A DISSERTATION ON

Development of Healthcare Robot for Patient Vital Monitoring System

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CERTIFICATE

The thesis entitled **"Development of Healthcare Robot for Patient Vital Monitoring System"** filed for the M.Tech to the Symbiosis Institute of Technology, Pune in Department of Robotics and Automation is based on my own work that I completed under the supervision of **Dr. Satish Kumar**. The dissertation has not been submitted elsewhere for award of any degree.

The content included in the dissertation that was taken from another source has been properly cited and/or acknowledged.

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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 healthcare industry is about to undergo a revolution that will improve patient care and healthcare monitoring by combining state-of-the-art robotics, artificial intelligence (AI), and cutting-edge technology [1, 2]. The incorporation of social robots [3–9] into healthcare systems has emerged as a ground-breaking option in this era of fast technology innovation, opening the door for a more effective, interactive, and customized approach to healthcare monitoring.

1.2 Smart Robot Application

A smart robot is an artificial intelligence (AI)-driven machine that can learn from its surroundings and from past experiences. It then enhances its skills using the knowledge it has gained. These robots can collaborate with people in addition to working side by side with them, picking up on human behavior and refining their own knowledge and skills [10].

Smart robotics is now being used by conventional businesses outside of manufacturing and automation. A fast developing technology, smart robots is used in many industries, including banking, healthcare, retail, agriculture, and logistics. And with these developments, engineers and researchers are creating the next generation of intelligent robots [11].

The emergence of Industry 4.0 [12] has enhanced the industrial sector overall and led to the creation of Smart Spaces [13] and, more precisely, Smart Factories. Smart Spaces are mostly used to track activities and applications, including power consumption or sensor and actuator status, inside a specified regulated area. Robotic systems have brought forth considerable changes to many aspects of human living [14]. Robots are used for a variety of hard and demanding tasks in both the industrial and academic realms, such as welding [15], packing [16], assembling [17], and more.

The notion behind Internet of Robotic Things (IoRT) is the most advanced robotics concept to date; it builds on the foundation of Cyber-Physical Systems (CPSs) to enable the Internet of Things (IoT) to be upgraded [18]. Modern robotics technologies have been blended with networking, cloud computing [19], and IoT protocols in IoRT systems [14] to produce new technologies. This form of connectedness has made it possible for smart devices to monitor events, integrate sensor data from several sources, and use both distributed and local intelligence to choose the best course of action [20]. This innovative approach uses many

technologies to complete complicated tasks and operate in a variety of contexts [21].
Surveillance, education, and health care are three areas where IoRT systems are considered to be very beneficial. Specifically, IoRT can help people with special needs—such as those with mental illness, stroke victims, the suffering community, amputees, and so on—in a variety of ways that are advantageous to the economy, society, and health [22, 23]. Robots with sensors and Internet of Things (IoT) devices are combined with various advantages to diagnose patient issues and give real-time health information, hence reducing the chance of human mistake, such as wrong medicine, dose, or procedure diagnosis [24]. In addition, the Internet of Things (IoRT) can be advantageous for several additional applications, including automated data gathering, personnel and patient tracking, sensing, and emergency tracking [25].
Smart robots have been adopted by many industries, increasing productivity and enhancing people's quality of life. A few well-known uses for smart robots are as follows [26]:

- **Manufacturing**: The integration of robotics in manufacturing processes aims to boost productivity and minimize expenses. These robots are designed to operate in challenging environments and undertake tasks like welding, packaging, and assembly.
- **Healthcare**: Within the healthcare sector, sophisticated robots lend support to surgeons during intricate procedures, aid patients with mobility issues, and automate various laboratory tasks.
- **Agriculture**: Robotics finds application in agriculture to optimize output and reduce labor costs. They undertake activities such as soil cultivation, harvesting, and crop monitoring.
- **Service Sector**: The service industry adopts smart robotic solutions to automate a range of tasks including surveillance, janitorial duties, and customer assistance.
- **Transportation**: Robotics is leveraged in transportation to enhance efficiency, cut down expenses, and bolster safety measures. This encompasses the deployment of autonomous vehicles and robotic systems for cargo handling.
- **Construction**: Smart robotics is increasingly utilized in construction to enhance productivity, mitigate costs, and improve workplace safety. They are involved in tasks such as site inspections and operating heavy machinery.

1.3 Importance

It's important to remember that "smart robots" does not just refer to artificial intelligence (AI) systems that are highly developed and featured in science fiction movies. Conversely, a sophisticated robot might be equipped with a greater range of devices that may not first appear to be "intelligent" [10]. A smart robot's behavior and decision-making might be influenced by the information it has acquired through machine learning or deep learning. When functioning, it uses data gathered from input sensors to guide its decisions.

A software-equipped, mechanically-built intelligent robot uses information from the past and present to make judgments. Interestingly, it took several generations of technological advancements to create "smart" robots. Smart robots are employed across a wide range of sectors, doing tasks including risky welding and providing instruction and stocking stores.

1.4 Healthcare Mobile Robot Market Size

The global market for mobile healthcare robots is expected to grow at a Compound Annual Growth Rate (CAGR) of over 16% from an estimated $3.34 billion in 2022 to a projected value of United States Dollar (USD) 10.88 billion by 2030. The aging of the global population, the introduction of advanced robotic technology in the healthcare sector, the scarcity of trained nurses and other healthcare professionals, and the increase in healthcare expenses are all driving factors in the market's expansion. Additionally, mobile robots enhance patient care, which is very advantageous for the medical field [27].

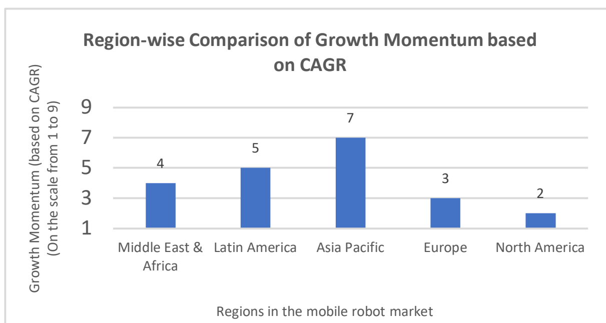


Fig.1. Comparing Growth Momentum by Region Using CAGR [27]

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

(Note: Growth Momentum is shown in the CAGRs of both the entire market and specific segments)

Figure 1 above provides a graphical representation of a market study of the use of smart mobile robots in the healthcare industry worldwide. With the use of intelligent mobile robots, growth momentum based on the CAGR% is supplied for various global locations. The growth momentum is measured on a scale from 1 to 9, with the Asia Pacific area having the highest growth momentum factor and the North American region having the lowest.

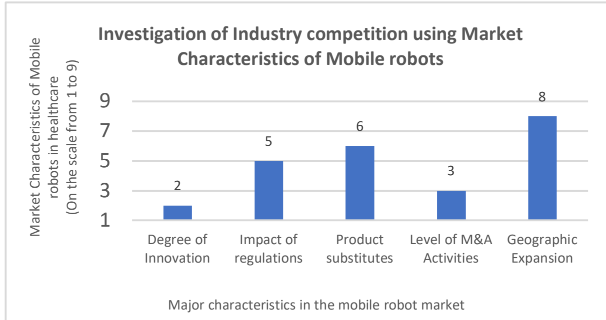


Fig. 2. Examining industry rivalry with a focus on mobile robot market characteristics [27]

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

Figure 2 above provides a graphical representation of the market characteristics study of smart mobile robots in the healthcare industry. The picture presents the market characteristics factor for several attributes of mobile smart robots. The factor representing market characteristics is a scale from 1 to 9, with the Geographic Expansion characteristic having the highest factor and the Degree of Innovation factor having the lowest.

Their management of risky, labor-intensive, and repetitive tasks like delivering supplies and medication might lead to better patient outcomes and quicker responses. They can also provide employees more time to focus on other crucial tasks. Furthermore, mobile robots boost output by streamlining workflows, reducing errors, and finishing tasks quickly and precisely. For instance, they might accurately measure and classify drugs, preventing mistakes that often occur in medical facilities [27].

