A DISSERTATION ON

RoboCare Connect

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

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IN

ROBOTICS & AUTOMATION

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The thesis entitled **"RoboCare Connect"** submitted to the Symbiosis Institute of Technology, Pune for the award of M. Tech in Robotics and Automation is based on my original work carried out under the guidance of **Dr. Satish Kumar**. The dissertation has not been submitted elsewhere for award of any degree.

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LIST OF ABBREVIATIONS

Abbreviation	Descriptions
AI	Artificial Intelligence
IoT	Internet of Things
RFID	Radio Frequency Identification
COVID	Coronavirus Diseases

CGM	Continuous Glucose Monitoring
ECG	Electrocardiogram
UV-C	Ultraviolet- C
RTLS	Real-Time Location Systems
HRI	Human Robot Interaction
DC	Direct Current
IR	Infrared Radiation
Vcc	Voltage Common Collector
RsT	Rest Pin
IRQ	Interrupt Pin
SCK	Serial Clock Pin
GPIO	General Purpose Input/Output
DSI	Display Serial Interface
MIPI	Mobile Industry Processor Interface
LED	Light Emitting Diode
CSI	Camera Serial Interface
JTAG	Joint Test Action Group
HDMI	High-Definition Multimedia Interface

Abstract

"RoboCare Connect" is an innovative combination of cutting-edge technology, healthcare, and modern robotics. The goal of this ground-breaking research is to completely transform how people manage their health in social settings. It presents a multifunctional system with the potential to revolutionize health monitoring in social contexts by utilizing the capabilities of a Raspberry Pi-based robot, RFID technology, heartbeat and temperature sensors, line following mechanisms, obstacle detection systems, and cloud-based connectivity.

The main goal of this project is to build a flexible, intelligent robot that can carry out health checks and independently follow predetermined routes. The use of RFID technology enables the robot to stop at designated checkpoints for health evaluations, offering a thorough picture of a person's health by gathering data in real-time from temperature and cardiac sensors. The robot's obstacle detection algorithms contribute to a safe and dependable monitoring procedure by guaranteeing the safety of both the robot and its surroundings.

Centralized data storage and analysis are made possible by the easy transfer of the gathered health data to a cloud-based server. In order to provide prompt actions in emergency circumstances, an alert system is designed to notify pertinent stakeholders whenever health metrics surpass certain limits.

By automating and improving health monitoring in social situations, the "Social Robot Health Monitoring System" project shows how modern technology may improve healthcare procedures. In addition to advancing the field of health monitoring, it opens the way for further advancements in social robots and healthcare automation. Through the provision of proactive, efficient, and reliable health monitoring systems, this invention has the potential to have an important impact on healthcare facilities, caregivers, and individuals.

Chapter 1

Introduction

1.1 Background

The world of healthcare is on the cusp of a transformation, one that brings together cutting-edge technology, Artificial Intelligence (AI), and innovative robotics to enhance patient care and healthcare monitoring [1, 2]. In this era of rapid technological advancement, the integration of social robots [3-9] into healthcare systems has emerged as a groundbreaking solution, paving the way for a more efficient, interactive, and personalized approach to healthcare monitoring.

1.2 Smart Robot Application

An AI-driven object that can learn from its environment and from previous experiences is referred to as a smart robot. It then uses this learned information to improve its capabilities. Not only can these robots work alongside humans, but they can also cooperate with them, learning from human behavior and improving their own comprehension and abilities [10].

Automation and manufacturing are no longer the only traditional industries using smart robotics. Smart robotics is a rapidly evolving technology that finds use in a wide range of sectors, including finance, medical, retail, agriculture, and logistics. And future intelligent robots are being created by researchers and engineers by utilizing these advancements [11].

The industrial sector as a whole has improved due to the development of Industry 4.0 [12], which has given rise to a phenomenon known as Smart Spaces [13] and, with greater precision Smart Factories. Smart Spaces are primarily used for monitoring applications and processes inside a designated controlled region, such as power usage or the condition of sensors and actuators. Numerous facets of human existence have changed significantly as a result of robotic systems [14]. Robots have been employed in both the industrial and academic domains to carry out a wide range of difficult and demanding operations, including welding [15], packaging [16], assembling [17], and more.

Using Cyber-Physical Systems (CPSs) to provide a solid basis for upgrading Internet of Things (IoT) itself, Internet of Robotic Things (IoRT) represents the most sophisticated robotics idea to date [18]. To create new technologies, contemporary robotic technologies have been combined with networking, cloud computing [19], and IoT protocols in IoRT systems [14]. Thanks to this kind of connectivity, smart devices can now combine sensor data from several sources, keep an eye on occurrences, and utilize both distributed and local intelligence to figure out what to do next [20]. To accomplish complex tasks and function in a diverse context, this new strategy makes use of several technologies [21].

In the fields of surveillance, education, and health care, IoRT systems are seen to be extremely valuable. In particular, IoRT can aid individuals with specific requirements, such as those with mental disabilities, stroke patients, suffering, amputees, and so forth, in many ways that are beneficial to society, the economy, and health [22, 23]. To reduce the possibility of human error, such as incorrect medication, dosage, or procedure diagnosis, robots equipped with sensors and IoT devices are integrated with many benefits to provide real-time health information and diagnose patient problems [24]. Moreover, the IoRT can offer several benefits in other uses, such as automated data collection, sensing, and tracking of patients, personnel, and emergencies [25].

Numerous sectors have embraced smart robots, which raises production levels and improves people's quality of life. The following are a few prominent applications for smart robotics [26]:

- **Manufacturing:** To increase productivity and cut expenses, robotics is being applied in the manufacturing process. They may operate in dangerous or challenging conditions for people and are employed for jobs like welding, packing, and assembling.

- **Healthcare:** Surgeons can receive assistance with intricate operations from smart robots, patients can receive mobility assistance, and laboratory activities can be automated.

- **Agriculture:** To increase productivity and lower labor expenses, robotics is applied in agricultural. They can be employed for activities including cultivating, harvesting, and tracking the development of crops.

- **Service sector:** The service industry is using smart robots to automate various jobs including security, cleaning, and customer service.

- **Transportation:** To boost productivity, cut expenses, and enhance safety, robotics is being applied in the transportation sector. They can be used for autonomous cars and the loading and unloading of goods.

- **Construction:** To boost productivity, cut expenses, and enhance safety, smart robotics is employed in the construction industry. Works like building inspections and operating heavy machinery may be done with them.

1.3 Importance

It is noteworthy that the phrase "smart robots" does not just relate to AI systems that are highly developed and shown in science fiction films. An smart robot, on the other hand, might have a wider variety of gadgets that might not seem "intelligent" at first [10]. Smart robot may behave and make decisions based on the knowledge it has gained via deep learning or machine learning. It bases its decision-making on information acquired from input sensors while operating.

Constructed and outfitted with software, a smart robot essentially makes decisions on its own by using both past and present information. Interestingly, the development of "smart" robots required multiple generations of technical advances. From giving guidance and stocking stores to doing dangerous welding duties, smart robots are used in many different industries.

1.4 Healthcare Mobile Robot Market Size

With a projected value of United States Dollar (USD) 10.88 billion by 2030, the global market for mobile healthcare robots is predicted to expand at a Compound Annual Growth Rate (CAGR) of around 16% from its estimated $3.34 billion in 2022. The advent of cutting-edge robotic technology in the healthcare industry, the world's aging population, the lack of qualified nurses and other healthcare workers, and rising healthcare costs are all factors contributing to the market's growth. Mobile robots also improves patient care, which is a big benefit for the healthcare industry [27].

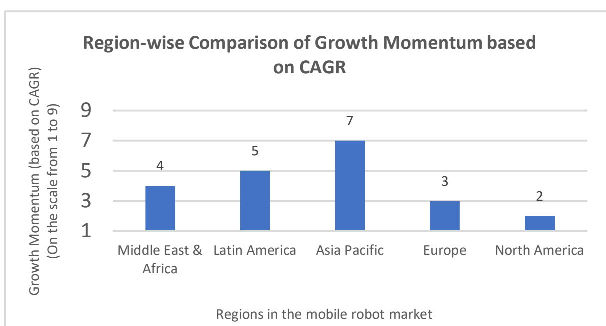


Fig.1. Region-wise Comparison of Growth Momentum based on CAGR [27]

(Courtesy: Healthcare Mobile Robots Market Analysis, 2022).

(Note: Both the overall market CAGR and segmental CAGR corresponds to Growth Momentum)

A market analysis of the global usage of smart mobile robots in the healthcare sector is made and is represented in the graphical form in the above figure 1. The growth momentum based on the CAGR% is provided for different regions of the world using smart mobile robots. The growth momentum is given in the scale of 1 to 9, where Asia Pacific region is found to possess higher growth momentum factor and North America region is found to possess lower growth momentum factor.

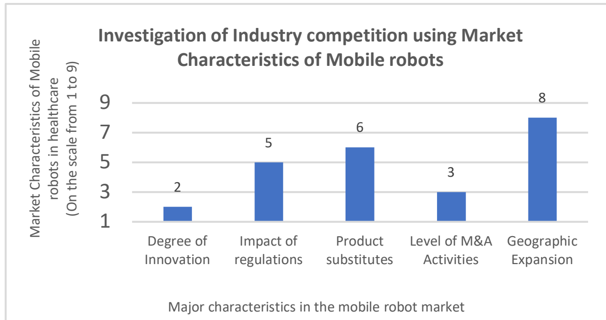


Fig. 2. Investigation of Industry competition using Market Characteristics of Mobile robots [27] (Courtesy: Healthcare Mobile Robots Market Analysis, 2022).

The market characteristics analysis of smart mobile robots in the healthcare sector is made and is represented in the graphical form in the above figure 2. The market characteristics factor for different characteristics of the smart mobile robots are provided in the figure. The market characteristics factor is given in the scale of 1 to 9, where the Geographic Expansion characteristic is found to possess higher factor and the Degree of Innovation factor is found to possess lower factor.

Better patient outcomes and faster responses can result from their handling of dangerous, time-consuming, and repetitive jobs like delivering supplies and medicine. They can also free up staff members to concentrate on other important duties. Additionally, mobile robots increase productivity by expediting and accurately completing jobs, decreasing mistakes, and optimizing workflows. For example, they may precisely administer and categorize medications, avoiding errors that frequently happen in healthcare institutions [27].

Prominent industry participants prioritize alliances, tactical teamwork, and geographic growth in developing and economically advantageous areas. At the Texas Medical Center (TMC) in Houston, Texas, ABB Ltd. opened its first worldwide base for healthcare research in October 2019. An array of cutting-edge technology, such as a mobile YuMi (could be referred as you and me) robot, are displayed at the center. By effectively handling a range of responsibilities linked to logistics and laboratory operations in hospital settings, this robot is designed with the specific intention of supporting medical and laboratory staff. ABB Ltd, Xenex Disinfection Services, Teradyne, VGo Communications, Inc., LLC, Awabot, Ateago Technology, Techcon, Amazon, Mobile Industrial Robots, Nordson Corp., and Toyota Motor Corp. are a few of the prominent companies in the industry [27].

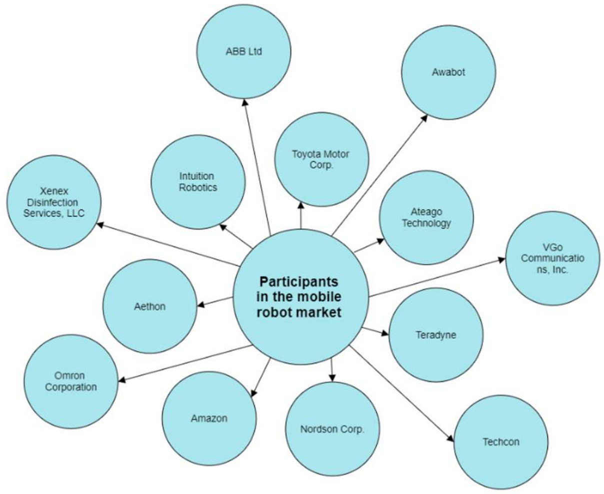


Fig.3. Participants in the mobile robot market [27]

(Courtesy: Healthcare Mobile Robots Market Analysis, 2022).

The participant companies existing in the global smart mobile robot market is shown in the above figure 3.

The different market categories of smart mobile robots in the healthcare sector are categorized in the below figure 4.

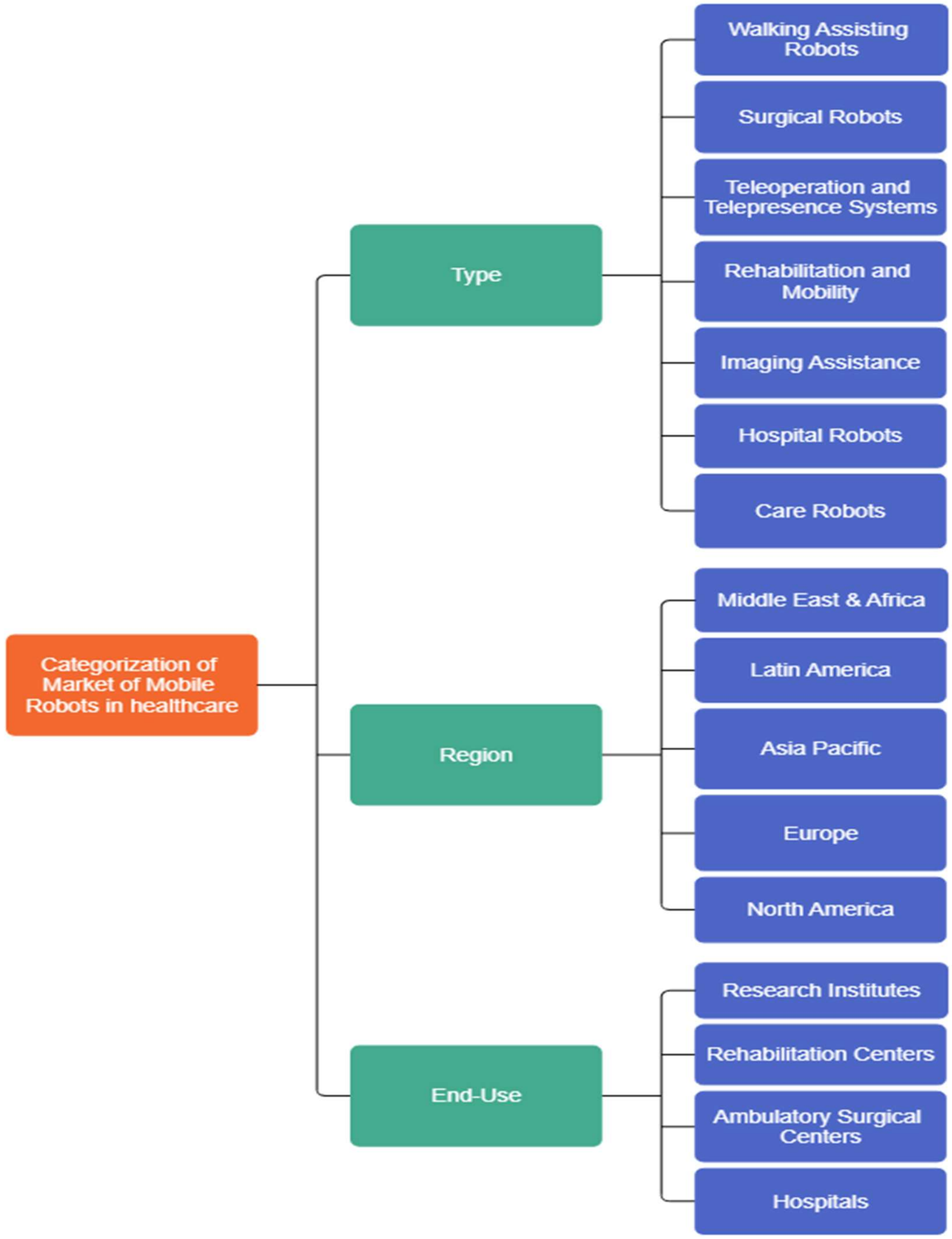


Fig.4. Categorization of Market of Mobile Robots in healthcare [27]

(Courtesy: Healthcare Mobile Robots Market Analysis, 2022).

1.5 Challenges

Smart robotics has both potential and problems, as any new technology does. Among the principal obstacles are [26]:

1) *Impact on society*: Although the exact effects of smart robots are yet unknown, they might have a significant influence on things like employment and the displacement of human labor.

