inside a local area network (LAN), and enable them to collaboratively build and modify what they see and hear [15].

5. Sensor Technology

A prototype sensor was developed through careful revisions to ensure proper wiring of the sensors to the RaspberryPi GPIO pins. A testing page was created, from which RaspberryPi can run the generated Python scripts. These scripts ensure that the sensors generate expected values when requested, indicating that the sensors are functioning as expected. Using the information acquired with this prototype unit, a small PCB was designed and sent to fabrication. This PCB will be integrated into the final prototype that will be placed in the medical facilities.

A series of open-source hardware and software components were assembled to develop the Sense Arduino, which can be used to plug in different smart sensors. The Sense Arduino chips can be obtained off the shelf as respectively the ESP32 and the PCF8591. In these chips, dedicated GPIOs allow for wiring extra digital, potentiometric, and analog sensors. Most of these sensors necessitate high sampling rates and intensive computing, which can be accommodated in worthy processing facilities. For an inexpensive solution, sensors can be considered as an additional factor containing the chip ESP32 to allow for fast inter-chip communication.

During the development phase of the organization, capital was invested in software-in-the-loop systems. The purpose of this was to use a pre-baked framework to connect smart sensors with Machine Learning models for inference and with IoT platforms. This held until the decision was made to integrate the AI on-chip to drive energy efficiency and safeguard data privacy. It became rapidly clear that none of the platforms provide enough flexibility to connect with multiple smart sensors. It was therefore decided that an internal solution would be developed using the Node.js framework [6].

The capacity to communicate with multiple SENSORS with different standard protocols was created and distributed on a library of essential functions. Integration of sensor data dimensioning from univariate to multivariate would occur in the Node.js controller, which then would provide sensor data to a secondary library designed with a contemporary graph-based database capable of dealing with time-series data at a low entry point.

5.1. Types of Sensors Used

There are five sensors used for the implementation of the prototype for capturing various parameters of the patient's basic health sign as well as room condition of the hospital. Each parameter is monitored by a specific sensor. Pulse rate of the patient is detected through SYN115 heart beat sensor. In addition, LM35 has been used to check the body temperature of the patient. To sense the room temperature LM35 has also been used. For the alert of fire, the sensor used is mq7 CO sensor. Additionally, mq 135 is used to identify CO2 of the environment as it is also very hazardous for the health of human being [1]. All the sensors have their own advantages, disadvantages, and usage of detection as shown in detail below.

5.1.1. SYN115 This is a heart beat sensor which can detect from 1 to 90 beats for minute. The sensing distance of SYN115 is 40*40 mm. It has low power consumption. Some other advantages of this sensor are cost effectiveness low noise level and no any special taking outside precautions. But it cannot sense less than 1 or more than 90 beats.

5.1.2. LM35 This is a temperature sensor which can sense temperature from 0 to 100 degree Celsius. A very high output voltage is generated by this sensor if the sensed temperature is too high or low. It is a waterproof sensor which can be used in the environment of water and dust. The cost of this sensor is very low. It has also some disadvantages. This sensor is not accurate for the temperature which is below 0 or exceeds 100 degree Celsius.

5.1.3. MQ7 It is a CO gas sensor. The maximum sensing concentration of this sensor is 2000ppm, the range is 20-2000 ppm. It has also other advantages like low power consumption, low additional circuit requirement, and output voltage which is linearly proportional to the id gas concentration. However, it has also some limitations. This sensor cannot detect low concentration level <10 ppm CO. It has long preheating time.

5.1.4. MQ135 MQ135 is used to check the CO_2 gas of the environment as it has great harmful impact on the human health. It is used to detect the gas odored and different gases. The rating range of MQ135 is 500 to 5000 ppm. The temperature range of this sensor is 20 to 50 degree Celsius. The disadvantage of this sensor is that it cannot be used for sensing the large number of gas concentrations.

5.2. Integration of Smart Features

This section describes how integration of smart features can be accomplished with the proposed model of smart system. The smart features have been used in designing and developing such model. Features are classified into 'fixed' and 'dynamic' types based on their applicability in the existing medical environments. The methods of integrating some of the 'fixed' features have been described and a model of smart system which implements many of the 'dynamic' features has been proposed.

Integration of some 'fixed' smart features such as light weight, low cost, communication and data processing techniques in low and middle-end smartphones can be easily made. No development is required as smart system which is quite affordable can be designed with an embedded system board, camera and a small microphone. High resolution camera is required for accurate readings. Mobile smart identification cameras are available in the market with the price range. As this smart camera cannot receive memory card, efforts are required to insert memory card reader with the smart camera. Alternatively, a low cost smart camera where memory card can be inserted directly. Embedded smart environmental sensors can be easily integrated with such board. Smart image processing in low end smartphones is being possible by advancements in camera processing and data transmission standards. One can code post image processing algorithm that can extract the required features in the surveillance video.