Leading industrial players place a high value on strategic partnerships, tactical cooperation, and expansion into growing and economically favorable regions. In October 2019, ABB Ltd. established its first global center for healthcare research at the Texas Medical Center (TMC) in Houston, Texas. The facility features a variety of cutting-edge technology, including a mobile robot named YuMi, which stands for "you and me." This robot is specifically made to help medical and laboratory workers by efficiently managing a variety of tasks related to logistics and laboratory operations in hospital environments. Among the well-known businesses in the sector are ABB Ltd., Xenex Disinfection Services, Teradyne, VGo Communications, Inc., LLC, Awabot, Ateago Technology, Techcon, Amazon, Mobile Industrial Robots, Nordson Corp., and Toyota Motor Corp [27].

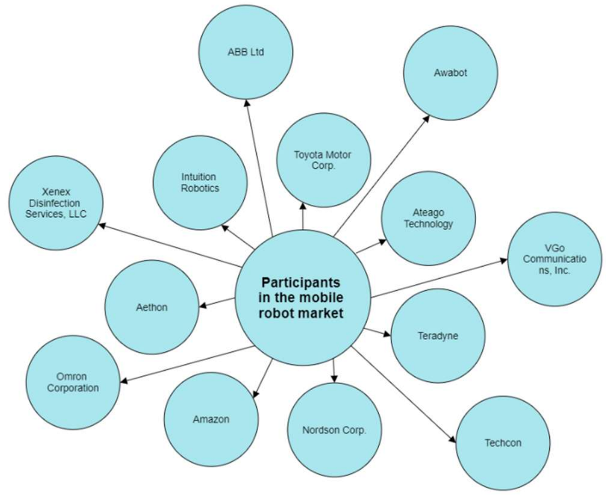


Fig.3. Participants in the mobile robot market [27]

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

Figure 3 above displays the firms that are currently participating in the worldwide market for smart mobile robots.

Figure 4 below lists the various market categories for smart mobile robots in the healthcare industry.

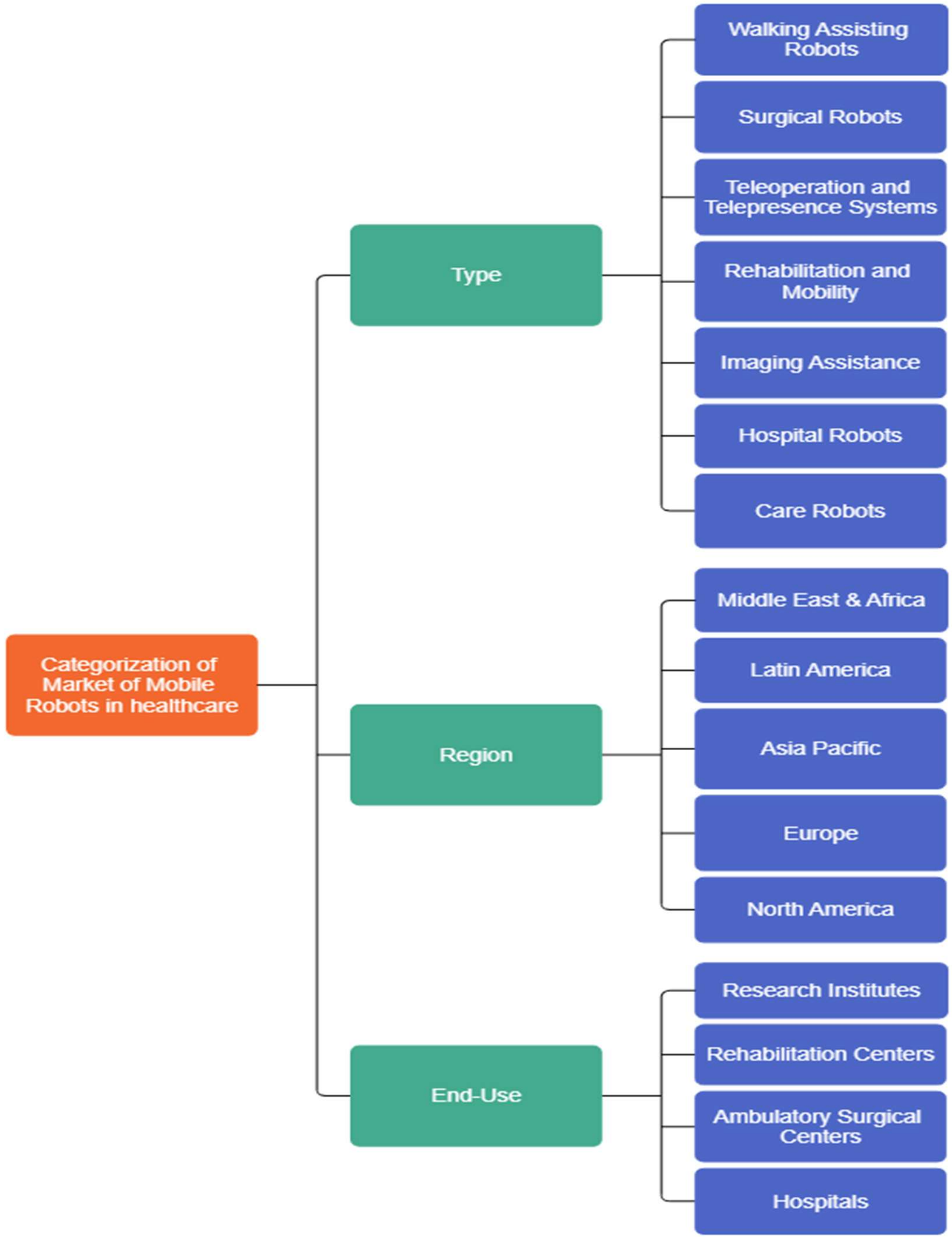


Fig.4. Classification of the Healthcare Mobile Robotics Market [27]

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

1.5 Challenges

Like any new technology, smart robots has its share of issues as well as opportunity. Some of the main challenges are [26]:

1) *Impact on society*: While the precise implication of intelligent robots needs to be determined, they may have a big impact on issues like employment and the replacement of human work.
2) *Technological difficulties:* The complex technology underlying smart robots presents a

number of challenges that must be overcome. These comprise reliability, scalability, and security-related problems.

3) *Cost:* Due to the high cost of developing and deploying smart robots, small business or developing nations may not be able to purchase them.
4) *Ethical Challenges:* Robotics may completely change the labor economy, raising ethical concerns about discrimination, privacy, and surveillance. Social robots should appear innocent and kind in order to reduce people's anxiety when they contact with them, particularly if they are used for strictly service purposes like assisting the elderly get up [28]. They also have to respond to human behavior and, if possible, human emotions. For example, they have to differentiate between the needs of a depressed patient and a healthy athlete recovering from a fracture [26]. The question of whether social robots should be taught to emulate human emotions like smiling in order to promote nonverbal communication is raised here. Given that the robot's simulation lacks feeling, one may conclude that it is lying. Many scientists believe that "ethically correct robots" ought to be capable of making moral decisions [28]. But without the scientific underpinnings of the human brain, is it still possible to form moral judgments? Not to add, would we really desire machines that could sense emotions and make ethical decisions in the first place? Ensuring data privacy, handling 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 are some of the other challenges and limitations in using social robots for healthcare monitoring with sensor data and Raspberry Pi [29].

1.6 How to overcome above issue faced?

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

- To stream production information and address security issues, centralized authentication and permission processes, data fragments, monitored operator control, distributed responsibility, and granular authorization can all be employed.
- Ethical issues need to be carefully considered when creating the behavior of embedded AI and social robots. Here are a few more detailed suggestions on appropriate practices and resources. Typically, in order to teach a computer to converse with a human, one must grasp not only the laws and moral precepts that govern human social interaction but also the thoughts, movements, and behaviors of people.
- Because smart robots can easily be scaled up or down to match the needs of the

business, it's an economical alternative.

- The societal implications of robots make us consider how advancements in robotics will affect the economy.

1.7 Significance

The significance of robotics cannot be overstated. Numerous industries can change as a result of its capacity to raise efficiency, reduce prices, and enhance safety and accuracy. From manufacturing to healthcare, smart robots has penetrated numerous industries, improving people's quality of life and overall productivity. Smart robots will have a significant impact on future developments due to the increasing demand for automation and advancements in technology. A thorough introduction to smart robotics is provided [26], together with details on its advancements, applications, benefits, potential, and challenges.