2) *Technological difficulties:* The technology of smart robots is intricate, posing several technological obstacles to be surmounted. These include issues related to security, scalability, and dependability.
3) *Cost:* Small firms or underdeveloped nations may not be able to afford the development and deployment of smart robots due to their high cost.
4) *Ethical Challenges:* The employment market might be upended by robotics, which also brings up moral issues like prejudice, privacy, and monitoring. To lessen people's concern while interacting with social robots, especially ones that do purely servicing tasks like helping the elderly get up, they should come across as harmless and kind [28]. Additionally, they must react to human behavior and, if at all feasible, human emotions. For instance, they must distinguish between the demands of a fit athlete healing from a fracture and a depressive sufferer [26]. To facilitate nonverbal communication, the topic of whether social robots should be programmed to mimic human emotions like smiling is posed here. It may be argued that the robot's simulation is lying since it is emotionless. According to a number of experts, "ethically correct robots" should be able to choose between both good and bad [28]. But can moral judgments be made in the absence of the biological basis of the human brain? Not to mention, would we really want emotion-sensing, ethical reasoning-capable robots in the first place? Other Challenges and limitations in using social robots for healthcare monitoring with sensor data and Raspberry Pi [29] include ensuring data privacy, addressing the ethical concerns of patient-robot interactions, handling sensor accuracy and reliability, overcoming high implementation costs, and addressing potential technological limitations in providing comprehensive healthcare support.

1.6 How to overcome above issue faced?

Now, let us see how to overcome the above pointed issues.

- Distributed responsibility, granular authorization, monitored operator control, data fragments, and centralized authentication and permission procedures may all be used to stream production information and solve security concerns.
- When developing the behavior of social robots and embedded AI, ethical considerations must be carefully taken into consideration. Here are some additional specific recommendations about acceptable procedures and material. Normally, training a computer to communicate with a person requires not only understanding the rules and moral principles that dictate human social interaction, but also understanding how

humans think, move, and behave.

- Smart robotics is an affordable option as it can readily scaled up or down to meet the demands of the company.
- The social impact that robots pose prompts us to think about the economic effects of robotic progress.

1.7 Significance

It is impossible to overestimate the importance of robots. Its ability to improve safety and accuracy, save costs, and increase efficiency might transform many sectors. Smart robotics has permeated many industries, from manufacturing to healthcare, raising general productivity and increasing people's quality of life. Future developments will be greatly influenced by smart robots, because of both the growing need for automation and technological breakthroughs. A comprehensive overview of smart robotics is given [26], together with information on its developments, uses, advantages, potential, and obstacles.

Among the fields in which intelligent robots is anticipated to have a big influence in the future are [26]:

- **AI:** Robots will be able to carry out more difficult activities, pick up new skills and adapt to new situations, and make decisions on their own thanks to the integration of AI.
- **IoT:** Robots will become even more self-sufficient and adaptive when IoT technology is incorporated into them. This will allow robots to interact and communicate with other systems and devices.
- **Collaboration between humans and robots:** As increasingly complex and user-friendly interfaces are created; robots will be able to work with humans productively and naturally.
- **Autonomous vehicles:** As autonomous vehicles become more advanced, smart robots will be crucial to their growth, improving both safety and efficiency of transportation.
- **Smart cities:** Robots will be utilized to enhance the operation and effectiveness of smart cities, from emergency response to infrastructure upkeep.
- **Space exploration:** Robots will be utilized for space exploration and to carry out jobs that are too risky or challenging for people.

1.8 Research Goal

The primary goal of this research is to investigate and develop innovative solutions for leveraging social robots in healthcare monitoring settings. In an era marked by aging populations and increasing healthcare demands, the integration of technology, particularly social robots, presents a promising avenue for improving the quality of care and patient outcomes [30]. We present the relevant research questions in the below table I.

Table I. Tabulation of Research Question and its discussion

S.NO	Research Question	Discussion
1	What is the purpose of this survey paper?	This survey paper reviews about the usage of social robots.
2	Which sector does this survey paper discuss about?	The usage of social robots in healthcare sector is reviewed in this survey paper.
3	Which platform is discussed in this survey paper?	The social robots converged with Raspberry platform is reviewed in this survey paper.
4	What does this survey offer?	The survey paper provides with the vast potential in revolutionizing the healthcare industry.

1.9 Research Objectives

1) Create healthcare-focused social robot prototype and design it in 3D using solid modeling tools.
2) Social Robot will constantly monitor patients as per the schedule duration.
3) Send the Collected data to cloud and trigger alert if any fluctuation reported in the assigned and observed vital data.
4) To create a project workflow timeline webpage by structuring content with HTML, styling it using CSS, and adding interactivity with JavaScript.

1.10 Research Gaps

1) Inadequate exploration of privacy and security considerations in health data collection for social robots.
2) Scarcity of studies on real-time health data collection using social robots.
3) Limited research on integrating RFID technology for social robot health monitoring.

1.11 Important Contributions

In this article, we will explore the convergence of social robots, Raspberry Pi, and healthcare monitoring systems [31-38], highlighting the vast potential they offer in revolutionizing the healthcare industry.

Our research aims to contribute to this evolving field in the following ways:

- **Human-Robot Interaction**: We aim to advance our understanding of how social robots can effectively interact with healthcare professionals and patients. This includes the development of natural language processing capabilities, emotional intelligence, and non-verbal communication skills to ensure that these robots can engage with users in a manner that is both empathetic and supportive.
- **Continuous Monitoring**: Our research seeks to enhance the capabilities of social robots to continuously monitor vital signs, medication adherence, and overall well-being. This is vital for patients with chronic illnesses, those recovering from surgery, or individuals requiring long-term care.
- **Personalization and Adaptation**: We will investigate the customization of social robots to meet the specific needs of patients, adapting to their individual preferences, medical conditions, and emotional states. This personalization is critical in providing effective support and encouragement.
- **Data Integration and Security**: Our research also focuses on the secure and ethical handling of patient data collected by social robots. We will explore ways to integrate this data into existing healthcare systems while ensuring stringent privacy and security measures are in place.
- **Clinical Validation**: We aim to conduct extensive trials and validation studies in healthcare settings to demonstrate the efficacy and benefits of using social robots in healthcare monitoring. This will involve collaborating with healthcare professionals, patients, and caregivers to gather insights and feedback.

Our ultimate goal is to contribute to the development of socially assistive robots that seamlessly integrate into healthcare environments, fostering better patient outcomes, improving the quality of care, and alleviating the burdens on healthcare professionals. This research is pivotal for advancing the state of the art in healthcare monitoring and ultimately improving the overall healthcare experience for patients and providers.

1.12 Paper Outline

In this section, we present the outline of our survey concentrating on the convergence of social robots, Raspberry Pi, and healthcare monitoring systems in below figure 5.

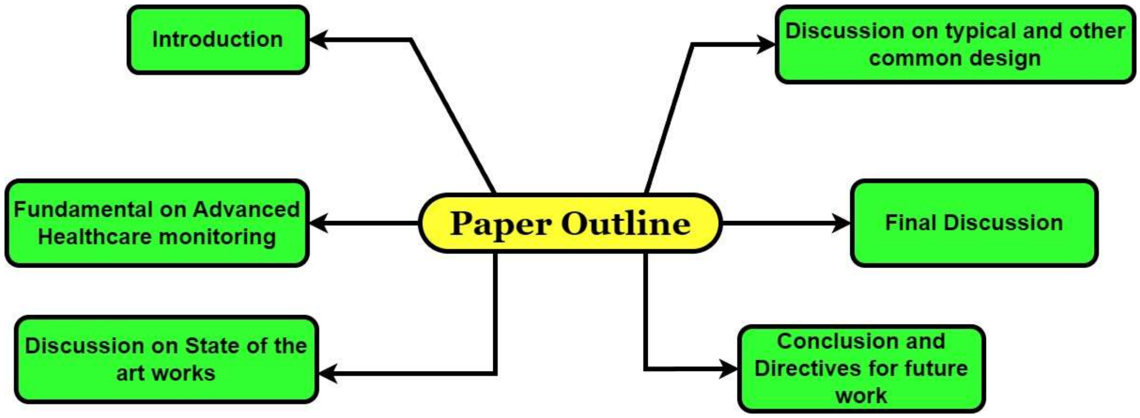


Fig. 5. Paper Outline

1.13 Paper Organization

Now, we organize the remaining sections of the entire manuscript in the following way:

Section 2 presents the fundamentals on advanced health care monitoring by discussing sensor technologies, introduction to healthcare monitoring and its advances, evolution, application domains, keys features, and key motivations of social robots in healthcare, and inclusion and exclusion criteria for social robots; Section 3 presents discussion on state-of-the-art works; Section 4 presents discussion on typical and other common designs; Section 5 presents final discussion; and finally, Section 6 presents conclusion and directives for future work.

Chapter 2

Health Tech Revolution

2.1 Fundamentals on Advanced Health Care Monitoring

Healthcare monitoring has come a long way from traditional paper records and periodic check-ups. With the advent of wearable devices, remote monitoring, and the IoT, healthcare monitoring has become more dynamic and continuous. However, these innovations still fall short of the potential offered by social robots equipped with ThingSpeak Raspberry Pi technology [39].

Healthcare professionals may now provide remote care thanks to social robots, which reduces expenses and increases accessibility. Instead of requiring hospital stays or regular medical visits, this technology allows patients to be monitored from home [40].

Today, social care delivery has the opportunity to incorporate both technical and human applications, and policy and practice are considering how to technologize care [41]. Assistive Technologies (ATs) like smartphone apps or screen readers [42]; and more advanced Assisted Living Technologies (ALTs) like telecare and telehealth, smart homes, or social robots [41, 43-45] are examples of technologies that are used in the administration, management, and provision of care. According to [43], 95% of United Kingdom (UK) social care providers employ digital technology in their business, mostly for staff communication requirements (which these days are probably cellphones). Though consideration of AT's potential or complications is still in its early stages, its usage is still common and regular [41, 46].

2.2 Sensor Technologies

Sensor technologies play a crucial role in various applications, from industrial automation to healthcare and consumer electronics [47]. Here's an explanation of each of the sensor technologies (as seen in the below figure 6):

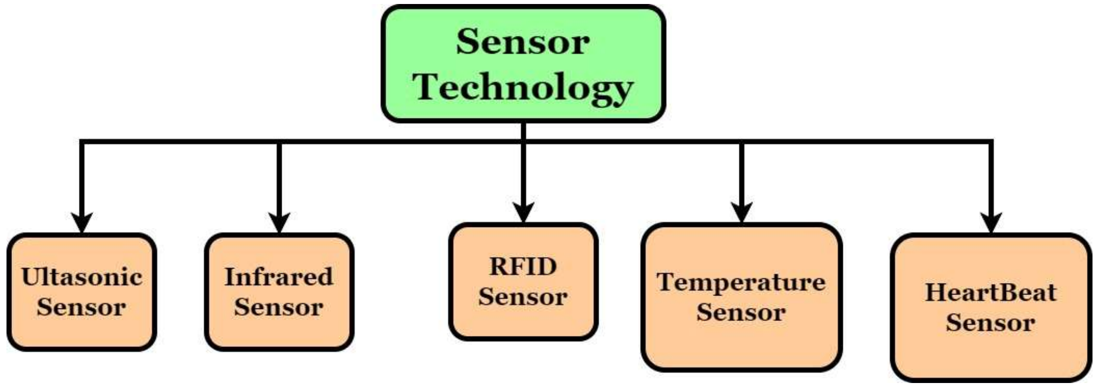


Fig.6. Different kinds of Sensors technology

1) Ultrasonic Sensors:

- Ultrasonic sensors use sound waves with frequencies higher than the human audible range (typically 20 kHz to 65 kHz) to measure distance or detect objects.
- They consist of a transmitter and a receiver. The transmitter emits ultrasonic pulses, which bounce off objects and return to the receiver.
- By measuring the time, it takes for the sound waves to travel and return, these sensors can calculate the distance between the sensor and the object.
- Ultrasonic sensors are commonly used in applications like proximity sensing, object detection, and distance measurement, such as in parking assist systems and industrial automation.

2) Infrared (IR) Sensors

- *IR sensors use IR light (radiation with wavelengths longer than visible light) to detect motion, heat, or proximity.*
- *Passive IR sensors detect changes in IR radiation to sense motion, making them suitable for motion-activated lighting and security systems.*
- *Active IR sensors emit and receive IR radiation, such as in Television (TV) remote controls or proximity sensors.*
- *IR sensors are used for applications like temperature measurement, presence detection, and remote-control systems.*

3) RFID Cards (Radio-Frequency Identification)

- RFID technology uses radio waves to communicate and identify objects or individuals wirelessly.

- RFID cards contain a microchip and an antenna. When they come into proximity with an RFID reader, the reader sends a radio signal that powers the card and retrieves data from the chip.
- Common applications include access control systems, contactless payment cards, tracking inventory, and identifying pets.

4) Temperature Sensors

- Temperature sensors measure temperature and provide data in digital or analog form.
- There are various types of temperature sensors, such as thermocouples, Resistance Temperature Detectors (RTDs), and thermistors, each with its own working principle and temperature range.
- Temperature sensors are used in a wide range of applications, from monitoring the temperature in Heating, Ventilation and Air Conditioning (HVAC) systems and industrial processes to controlling the temperature in household appliances and medical devices.

5) Heartbeat Sensors

- Heartbeat sensors, also known as heart rate monitors, detect and measure a person's heart rate or pulse.
- They often use optical or electrical methods to monitor blood flow and detect the pulsing of blood vessels.
- Heartbeat sensors are widely used in wearable fitness trackers, medical devices, and sports equipment to monitor the user's heart rate during physical activities.

These sensor technologies serve various purposes and are essential components in many aspects of modern life, from improving safety and convenience to enhancing healthcare and industrial processes.

2.3 Introduction to healthcare monitoring and its advances

The field of healthcare has witnessed significant advancements over the years, and the integration of technology has played a pivotal role in improving patient care, diagnosis, and treatment. Among these technological innovations, social robots have gained attention due to their potential to transform the healthcare landscape. These robots are designed to assist patients, healthcare professionals, and caregivers by providing companionship, monitoring vital signs, and offering support in various healthcare tasks. Moreover, the integration of IoT technologies, such as ThingSpeak and Raspberry Pi, has further expanded the capabilities of social robots in healthcare monitoring [48].

Healthcare monitoring is a critical aspect of patient care, especially for those with chronic illnesses or the elderly [49]. It is used for observation and measurement of patient's health parameters such as heart rate, respiratory rate, temperature, blood-oxygen saturation, and many other parameters of critically ill patients [50]. Such accurate and immediate information are useful for making crucial decision for effective patient care.

Regular monitoring of vital signs, medication adherence, and overall well-being is essential for early intervention and improving patient outcomes [51]. However, traditional monitoring methods can be invasive, inconvenient, and costly. Social robots equipped with healthcare monitoring capabilities offer a more patient-centric, non-intrusive, and cost-effective approach to addressing these challenges.

ThingSpeak, an IoT platform, allows for the collection and analysis of real-time data from various sensors and devices. Combining ThingSpeak with Raspberry Pi, a versatile and affordable single-board computer, provides an efficient and customizable way to integrate healthcare monitoring devices and sensors into a social robot [52]. This synergy creates a robust platform for real-time data acquisition, analysis, and transmission, making it an ideal choice for healthcare monitoring.

Now, let us see examples of social robots which are commercially available in medical sector currently as per [53] in the below figure 7.

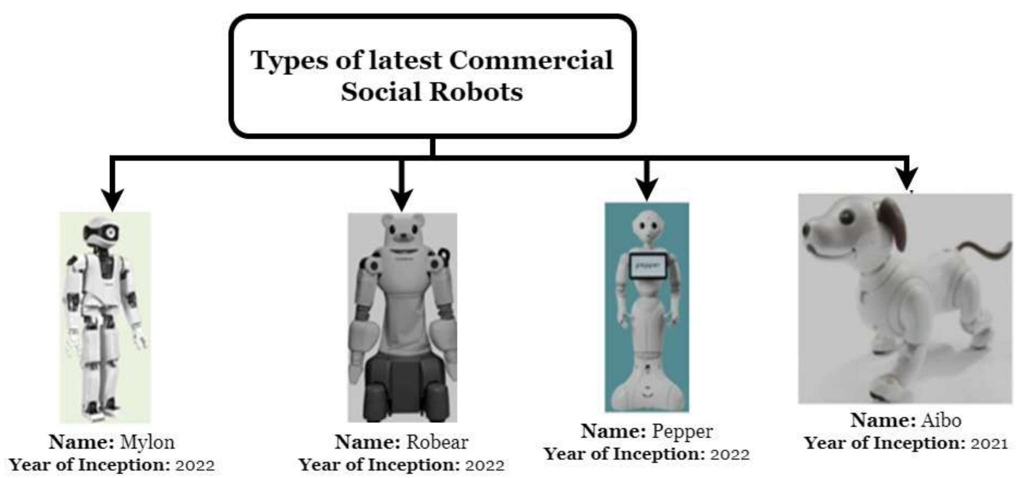


Fig. 7. Examples of commercially available social robots.