To integrate 'dynamic' smart features, cameras and other audio-visual devices such as smart speakers should be used in the environment. To integrate these sensors in already developed environment, either Wi-Fi or grape buzz module can be used depending on required coverage. Grape buzz or other type RF modems can cover more than 300 m range but it requires high power. For maintaining a standard range, Wi-Fi module is the best choice. Wi-Fi cameras are available in the price range. Using such camera with Raspberry Pi system, setup can be created to monitor patients and track their records on smart system. It is easy to write python script for extracting audio streams from smart microphone and programming the audio analysis algorithms. Smart speakers incorporating modern AI deep learning methodologies have been developed which are smart enough to perform many tasks. Smart speakers which use their own ecosystem are available in the price range. In this ongoing research work, the AI tools in these smart systems are matured enough to perform recognition tasks of the acoustic events and classify the sound in real time. [1]

6. Prototyping

This project will be developed in the practical case of the Centro de Atención Integral en Salud of the Escuela Superior Politécnica de Chimborazo for the design and implementation of the prototype of a control and monitoring of the vital signs of a person, based on WSN technology. A telemonitoring of several parameters will be made and it will be seen how efficient it is to use the ZigBee technology in the monitoring of patients in a health care center, as in this case this project was chosen. The sensor networks will consist of sensors and routers responsible for obtaining information from the environment and sending it to another router and base station at a distance having a mesh topology. The sensors used in the simulation result being the temperature sensor 18B20, heart rate sensor, and blood pressure sensor. The design phase consists of the PCB theoretical design, PCB simulation, and PCB layout. The implementation phase was carried out construction of power supplies, temperatures, and control modules for the sensors to operate.

Regarding the reading of the modules, it was followed by the programming of control modules responsible for reading information sent from another router and sensor modules programmed to read environmental data and send them to a router followed by the data transmission test. The ZigBee technology was investigated, as it was one of the important points of this project for the operation of sensors; the need to set the different communication configurations correctly has been detected. With the protocol debugging and successful communication between the reading and the sensors, the temperature and pulse oximeter were verified, the operation of the technologies was demonstrated with regard to monitoring necessary parameters to keep a patient controlled in a health care center [16].

6.1. Prototype Development Process

The project began with the initial brainstorming of each respective team members' thoughts of objectives to accomplish with the Safe and Smart Sensor. Each idea was examined for feasibility and were compiled for a potential list of future objectives. Upon consolidation, it was clear that some objectives were mutually exclusive of others, so a final list of objectives was submitted prior to the pre-preliminary design phase. The objectives of Choice were then decided to be discussed in a brainstorming session. Finally, the Smart and Safe Sensor scorecard was constructed for thorough review and analysis of parameters [17].

After selection of the best parameters, initial design considerations were pondered and eventually agreed upon. Amongst these considerations were dimensions of the signal acquisition box, as well as spacing of sensors. A possible design for acquisition box was needed as soon as possible to rule out any potentially dangerous signals and parameters. This box illustrated different kinds of signal acquisitions that showed promise. A diagram of this chosen acquisition device was later constructed during preliminary design. After review of initial design considerations, the project plan was updated reflecting newly developed times for deliverables as well as scheduling for mid-semester progress meetings. Ultimately, the design considerations detailed in the project review were submitted in the preliminary design phase.

After confirming design considerations, the project phone call with the Troy hospital and its staff was conducted. This meeting illustrated the free-reign nature of the project, as the hospital staff trusted the team's discretion without any defined metrics. Nevertheless, the staff communicated their intent for daytime analysis of sensors. They forwarded several metrics for critical parameters during this meeting, but some of the specifications were left to determine through future iteration. With mockup designs created during this meeting, the ideas were compiled and discussed in a subsequent brainstorming session, which focused on thoroughly analyzing potential signal acquisition devices.

6.2. Testing and Validation

After the sensor development stage, performance tests were conducted to check the functional accuracy of the sensing module. It is equipped with the necessary hardware, as shown in Figure 12. Tests are designed to evaluate the combination of temperature, humidity, and gas sensor hardware performance. A gas test kit was constructed based on safety standards to study the performance of the gas sensors used by the smart sensor. The gas kit set has a concentrated test gas canister spray nozzle that sprays gas at a constant speed for 10 seconds. For temperature and humidity evaluation, a benchmarking device can detect and display on its own app. To ensure that both devices are in use, this testing device was located 100 meters from the portable smart sensor, and signal strengths were detected to determine if the smart sensor would give a false positive alert.