It is projected that intelligent robots will play a significant role in the following disciplines in the future [26]:

- **AI Integration**: Through the incorporation of AI, robots will undertake more complex tasks, acquire new skills, adapt to different scenarios, and make independent decisions.
- **IoT Integration**: Integration of IoT technology will further enhance the autonomy and adaptability of robots, enabling them to communicate and interact with other devices and systems seamlessly.
- **Human-Robot Collaboration**: With the development of more sophisticated and user-friendly interfaces, robots will collaborate with humans in a more productive and natural manner.
- **Autonomous Vehicles**: The advancement of autonomous vehicles will rely heavily on smart robots, improving transportation safety and efficiency.
- **Smart Cities**: Robots will play a vital role in enhancing the functionality and efficiency of smart cities, contributing to tasks ranging from emergency response to infrastructure maintenance.
- **Space Exploration**: Robots will be essential in space exploration endeavors, undertaking tasks too perilous or challenging for humans.

1.8 Research Goal

This project aims to explore and create novel approaches for utilizing social robots in healthcare monitoring environments. The use of technology, especially social robots, offers a viable way to enhance patient outcomes and care quality in an era characterized by aging populations and rising healthcare needs [30]. The table I below contains the pertinent research questions.

TABLE I. RESEARCH QUESTION TABULATION AND DISCUSSION

S.NO	Research Question	Discussion
1	What is this survey paper intended to accomplish?	This survey article examines the application of social robots.
2	Which industry is the subject of this survey paper?	This survey article reviews the application of social robots in the healthcare industry.
3	Which platform does this survey article discuss?	This survey article reviews how the Raspberry platform and social robots have merged.
4	What is the benefit of this survey?	The survey paper has enormous promise for transforming the healthcare sector.

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 endeavors to make significant contributions to the evolving field through the following objectives:

- **Enhancing Human-Robot Interaction**: Our focus lies in advancing the understanding of social robots' ability to engage effectively with healthcare professionals and patients. This entails developing their natural language processing, emotional intelligence, and non-verbal communication skills to ensure empathetic and supportive interactions.
- **Continuous Monitoring**: We seek to augment the capabilities of social robots to continuously monitor vital signs, medication adherence, and overall well-being. This is particularly crucial for patients with chronic illnesses, post-surgery recovery, or those in need of long-term care.
- **Personalization and Adaptation**: Our research investigates the customization of social robots to cater to the unique needs of individual patients, adapting to their preferences, medical conditions, and emotional states. This tailored approach is essential for providing effective support and encouragement.
- **Data Integration and Security**: We also prioritize the secure and ethical handling of patient data collected by social robots. Our focus is on integrating this data into existing healthcare systems while implementing rigorous privacy and security measures.
- **Clinical Validation**: Our research involves conducting comprehensive trials and validation studies in healthcare settings to demonstrate the efficacy and benefits of employing social robots in healthcare monitoring. Collaboration with healthcare professionals, patients, and caregivers will be instrumental in gathering insights and feedback.

Our overarching goal is to contribute to the development of socially assistive robots that seamlessly integrate into healthcare environments, thereby promoting better patient outcomes, enhancing the quality of care, and alleviating the workload on healthcare professionals. This research plays a pivotal role in advancing healthcare monitoring practices and ultimately enhancing the overall healthcare experience for both patients and providers.

1.12 Paper Outline

In this section, we outline our survey focusing on the intersection of social robots, Raspberry Pi, and healthcare monitoring systems, as depicted in Figure 5 below.

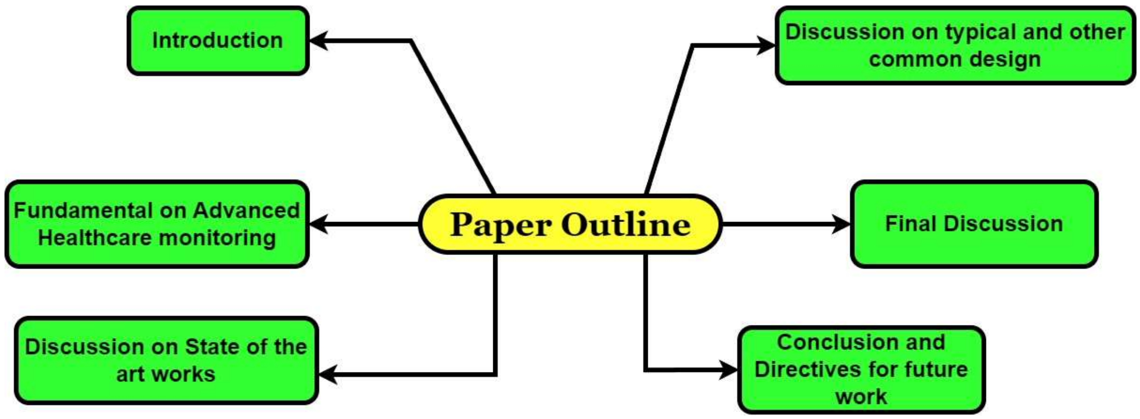


Fig. 5. Paper Outline

1.13 Paper Organization

In the forthcoming sections, the manuscript is structured as follows: Section 2 provides an exploration into the basics of advanced healthcare monitoring, covering topics such as sensor technologies, an overview of healthcare monitoring and its advancements, the evolution of this field, its application domains, key features, and the primary motivations behind the utilization of social robots in healthcare. Additionally, it outlines the criteria for the inclusion and exclusion of social robots. Section 3 delves into a discussion of the current state-of-the-art works. Following that, Section 4 examines typical and other common designs. Section 5 proceeds with the final discussion, while Section 6 wraps up the manuscript with the conclusion and offers directions for future research.

Chapter 2

Health Tech Revolution

2.1 Fundamentals on Advanced Health Care Monitoring

Healthcare monitoring has evolved significantly beyond traditional paper records and periodic check-ups. The emergence of wearable devices, remote monitoring, and the Internet of Things (IoT) has made healthcare monitoring more dynamic and continuous. However, these advancements still do not fully harness the potential offered by social robots equipped with ThingSpeak Raspberry Pi technology [39].

The integration of social robots into healthcare facilitates remote care delivery by healthcare professionals, leading to cost reduction and increased accessibility. This technology enables patients to be monitored from the comfort of their homes, eliminating the need for frequent hospital stays or medical visits [40].

Presently, social care delivery is at a juncture where both technical and human applications can be integrated, prompting policymakers and practitioners to contemplate the technologization of care [41]. Assistive Technologies (ATs) such as smartphone apps or screen readers [42], along with more advanced Assisted Living Technologies (ALTs) like telecare, telehealth, smart homes, and social robots [41, 43-45], play crucial roles in the administration, management, and provision of care. According to [43], 95% of social care providers in the United Kingdom (UK) utilize digital technology in their operations, primarily for staff communication purposes, predominantly through cellphones. While the consideration of AT's potential and complications is still in its nascent stages, its utilization remains widespread and consistent [41, 46].