2.4 Significance of integrated systems

The integration of social robots into healthcare monitoring, powered by ThingSpeak and Raspberry Pi, holds substantial significance in several ways:

- **Enhanced Patient Engagement**: Social robots have the potential to engage patients actively in their own healthcare by providing reminders for medication, exercise, and other self-care activities. They offer emotional support, decreasing feelings of loneliness and anxiety, which are common in long-term healthcare scenarios.

- **Early Intervention**: Early detection of health issues is critical in healthcare. Social robots, equipped with advanced monitoring capabilities, can alert healthcare professionals and family members to any anomalies in a patient's health status, allowing for timely intervention and potentially avoiding medical emergencies.

- **Reduced Healthcare Costs**: By facilitating remote monitoring and reducing the need for frequent in-person visits, social robots can significantly reduce healthcare costs for both patients and providers. This is especially important in the context of an aging population with a higher prevalence of chronic diseases.

- **Customizability and Scalability**: ThingSpeak and Raspberry Pi offer a versatile platform for integrating and customizing various sensors and devices, making it adaptable to a wide range of healthcare scenarios and patient needs. It allows for scalability and ease of deployment in various healthcare settings.

2.5 Evolution of Social Robots

Researchers have come up with various terms to define social robots in the Human–Robot Interaction literature such as:

- **Socially evocative:** Robots that rely on the human tendency to anthropomorphize and capitalize on feelings evoked, when humans nurture, care or involve with their “creation” [54].

- **Socially situated:** Robots that are surrounded by a social environment which they perceive and react to. Socially situated robots are able to distinguish between other social agents and various objects in the environment [55].

- **Sociable:** Robots that proactively engage with humans in order to satisfy internal social aims (drives, emotions, etc.). These robots require deep models of social cognition [54, 55].

- **Socially intelligent:** Robots that show aspects of human-style social intelligence, based on possibly deep models of human cognition and social competence [56].

- **Socially interactive robots:** Robots for which social interaction plays a key role in peer-to-peer Human–Robot Interaction, different from other robots that involve 'conventional' Human–Robot Interaction, such as those used in teleoperation scenarios [39].

2.6 Application domains of Social Robots

There are many studies that use social robots in various application domains such as education, healthcare or service. So much so, that it becomes challenging to follow new social robot designs, implementations and findings. This leads to the need for a survey and review of papers in social robotics.

Previous review articles have been working on different aspects of social robotics. For example, some review papers cover the use of social robots in different applications such as social robots used in education [57], in autism therapy [58], dementia care [59] or in service applications [60]. Other review articles focused on the interaction between social robots and specific target groups such as children [30], older adults [61] or students [62].

2.7 Key Features of Social Robots in Healthcare Monitoring

- **Continuous Vital Signs Monitoring:** Social robots are capable of monitoring vital signs such as heart rate, blood pressure, and oxygen saturation in real-time. This continuous monitoring provides immediate feedback to both patients and healthcare professionals [57].

- **Behavior Analysis:** Social robots equipped with ThingSpeak Raspberry Pi can analyze patient behaviour and movement patterns to detect signs of discomfort or distress. This level of insight is invaluable for providing timely care and intervention.

- **Medication Reminders:** These robots can assist in medication management by providing reminders and ensuring patients take the right medications at the right time, thus reducing the risk of non-compliance.

- **Interactive Communication:** Social robots are designed to interact with patients in a natural and engaging manner. They can provide information, answer questions, and offer companionship, which can be particularly beneficial for patients experiencing isolation.

- **Integration with Health Records:** Data collected by social robots can be seamlessly integrated into patients' electronic health records, creating a comprehensive patient profile that healthcare providers can access and analyze.

2.8 Key Motivations for Social Robots in Health Care Monitoring

The healthcare landscape is undergoing a paradigm shift driven by an aging global population, rising chronic diseases, and the increasing demand for quality healthcare services [63, 64]. Traditional healthcare models are often overwhelmed by these challenges, leading to a need for innovative solutions that can not only improve the quality of care but also reduce the burden on healthcare professionals. Enter social robots equipped with ThingSpeak Raspberry Pi technology, which have the capability to address these issues effectively [54].

Chronic illnesses, mental health issues, and the need for continuous monitoring have become more prevalent than ever before. This is where social robots come into play. These robots are equipped with the ability to engage with patients in a human-like manner, thereby providing essential emotional support and a sense of companionship, especially to those suffering from isolation and loneliness [65].

Social robots are a burgeoning field within robotics, aimed at creating machines that can interact with humans in a human-like manner [66]. They have gained significant traction in various sectors, including healthcare, where they have the potential to bridge the gap between patients, healthcare providers, and caregivers. These robots can offer companionship, support, and essential monitoring services while maintaining a constant connection with healthcare systems [55]. Let us see the key motivations via the below figure 8.

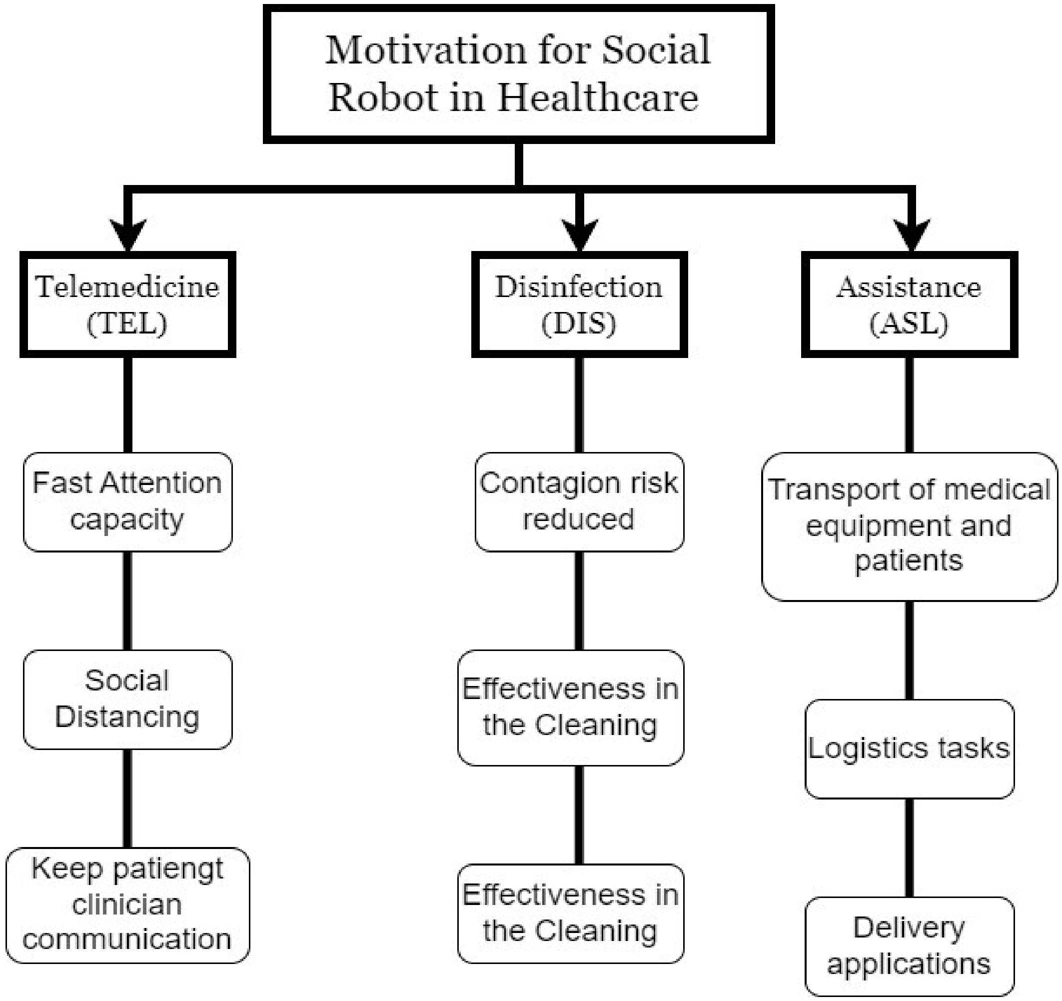


Fig. 8. Motivation for RoboCare Connect

Recent advancements in social robots for healthcare monitoring systems involve utilizing sensors and Raspberry Pi technology [67]. These robots can collect and analyze patient data through sensors, providing health information and support, enhancing patient care, and facilitating early intervention [68-70].

- **Compassionate Companionship:** Social robots possess a unique ability to establish an emotional connection with patients, offering companionship and reducing feelings of isolation, which is particularly important for those confined to long-term care facilities or home care settings.

- **Enhanced Patient Engagement:** Social robots can stimulate patient engagement by offering reminders for medication, exercise routines, and dietary habits, ultimately leading to better adherence to care plans and improved health outcomes.

- **Continuous Monitoring:** These robots can continuously monitor patient vital signs, activity levels, and medication adherence, ensuring immediate responses to any deviations or emergencies, thus reducing hospital readmissions and improving patient health.
- **Data Analytics and Reporting:** The data collected by social robots can be analyzed to provide healthcare professionals with valuable insights into patient behavior and health trends, enabling more informed and proactive decision-making.
- **Personalized Care:** Social robots can be programmed to deliver personalized care plans based on individual patient needs, adjusting their interactions and reminders accordingly.
- **Cost Efficiency:** Over time, the investment in social robots can lead to cost savings, reducing the burden on healthcare systems while improving the overall quality of care.
- **Improved Mental Health:** These robots can offer mental health support through interactive therapy sessions and monitoring of emotional well-being, helping patients better manage stress, anxiety, and depression.

2.9 Inclusion and exclusion

Inclusion and exclusion criteria are essential components of a research study or a program involving social robots in healthcare monitoring. These criteria help ensure that the selection of participants is consistent and appropriate for the study's objectives. Here are some example inclusion and exclusion criteria for using social robots in healthcare monitoring:

Inclusion and exclusion criteria should be tailored to the specific context and goals of the healthcare monitoring study, ensuring that the participants are representative of the target population and that the results are meaningful and ethical. Additionally, they should be documented and clearly communicated to all stakeholders involved in the study. A tabulation containing the inclusion and exclusion criteria have been mentioned in the following table II:

TABLE II. TABULATION OF INCLUSION AND EXCLUSION

Inclusion criteria	Exclusion criteria
Articles of user studies with people aged 65 and older Evidence of user studies with people aged less than 65 years old Articles focused on telepresence robot(s) Articles of user studies with people aged 65 and older	Evidence of user studies with people aged less than 65 years old
Articles focused on telepresence robot(s)	Evidence focused on forms of technology other than telepresence robots
Articles focused on social connection in a healthcare setting with formal care provided by paid staffArticles focused on telepresence robot(s) Articles focused on social connection in a healthcare setting with formal care provided by paid staff	Evidence focused on settings without formal care (i.e., home care)
Peer-reviewed journal articles or full reports available on the internet	Only abstracts available
Publications in English Publications in English	Non-English publications

Chapter 3

Literature Review

3.1 Discussion on State of the Art Works

IoT makes all objects become interconnected and smart, which has been recognized as the next technological revolution. As its typical case, IoT-based smart rehabilitation systems are becoming a better way to mitigate problems associated with aging populations and shortage of health professionals. Although it has come into reality, critical problems still exist in automating design and reconfiguration of such a system enabling it to respond to the patient’s requirements rapidly. This paper presents an ontology-based Automating Design Methodology (ADM) for smart rehabilitation systems in IoT. Ontology aids computers in further understanding the symptoms and medical resources, which helps to create a rehabilitation strategy and reconfigure medical resources according to patients’ specific requirements quickly and automatically. Meanwhile, IoT provides an effective platform to interconnect all the resources and provides immediate information interaction. Preliminary experiments and clinical trials demonstrate valuable information on the feasibility, rapidity, and effectiveness of the proposed methodology [71].

This article describes a Body Area Network (BAN) for measuring an Electrocardiogram (ECG) signal and transmitting it to a smartphone via Bluetooth for data analysis. The BAN uses a specially designed Planar Inverted F-Antenna (PIFA) with a small form factor, realizable with low-fabrication cost techniques. Furthermore, due to the human body's electrical properties, the antenna was designed to enable surface-wave propagation around the body. The system utilizes the user's own smartphone for data processing, and the built-in communications can be used to raise an alarm if a heart attack is detected. This is managed by an application for Android smartphones that has been developed for this system. The good functionality of the system was confirmed in three real-life user case scenarios [72].

The level of documentation of vital signs in many hospitals is extremely poor, and respiratory rate, in particular, is often not recorded. There is substantial evidence that an abnormal respiratory rate is a predictor of potentially serious clinical events. Nurses and doctors need to be more aware of the importance of an abnormal respiratory rate as a marker of serious illness. Hospital systems that encourage appropriate responses to an elevated respiratory rate and other abnormal vital signs can be rapidly implemented. Such systems help to raise and sustain awareness of the importance of vital signs [73].

Extensive research has been dedicated to the exploration of various technologies such as Information Technology (IT) in complementing and strengthening existing healthcare services. In particular, the IoT has been widely applied to interconnect available medical resources and provide reliable, effective and smart healthcare service to the elderly and patients with a chronic illness. The aim of this paper is to summarize the applications of IoT in the healthcare industry and identify the intelligentization trend and directions of future research in this field. Based on a comprehensive literature review and the discussion of the achievements of the researchers, the advancement of IoT in healthcare systems have been examined from the perspectives of enabling technologies and methodologies, IoT-based smart devices and systems, and diverse applications of IoT in the healthcare industries. Finally, the challenges and prospects of the development of IoT based healthcare systems are discussed in detail [74].

A number of technologies can reduce overall costs for the prevention or management of chronic illnesses. These include devices that constantly monitor health indicators, devices that auto-administer therapies, or devices that track real-time health data when a patient self-administers a therapy. Because they have increased access to high-speed Internet and smartphones, many patients have started to use mobile applications (apps) to manage various health needs. These devices and mobile apps are now increasingly used and integrated with telemedicine and telehealth via the medical Internet of Things (mIoT). This paper reviews mIoT and big data in healthcare fields, mIoT is a critical piece of the digital transformation of healthcare, as it allows new business models to emerge and enables changes in work processes, productivity improvements, cost containment and enhanced customer experiences [75].

In this busy world most of the working people are failed to care about their health. They think that is not the big issue, but the truth is, this leads to severe health problems. These are due to the lack of routine monitoring the health. this system is mainly used to monitor the person's health who are busy at their work. By this innovative project, it becomes possible to monitor the patient's health routinely by using the respective sensors. By using this project, we can know whether the person is having the danger of cardiac arrest, fever. The parameters measured are temperature, heartbeat, and pulse by using respective sensors. The data from the sensors are given to the Arduino Uno. The biomedical sensors here are connected to Arduino UNO to read the data which in turn interfaced to an Liquid Crystal Display (LCD) /serial monitor to see the output [76].

Now, let us present the analysis and main outcomes from the major research works [32, 71-75, 77, 78] in the below table III.