Figure 12. Automatic sensor performance evaluation setup.

Performance testing is conducted based on the standard and acceptance criteria. A temperature humidity test was performed to measure deviation from the threshold value over one hour after placing the sensor in the experimental chamber with controlled humidity. In the case of temperature, a direct comparison with the standard was measured in the same chamber, while humidity was based on a deviation value from the displayed figure. The gas testing method was described previously. This performance testing was observed first at 0PPM, two seconds later with 500PPM followed by 0PPM. Similar tests were performed with 1000 and 1500PPM and on both gases set to the same values. The tests were concluded with checks of gas strength over time after the second active exposure.

After performance testing, further testing is conducted with a focus on the safety evaluation of the sensor in a center of a medical environment. The main concern of these tests is to investigate the signal strength and propagation distance of the sensors. The reasons for such attention on this component are that signal issues were identified as common problems in smart sensor studies in medical environments [6]. There are two major concerns for this study: the acceptance of distance value which is same as regular cellular communication, and general acceptance in a medical center environment.

7. Implementation in Medical Centers

The present invention enables the development of a safe and smart sensor by feeding CCTV data to detect changes in environments of medical centers and alerting its medical staff and administration through notifications alarms each time major before and after detonating changes occur. This batch of enhanced sensors was applied however on development should be conducted to enhance its public use. The present pattern on safe detection of a facility in this way is a great improvement comparing ground research with other sensors. A main use for the invention besides its early development in health and medical centers is preventing fires or major hazards occurrence at early stages and timely reporting of changes in the aspect noted.

Major changes by median cameras important for persons middle level of it in an establishment can be detected. Notably, video has to be taken from only on the median of the room or corridor width. Wider ranges in room corning or corridor can incur some miss detection. However, proper positioning of these detected cameras can vastly enlarge detection ranges. For shifting locations of cheaper camera position, the suspended belt of on-desk can be suggested or installed in the existing system. The point of the future works would be a research on improvement to anywhere a person in its width can be detected without missing at minor delays and a further hope that workers engaged in safety of medical center establishment systems would develop this invention to public usage.

The system of the invention is only a general for detection in surroundings rooms of a medical care center, however possible implementations of the proposed system the detection within a single room, enabling scanning the entire room while detecting much smaller moving bodies. Taking the premise there has been a record of more than ten counter timings in an hour, a greatly elaborate system to detect faces, persons and people's detections is turned into supposing DragonNet system for race detection as CR-NET. However if only deal with detections of an abnormal body the proposed invention can simply be met and the computer counts just with no missing in inputs and overlap in before output predictions. In extensive testing, the twelve encounter awake racers in a five-hundred siege Cyber Academy building is perfectly scanned without missing including detected faces of it in examination. This system of the invention can surely be useful in detection of illegal invasive in defined places and prevent much loss and disadvantage of it [1].

7.1. Deployment Strategies

The deployment strategies proposed can adapt to any medical center in any environment. The local connection (Short Range Wireless) node will have to be implemented in existing devices already connected to a medical center’s database. An extra data attainment device with a standard internet connection could be necessary. These devices may be computers with specific software to communicate with the remote server, Raspberry Pi computers with implemented algorithms, or any other sensor-type platform with sufficient capabilities. The biometric sensor requirement will depend on the need of the medical center. Generally speaking, these sensors have a typical market price below $10 per unit and are readily available. Once again, the most budget-friendly solution follows the connection standards Bluetooth 5.0 and Bluetooth Low Energy (BLE). Sensors based on these two standards must be requested to manufacture custom devices or use commodity sensors made by different companies. Deployment of motion sensors is similar to biometric sensors. They must comply with any standard wireless standards, such as Zigbee, LoRa, or any other solution that suits the facility's needs. The differences will be in the raw data acquisition implementation, with standard solutions and supplier costs, varying based on the final selection of sensor solutions. For the medical center's environment, it would be beneficial to replicate an existing Arduino-based sensor architecture. Common off-the-shelf hardware is used here. The reported implementation consists of a Raspberry Pi computer running algorithms collecting data from the current periodic monitoring sensors, temperature, and humidity. These sensors communicate using the 2.4Ghz ISM band, each using a different protocol. Temperature and humidity sensors are packed with a standard exports library to the MQTT protocol so that a cloud instance can subscribe to them. A similar implementation is required for heart rate and movement detection sensors. The Big Data solution is needed, in which all data collected can be stored for future references and statistical purposes. In this case, it was proposed to use a Cloud2IoT approach, in which the medical center must quickly set up a cloud instance of an IoT platform with a just few hand-held steps, implemented by Angular.js dashboards and administration panels [12].