2.2 **Sensor Technologies**

Sensor technologies are indispensable across a range of applications, spanning from industrial automation to healthcare and consumer electronics [47]. Here's a detailed overview of each sensor technology, as illustrated in Figure 6:

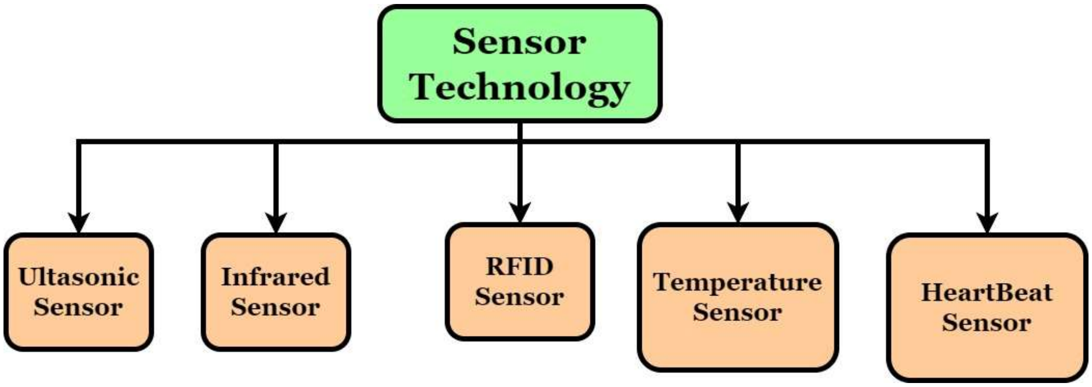


Fig.6. Different kinds of Sensors technology

1. **Ultrasonic Sensors:**
   - Ultrasonic sensors operate using sound waves at frequencies higher than the human audible range (typically 20 kHz to 65 kHz) to measure distance or detect objects.
   - Comprising a transmitter and a receiver, these sensors emit ultrasonic pulses, which bounce off objects and return to the receiver.
   - By calculating the time taken for the sound waves to travel and return, ultrasonic sensors determine the distance between the sensor and the object.
   - Widely utilized in proximity sensing, object detection, and distance measurement applications, including parking assist systems and industrial automation.
2. **Infrared (IR) Sensors:**
   - IR sensors utilize infrared light (radiation with wavelengths longer than visible light) to detect motion, heat, or proximity.
   - Passive IR sensors detect changes in IR radiation, making them suitable for motion-activated lighting and security systems.
   - Active IR sensors emit and receive IR radiation, found in devices like TV remote controls or proximity sensors.
   - Applications include temperature measurement, presence detection, and remote-control systems.
3. **RFID Cards (Radio-Frequency Identification):**
   - RFID technology employs radio waves for wireless communication and identification of objects or individuals.
   - Consisting of a microchip and an antenna, RFID cards are powered by radio signals from an RFID reader, retrieving data from the chip when in proximity.

- Commonly used in access control systems, contactless payment cards, inventory tracking, and pet identification.

4. **Temperature Sensors:**
   - Temperature sensors gauge temperature and provide data in digital or analog format.
   - Various types such as thermocouples, Resistance Temperature Detectors (RTDs), and thermistors exist, each with distinct working principles and temperature ranges.
   - Deployed in applications ranging from monitoring HVAC systems and industrial processes to regulating household appliance and medical device temperatures.
5. **Heartbeat Sensors:**
   - Heartbeat sensors, or heart rate monitors, measure a person's heart rate or pulse.
   - They utilize optical or electrical methods to monitor blood flow and detect pulsing blood vessels.
   - Found in wearable fitness trackers, medical devices, and sports equipment, they monitor users' heart rates during physical activities.

These sensor technologies serve diverse purposes and are integral components in various aspects of modern life, contributing to safety, convenience, and advancements in healthcare and industrial processes.

2.3 Introduction to healthcare monitoring and its advances

The healthcare field has undergone significant advancements, with technology playing a crucial role in enhancing patient care, diagnosis, and treatment. Among these innovations, social robots have emerged as promising tools capable of reshaping the healthcare landscape. These robots are designed to assist patients, healthcare professionals, and caregivers by providing companionship, monitoring vital signs, and supporting various healthcare tasks. Furthermore, the integration of IoT technologies like ThingSpeak and Raspberry Pi has further expanded the capabilities of social robots in healthcare monitoring [48].

Healthcare monitoring holds immense importance in patient care, particularly for individuals with chronic illnesses or the elderly [49]. It involves observing and measuring various health parameters such as heart rate, respiratory rate, temperature, and blood-oxygen saturation, especially in critically ill patients [50]. Access to accurate and immediate information is crucial for making timely decisions to ensure 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 patient-centric, non-intrusive, and cost-effective approach to address these challenges.

ThingSpeak, an IoT platform, facilitates the collection and analysis of real-time data from diverse sensors and devices. By integrating ThingSpeak with Raspberry Pi, a versatile and affordable single-board computer, an efficient and customizable solution is created to incorporate healthcare monitoring devices and sensors into a social robot [52]. This integration enables real-time data acquisition, analysis, and transmission, making it an ideal platform for healthcare monitoring.

Next, let's explore examples of commercially available social robots in the medical sector, as outlined in [53], in Figure 7 below.

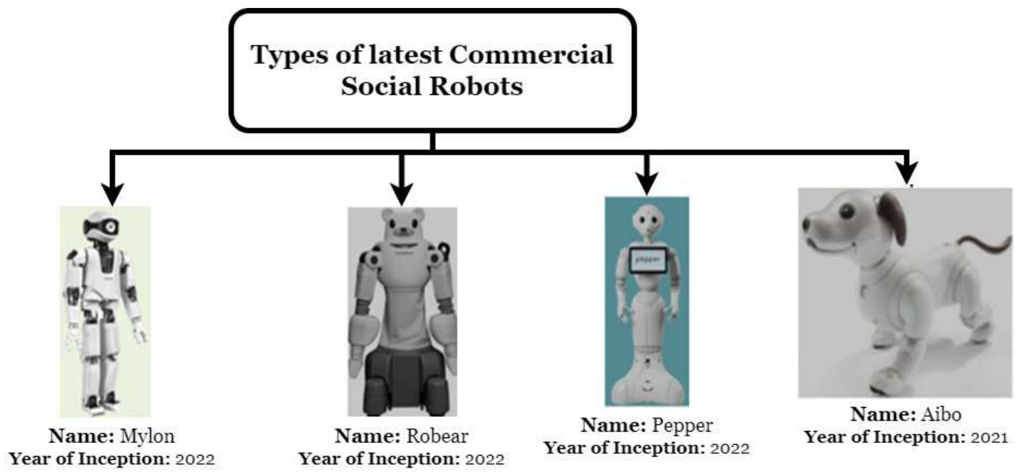


Fig. 7. Examples of commercially available social robots.

2.4 Significance of integrated systems

The integration of social robots into healthcare monitoring, powered by ThingSpeak and Raspberry Pi, holds significant importance for several reasons:

1. **Enhanced Patient Engagement**: Social robots empower patients to actively participate in their healthcare journey by providing reminders for medication intake, exercise routines, and other self-care activities. They offer emotional support, alleviating feelings of loneliness and anxiety often experienced in long-term healthcare situations.
2. **Early Intervention**: Timely detection of health issues is paramount in healthcare. Social robots, equipped with advanced monitoring capabilities, can promptly alert

healthcare professionals and family members to any deviations in a patient's health status. This early warning system enables timely interventions, potentially averting medical emergencies.

3. **Reduced Healthcare Costs**: By enabling remote monitoring and minimizing the necessity for frequent in-person visits, social robots contribute to significant cost savings for both patients and healthcare providers. This is particularly crucial given the aging population and the increasing prevalence of chronic diseases.
4. **Customizability and Scalability**: ThingSpeak and Raspberry Pi provide a flexible platform for integrating and tailoring various sensors and devices according to specific healthcare needs. This versatility allows for seamless adaptation to diverse healthcare scenarios and patient requirements. Additionally, it facilitates scalability and straightforward deployment across different healthcare settings.

The integration of social robots with ThingSpeak and Raspberry Pi not only enhances patient care and engagement but also contributes to cost-effectiveness and adaptability in modern healthcare environments.

2.5 Evolution of Social Robots

In the Human-Robot Interaction literature, researchers have coined various terms to define social robots, including:

1 **Socially Evocative Robots**: These robots leverage humans' inclination to anthropomorphize, eliciting emotions when individuals nurture, care for, or engage with them [54].

2 **Socially Situated Robots**: These robots are situated within a social environment, perceiving and reacting to the social cues and objects in their surroundings. They can differentiate between other social agents and various objects in the environment [55].

3 **Sociable Robots**: Sociable robots actively engage with humans to fulfill internal social objectives, such as drives or emotions. They require sophisticated models of social cognition to interact effectively [54, 55].

4 **Socially Intelligent Robots**: These robots exhibit characteristics of human-style social intelligence, drawing from potentially intricate models of human cognition and social competence [56].

5 **Socially Interactive Robots**: Unlike robots used in conventional Human-Robot Interaction scenarios, socially interactive robots prioritize peer-to-peer interaction.