TABLE III. RESEARCH ANALYSIS & MAIN OUTCOME

Authors and citations	Title	Year	Techniques	Gap Finding	Main Outcomes
Fan, Y. J., Yin, Y. H., Da Xu, L., Zeng, Y., & Wu, F. [71]	IoT based smart rehabilitation system	2014	Virtual Reality (VR)/ Augmented Reality (AR) technique	Focus on developing advanced encryption and authentication methods	Ontology-based ADM
Wolgast, G., Ehrenborg, C., Israelsson, A., Helander, J., Johansson, E., & Manefjord, H. [72]	Wireless BAN for Heart Attack Detection	2016	Designed PIFA	To improve detection capabilities, research should explore the integration of additional sensors	Measuring an ECG signal and transmitting it to a smartphone via Bluetooth for data analysis
Islam, M. M., Rahaman, A., & Islam, M. R. [73]	Development of Smart Healthcare Monitoring System in IoT Environment.	2020	Pulse rate detection system based on a noninvasive technique	Lack of standardized protocols and frameworks for integration	A smart healthcare system in IoT environment
Yuehong, Y. I. N., Zeng, Y., Chen, X., & Fan, Y. [74]	IoT in healthcare: An overview	2015	Advancement of IoT in healthcare systems	Vulnerabilities that may compromise patient information	IoT-based smart devices and systems, and diverse applications
Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K. S. [75]	The IoT for Health Care: A Comprehensive Survey	2016	Integrated with telemedicine and telehealth	Holistic examination of this transformative technology's impact	Studied and analysis on telemedical and telehealth by IoT Network for health care (hereafter ‘‘the IoThNet’’)
Koshti, M., Ganorkar, S., & Chiari, L. [78]	IoT Based Health Monitoring System Using Arduino Uno	2023	Arduino UNO, LCD Display, MAX30100 pulse oximeter	Limitations in terms of sensor accuracy and the range of parameters	IoT based Health Monitoring System Arduino UNO
MohanKumar, M., Kirthana, S., Pavithra Banu, N., JB, P. M. S., & Madhumitha, M. [77]	Multi-Parameter Smart Health Monitoring System Using Arduino-Uno	2021	Arduino-UNO as the 8-bit micro-controller, Atmega 328. LM 35, XD-58C for cardiac beat rate	Can process the collected data and provide meaningful insights or alerts	Constantly, efficiently and centrally to track the temperature and heartbeat of the patient.
Jebane, P., Anusuya, P., Suganya, M., Meena, S., & Diana, M. [32]	IOT Based Health Monitoring and Analyzing System Using Thing speak Cloud & Arduino	2018	Arduino sensors, and ESP 8266 wireless module	Investigate how to safeguard patient data, prevent unauthorized access	Monitors continuously of any abnormalities or emergencies

3.2 Current Trends

In "Health Monitoring Technologies" encompass a dynamic and evolving landscape in healthcare. It's crucial to understand these trends to contextualize the development and significance of the "Social Robot Health Monitoring System." Here's a detailed exploration of current trends in health monitoring technologies:

1. **Wearable Health Devices**: Wearable technology has revolutionized personal health monitoring. Devices like smartwatches, fitness trackers, and even smart clothing can track various health parameters such as heart rate, activity levels, sleep patterns, and more. These devices have gained popularity due to their convenience, allowing users to continuously monitor their health in real-time.
2. **Remote Patient Monitoring**: With the advancement of telemedicine and IoT, remote patient monitoring has become a significant trend. Patients can now be monitored from the comfort of their homes, reducing the need for frequent hospital visits. Medical 4 professionals can remotely track patients' vital signs, chronic conditions, and adherence to treatment plans, improving patient outcomes and reducing healthcare costs.
3. **Mobile Health (mHealth) Applications**: The proliferation of smartphones has led to the development of a vast array of mobile health applications. These apps help individuals monitor their health, providing resources for fitness, nutrition, medication reminders, and symptom tracking. They also facilitate communication with healthcare providers and offer access to telemedicine services.
4. **Data Analytics and Artificial Intelligence**: The integration of data analytics and artificial intelligence (AI) has enhanced health monitoring and diagnostics. AI algorithms can analyze large datasets, identify trends, and provide insights into a patient's health. Machine learning models can predict disease progression and suggest personalized treatment plans, ultimately leading to more effective healthcare.
5. **Internet of Things (IoT)**: IoT devices have found extensive applications in health monitoring. These interconnected devices can collect and transmit health data to central systems. Examples include smart scales, blood pressure monitors, and glucometers that automatically share data with healthcare providers, ensuring that any critical changes in a patient's condition are quickly identified and addressed.

6. **Personalized and Predictive Healthcare**: Health monitoring is increasingly shifting towards personalization. Rather than one-size-fits-all approaches, healthcare is becoming more tailored to individual needs. Predictive analytics can anticipate health issues, enabling early intervention. Personalized health plans and treatments improve outcomes by accounting for an individual's unique genetic, lifestyle, and environmental factors.
7. **Telemedicine and Virtual Health**: The COVID-19 pandemic accelerated the adoption of telemedicine and virtual health services. Remote consultations with healthcare professionals, prescription management, and remote monitoring have all become standard practices. This trend is likely to continue as it provides accessible and efficient healthcare services.
8. **Continuous Glucose Monitoring (CGM) for Diabetics**: For individuals with diabetes, continuous glucose monitoring (CGM) devices have become a game-changer. These devices track blood glucose levels in real-time and provide alerts when levels are too high or too low. They not only improve diabetes management but also enhance quality of life. 5
9. **Non-Invasive Health Monitoring**: Advances in non-invasive monitoring technologies have made it possible to measure various health parameters without the need for invasive procedures. For instance, non-invasive blood pressure monitors, smart thermometers, and wearable electrocardiogram (ECG) devices offer convenient and comfortable monitoring options.
10. **Mental Health Monitoring**: Mental health monitoring is gaining recognition as an essential component of overall health. Mobile apps and wearable devices are being developed to track emotional well-being, stress levels, and sleep quality. These technologies are contributing to improved mental health awareness and support.

Understanding these trends in health monitoring technologies is critical because the "Social Robot Health Monitoring System" fits into this dynamic landscape. It leverages these trends by providing a socially interactive, autonomous robot capable of integrating wearable health sensors and delivering real-time health assessments. It aligns with the direction of healthcare and technology by offering a proactive and innovative approach to health monitoring in social settings.

3.3 Principles and Operation

The "Social Robot for Health Monitoring System" operates on the principles of integrated sensor technology, automation, and data analysis to provide comprehensive health monitoring and support in social settings.

1. **Sensor Integration**: The core principle is the integration of multiple sensors, including RFID technology for navigation, heartbeat and temperature sensors for 10 health data collection, and ultrasonic sensors for obstacle detection. These sensors work collectively to provide real-time data and ensure the robot's safe navigation.
2. **Navigation and Localization:** The robot uses RFID technology to navigate predefined routes. RFID tags serve as checkpoints, allowing the robot to stop at predetermined locations for health assessments. This principle ensures the robot moves efficiently and accurately within the environment.
3. **Health Data Collection:** The robot's heartbeat and temperature sensors are designed to collect vital health data from individuals. These sensors are non-invasive, making the health assessment process comfortable for the user.
4. **Obstacle Detection and Response**: The robot's ultrasonic sensors detect obstacles in its path and trigger a response, ensuring the safety of both the robot and the individuals in its vicinity.
5. **Data Analysis and Connectivity:** Health data collected by the robot is analyzed and transmitted to a web server, ensuring centralized data storage and easy access for healthcare professionals and caregivers. This principle ensures that health data is readily available for analysis and decision-making.
6. **Alert System:** An alert system is integrated to notify relevant parties when health parameters surpass predefined thresholds. This principle provides timely intervention in case of critical health events.

The operation of the "Social Robot for Health Monitoring System" revolves around these principles, enabling the robot to autonomously navigate, conduct health assessments, ensure safety, and provide a centralized platform for health data storage and analysis. This innovative approach aims to enhance health monitoring in social settings, improving the well-being of individuals and supporting healthcare professionals and caregivers in their roles.

3.4 Use Cases

The "Social Robot for Health Monitoring System" offers a wide range of use cases in various healthcare and social settings, making it a versatile tool for proactive health management and support. Some key use cases include:

1. **Hospitals and Clinics**: In healthcare institutions, the robot can conduct routine health assessments for patients, monitor vital signs, and alert healthcare professionals when critical thresholds are reached, enhancing patient care.
2. **Nursing Homes and Assisted Living Facilities**: The robot can provide companionship to residents, assist with daily tasks, and continuously monitor their health, reducing feelings of isolation and ensuring timely care.
3. **Home Healthcare**: For individuals receiving home healthcare, the robot can collect health data, remind patients to take medication, and offer a connection to healthcare providers through telemedicine.
4. **Rehabilitation Centers**: In rehabilitation settings, the robot can guide patients through exercises, track progress, and provide emotional support during recovery.
5. **Schools and Special Education Centers**: The robot can help monitor the health of students, particularly those with special needs, ensuring their safety and well being.
6. **Disaster Response**: In disaster-stricken areas, the robot can assist in providing healthcare services, monitor the health of survivors, and relay vital information to emergency responders.
7. **Elderly Companionship**: The robot can serve as a friendly companion for elderly individuals, engaging in conversations and activities to reduce loneliness.
8. **Remote Health Monitoring**: In remote or underserved areas, the robot can autonomously navigate and conduct health assessments, serving as a telemedicine hub.
9. **Health and Wellness Promotion**: The robot can promote healthy lifestyles by offering exercise guidance, nutritional advice, and monitoring progress for individuals looking to improve their overall health.
10. **Research and Data Collection**: The robot can be deployed for health-related research, collecting valuable data and contributing to the advancement of healthcare knowledge. The "Social Robot for Health Monitoring System" demonstrates its adaptability and potential across a spectrum of healthcare and social scenarios, enhancing the quality of care, ensuring patient safety, and supporting healthcare professionals and caregivers in various environments.

Chapter 4

Methodology

4.1 Research Design

The social robot in healthcare monitoring performs tasks such as delivering medication, recording vital signs, and offering companionship to patients [40]. It ensures a safe and efficient environment while allowing healthcare professionals to focus on critical tasks. The data collected by the various sensors is transmitted to ThingSpeak, where it can be analyzed to identify patterns, trends, or anomalies in patients' health. This technology not only enhances patient care but also offers a level of independence and assistance to individuals in need, ultimately improving the quality of healthcare services.

4.1.1 Discussion on typical design

This design (as seen in the below figure 9) creates a versatile and responsive social robot capable of enhancing healthcare monitoring and patient care by collecting and analyzing vital data, ensuring patient safety, and improving overall healthcare service delivery with important elements, which are as follows:

- **Ultrasonic Sensor:** The ultrasonic sensor is used to detect obstacles and navigate through the environment safely, ensuring the robot can move around without collisions [79].
- **IR Sensor:** IR sensors aid in tracking patient movements and interactions, allowing the robot to respond to their needs more effectively [69].
- **RFID Cards:** RFID technology is employed for patient identification and access control [80]. Patients wear RFID cards, enabling the robot to identify and provide personalized care.
- **Temperature Sensor:** Monitoring patient temperature is crucial in healthcare [81]. The temperature sensor helps the robot keep track of a patient's well-being and detect any anomalies [82].
- **Heartbeat Sensor:** The heartbeat sensor is employed for real-time monitoring of the patient's vital signs, alerting healthcare providers in case of irregularities [83].
- **Raspberry Pi:** The Raspberry Pi serves as the central processing unit, running the robot's software, managing data from sensors, and facilitating communication with healthcare professional.

- **Motor Driver:** The motor driver controls the robot's movement, enabling it to navigate through the healthcare facility efficiently and reach patients in need [84].
- **ThingSpeak:** ThingSpeak is a cloud-based platform used to store, analyse, and visualize the collected sensor data. It provides real-time access to healthcare professionals and family members, enabling them to monitor patients' health remotely.

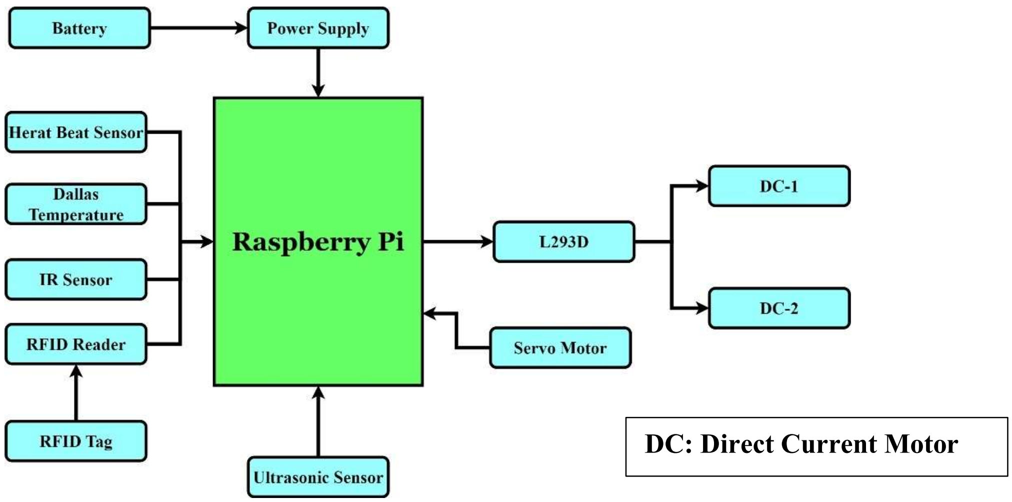


Fig. 9. Pictorial representation of the typical Design

4.1.2 Discussion on other designs

1) ***Design 1***: In another design, a robot is designed which have IR sensors and Ultrasonic sensors. The robotic vehicle uses ultrasonic sensor for detecting distance between 2 individuals in a queue. If any 2 individuals are found having less than threshold distance between them robot will be move other side. If the rule is violated, then RFID tag will be read patient id. Intelligent physical robots based on AI have been argued to bring about dramatic changes in health care services. Previous research has examined the use of intelligent physical robots in the health care context from different perspectives; however, an overview of the antecedents and consequences of intelligent physical robot use in health care is lacking in the literature.

2) ***Design 2*****:** Compare to the previous methods of paper [76], there we are discussing about there is no social distance monitoring systems has been developed. The person needs to monitor the patient in the que and need to alert the people to stand 6 feet away all the time.

- The Smart Alarms consists of an alarm algorithm that considers multiple vital signs when monitoring a post Coronary Artery Bypass Graft (post-CABG) surgery patient. The nature of this condition enables the algorithm to focus on monitoring the patient.
- Radio Frequency 433 (RF433) Megahertz (MHz) transmitter and receiver modules are commonly used in wireless communication systems for various applications such as remote control, data transmission, and wireless sensor networks. They operate at a frequency of 433 MHz, making them suitable for short-range wireless communication by this the rover is going to collect the patent data.
- The ESP8266 can be a vital component in a health monitoring system, enabling the collection and transmission of health data to a remote server for real-time monitoring and analysis. It provides a cost-effective and efficient way to implement connected health monitoring solutions that can benefit patients, healthcare providers, and caregivers.

Their effectiveness hinges on factors like human-like interaction, adaptability, reliability, and adherence to ethical standards. To excel, they must demonstrate a deep understanding of patients' emotional needs, privacy and security, and seamless integration into existing healthcare systems. Ensuring high-quality social robots in healthcare requires rigorous testing, continuous improvement, and adherence to rigorous safety and ethical standards to enhance patient outcomes, reduce healthcare burdens, and complement human care providers effectively.

4.2 System Architecture

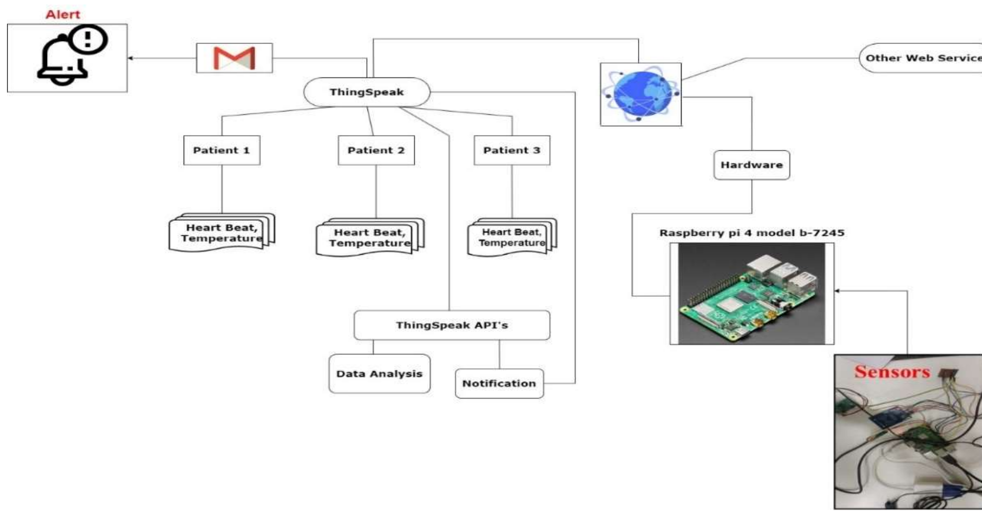


Fig. 10. Proposed Architecture for Research Study

4.2.1 Hardware Components

With reference to Figure 6, the hardware components of the system comprise the social robot's physical infrastructure. This comprises the power system, wheels, motors, and chassis of the robot, as well as a variety of sensors including the RFID reader, temperature sensor, heartbeat sensor, and ultrasonic sensor. Carefully considered design ensures that the hardware components are sturdy, portable, and capable of withstanding the rigors of social and healthcare contexts. The sensors are placed carefully for best data gathering and obstacle detection, and the chassis is frequently built for stability and mobility.