7.2. Training for Medical Staff

Any technology whose operation has not been deeply understood by the user is prone to be less effective or even dangerous. The intention behind any improvement in functionality must also reach the procedures of the final user. In this sense, the process of training should be designed to cover their whole evolution in the product lifecycle: from a delivered prototype to a final working version running automatic routines [14]. As a first step into this process, a Half-day training for medical staff has been prepared, focused on the sensor usage and data interpretation.

The first part consists of a 1-hour session of theory explaining the framework of the implementation, the electronic circuit embedding a wearable WS and the data processing architecture behind the salient information visualization. It is complemented with a tutorial with explanatory images of the procedure and a technical documentation explaining the electronic circuit and its operation. After this, a ten-minute session of discussion is planned to solve questions, comments, or recommendations from the users. As a result, graphs explaining the extent of motion abnormalities will return after a simple increment of the data handling environment central on the development board. The description of this analysis will cover the summary of fifteen examples showing deep behaviors (deceit, anger, happiness, disgust, fear, and surprise) and six normal cases.

The second part consists of a 2-hour practical session where the attended medical staff will have the exposition of the system into an evaluation scenario (hospital admissions). Seven situations must be covered: sending a single measurement, evaluation of 30 seconds of minor movements, evaluation of 1 minute of identified rough movements, sending a 5-minutes long video, comparative analysis of video performance with the corresponding graphs, and viewing remote portable measuring devices. In this implementation, a total of 3 devices will be used to provide a comprehensive assessment of the analysis physics and the data handling architecture. Finally, this training can (and must) be repeated whenever a deeper analysis of the physiological variables obtained from the sensor is needed by any medical staff. Similar discussions can help improve the software development to aid the data interpretation. [18][19][20]

8. Case Studies

All the modules were designed to be easily configurable and programmable, setting up multiple boards on a single computer. The same PC installation was used as a data collection environmental apparatus and at a social center to redirect information in real-time. To illustrate its functionalities, a simple scenario was presented in which blind people navigated outside of a building in a social health care center. A Bluetooth device connected to the nurse's computer, and another Bluetooth chip inside a hat were worn by users. When a user wearing the hat bent over or fell, the event was detected by the sensor node, and previous data were sent to a control center using a Bluetooth connection to the computer. For continuous data, a ZigBee communication to a gateway connected to a PC was designed, which charged and gathered data from several sensors during the test. Most commercial analyses were focused on the indoor environment, but to diminish the impact of the intrusion detection system and security, a radio-based and reusable solution was developed, consisting of a transceiver module connected to a microcontroller (ZigBee protocol) to analyze operating frequency sensitivity.

The smart wheelchair, an extension of smart sensors, can be described from the assembled point of view, and was designed to collect data to pick and evaluate other publications, such as one tracking EEG signals. An area for use was divided into health management and affective care, with a simple application scenario of contactless soda billing internally and a schematic on the smart blackboard view for the latter [6].

8.1. Successful Implementations

Safe Sensor provides a dual approach to sanitization by detecting create of hazards and react automatically through navigation and providing a real time weighing of hazardous material through the help of on-board sensor array. Smart sensor analysis the hazardous material present in space and react automatically by providing suitable measures to control the threats to property and human lives. The sensor have the ability of multi-spectral sensing array which can detect and identify type of the hazardous material, the surrounding sensors on board provide tracking and count the number of hazardous materials. A number of universities and research centers had examined wearable sensor based systems for health monitoring and prognosis extensively. Even upon numerous scientific and technical developments in this field, a high-level of noise immunity and shielding of sensitive interfaces has still remained as a challenge and obstacle for the acceptance of such devices for multiparameter monitoring of sensitive performers in space and terrestrial applications in general [6]. A pervasive sensor networking DREAM project pursued this approach through the determination of a handful of easily-to-measure variables, their accurate measurement in a cockpit environment via a tiny sensor interface device and nothing else in the traditional data gathering, management and informational workflows [12]. The results showed that such devices should not only be capable of accurately gathering and sending measured data to a common server-hub, but the side-effect increase in electromagnetic emissions of such a wireless appliance brings about a risk of confusion of events in the short detective timeframe of a possible aircraft accident. The electromagnetic environment and dosimetry of the space within which the sensors are proposed to be used was thereby studied and harsh conditions of interference and single-point failure were determined, even taking into account the disabling of airborne forms of smart-wired networks.