They play a distinct role in Human-Robot Interaction, particularly in scenarios where teleoperation is not involved [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 can monitor vital signs like heart rate, blood pressure, and oxygen saturation in real-time. This continuous monitoring offers immediate feedback to both patients and healthcare professionals, aiding in timely intervention [57].
- **Behavior Analysis**: Equipped with ThingSpeak Raspberry Pi technology, social robots can analyze patient behavior and movement patterns to detect signs of discomfort or distress. This insight enables prompt care and intervention when needed.
- **Medication Reminders**: Social robots can assist in medication management by providing reminders to patients, ensuring they take their medications at the correct times. This helps reduce the risk of medication non-compliance and improves treatment outcomes.
- **Interactive Communication**: Designed to interact with patients in a natural and engaging manner, social robots can provide information, answer questions, and offer companionship. This interaction is especially beneficial for patients experiencing isolation, enhancing their overall well-being.
- **Integration with Health Records**: Data collected by social robots can seamlessly integrate into patients' electronic health records. This integration creates comprehensive patient profiles that healthcare providers can access and analyze, aiding in informed decision-making and personalized care delivery.

2.8 Key Motivations for Social Robots in Health Care Monitoring

- The healthcare landscape is undergoing a significant transformation due to factors such as an aging global population, increasing prevalence of chronic diseases, and a growing demand for high-quality healthcare services [63, 64]. Traditional healthcare models often struggle to cope with these challenges, necessitating innovative solutions that not only enhance care quality but also alleviate the burden on healthcare professionals. Social robots equipped with ThingSpeak Raspberry Pi technology emerge as promising solutions to address these issues effectively [54].
- With chronic illnesses, mental health issues, and the need for continuous monitoring becoming increasingly prevalent, social robots play a crucial role. These robots possess the capability to engage with patients in a human-like manner, offering essential emotional support and companionship, particularly to individuals experiencing isolation and loneliness [65].
- Social robots represent a rapidly growing field within robotics, aiming to create machines capable of interacting with humans in a human-like manner [66]. They have garnered significant attention across various sectors, including healthcare, where they hold the potential to bridge the gap between patients, healthcare providers, and caregivers. These robots can provide companionship, support, and vital monitoring services while maintaining seamless connectivity with healthcare systems [55]. Let's explore the key motivations through Figure 8 below.

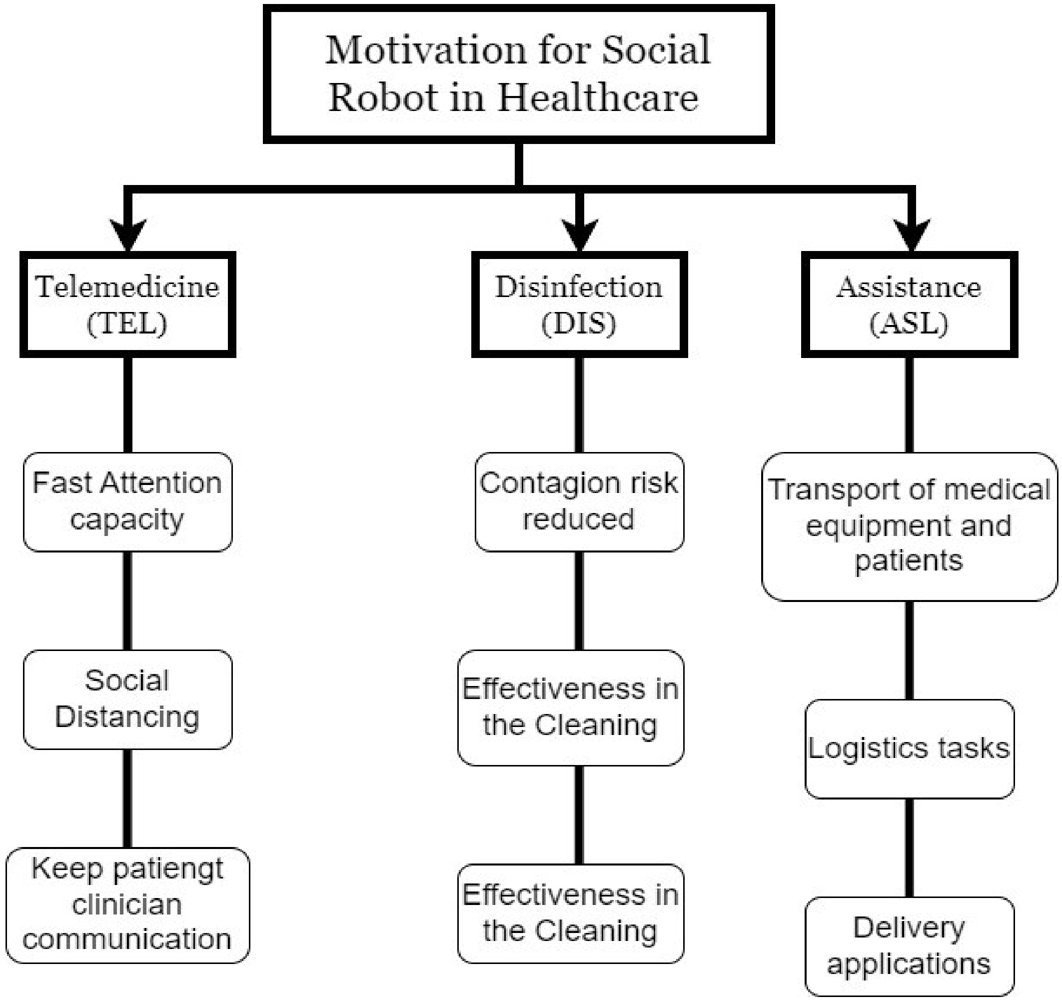


Fig. 8. Motivation for RoboCare Connect

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

- **Compassionate Companionship**: Social robots possess a unique capability to establish emotional connections with patients, offering companionship and alleviating feelings of isolation, which is particularly crucial for individuals in long-term care facilities or home care settings.
- **Enhanced Patient Engagement**: Social robots can foster patient engagement by offering reminders for medication intake, exercise routines, and dietary habits, leading to improved adherence to care plans and better health outcomes.
- **Continuous Monitoring**: These robots can continuously monitor patient vital signs,

activity levels, and medication adherence, enabling prompt responses to deviations or emergencies, thereby reducing hospital readmissions and enhancing 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, facilitating informed and proactive decision-making.
- **Personalized Care**: Social robots can be programmed to deliver personalized care plans tailored to individual patient needs, adjusting their interactions and reminders accordingly.
- **Cost Efficiency**: Over time, investment in social robots can lead to cost savings, relieving the strain on healthcare systems while enhancing care quality overall.
- **Improved Mental Health**: These robots can provide mental health support through interactive therapy sessions and monitoring of emotional well-being, aiding patients in managing stress, anxiety, and depression effectively.

2.9 Inclusion and exclusion

Inclusion and exclusion criteria play a pivotal role in research studies or programs involving social robots in healthcare monitoring. These criteria ensure that participant selection remains consistent and aligns with the study's objectives. Here are some example inclusion and exclusion criteria for using social robots in healthcare monitoring:

Inclusion Criteria:

- Age: Participants must be within a specified age range, such as adults aged 18 and above.
- Medical Condition: Participants must have a specific medical condition relevant to the study, such as chronic illness or mobility impairment.
- Consent: Participants must provide informed consent to participate in the study and interact with the social robots.
- Language Proficiency: Participants must have a sufficient level of language proficiency to communicate effectively with the social robots.
- Availability: Participants must be available and willing to commit to the study's schedule and duration.

Exclusion Criteria:

- Cognitive Impairment: Individuals with severe cognitive impairments that may hinder their ability to interact meaningfully with the social robots.
- Severe Medical Conditions: Participants with severe medical conditions that may pose

risks to their safety or interfere with the study's objectives.

- Language Barriers: Individuals with limited language proficiency that may hinder their ability to understand and respond to the social robots' instructions or prompts.
- Lack of Consent: Participants who are unable or unwilling to provide informed consent to participate in the study.
- Conflicting Commitments: Individuals with conflicting commitments or obligations that may prevent them from fully participating in the study.

It's important to note that these criteria should be tailored to the specific context and goals of the healthcare monitoring study, ensuring that 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.