4.2.2 Software Components

With reference to Figure 6, the social robot's brain is made up of software components. Important components include the operating system, communication protocols, and control algorithms. The platform required to run control algorithms and manage data is provided by the operating system. Obstacle avoidance, autonomous navigation, and health assessment processes are made possible by control algorithms. In order to send health data to a centralized server for real-time monitoring and analysis, communication protocols are essential.

4.2.3 Interactions

With reference to Figure 6, Interactions comprise the manner in which the social robot interacts with people in its surroundings. This includes voice recognition, gesture interpretation, and emotional response systems in human-robot interactions. The goal of the robot's interactions is to improve the user experience in social and medical contexts by being approachable and sympathetic. In addition, the system's interactions involve reacting to barriers found while navigating, guaranteeing the security of the robot and its environment.

4.3 Development Process

4.3.1 Hardware Design

The actual robot is created during the hardware design phase. This entails building the chassis with stability and mobility in mind, choosing wheels and motors that make navigating easier, and setting up the power supply to run continuously. The integration and layout of sensors are carefully considered in order to align them for optimal data collecting and obstacle detection efficiency. For hardware design to result in a well-organized and working robot, rigorous planning and prototyping are necessary.

4.3.2 Sensor Integration

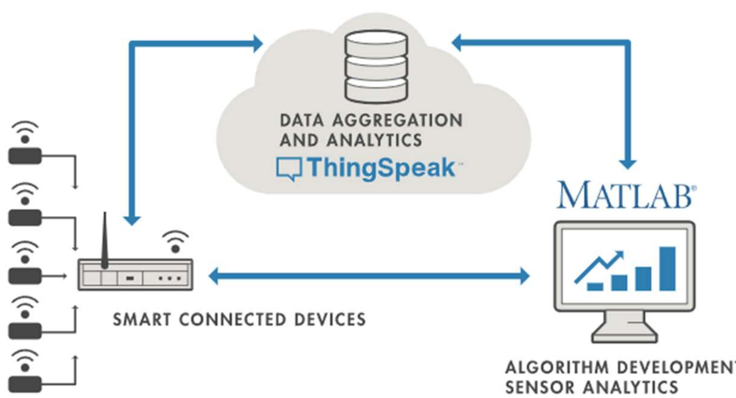


Fig.11. Block Diagram of Sensor Integration with MATLAB

A critical phase in the development process is the integration of sensors. Every sensor—heartbeat, temperature, RFID, and ultrasonic—needs to be properly included into the hardware and software elements. To guarantee reliable data gathering and obstacle detection, calibration and testing are essential. In order to provide safe navigation and efficient health monitoring, sensor integration also entails establishing sensor parameters and algorithms.

4.3.3 Software Development

The development of the robot's control algorithms, which enable smooth autonomous navigation, health assessment processes, and obstacle avoidance, is the main goal of the software development process. Programming, machine learning, and artificial intelligence proficiency are required for this phase. The software development process also includes the creation of safe communication protocols for sending data to a central server, which is an essential component of the system.

4.3.4 Connectivity Setup

Configuring the robot to connect to a web server or cloud platform is part of the connection configuration. This entails putting in place authentication procedures, creating secure data transmission routes, and making sure that data privacy and security laws are followed. Setting up connectivity is essential for collecting and analyzing data in real-time, giving caregivers and medical professionals access to the most recent health information, and allowing alarm systems.

4.3.5 Data Collection and Analysis

The process of obtaining health information from people during health assessments is known as data collection and analysis. Heart rate, temperature, and other pertinent variables are included in this data. After gathering, the data is sent to a cloud platform or centralized server for analysis. In order to understand the data, identify patterns, and provide insights, the analysis phase makes use of machine learning and data analytics tools. It makes it possible to identify aberrant health markers, which may lead to alarms and early actions. The system's primary function is to provide real-time health monitoring and assistance. This is accomplished through data collecting and analysis.

4.4 Testing and Validation

The testing and validation phase is crucial to ensure the system's functionality, reliability, and safety. It involves a series of tests, including:

1. **Functionality Testing**: To assess whether the robot can autonomously navigate, stop at RFID checkpoints, collect health data accurately, and respond to obstacles.
2. **Safety Testing:** To confirm that the robot's obstacle detection system operates effectively and that it poses no harm to users.

3. **Data Accuracy Testing:** To verify the accuracy of health data collected by the robot's sensors.
4. **Connectivity Testing**: To ensure that data is successfully transmitted to the centralized server for analysis.
5. **User Experience Testing**: To evaluate the robot's interactions with users, including its ability to provide a friendly and empathetic experience.
6. **Long-Term Performance Testing**: To assess the robot's durability and performance over extended periods of operation.

Testing and validation are iterative processes that help identify and rectify issues, ensuring the system meets the intended goals and standards of operation.

Chapter5

System Design and Implementation

5.1 Robot Hardware

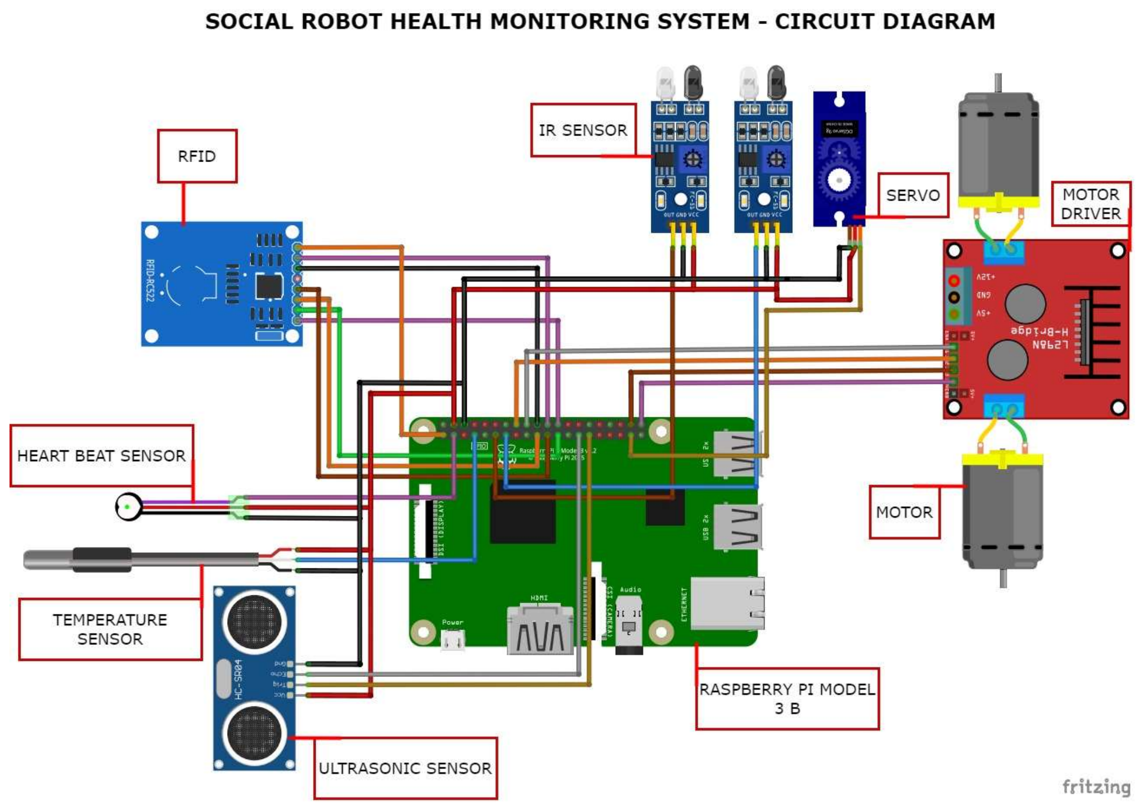


Fig. 12. Social Robot Health Monitoring System Circuit Diagram

5.1.1 Chassis

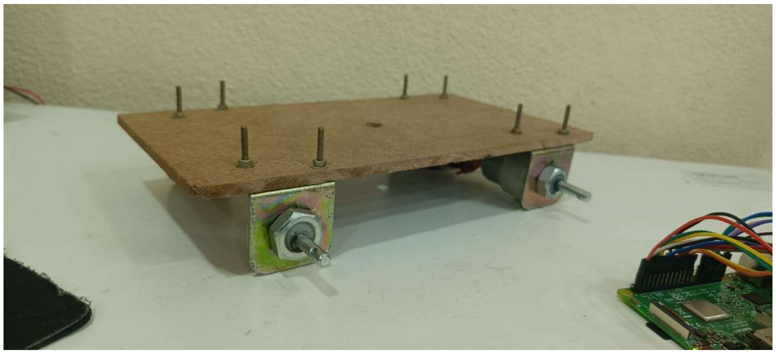


Fig. 13. Chassis

The physical framework that serves as the health monitoring robot's base is called the chassis. Because of its stability, robustness, and mobility, the robot can move through social and medical settings with ease. In addition to having wheels that allow for mobility, the chassis may also have shock absorption or suspension systems to improve stability and reduce vibrations. The weight, strength, and general performance of the robot are all impacted by the materials chosen, therefore selection is crucial. The chassis serves as a strong basis for the system and is carefully designed and tested to guarantee that it can endure the rigors of healthcare and social environments.

5.1.2 Motors and Wheels

Fig. 14. White Robotic Wheel (70mm x 35mm)

TABLE IV. WHEEL SPECIFIFCATION TABLE

Sr. No.	Details	Specification
1	Color	White
2	Diameter	70mm x 35mm
3	Material	Plastic
4	Shape	Round
5	Wheel Coating Material	Silicon Rubber

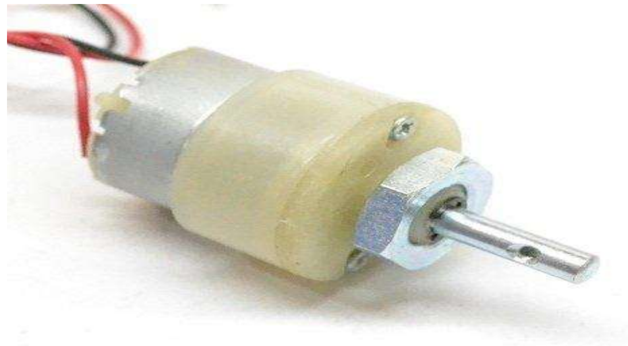


Fig. 15. 12 Volts Direct Current Motor

TABLE V. DIRECT CURRENT MOTOR SPECIFICATION TABLE

Sr. No.	Details	Specification
1	Revolutions per Minute	100
2	Shaft Diameter	6mm (with internal hole)
3	Shaft Length	15mm
4	Motor Diameter	28.5mm
5	Torque	12 kg-cm
6	Voltage	6 to 24

Motors and wheels are integral components of the robot's hardware, enabling movement and navigation. Motors are carefully selected to provide precise control over the robot's speed and direction. Wheels are designed for optimal traction and maneuverability, allowing the robot to traverse different surfaces and environments. The design of the motors and wheels is tailored to facilitate smooth and accurate movement, critical for the robot's ability to autonomously navigate predefined routes, stop at RFID checkpoints, and respond to obstacles. Robust motor and wheel systems are essential to the reliability and efficiency of the robot.

5.1.3 Power System

Fig. 16. 12 Volts Direct Current Battery

The parts of the robot that provide and control electrical energy are referred to as its power system. Batteries or other power sources, circuits for power control, and charging systems fall within this category. The power system is built to run continuously, allowing the robot to travel and conduct health checks for the duration of its allotted operational period. Furthermore, the power supply is designed to be as energy-efficient as possible, extending the robot's use before it has to be recharged. To ensure that the robot can finish its work, redundancy and fail-safes are frequently built to prevent unexpected shutdowns. The goal of the power system design is to achieve a balance between operational dependability and energy autonomy.

5.2 Sensor Integration

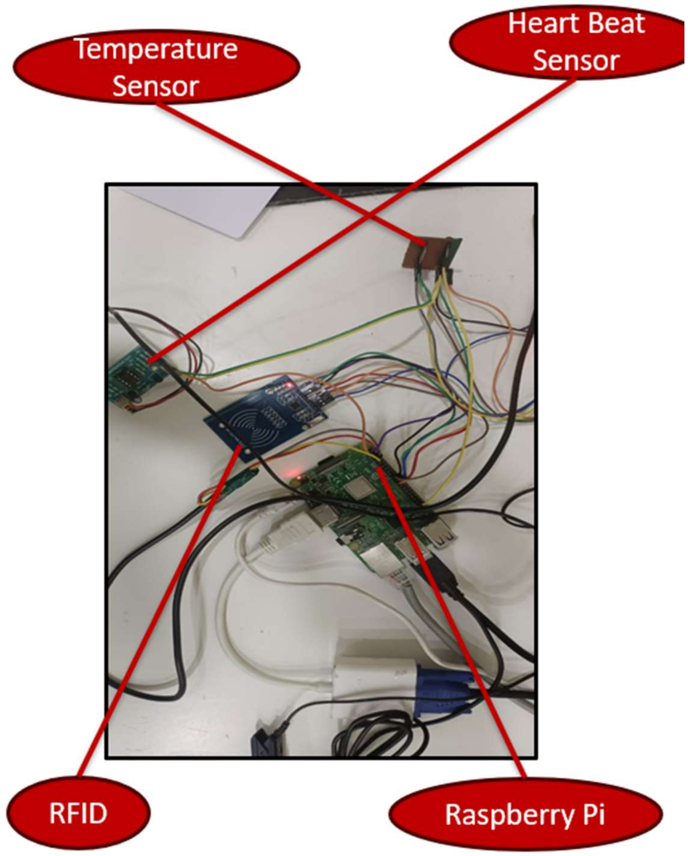


Fig. 17. Sensors Integration

5.2.1 RFID Reader

Fig. 18. Radio Frequency Identification

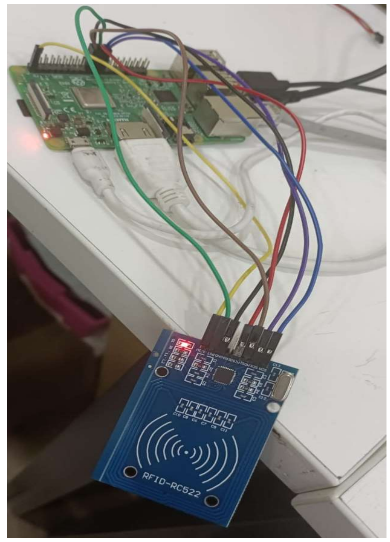


Fig. 19. Interfacing of Radio frequency Identification with Raspberry Pi Model 3 B

An essential sensor for the health monitoring robot is the RFID reader. Its purpose is to scan RFID tags positioned within the robot's working area at prearranged checkpoints. The antennae and communication modules required for the RFID reader to interact with the tags are installed. In order to guarantee that the robot can precisely stop at specified checkpoints for health checks, its design strives to maximize reading accuracy and range. Careful placement is required to line the RFID reader with the RFID tag locations during integration, allowing for easy navigation and health data gathering.

TABLE VI. RC522 Pin Configuration

Pin Number	Pin Name	Description
1	Vcc	Used to Power the module, typically 3.3V is used
2	RST	Reset pin – used to reset or power down the module
3	Ground	Connected to Ground of system
4	IRQ	Interrupt pin – used to wake up the module when a device comes into range
5	MISO/SCL/Tx	MISO pin when used for SPI communication, acts as SCL for I2c and Tx for UART.
6	MOSI	Master out slave in pin for SPI communication
7	SCK	Serial Clock pin – used to provide clock source
8	SS/SDA/Rx	Acts as Serial input (SS) for SPI communication, SDA for IIC and Rx during UART

What is RFID technology and how does it work?