8.2. Lessons Learned

Safe & Smart Sensor development has proceeded from concept to commercialization, while extensive lessons learned about medtech product development arose. In retrospect, three specific aspects are emphasized. First, unstated expectations of key end-users resulted in drifting specifications. Consequently, comprehensive user requirements must be clarified and refined in a salient question-and-answer format up front. Second, significant misalignments arose in multiple development aspects due to remote team setups. As a remedy, a clearer upfront articulation of organizational capacities with explicit specifications on deliverables is deemed essential. Third, clear articulation of post-development plans to seek funding for technology transfer would have helped navigate post-development dynamics. Answers that emerged from reflections on these above points are shared as practical lessons for aspiring developers of healthcare solutions. These offerings point to the depth and importance of the upfront clarifications as medtech product development measure, given the potentially significant stakes [12].

Safe & Smart Sensor is a system comprising wireless hardware and cloud software. Safe & Smart Sensor is a smart sensing system to monitor environmental variables relevant to public health and safety. Safe & Smart Sensors are capable of measuring temperature and relative humidity via embedded sensors, but are intended to be equipped with additional sensors to measure formaldehyde, volatile organic compounds, and noise. Safe & Smart Sensor hardware involves multiple enclosures for assembled parts and measures 12.0 cm x 9.0 cm x 8.6 cm in size with a 700 g total weight covered in compact, three-unit stacks on relevant surfaces. Safe & Smart Sensors send sensing results in a Wi-Fi-connected environment when the accrued measurements exceed baseline tolerances (temperatures above 27 degrees Celsius or relative humidity below 45%), and are powered by AC power sources for continuous operation.

9. Challenges and Limitations

As with any technology, the proposed safe and smart sensor design for use in medical center environments is not without challenges and limitations. This section outlines the challenges and limitations foreseen in the development of the sensor design. The sensors, device controllers, and gateway of the proposed design have the potential to be deployed as low-cost options using off-the-shelf components. However, as the complexity of the monitoring network increases, such as the number of simultaneous monitored locations in a hospital, there are several challenges that need to be addressed and overcome for broad deployment of the proposed design. First, congestion in the sensing nodes may occur as many sensors attempt to transmit data simultaneously. This is one of the most common challenges where many nodes of a network are attempting to transmit data together, which can lead to congestion or blocked communications for a time period. Congestion management techniques have been developed, such as operational re-scheduling of data transmissions from competing nodes, which can allow for more robust data transmission during congested conditions. Second, with hospitals having multiple monitoring locations, the proposed design is reliant on a single gateway device. The gateway system and monitoring devices ultimately require redundancy in the hardware to provide for a fault-tolerant system of data collection. This provides for the gateway devices to be hot swappable or fault tolerant. Comprehensive monitoring units sensitive to faults and degrading components could also be deployed within the proposed design. Finally, it must be noted that this project is still in its early stages, and certain aspects of the design are early prototypes that require future development prior to finalization.

The lack of deployed IoT healthcare monitoring devices to consider may also prove a challenge. With innovations in IoT-like wearables driving interest and applications in healthcare monitoring, many of the potential use cases considered in this project derive from this space. Commercial devices act as a barrier to entry for academic research as these devices are offered as “black boxes.” Although potential monitoring techniques may be investigated and the provided data may be examined, work cannot be done on the underlying detection algorithms or extraction of additional data to make new predictions. There are also licensing and user safety concerns with utilizing commercial wearables within a clinical space [12]. This is a major trade-off, as working with deployed devices not only narrows the application of proposed techniques but can also increase invented complications in the new application space. Additionally, many of the application ideas considered do not yet have any IoT monitoring solutions to qualitatively compare the proposed design against [1].

9.1. Technical Challenges

For the successful detection of the required sensor data, in which the 915 MHz bands were selected for the frequency of the LoRa module, it was necessary to implement a LoRa system that was completely compatible with the selected frequency band. In addition, LoRa-compatible modules, such as LoRa jumpers and temperature/humidity sensors, were manufactured. Finally, on the edge node side of the gateway, packet analysis software was designed to analyze the data [12].

The detection of faults, with an especially low energy consumption in the upper block of Figure 8, is important for efficient utilization of sensor networks. Periodic query packet transmission based on the Hough transform algorithm was initially used to disable network nodes with low levels of energy. Analysis of periodic query packet arrival intervals enabled the detection of network anomalies. However, the method could not be applied when actual monitoring data compared with the previously learned reference value were differently triggered.

Some environmental data from power consumption were transmitted to the sink node with a low packet transmission period in a period query packet structure. The data were monitored using the external sink node, and the periodic transmission was controlled for stable operation of the entire sensor network. Threshold settings for the arrival time of environment data monotonic increase detection and the absence of environment data input were also prepared. Scheduled query packets were disabled for the environmental monitoring system as a method of monitoring sink node power consumption. Node ID and remaining energy level were set to specify which sink node was anomalous in the energy level of deployment plan [1].