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	Non-English publications

Chapter 3

Literature Review

3.1 Discussion on State of the Art Works

The integration of IoT technology is heralded as the next technological revolution, facilitating the interconnection and smart capabilities of various objects. In the realm of healthcare, IoT-based smart rehabilitation systems are emerging as a promising solution to address challenges associated with aging populations and a shortage of healthcare professionals. Despite their potential, there are significant challenges in automating the design and reconfiguration of these systems to respond rapidly to patient needs.

One approach to address these challenges is presented in a paper proposing an ontology-based Automating Design Methodology (ADM) for smart rehabilitation systems in IoT. This methodology utilizes ontology to enhance computers' understanding of symptoms and medical resources, enabling the creation of rehabilitation strategies and automatic reconfiguration of medical resources based on patient-specific requirements. Additionally, IoT serves as an effective platform for interconnecting resources and facilitating immediate information exchange. Preliminary experiments and clinical trials demonstrate the feasibility, rapidity, and effectiveness of this methodology [71].

Another article discusses the development of a Body Area Network (BAN) for measuring Electrocardiogram (ECG) signals and transmitting them to a smartphone via Bluetooth for data analysis. The BAN utilizes a specially designed Planar Inverted F-Antenna (PIFA) with a small form factor and low-fabrication cost techniques. The system leverages surface-wave propagation around the human body due to its electrical properties. Data processing is performed on the user's smartphone, and an application for Android smartphones is developed to raise an alarm in case of a detected heart attack. The system's functionality is validated through three real-life user case scenarios [72].

Furthermore, there is a significant issue regarding the documentation of vital signs in many hospitals, particularly the poor documentation of respiratory rate. Abnormal respiratory rates serve as predictors of potentially serious clinical events, emphasizing the importance of appropriate responses to elevated respiratory rates and other abnormal vital signs. Hospital systems that encourage such responses can be rapidly implemented to raise and sustain awareness of vital sign importance [73].

Extensive research has been conducted on the application of IoT in healthcare, aiming to interconnect medical resources and provide reliable and effective healthcare services to the elderly and patients with chronic illnesses. A comprehensive literature review identifies the advancements of IoT in healthcare systems, including enabling technologies and methodologies, IoT-based smart devices and systems, and diverse applications in the healthcare industry. The paper also discusses the challenges and prospects of IoT-based healthcare systems' development [74].

Moreover, various technologies, such as the medical Internet of Things (mIoT) and big data analytics, are explored for their potential to reduce overall costs in chronic illness prevention and management. Mobile applications (apps) integrated with mIoT are increasingly used by patients to manage health needs and are integrated with telemedicine and telehealth services. This integration allows for productivity improvements, cost containment, and enhanced customer experiences in healthcare delivery [75].

Lastly, an innovative project aims to address the lack of routine health monitoring among busy individuals by developing a system to monitor health parameters such as temperature, heartbeat, and pulse using biomedical sensors connected to an Arduino Uno. The data is displayed on a Liquid Crystal Display (LCD) or serial monitor for easy access [76].

Let's now display the analysis and key findings from the significant research projects [32, 71-75, 77, 78] in table III below.

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

Among the duties carried out by the social robot in healthcare monitoring are drug delivery, vital sign recording, and patient companionship [40]. It lets medical staff concentrate on important duties while maintaining a safe and effective environment. The information gathered from the different sensors is sent to ThingSpeak, where it may be examined to find trends, patterns, or abnormalities in the health of the patients. This technology not only improves patient care but also gives those in need a measure of freedom and support, which raises the standard of healthcare services in the end.

4.1.1 Discussion on typical design

Important components of this design (shown in figure 9 below) include the following: they ensure patient safety, collect and analyze vital data, and improve overall healthcare service delivery to create a versatile and responsive social robot that can improve healthcare monitoring and patient care.

- **Ultrasonic Sensor**: Utilized for obstacle detection, the ultrasonic sensor ensures the robot navigates its environment safely, avoiding collisions [79].
- **IR Sensor**: These sensors track patient movements and interactions, enabling the robot to respond more effectively to their needs [69].
- **RFID Cards**: Employed for patient identification and access control [80], RFID technology enables personalized care by allowing the robot to identify patients via RFID cards they wear.
- **Temperature Sensor**: Crucial for healthcare, temperature sensors enable the robot to monitor patient well-being and detect anomalies [81, 82].
- **Heartbeat Sensor**: Used for real-time monitoring of vital signs, the heartbeat sensor alerts healthcare providers to irregularities in the patient's condition [83]. **Raspberry Pi**: Serving as the central processing unit, the

Raspberry Pi runs the robot's software, manages sensor data, and facilitates communication with healthcare professionals.

- **Motor Driver**: Controls the robot's movement, allowing it to navigate healthcare facilities efficiently and reach patients in need [84].
- **ThingSpeak**: A cloud-based platform for storing, analyzing, and visualizing sensor data, ThingSpeak provides real-time access to healthcare professionals and family members for remote patient monitoring.

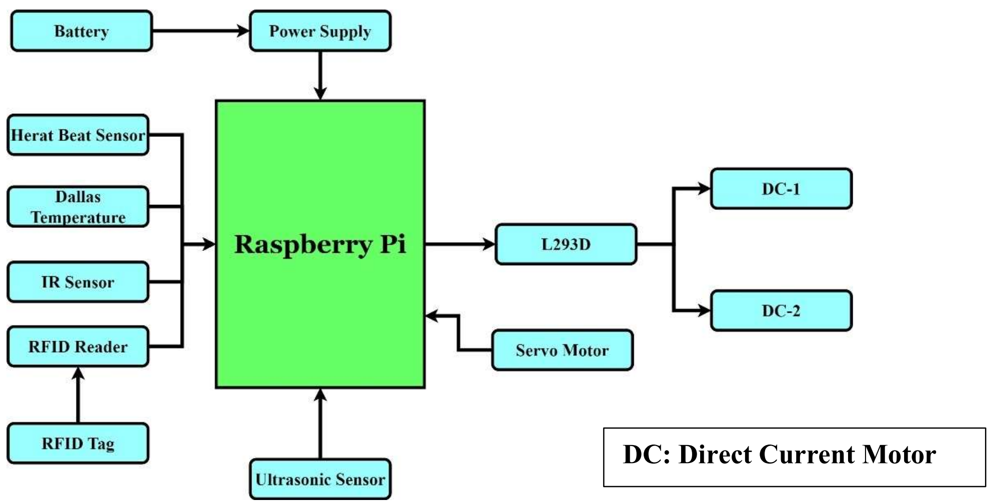


Fig. 9. Pictorial representation of the typical Design

4.1.2 Discussion on other designs

1) ***Design 1***: proposes a robot equipped with IR sensors and ultrasonic sensors. This robotic vehicle utilizes ultrasonic sensors to detect the distance between individuals in a queue. If the distance between any two individuals falls below a predefined threshold, the robot will move to the other side to maintain social distancing. In case of violation of this rule, the robot will read the RFID tag of the patient ID. Intelligent physical robots, driven by AI, have the potential to revolutionize healthcare services. While previous research has explored the use of intelligent physical robots in healthcare from various angles, there is a gap in the literature regarding an overview of the antecedents and consequences of their use in healthcare contexts.
2) ***Design 2:*** introduces a smart alarm system aimed at monitoring post-Coronary Artery Bypass Graft (post-CABG) surgery patients, addressing the lack of social distance monitoring systems discussed in the previous method [76].
    - Unlike conventional methods where individuals need to monitor patients in queues and manually alert others to maintain a safe distance, the Smart Alarms system features an alarm algorithm that considers multiple vital signs for patient monitoring.
    - The system utilizes Radio Frequency 433 (RF433) Megahertz (MHz) transmitter and receiver modules for wireless communication, facilitating data transmission from the rover to collect patient data. These modules operate at a frequency of 433 MHz, making them suitable for short-range wireless communication.
    - In addition, the ESP8266 is highlighted as a crucial component in health monitoring systems. It enables the collection and transmission of health data to a remote server for real-time monitoring and analysis. The ESP8266 offers a cost-effective and efficient solution for implementing connected health monitoring solutions, benefiting patients, healthcare providers, and caregivers alike.

The effectiveness of social robots in healthcare is contingent upon several key factors, including their ability to engage in human-like interaction, adapt to diverse situations, maintain reliability, and adhere to ethical standards. To truly excel in their role, these robots must demonstrate a profound understanding of patients' emotional needs, respect privacy and security measures, and seamlessly integrate into established healthcare systems.