RFID or Radio Frequency Identification system consists of two main components, a transponder/tag attached to an object to be identified, and a Transceiver also known as interrogator/Reader.

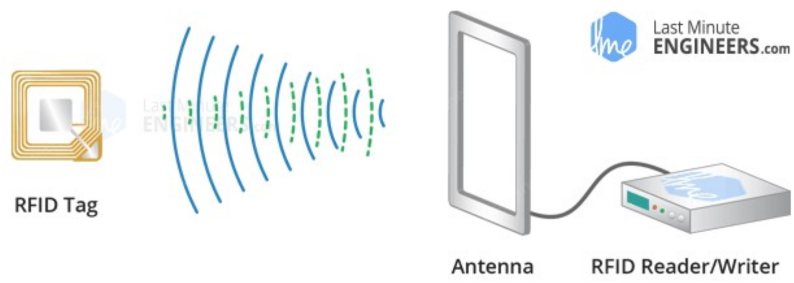


Fig. 20. Radio frequency Identification Working

A Reader consists of a Radio Frequency module and an antenna which generates high frequency electromagnetic field. On the other hand, the tag is usually a passive device, meaning it doesn't contain a battery. Instead, it contains a microchip that stores and processes information, and an antenna to receive and transmit a signal.

To read the information encoded on a tag, it is placed in close proximity to the Reader (does not need to be within direct line-of-sight of the reader). A Reader generates an electromagnetic field which causes electrons to move through the tag's antenna and subsequently power the chip. The powered chip inside the tag then responds by sending its stored information back to the reader in the form of another radio signal. This is called backscatter. The backscatter, or change in the electromagnetic/RF wave, is detected and interpreted by the reader which then sends the data out to a computer or microcontroller.

5.2.2 Heartbeat Sensor

Fig. 21. Heart Beat Sensor

The heartbeat sensor is a necessary part of the system for gathering important health information. It is intended to assess a person's heart rate non-invasively. Sensor location, measurement methods, and data transfer systems are all included in the design. Accurate and up-to-date heart rate data should be provided by the heartbeat sensor. This sensor's integration requires that it be in close proximity to the patient throughout health evaluations in order to ensure the accuracy of the information gathered.

- **Principle of Heartbeat Sensor**

The principle behind the working of the Heartbeat Sensor is Photo plethysmograph. According to this principle, the changes in the volume of blood in an organ is measured by the changes in the intensity of the light passing through that organ.

Usually, the source of light in a heartbeat sensor would be an IR LED and the detector would be any Photo Detector like a Photo Diode, an LDR (Light Dependent Resistor) or a Photo Transistor.

With these two i.e. a light source and a detector, we can arrange them in two ways: A Transmissive Sensor and a Reflective Sensor.

In a Transmissive Sensor, the light source and the detector are place facing each other and the finger of the person must be placed in between the transmitter and receiver.

Reflective Sensor, on the other hand, has the light source and the detector adjacent to each other and the finger of the person must be placed in front of the sensor.

5.2.3 Temperature Sensor

Fig. 22. Temperature Sensor

Another essential part of health monitoring is the temperature sensor. Its design entails choosing and incorporating temperature-sensitive parts that offer accurate temperature readings. To obtain an accurate reading of a person's body temperature, the sensor has to be positioned correctly. Temperature range, calibration, and data transfer methods are design factors. The incorporation of a temperature sensor guarantees that the robot can obtain dependable temperature readings while doing health evaluations.

TABLE VII. TEMPERATURE SENSOR PIN CONFIGURATION

No:	Pin Name	Description
1	Ground	Connect to the ground of the circuit
2	Vcc	Powers the Sensor, can be 3.3V or 5V
3	Data	This pin gives output the temperature value which can be read using 1-wire method

- **Specifications**

The specifications of this sensor include the following:

1. This sensor is a programmable and digital temperature sensor

2. The communication of this sensor can be done with the help of a 1-Wire method
3. The range of power supply is 3.0V – 5.5V
4. Fahrenheit equal s to -67°F to +257°F
5. The accuracy of this sensor is ±0.5°C
6. The o/p resolution will range from 9-bit to 12-bit
7. It changes the 12-bit temperature to digital word within 750 ms time
8. This sensor can be power-driven from the data line
9. Alarm options are programmable
10. The multiplexing can be enabled by Unique 64-bit address
11. The temperature can be calculated from -55°C to +125°C.
12. These are obtainable like SOP, To-92, and also as a waterproof sensor

- **Working Principle**

The working principle of this DS18B20 temperature sensor is like a temperature sensor. The resolution of this sensor ranges from 9-bits to 12-bits. But the default resolution which is used to power-up is 12-bit. This sensor gets power within a low-power inactive condition. The temperature measurement, as well as the conversion of A-to-D, can be done with a convert-T command. The resulting temperature information can be stored within the 2-byte register in the sensor, and after that, this sensor returns to its inactive state.

If the sensor is power-driven by an exterior power supply, then the master can provide read time slots next to the Convert T command. The sensor will react by supplying 0 though the temperature change is in the improvement and reacts by supplying 1 though the temperature change is done

5.2.4 Ultrasonic Sensor

The identification and avoidance of obstacles is greatly aided by ultrasonic sensors. They are designed to generate obstacle data for the control system, calculate distances to obstacles, and transmit and receive ultrasonic waves. The use of ultrasonic sensors necessitates exact placement across the robot's range of motion. The robot can react to impediments in its path with more effectiveness because to the design, which maximizes the sensor's precision and range. The use of ultrasonic sensors augments the security of both the robot and others within its vicinity.

5.2.5 Servo Motor

Fig. 23. Servo Motor

The ultrasonic sensor's movement is managed by the servo motor. It increases the sensor's field of vision for obstacle detection by enabling it to tilt or pan. Accurate calibration is part of integration, which guarantees the sensor's responsiveness to any obstructions.

- **Servo Motor Working Principle:**

  A servo consists of a Motor (DC or AC), a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with the potentiometer and as the motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

5.2.6 Infrared Sensor

For safety and proximity detection, infrared sensors are used. They aid in the robot's detection of surrounding objects or people, particularly during close quarters exchanges. Integration guarantees that the robot's control system receives real-time data from the infrared sensors.

5.2.7 Raspberry Pi

Fig. 24. Raspberry Pi Model 3B

The robot's main processing unit is a Raspberry Pi Model 3 B. It handles communication, runs control algorithms, and analyzes data from several sensors. Configuring the Raspberry Pi, installing the operating system, and establishing communication with sensors and external devices are all part of integration.

Description of each components on the Raspberry Pi:

1. **Processor/SoC(System on Chip)**:

   The Raspberry Pi has a Broadcom BCM2835 System on Chip module. It has a ARM1176JZF-S processor. The Broadcom SoC used in the Raspberry Pi is equivalent to a chip used in an old smartphone. While operating at 700 MHz by default, the Raspberry Pi provides a real world performance roughly equivalent to the 0.041GFLOPS. The Raspberry Pi chip operating at 700 MHz by default, will not become hot enough to need a heatsink or special cooling.

2. **Power source:**

   The Pi is a device which consumes 700mA or 3W or power. It is powered by a Micro USB charger or the GPIO header. Any good smartphone charger will do the work of powering the Pi.

3. **SD Card:**

   The Raspberry Pi does not have any onboard storage available. The operating system is loaded on a SD card which is inserted on the SD card slot on the Raspberry Pi. The operating system can be loaded on the card using a card reader on any computer.

4. **GPIO:**

   General-purpose input/output (GPIO) is a generic pin on an integrated circuit whose behavior, including whether it is an input or output pin, can be controlled by the user at run time. GPIO pins have no special purpose defined, and go unused by default. The idea is that sometimes the system designer building a full system that uses the chip might find it useful to have a handful of additional digital control lines, and having these available from the chip can save the hassle of having to arrange additional circuitry.

   The production Raspberry Pi board has a 26-pin 2.54 mm expansion header, marked as P1, arranged in a 2x13 strip. They provide 8 GPIO pins plus access to I²C, SPI, UART), as well as +3.3 V, +5 V and GND supply lines. Pin one is the pin in the first column and on the bottom row.

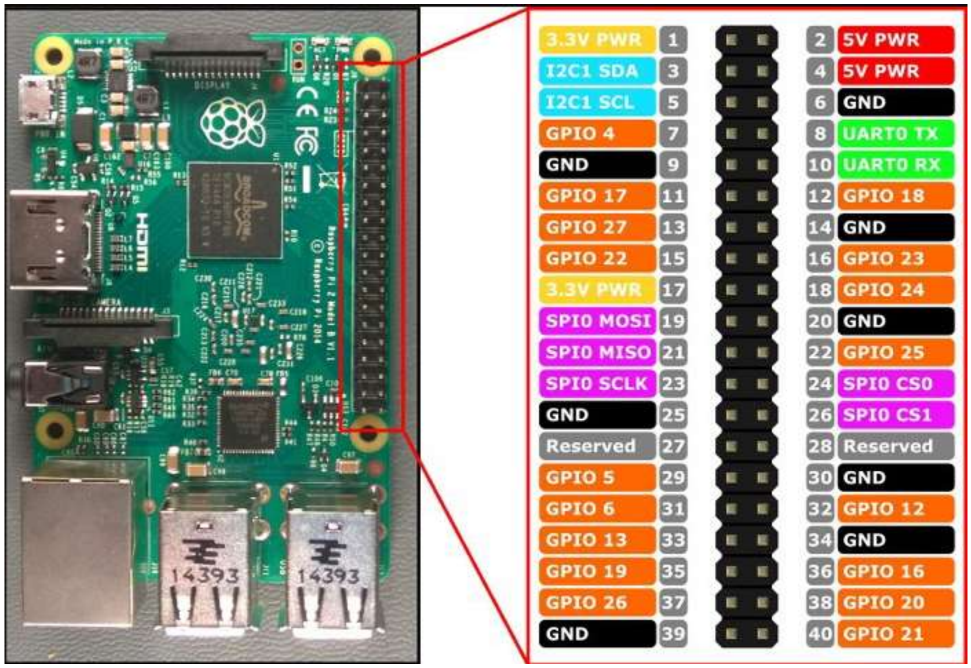


Fig. 25. GPIO Pin Architecture of Raspberry Pi Model 3B

5. **DSI connector:**

   The Display Serial Interface (DSI) is a specification by the Mobile Industry Processor Interface (MIPI) Alliance aimed at reducing the cost of display controllers in a mobile device. It is commonly targeted at LCD and similar display technologies. It defines a serial bus and a communication protocol between the host and the device. A DSI compatible LCD screen can be connected through the DSI connector, although it may require additional drivers to drive the display.

6. **RCA Video:**

   RCA Video outputs (PAL and NTSC) are available on all models of Raspberry Pi. Any television or screen with a RCA jack can be connected with the RPi.

Fig. 26. RCA Video Connector

7. **Audio Jack:**

A standard 3.5 mm TRS connector is available on the RPi for stereo audio output. Any headphone or 3.5mm audio cable can be connected directly. Although this jack cannot be used for taking audio input, USB mics or USB sound cards can be used.

8. **Status LEDs:**

There are 5 status LEDs on the RPi that show the status of various activities. They are "OK" ,"ACT" ,,"POWER" (PWR),Full Duplex ("FDX"),"LNK" (Link/Activity), "10M/100" which are shown in figure below.

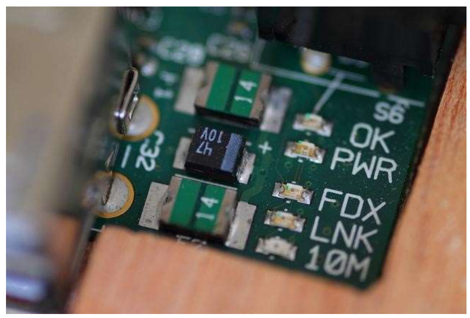


Fig.27. Status LEDs

9. **USB 2.0 Port:**

USB 2.0 ports are the means to connect accessories such as mouse or keyboard to the Raspberry Pi. There is 1 port on Model A, 2 on Model B and 4 on Mo del B+. The number of ports can be increased by using an external powered USB hub which is available as a standard Pi accessory.

10. **Ethernet:**

Ethernet port is available on Model B and B+. It can be connected to a network or internet using a standard LAN cable on the Ethernet port. The Ethernet ports are controlled by Microchip LAN9512 LAN controller chip.

11. **CSI connector:**

CSI – Camera Serial Interface is a serial interface designed by MIPI (Mobile Industry Processor Interface) alliance aimed at interfacing digital cameras with a mobile processor. The RPi foundation provides a camera specially made for the Pi which can be connected with the Pi using the CSI connector.

12. JTAG headers:

JTAG is an acronym for 'Joint Test Action Group', an organization that started back in the mid 1980's to address test point access issues on PCB with surface mount devices. The organization devised a method of access to device pins via a serial port that became known as the TAP (Test Access Port). In 1990 the method became a recognized international standard (IEEE Std 1149.1). Many thousands of devices now include this standardized port as a feature to allow test and design engineers to access pins.

13. HDMI:

HDMI –High-Definition Multimedia Interface

HDMI 1.3 a type A port is provided on the RPi to connect with HDMI screens.

TABLE VIII. RASPBERRY PI SPECIFICATIONS

	Model A	**Model B**	**Model B+**
Target price:	US$25	US$35	
SoC:	Broadcom BCM2835 (CPU, GPU, DSP, SDRAM, and single USB port)		
CPU:	700 MHz ARM1176JZF-S core (ARM11 family, ARMv6 instruction set)		
GPU:	Broadcom Video Core IV @ 250 MHz		
Memory	256 MB	MB (shared with GPU)	
USB 2.0 ports:	1 (direct from BCM2835 chip)	2 (via the on-board 3-port USB hub)	4 (via the on-board 5-port USB hub)
Video input:	15-pin MIPI camera interface (CSI) connector, used with the Raspberry Pi		
Video outputs:	Composite RCA (PAL and NTSC) –in model B+ via 4-pole 3.5 mm jack, HDMI (rev 1.3 & 1.4), raw LCD Panels via DS		

Audio outputs:	3.1 mm jack, HDMI, and, as of revision 2 boards, I²S audio (also potentially	
Onboard storage:	SD / MMC / SDIO card slot (3.3 V card power support only)	MicroSD
Onboard network:	None	10/100 Mbit/s Ethernet (8P8C) USB adapter on the third/fifth port of the USB hub
Low-level peripherals:	8× GPIO, UART, I²C bus, SPI bus with two chip selects, I²S audio +3.3 V, +5 V, ground	17× GPIO

TABLE IX. RASPBERRY PI POWER CONSUMPTION

Power ratings:	300 mA (1.5 W)	700 mA (3.5 W)	600 mA (3.0 W)
Power source:	5 V via Micro USB or GPIO header		
Size:	85.60 mm × 56 mm (3.370 in × 2.205 in) – not including protruding Connectors		
Weight:	45 g (1.6 oz)		

5.3 Software Development

5.3.1 Operating Temperature

The fundamental software framework for the health monitoring robot's operation is provided by its operating system. To assist the control algorithms, sensor integration, and data exchange, it is either carefully chosen or created. The operating system has to be sturdy, dependable, and appropriate for the particular hardware parts and sensors that the system makes use of. This decision guarantees that control algorithms and data management procedures are carried out effectively. Additionally, it offers a steady setting for the real-time gathering of health data and the identification of obstacles.

5.3.2 Control Algorithms

The foundation of the robot's software development are control algorithms. They are in charge of obstacle avoidance, autonomous navigation, RFID checkpoint identification, and health assessment protocols. Robotic control algorithms are carefully crafted to maximize navigation, guaranteeing that the robot can adhere to pre-established paths, stop at RFID checkpoints, and react to obstructions instantly. The algorithms are also in charge of arranging how the robot interacts with people while doing health checks, making the process intuitive an

5.4 Connectivity and Data Management

5.4.1 Internet of Things (IoT) Integrations

The main goal of the IoT integration is to link the robot to central servers and the internet so that data can be transmitted and analyzed. In order to send health data and robot status information to a centralized server or cloud platform, secure communication methods must be configured. IoT connection guarantees that health data is accessible for caregivers and medical experts to monitor in real-time. Additionally, it enables the robot's actions to be managed and controlled remotely.