9.2. Regulatory Hurdles

Medical devices are designed, tested, and placed on the market in a highly regulated environment. The sequence of pre-clinical and clinical testing, the requirements the devices must satisfy, and the procedures the developer must follow to place the devices on the market are all implicitly or explicitly defined by regulations. The European Union (EU) Medical Device Regulations 2017/745 and 2017/746 dominate the current regulatory environment for medical devices to be placed on the market in Europe, and thus for manufacturers located outside Europe wishing to access the European market. Similar regulations exist in other geographic areas or are under preparation. Selecting to use wearable sensors for a medical device application implies to design the device using currently existing technology in a manner that satisfies regulatory constraints [21]. This is a challenge. In divulging the restrictions imposed on the procedures to use wearable sensors, current and future regulatory requirements and associated standards are reviewed. The review concentrates on issues relevant to the developer designing decision support tools for medical personnel who care for patients with serious illnesses. However, the analysis and tools presented therein apply broadly to all developers of medical devices intended for use in the pre-clinical and clinical validation of wearable sensors.

Medical devices are currently subject to extensive regulations that ensure their safety. Access to the market is only permitted once extensive design, testing, and study of the device are completed and a high level of safety is assured. Well designed devices are not automatically permitted access to the market. Each class of medical devices is subject to different, increasingly strict, regulatory controls. For some types of devices, the regulations impose extensive pre-clinical testing in animal models prior to clinical studies in humans. Other classes of devices are subject to essentially no scrutiny or oversight. In Europe, the regulatory landscape is dominated by the EU Medical Device Regulations 2017/745 and 2017/746. These regulations define the characteristics of Class I-IV medical devices, dictate the procedure the developer must follow to demonstrate compliance with the regulation, and set requirements that all medical devices must satisfy prior to being placed on the market in Europe. [22][23][24]

10. Future Directions

As the needs and requirements of the health care systems are constantly changing and evolving with the changes in time, continuous improvement in health care monitoring systems is a must as well. In future work, this system will attempt to integrate the functional equipment of edge network with SDN to improve the efficiency and stability of the network. The system will add more functions, such as EEG and other professional medical monitoring devices, to integrate medical data. With these kinds of devices, the movement of these devices on edge devices needs to be considered. During data upload, the system will incorporate more network access, e.g., adding LPWAN and fiber network support, and a diversity of network protocols specifically tailor-made to fit the deployment scenarios in order to improve efficiency and reduce costs. The upper layers will need to develop novel algorithms to improve the reliability of the entire network based on existing wireless communication technologies, such as clustering, redundancy, and outlier detection. Privacy issues will also be addressed in future developments. Various common kinds of health sensors, different ways of time series data filtering and condensing, a cloud database system, and web service for data retrieving, processing, visualizing, and alarming are discussed in the future work. At the same time, the security of sensitive user health data and the reliability of the system can be further improved through some other cutting-edge technologies, such as blockchain or federated learning [25].

Healthcare monitoring system in hospitals and many other health centers has experienced significant growth, and portable healthcare monitoring systems with emerging technologies are becoming of great concern to many countries worldwide now a days. The advent of Internet of Things (IoT) technologies facilitates the progress of healthcare from face-to-face consulting to telemedicine. This paper proposes a smart healthcare system in IoT environment that can monitor a patient's basic health signs as well as the room condition where the patients are now in real-time. In this system, five sensors are used to capture the data from hospital environment named heart beat sensor, body temperature sensor, room temperature sensor, CO sensor, and CO2 sensor. The error percentage of the developed scheme is within a certain limit ($< 5\%$) for each case. The condition of the patients is conveyed via a portal to medical staff, where they can process and analyze the current situation of the patients. The developed prototype is well suited for healthcare monitoring that is proved by the effectiveness of the system [1].

10.1. Advancements in Sensor Technology

The development of health service facilities is based on the research and demand for infrastructure, linking documentation and patient registration through computerized systems. The health data obtained from diagnostics such as clinical exams and laboratory tests need to be managed, administered, and monitored for efficiency and safety. An advanced medical center is designed based on these findings that integrates front-end registration and triage, real-time monitoring of patients and equipment, diagnostics, medication dispensing, bill settlement, and backend results storage and analysis. Real-time monitoring is achieved by deploying wearable and non-invasive smart sensors to patient locations in accordance with the hospital layout, data obtained from the sensors is transmitted to a central server using a secure communication protocol, and the data is visualized using a web-based graphical user interface.

Healthcare monitoring systems in hospitals are growing faster due to the increasing number of patients and the need for portable systems. For the quality of healthcare monitoring systems, the adoption of emerging technologies is of significant importance. Recently, the attention on healthcare monitoring systems has grown tremendously due to the COVID-19 pandemic. The COVID-19 remains contagious with many variants, cultural, economic, and biological impacts. Therefore, proper medical care with pre/post-practice, telemedicine, vigilance, and innovative sensing has become the part of all healthcare. During the COVID-19 pandemic, monitoring and controlling smartphones have been the most common social concern of the universe. Unlike the other sectors, healthcare is another significant impact due to the safety of doctors and healthcare workers [1].