Achieving high-quality social robots in healthcare necessitates rigorous testing procedures, continuous refinement, and strict adherence to safety and ethical standards. By prioritizing these aspects, social robots can contribute significantly to enhancing patient outcomes, alleviating healthcare burdens, and complementing the efforts of human care providers effectively.

4.2 System Architecture

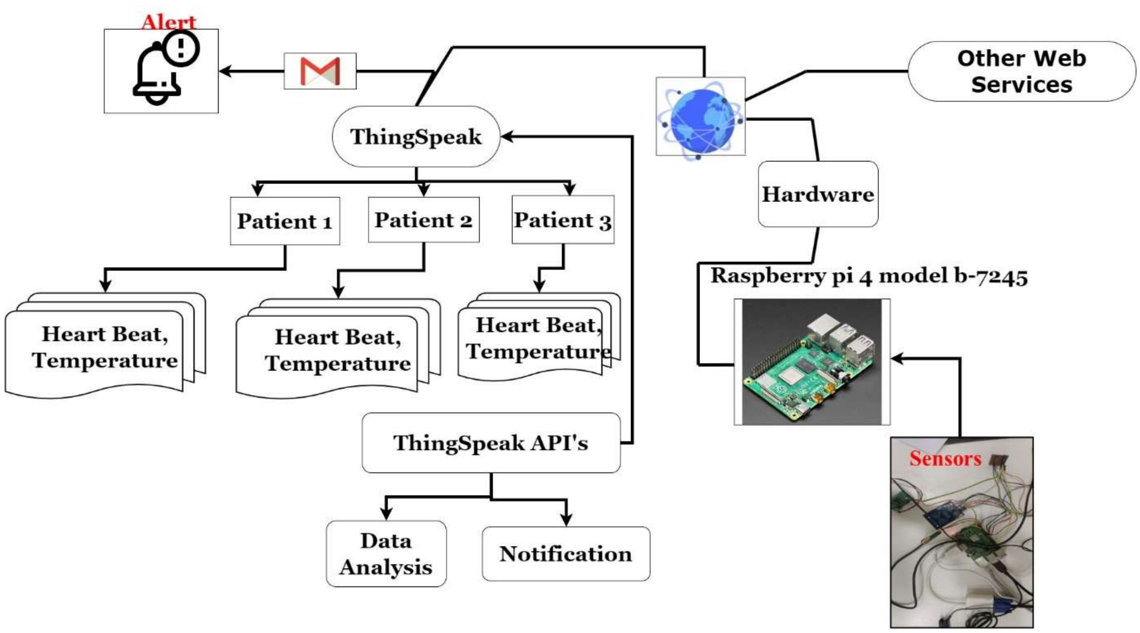


Fig. 10. Proposed Architecture for Research Study

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

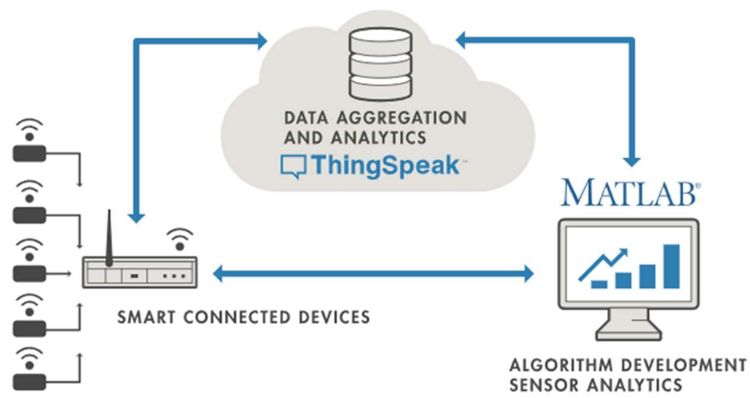


Fig.11. Block Diagram of Sensor Integration with MATLAB

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.