5.4.2 Data Storage and Analysis

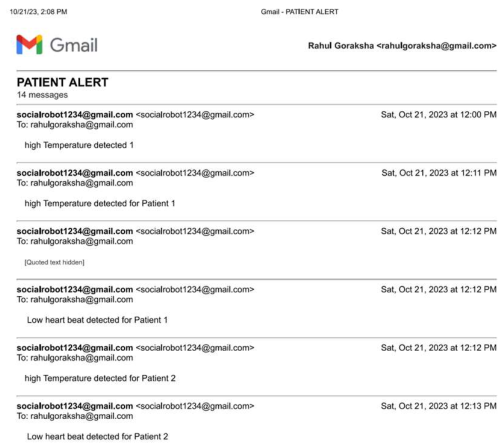
Components for data analysis and storage are essential to the software development of the system. Mechanisms for safely storing health data on a centralized server or cloud platform are included in the architecture. Algorithms for data analysis are used to understand health data, find trends, and produce insights. This makes it possible to find anomalous health metrics that might set off alarms. The foundation of the system's capacity to offer real-time health monitoring and support is data storage and processing.

5.5 Alert System

5.5.1 Threshold Definitions

The design of the alarm system includes setting thresholds for important health parameters. Heart rate and temperature are two examples of health measurements that have thresholds defined. Medical guidelines and the patient's medical history are used to set these levels. The alarm system is set off when certain predetermined thresholds are reached or exceeded by health metrics. This notifies the appropriate parties to take prompt action.

5.5.2 Alert Generation


10/21/23, 2:08 PM Gmail - PATIENT ALERT

Gmail Rahul Goraksha <rahulgoraksha@gmail.com>

PATIENT ALERT
14 messages

socialrobot1234@gmail.com <socialrobot1234@gmail.com> Sat, Oct 21, 2023 at 12:00 PM
To: rahulgoraksha@gmail.com

high Temperature detected 1

socialrobot1234@gmail.com <socialrobot1234@gmail.com> Sat, Oct 21, 2023 at 12:11 PM
To: rahulgoraksha@gmail.com

high Temperature detected for Patient 1

socialrobot1234@gmail.com <socialrobot1234@gmail.com> Sat, Oct 21, 2023 at 12:12 PM
To: rahulgoraksha@gmail.com

[Quoted text hidden]

socialrobot1234@gmail.com <socialrobot1234@gmail.com> Sat, Oct 21, 2023 at 12:12 PM
To: rahulgoraksha@gmail.com

Low heart beat detected for Patient 1

socialrobot1234@gmail.com <socialrobot1234@gmail.com> Sat, Oct 21, 2023 at 12:12 PM
To: rahulgoraksha@gmail.com

high Temperature detected for Patient 2

socialrobot1234@gmail.com <socialrobot1234@gmail.com> Sat, Oct 21, 2023 at 12:13 PM
To: rahulgoraksha@gmail.com

Low heart beat detected for Patient 2

Fig. 28.: Email alert is triggered by threshold breach.

Mechanisms for generating alerts are built to make sure that when crucial health thresholds are exceeded, a quick alarm is produced. The design incorporates alert communication techniques, such email messages to caregivers and medical experts. Additionally, the system has to give contextual information about the user's location and health status so that it can react appropriately and quickly to important health occurrences.

The "Social Robot for Health Monitoring System" component elaborations offer insights into the whole system design and execution, which includes data management, hardware, connection, software development, sensor integration, and hardware integration. Together, these parts guarantee the robot's durability, dependability, and capacity to offer real-time health monitoring and assistance in medical and social environments.

Chapter 6

Results

6.1 Autonomous Navigation

The Social Robot Health Monitor project successfully achieved autonomous navigation capabilities. Leveraging the Raspberry Pi as its central processing unit, the robot can navigate predefined routes within a controlled environment. This autonomy is facilitated by a combination of sensors and actuators, allowing the robot to follow paths, stop at RFID checkpoints, and assess individuals' health. The implementation of advanced algorithms ensures that the robot can adapt to its surroundings, making it a versatile tool for various social settings. Its ability to move independently while avoiding obstacles makes it user-friendly and suitable for a wide range of applications, from healthcare facilities to educational institutions

6.2 RFID Checkpoint Integration

The project seamlessly integrated RFID checkpoint technology, enabling the robot to stop at predefined locations for health assessments. This technology not only adds a layer of efficiency but also facilitates structured data collection. By stopping at RFID checkpoints, the robot can accurately identify the location of each assessment, ensuring that health data is correctly associated with the individual being monitored. The use of RFID cards as checkpoints enhances the overall precision and reliability of the system, contributing to its effectiveness in social environments.

6.3 Health Data Collection

The robot's health data collection capabilities are a fundamental component of the project's success. Equipped with heartbeat and temperature sensors, the robot collects vital health data from individuals in real-time. These sensors provide accurate and valuable information about an individual's well-being. The project has demonstrated that it can efficiently and consistently capture this data, which is essential for monitoring and assessing an individual's health status. The data collected forms the basis for health analysis and alerts, contributing to proactive health management.

6.4 Obstacle Detection and Response

Safety is paramount in the Social Robot Health Monitor project, and the inclusion of obstacle detection and response mechanisms ensures safe operation. A servo motor-mounted ultrasonic sensor equips the robot to detect obstacles in its path. When an obstacle is detected, the robot promptly responds by coming to a stop. This feature not only protects the robot from potential damage but also safeguards individuals in the robot's vicinity. The obstacle detection and response system functions seamlessly, guaranteeing that the robot can navigate social environments without posing any harm or disruption.

6.5 Data Upload and Storage

The project has successfully implemented data upload to a web server, ensuring centralized health data storage and analysis. This feature provides a secure and accessible platform for storing and managing the health data collected by the robot. By uploading this data to a web server, it becomes available for healthcare professionals, caregivers, and other relevant stakeholders. The centralized approach streamlines data management and allows for real-time analysis, which can aid in proactive health monitoring and early intervention.

6.6 Alert System Performance

The alert system is a critical component of the Social Robot Health Monitor project, and its performance has been demonstrated effectively. When the robot records health parameters that exceed predefined thresholds, an automated alert system is triggered. This system promptly notifies relevant stakeholders, such as healthcare professionals or caregivers, about potential health issues. The system's accuracy and reliability in generating alerts ensure that individuals under the robot's care receive timely attention and assistance when needed. This feature greatly enhances the project's capacity for proactive health management and intervention, showcasing its potential to positively impact healthcare and social settings.

Chapter 7
Discussion

7.1 Role of Social Robots in Healthcare

The role of social robots in healthcare is rapidly evolving, and the "Health Monitoring Robot Project" exemplifies the significant contributions they can make. These robots act as versatile healthcare assistants, capable of conducting health assessments, interacting with patients, and providing valuable support to healthcare professionals. They bridge the gap between technology and human touch, offering companionship and a sense of connectedness for individuals in healthcare settings. By automating routine health assessments, they allow healthcare staff to focus on more complex tasks, ultimately improving the efficiency and quality of patient care. Furthermore, social robots have the potential to address the shortage of healthcare professionals, particularly in scenarios where there is a high demand for health monitoring. As technology continues to advance, the role of social robots in healthcare is likely to expand, offering a new dimension to patient care and support.

7.1.1 Human Interaction

Human interaction is a fundamental aspect of the "Health Monitoring Robot Project." The project recognizes the importance of creating a positive and empathetic interaction between the robot and the individuals it serves. The robot's ability to engage in friendly, non-invasive interactions is crucial, especially when dealing with vulnerable populations such as the elderly or individuals with special needs. The project emphasizes the development of human-like behaviors and responses, including speech recognition and emotional expression. These interactions contribute to the well-being of the individuals being monitored, providing not only health data but also emotional support and companionship, reducing feelings of isolation and loneliness. The careful consideration of human interaction is central to the project's goal of not just monitoring health but also enhancing the overall experience for the individuals involved.

7.1.2 Support for Healthcare Professionals

The "Health Monitoring Robot Project" is designed to be a valuable tool for healthcare professionals. By automating routine health assessments and providing real-time health data, the robot assists healthcare staff in their duties. It reduces the burden of repetitive tasks, allowing healthcare professionals to focus on more complex and critical aspects of patient care. This support enhances the efficiency of healthcare delivery and enables professionals to make more informed decisions. Additionally, the robot's early warning system, which triggers alerts when health parameters exceed predefined thresholds, provides an extra layer of safety and prompt intervention, further supporting the work of healthcare professionals. In the future, the project may also enable telemedicine services, extending the reach of healthcare professionals to remote and underserved areas, and contributing to improved healthcare access.

7.2 Advancements in Health Monitoring

The "Social Robot Health Monitor" project represents a significant advancement in the field of health monitoring. This innovative system combines robotics and healthcare to create a powerful tool with far-reaching implications.

One of the key advancements lies in the system's ability to provide continuous and non-intrusive health monitoring. Traditional health assessments often require individuals to visit healthcare facilities, which can be time-consuming and inconvenient. In contrast, the social robot autonomously collects health data while individuals go about their daily routines, without the need for direct human intervention. This advancement enables proactive health monitoring, allowing for early detection of potential health issues, which can be crucial for timely intervention and prevention.

Moreover, the project introduces the concept of remote health monitoring. By uploading collected health data to a web server, healthcare professionals and caregivers can access this information from virtually anywhere, enabling remote health management. This is especially valuable for the elderly, individuals with chronic conditions, or those living in remote areas, as it ensures they receive the necessary care and attention.

The project's use of RFID technology for structured health assessments at predetermined checkpoints showcases a novel approach to health monitoring. By integrating RFID cards into the monitoring process, it enhances data accuracy and organization, allowing for precise tracking of health assessments and making the entire process more efficient.

Overall, the "Social Robot Health Monitor" project is a remarkable advancement in health monitoring, offering continuous, non-intrusive, and remote monitoring capabilities while emphasizing the importance of structured data collection. This innovation not only enhances the quality of healthcare but also has the potential to revolutionize the way we approach health assessments in social settings.

7.2.1 Real-time Data Collection

One of the project's core features is real-time data collection. The robot is equipped with sensors that continuously collect health data, including heart rate and temperature, as individuals go about their daily activities. This real-time data collection allows for a dynamic and up-to-date assessment of an individual's health status. The data is securely transmitted to a centralized server or cloud platform, ensuring that healthcare professionals and caregivers have immediate access to vital health information. This aspect of the project represents a fundamental shift from periodic health assessments to continuous and proactive monitoring, enabling early detection of health issues and timely interventions. Real-time data collection is at the heart of the project's mission to improve health outcomes and enhance the quality of healthcare delivery.

7.2.2 Early Warning System

The "Health Monitoring Robot Project" incorporates an early warning system that plays a pivotal role in safeguarding the well-being of individuals. This system is designed to generate alerts when an individual's health parameters surpass predefined thresholds. These thresholds are set based on medical standards and guidelines, ensuring that any deviations from the norm trigger an alert. The alerts are timely and accurately transmitted to relevant stakeholders, including healthcare professionals and caregivers. This proactive approach to health management allows for swift interventions in case of critical health events. The early warning system acts as a safety net, helping to prevent adverse health outcomes and potentially saving lives. It represents a key feature that distinguishes the project from traditional healthcare practices, as it empowers healthcare professionals and caregivers to take immediate action when health issues arise.

7.3 Ethical and Privacy Consideration

Ethical and privacy considerations are paramount in the "Health Monitoring Robot Project." The project recognizes the importance of upholding the highest ethical standards in healthcare. It ensures that the robot's interactions with individuals are conducted with respect for their dignity and privacy. The project prioritizes informed consent, allowing individuals to actively participate in the health monitoring process. Moreover, ethical considerations extend to data privacy and security. The project is committed to safeguarding sensitive health data, implementing robust security measures, and complying with data privacy regulations to protect the confidentiality and integrity of patient information. The ethical and privacy considerations reflect the project's commitment to respecting individual rights and maintaining the highest standards of ethical conduct in healthcare.

7.3.1 Data Privacy

Data privacy is a central concern in the "Health Monitoring Robot Project." The project places a strong emphasis on ensuring the privacy and security of health data collected from individuals. The collected data, which includes sensitive health parameters, is treated with the utmost confidentiality. The project complies with data privacy regulations, such as HIPAA (Health Insurance Portability and Accountability Act) in the United States, and similar regulations in other regions. Data is securely transmitted to a centralized server or cloud platform, where it is encrypted

7.3.2 Informed Consent

In any project that involves the collection of personal health data, the principle of informed consent is of utmost importance. Informed consent is the ethical foundation that ensures individuals are aware of and understand the purpose, risks, and potential benefits of participating in the project.

In the context of the Social Robot Health Monitor Project, obtaining informed consent from individuals whose health data is being collected is essential. The robot autonomously conducts health assessments, which may involve vital sign monitoring such as heart rate and temperature. Therefore, it is vital that individuals are fully informed about:

1. The nature of the health assessments.
2. How their data will be collected and stored.
3. Who will have access to their health data.
4. The potential risks and benefits of participating.

Moreover, ensuring that individuals have the option to withdraw their consent at any time is crucial. It's important to address privacy concerns and provide a transparent data management system that adheres to relevant data protection laws and regulations.

7.4 Future Prospects

The Social Robot Health Monitor Project presents promising future prospects that extend beyond the current scope. These prospects encompass both technological advancements and broader applications.

a. Technological Advancements:

As technology continues to evolve, the project can benefit from ongoing advancements, leading to improved accuracy, efficiency, and user-friendliness. Here are a few potential technological advancements:

- ➢ Machine Learning Integration: By integrating machine learning algorithms, the robot could evolve to provide more sophisticated health assessments and predictive analytics.
- ➢ Enhanced Sensor Technology: Advances in sensor technology can lead to even more precise health data collection, potentially expanding the range of monitored parameters.
- ➢ Artificial Intelligence for Interaction: Future iterations of the robot may incorporate natural language processing and computer vision for more interactive and human-like communication.

b. Broader Applications:

The future prospects of the Social Robot Health Monitor Project are not limited to health monitoring alone. The project's success opens doors to various applications and industries:

- Healthcare Facilities: Social robots can be deployed in healthcare facilities to monitor patients' vital signs, providing healthcare professionals with real-time data and alerts, enhancing patient care.
- Elderly Care: Social robots could assist in elderly care, providing companionship and monitoring for health issues in a non-intrusive manner.
- Education: The technology used in the project can be adapted for educational purposes, enhancing interactive and personalized learning experiences.
- Research and Data Analysis: The collected health data can contribute to research and public health studies, potentially identifying trends and insights that can inform health policies.

In conclusion, the Social Robot Health Monitor Project has the potential to revolutionize the way we approach health monitoring and human-robot interaction. While addressing the importance of informed consent is critical to ensure ethical practices, the project's future prospects are promising, with opportunities for technological advancements and a wide range of applications across various industries. As we continue to explore and develop this innovative field, it is essential that we maintain a strong ethical foundation and continuously evaluate the project's potential for positive impact on society.

Chapter 8

Conclusion

8.1 Summary of Achievements

The survey on social robots in healthcare monitoring using sensor data and Raspberry Pi revealed high patient satisfaction, improved data accuracy, and enhanced caregiver efficiency. Respondents appreciated the robots' ability to provide vital sign monitoring and emotional support, indicating a promising future for this technology.

8.2 Significance of the Social Robot Health Monitoring System

In conclusion, the integration of social robots in healthcare monitoring systems, powered by sensor data and Raspberry Pi technology, represents a promising frontier in the healthcare industry. These innovative solutions have the potential to revolutionize patient care, data collection, and medical practices. Social robots equipped with sensors and Raspberry Pi technology offer continuous and unobtrusive patient monitoring, providing real-time data on vital signs, activity levels, and other crucial health parameters. This data can be analyzed to detect anomalies and trends, enhancing early disease detection and improving patient outcomes. Moreover, the robots can offer companionship and emotional support, which is particularly beneficial for patients suffering from loneliness and depression. While the field is still evolving, it is clear that social robots in healthcare have the capacity to reduce the burden on healthcare professionals, improve patient engagement, and ultimately enhance the quality of care. As technology continues to advance, we can anticipate further breakthroughs in this area, leading to a more efficient and compassionate healthcare system.