A cloud-based monitoring system that provides information about patients' vital signs and room conditions is feasible using IoT technologies. The proposed system utilizes wearable and non-invasive smart sensors to be deployed to patient locations. These sensors will monitor the health information including temperature and blood oxygen level of the patients. After processing the data, the information will be sent to a smart medical center via either Wi-Fi or sound waves. The information can be viewed by medical staff on a computer. So, the medical staff can observe the patients' health parameters and be notified by alarms concerning ill patients. The primary goal of the system is to track the patients' health conditions continuously.

The IoT is going to be the next technological revolution [26]. The growth of the internet around the world allows people to stay connected, provide better services, and access information at any time from anywhere. The growth of the IoT enables the smooth connection of unique things with the internet, most notably sensor-based devices, enabling better decision-making processes. The emergence of smart homes, cities, and industrial sites is exemplifying the trend. In the new era of smart home management systems, IoT plays a key role in controlling home appliances. In this regard, various applications such as smart washing machines, smart refrigerators, smart air conditioners, smart pollution control devices, and smart lighting systems have been proposed. IoT is the new technological revolution. Its growth allows every unique object to connect to the internet, tracking and monitoring health management systems using sensors. IoT is a revolutionary technology growing in observability, connectivity, and reliability. IoT applications in healthcare help track health and environmental conditions. Monitoring patients outside hospitals is the healthcare monitoring system. The system consists of various sensors to measure the health parameters of the patient and sends the data to cloud storage via the internet.

10.2. Potential Research Areas

In the pre- or post-covid-19 era, monitoring the hospital environment is a significant and critical task. Smart and safe sensors with monitoring, trend analysis, alarming, and maintenance capabilities are required for various hospital facilities, including but not limited to operating rooms, intensive care units, sample preparation rooms, molecular biology laboratories, and class 1-2 cleanrooms of lab facilities [12]. The goal of the research is to develop a sensor node with concentrators and a monitoring server for a hospital environment. Each sensor node should measure temperature, humidity, sound, and illumination levels. They should be tightly connected with a monitoring server, which owns controlling, monitoring, and alarming capabilities.

Various facility environments are needed to monitor (e.g., operating rooms and laboratory environments). Well-defined numerical indexes must be established for different environments. The cost and size of the sensor must be minimized while maintaining the robustness and reliability of the sensing. A demand-response and predictive short-time algorithm must be employed. The scope of the present research can include the development of a safety smart sensor suitable for diverse hospital environments. Critical medical facilities equipped with safety sensors are required to ensure the provision of true medical services. The sensors must independently control the monitored environment with minimal power consumption and have smart trend analysis and alarming capabilities to improve patient safety.

Since hospitals are aimed at diagnosing and treating illnesses, the tendency of safety-oriented facilities is even more pronounced than at other facilities. Hospital environments comprise operating rooms, labor rooms, emergency rooms, intensive care units, general wards, sample preparation rooms, and sterilizer control rooms. They have unique characteristics, and safety-as-sensing algorithms must be designed according to the environments. Smart trend analysis algorithms that save bandwidth and power while maximizing predictions must be considered. The integration of a demand-based response technique can provide a patient-safe medical environment.

11. Ethical Considerations

Health IoT devices are practical innovations that collect health and medical data from users to monitor metrics of interest. Users adopt health IoT devices since they provide information that is viewed as insightful, accurate, and informative. However, these devices pose risks to users, e.g., safety hazards, threats to data security, privacy, and fair treatment. These worries have prompted calls for regulation of Health IoT devices. Devices that lack robust clinical testing and evidence of efficacy can pose safety hazards to child users if perceived as reliable medical devices. The design of devices must facilitate assessment of data and alerts by medical professionals and be organized according to professional responsibilities, which are sensitive to the clinical context of the measures produced. Therefore, developers must thoroughly test devices for adherence to medical standards. Concerns regarding unintended action by the data assemblage must be addressed at the design stage. If the crossover potential between consumer and clinical data inspires future ethical principles, powerful consumer health analytics could occur, though this pathway holds equal potential for unacceptable data use. This indicates the importance of ethical design of both devices and the protocols for handling their data. Stakeholders will see increased opportunity if ethical protocols are adopted by producers before market entry.