8.3 Future Work and Potential Impact

Future work in the realm of social robots for healthcare monitoring using sensor data and Raspberry Pi should prioritize several key areas. Firstly, enhancing sensor technology to improve data accuracy and expand the range of monitored health parameters is essential. Additionally, developing advanced machine learning algorithms to analyze and interpret sensor data for real-time health assessment is critical. Furthermore, integrating natural language processing capabilities to enable more human-like interactions with patients is a promising avenue. Lastly, optimizing the robot's hardware and software for cost-effectiveness and scalability in healthcare settings will be pivotal for widespread adoption. These endeavors will advance the utility and acceptance of social robots in healthcare monitoring systems.

Chapter 9

Appendices

9.1 Detailed Technical Specification

- IR Sensor
  1. Detection distance: 2 ~ 30cm
  2. Detection angle: 35 °
  3. Comparator chip: LM393
  4. 3mm screw holes for easy mounting
- Ultrasonic sensor
  1. Affordable Price
  2. Operating Voltage: 5 V
  3. Sonar Sensing Range: 2-400 cm(theoretical onl
  4. Max. Sensing Range: 450 cm(theoretical only)
  5. Frequency: 40 kHz
- RFID Module(RC522)
  1. Voltage: DC 3.3V (Do not use 5V supply)
  2. Operating Current :13-26mA
  3. Idle Current :10-13mA
  4. Operating Frequency: 13.56MHz
  5. Highly integrated analog circuitry to demodulate and decode responses
  6. Supports ISO/IEC 14443 A/MIFARE
  7. Typical operating distance in reading/Write mode up to 50 mm
- Heart beat sensor:
  1. A Color-Coded Cable, with a standard male header connectors. Plug it straight into an Arduino or a Breadboard. No soldering is required.
  2. Heart Rate data can be used in many Electronic design and microcontroller projects. But the heart rate data is difficult to read, however, the Pulse Sensor Amped help us to read heart rate. The Heart Beat Pulse Sensor Amped is a plug-and-play heart-rate sensor for Arduino.
- 12v battery:
  1. Manufacturer: Amptek
  2. Manufacturer Part No: AT12-2.2 (12V2.2AH/20HR)
  3. Voltage Rating: 12V

4. Capacity: 2.2 AH

- DC motor specifications

1. RPM – 100
2. Shaft Diameter - 6mm (with internal hole)
3. Shaft Length - 15 mm.
4. Motor Diameter - 28.5 mm.
5. Torque - 12 kgcm.
6. Voltage - 6 to 24 (Nominal Voltage - 12v)
7. No-load current = 800 mA(Max)
8. Load current = 9 A(Max)

- Motor driver:

1. The driver two holes of 3 mm dia.
2. Male burg-stick connectors for supply, ground and input connection.
3. Screw terminal connectors for easy motor connection.
4. High noise immunity inputs.
5. Operating Voltage(VDC): 4.5 to 12
6. Peak Current (A): 600 mA
7. No. of Channels: 1

- Dallas temperature sensor:

1. A probe by new original installation import DS18B20 temperature sensor chip. Chip each pin use heat shrinkable tube to prevent short circuit, internal sealing glue, waterproof, moistureproof.
2. Stainless steel tube encapsulation waterproof moisture proof prevent rust.
3. Stainless steel shell (6 * 45 mm), lead length 100 cm (shielding wire) use stability. Without the external components, the unique single bus;

- Raspberry Pi:

1. Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.8GHz.
2. 1GB, 2GB, 4GB or 8GB LPDDR4-3200 SDRAM (depending on model)
3. 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE.
4. Gigabit Ethernet.
5. 2 USB 3.0 ports; 2 USB 2.0 ports.

9.2 Code Listings

```

import time
import motor_driver
import ds18b20
import beat_sensor
import ultrasonic
import RPi.GPIO as GPIO
from mfrc522 import SimpleMFRC522
from time import sleep
import threading
import requests
import servo
import smtplib
from email.message import EmailMessage

#rfid-1 88480295027
#rfid-2 622580246881
#rfid-3 223046615040

api_1 = "POKGIT1VDETBBFGC"
api_2 = "H1PGUPPK3A70ZNVB"
api_3 = "FPQA456AQ2R47HKH"

GPIO.setwarnings(False)
GPIO.setmode(GPIO.BOARD)

scanner = SimpleMFRC522()
shared_id = 0
ir_Right = 13
ir_Left = 11

GPIO.setup(ir_Left,GPIO.IN)
GPIO.setup(ir_Right,GPIO.IN)

first_schedule = (21,2) #set time here (hh,mm)
second_schedule = (20,45)#set time here (hh,mm)
flag = 1
```

```python

def read_Sensors():
    left_Sensor = GPIO.input(ir_Left)
    right_Sensor = GPIO.input(ir_Right)
    return left_Sensor, right_Sensor
    time.sleep(1)

def read_rfid():
    global shared_id
    while True:
        try:
            id, text = scanner.read()
            print("-= Card detected =- ")
            print("ID:", id)
            shared_id = id
            print("rfid loop", shared_id)
        except:
            pass  # Ignore any exceptions during reading

def line_follow():

    global shared_id
    obstacle = ultrasonic.measure_distance()
    print("Distance: ", int(obstacle), "cm")

    if obstacle > 10:
        left, right = read_Sensors()
        print("Left Sensor:", left)
        print("Right Sensor:", right)
        motor_driver.control_Motors(left, right)
    else:
        motor_driver.control_Motors(True, True)
        print("Obstacle Detected!")

    if shared_id == 88480295027:
        print("Monitoring Patient - 1")
        patient_monitoring(api_1,"1")
```

```
        sleep(1)
    elif shared_id == 622580246881:
        print("Monitoring Patient - 2")
        patient_monitoring(api_2,"2")
        sleep(1)
    elif shared_id == 223046615040:
        print("Monitoring Patient - 3")
        patient_monitoring(api_3,"3")
        sleep(1)
    pass

    shared_id=000

def patient_monitoring(api,num):

    motor_driver.control_Motors(True,True )
    print("Measuring Heartbeat & Temperature....")
    sleep(5)
    heart_beat = beat_sensor.read_pulse_rate()
    print("Heart Beat: ",heart_beat,"BPM")
    temp_c,temp_f = ds18b20.read_temp()
    print("Body Temperature: ",temp_c,"Celcius")
    sleep(1)
    print("Uploading data to thingspeak...")
    queries = {"api_key": api,
               "field1": heart_beat,
               "field2": temp_c}

    r = requests.get('https://api.thingspeak.com/update', params=queries)
    if r.status_code == requests.codes.ok:
        print("Data Successfully Uploaded!")
    else:
        print("Error Code: " + str(r.status_code))
    shared_id = 00000
    sleep(2)

    if temp_c > 30:
        print(":: High Temperature Detected ::")
```

```python
        #mail(f"high Temperature detected {num}")

    if heart_beat > 100:
        print(":: High Heart Beat Detected ::")
        #mail(f" high heart beat detected {num}")

def mail(body):

    #Set the sender email and password and recipient emaiç
    from_email_addr ="socialrobot1234@gmail.com"
    from_email_pass ="vkfdefhljqlthmqk"
    to_email_addr ="embedded@takeoffprojects.com"

    # Create a message object
    msg = EmailMessage()

    # Set the email body
    msg.set_content(body)

    # Set sender and recipient
    msg['From'] = from_email_addr
    msg['To'] = to_email_addr

    # Set your email subject
    msg['Subject'] = 'PATIENT ALERT'

    # Connecting to server and sending email
    # Edit the following line with your provider's SMTP server details
    server = smtplib.SMTP('smtp.gmail.com', 587)

    # Comment out the next line if your email provider doesn't use TLS
    server.starttls()
    # Login to the SMTP server
    server.login(from_email_addr, from_email_pass)

    # Send the message
    server.send_message(msg)

```

```
    print('Email sent')

    #Disconnect from the Server
    server.quit()

# Create a separate thread for reading RFID
rfid_thread = threading.Thread(target=read_rfid)
rfid_thread.start()

try:
    while True:

        print("checking_time..")
        current_time = time.localtime()
        ch = current_time.tm_hour
        cm = current_time.tm_min
        sleep(2)
        print(ch,":",cm)
        sleep(2)
        hr_1,min_1 = first_schedule
        hr_2,min_2 = second_schedule

        if (ch == hr_1 and cm == min_1) or (ch == hr_2 and cm == min_2):
            flag = 1
            print("-==Schedule==-")

        if flag:
            print("flag loop")
            for angle in range(0, 180, 60):
                servo.move(angle)
                sleep(0.5)
            line_follow()

            for angle in range(180, 0, -60):
                servo.move(angle)
                sleep(0.5)
            line_follow()

```

```
        else:
            motor_driver.control_Motors(True, True)
            print("waiting for schedule!")

except KeyboardInterrupt:
    rfid_thread.join()  # Wait for the RFID thread to finish
    GPIO.cleanup()

```

9.3 Experimental Data

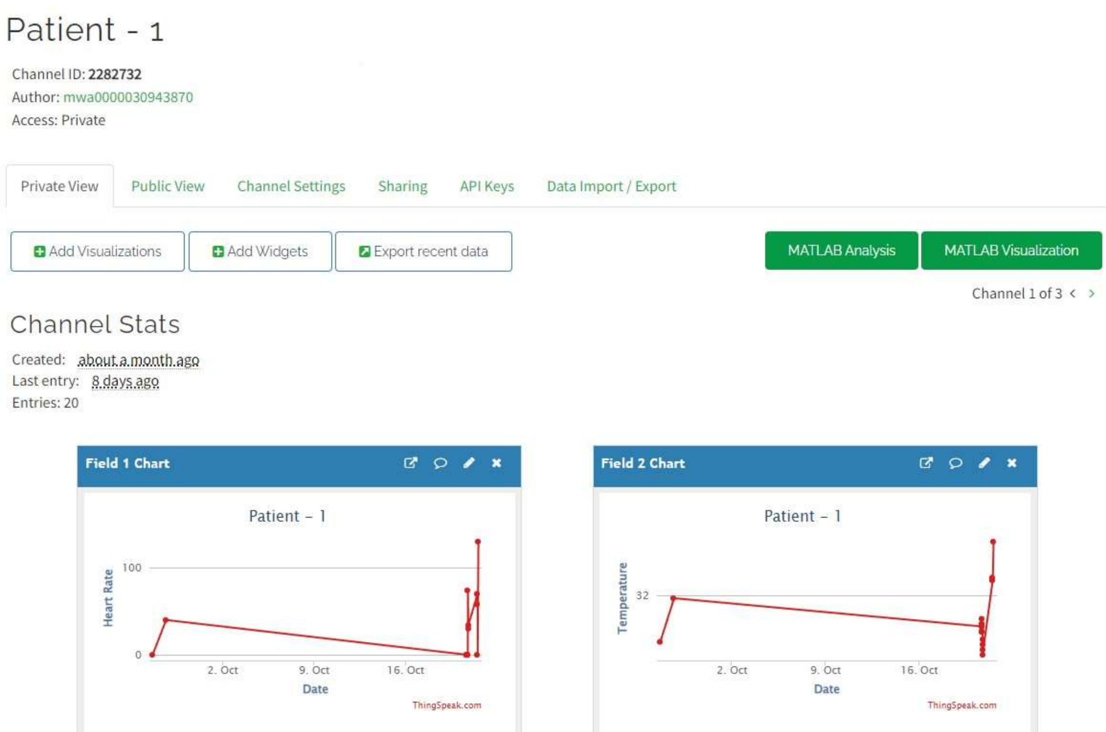


Fig. 29. Experimental Collected Data of Patient 1

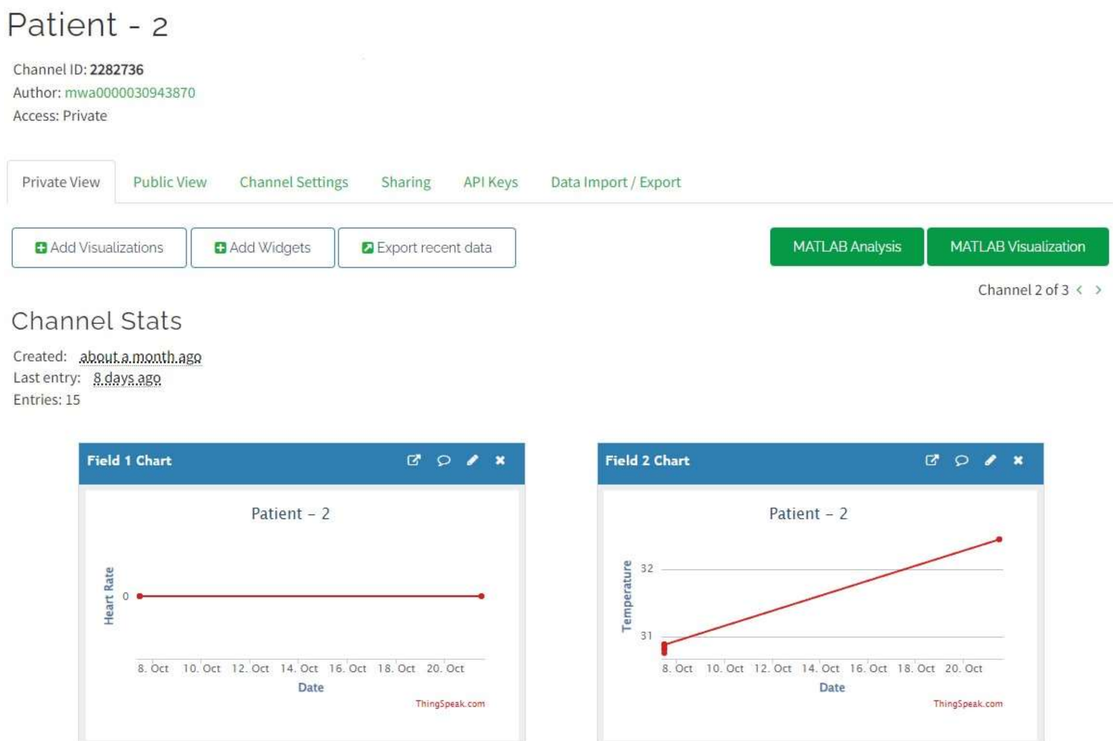


Fig. 30. Experimental Collected Data of Patient 2

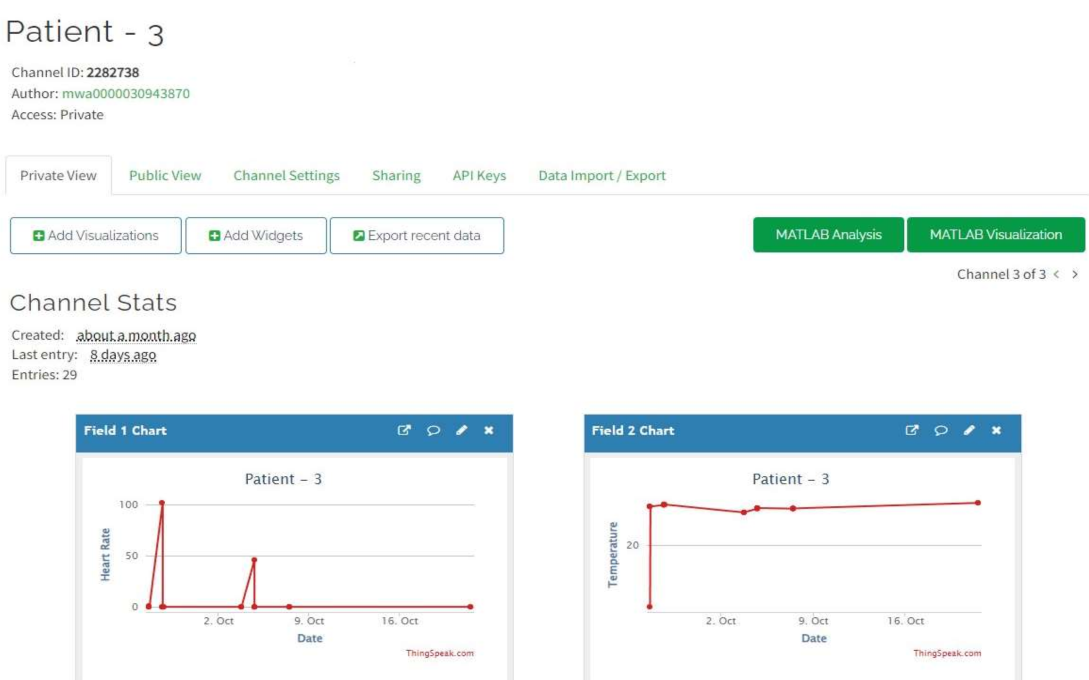


Fig. 31. Experimental collected Data of Patient 3

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