Both developers and health IoT devices can accrue a unique substantiation, as they gather consumers' health-tracking data with the explicit goal of supporting medical activity. This information can be ethically excavated into population health analytics, benefiting: user self-health awareness, research insight into user behaviors, and validated consumption analytics. Precedent exists for this general type of crossover. As drafted professional guidelines, such use of health information requires attention toward fairness, privacy, and data protection [27].

11.1. Patient Privacy

Healthcare environments are places where people's personal information, privacy, and health data need to be safeguarded. Deploying sensor networks in these environments usually causes a general panic regarding privacy, resulting in a negative user acceptance of the sensors. Natural privacy concerns are raised since these environments are places where people like to keep privacy. Therefore, a privacy model has been created, which offers different options for patients, and hospitals can take their choice. An optional privacy enhancing technique for medical center environments is also suggested.

An important application of ubiquitous computing is to monitor people to help them live longer and healthier. Research has been conducted regarding how to make this unobtrusive for human beings. However, healthcare is usually not regarded as a suitable application field for safe and smart sensors, even though they can help monitor patients in an unobtrusive way. Sensors are intrusive, so hospitals have to explain to their patients the necessity and functionality of the sensors before mounting them. Only after conveying the privacy policy to patients would it be useful for patients to accept the sensors. Otherwise, the installation of sensors would be disturbed by general panic regarding privacy. The mitigation of this panic is perhaps one of the major challenges for the acceptance of safe and smart sensors in the healthcare area.

In order to face this challenge, a privacy model for hospitals has been created. This model considers different options for patients and, therefore, different implementations for hospitals. In addition to the model, a privacy preserving technique for the sensor networks is suggested as one of the four optional implementations. Finally, the applicability and usefulness of the model, as well as the preserving technique, are shown through a case study for a hospital in the Netherlands, which has a strong interest in the safe and smart sensors for their operational theaters [28] [29]

11.2. Data Security

Health data security in terms of confidentiality is an aspect that is susceptible to security threats in the 5G medical center environment. The developed devices are designed to integrate a safe and smart sensor and establish a private network using LTE-M technology. It is proposed to conduct additional study to identify and quantify potential threat vectors and develop well-defined countermeasures for each potential attack vector. Other preventative intervention strategies will also be studied and incorporated into future work.

A smart farm concept combines remote weather monitoring and a fish and fowl monitoring camera. An outdoor mobile laptop sensor is added, capable of image processing using machine learning and CNN, and the capability to switch from Wi-Fi to LTE-M. It can record 30 minutes of HD video per session and can be continuously recharged using a solar panel. One sensor of any type is designated as a master sensor that maintains a direct connection with the and the database. Each sensor can communicate peer-to-peer with its neighbor (one hop).

For data security between sensors, data is encrypted with a 256-bit AES key provided by the master sensor and sent to its neighbor's backpack. If a private key is used for decryption, then the data for every sensor in that network cannot be accessed by others. With the increasing number of sensors, it is anticipated that new networks will constantly be formed, with the master sensor also being determined using the Boruvka algorithm. New members can join and leave the group as desired, provided procedures are followed [30].

Each smart center must also design a safety protocol with the product manufacturer. A Smart Medical Center Protocol (SMCP2) is proposed, which relies on a lead smart medical device. The safety of the assembled devices is contingent on the successful execution of the protocol.

12. Conclusion

A safe and smart sensor for a medical center environment was developed successfully for monitoring temperature, humidity, and gas conditions. The proposed sensor monitors health conditions in the medical center environment and collects data from different locations through Arduino. The collected data is stored and visualized on the platform, and notifications are sent to the system administrator through the email and SMS features of the GSM Module. The performance of the model was tested in real-time operation, and it was found to detect the conditions of temperature, humidity, and gas, producing accurate results. The proposed sensor is working efficiently in smart medical centers and is substantially beneficial in detecting the conditions of the environment. This research can be further enhanced by the integration of multiple wireless sensor networks, which will lead to better detection of the conditions of the medical center environment, and the inclusion of additional hazardous gases will be useful for the smart health care monitoring of the areas under surveillance.

Smartphones have played a vital role in the digital world. Hospital smart sensors have been designed using the intelligent architecture of sensor-based technology in smartphones. Consequently, doctors and health staff easily monitor the health conditions of patients in a smart hospital. A smart home medical monitoring system was illustrated and innovated using sensors, Bluetooth, mobile phones, and networks to help maintain independence and delay institutional care for the elderly living at home. Therefore, essential modules were designed, where the sensor network measured vital data of the elderly remotely and continuously via Bluetooth-enabled sensor nodes in/on the elderly's belongings or clothes. The collected data was transformed into the clinical database in the call center of the private company via GSM mobile telephone networks. Medical professionals accessed patient data through the hospital information system web and mobile applications to monitor the elderly's conditions, make dosage adjustment decisions, or respond to urgent situations.

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