Chapter 5

System Design and Implementation

5.1 Robot Hardware

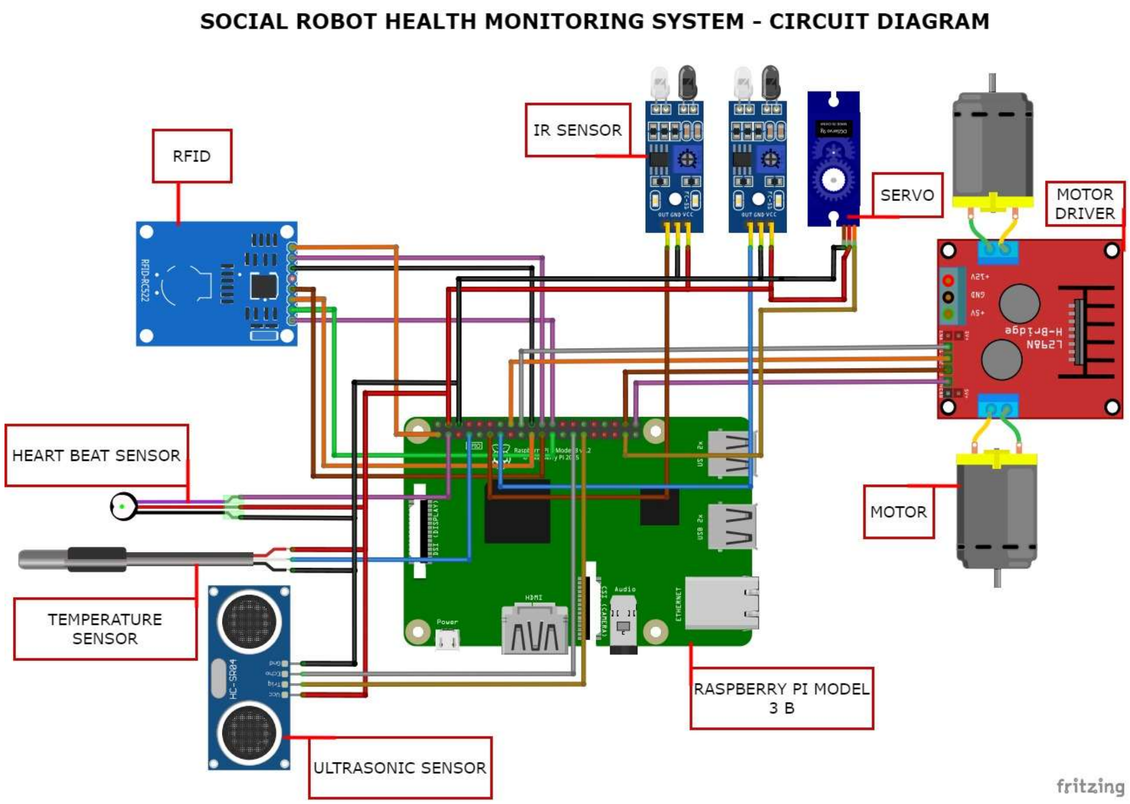


Fig. 12. Social Robot Health Monitoring System Circuit Diagram

5.1.1 Chassis

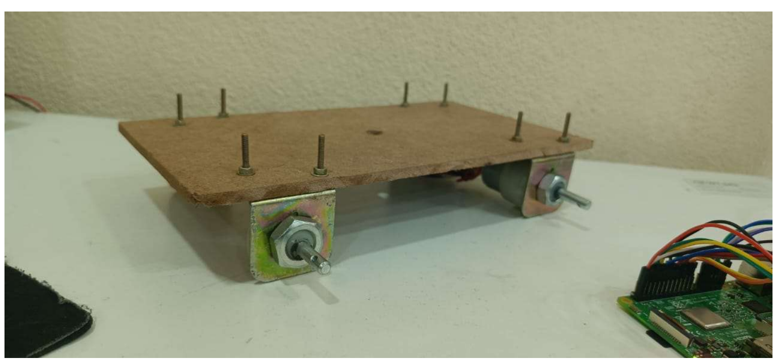


Fig. 13. Chassis

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

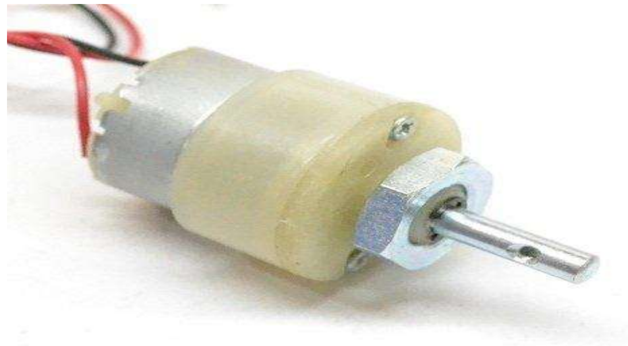


Fig. 15. 12 Volts Direct Current Motor

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

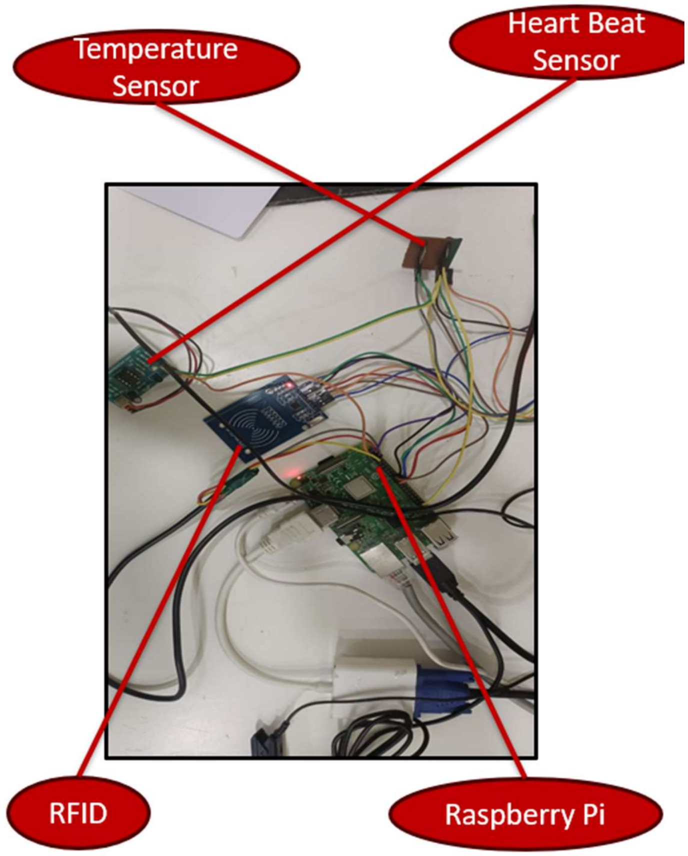


Fig. 17. Sensors Integration

5.2.1 RFID Reader

Fig. 18. Radio Frequency Identification

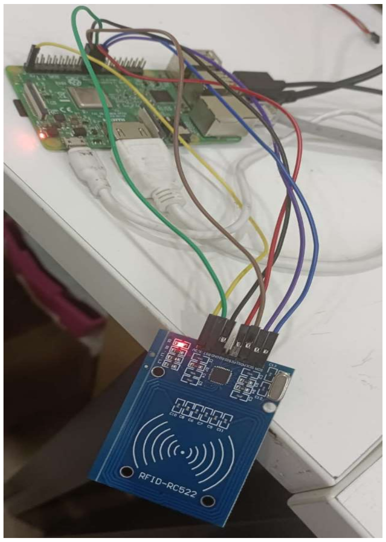


Fig. 19. Interfacing of Radio frequency Identification with Raspberry Pi Model 3 B

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.

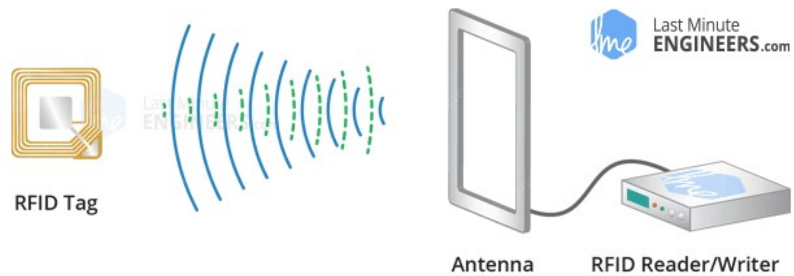


Fig. 20. Radio frequency Identification Working

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 I^2C, 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.

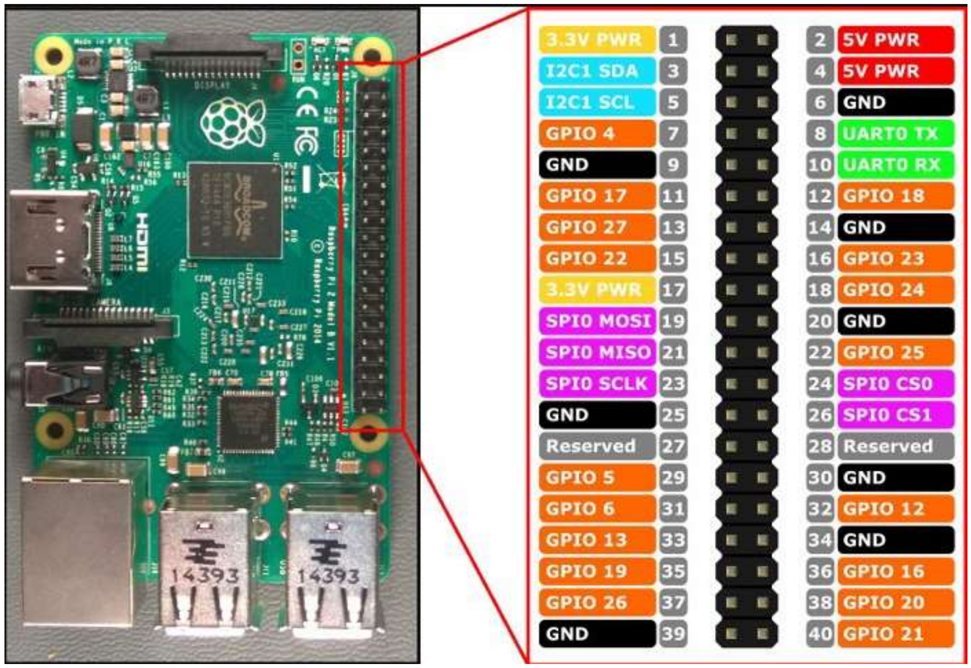


Fig. 25. GPIO Pin Architecture of Raspberry Pi Model 3B

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.

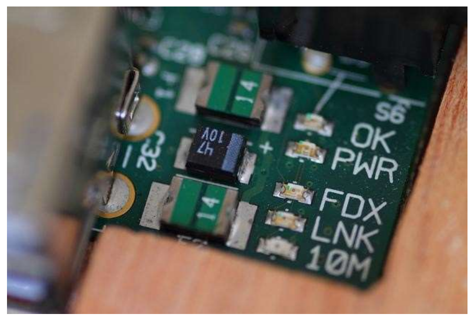


Fig.27. Status LEDs

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

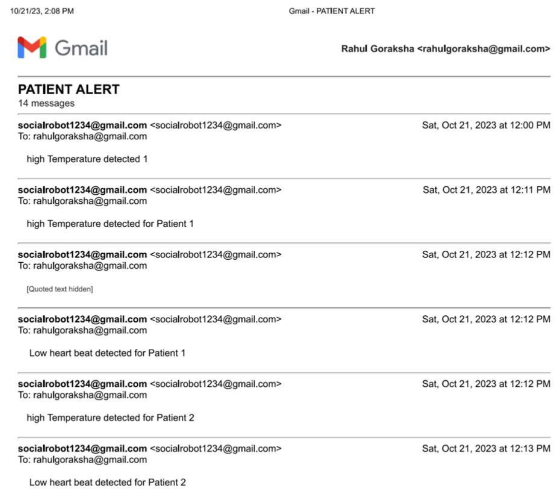
Components for data analysis and storage are essential to the software development of the system. Mechanisms for safely storing health data on a centralized server or cloud platform are included in the architecture. Algorithms for data analysis are used to understand health data, find trends, and produce 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

Appendix -A 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.

Appendix -B 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


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)
```

```python

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

```

Appendix -C Experimental Data

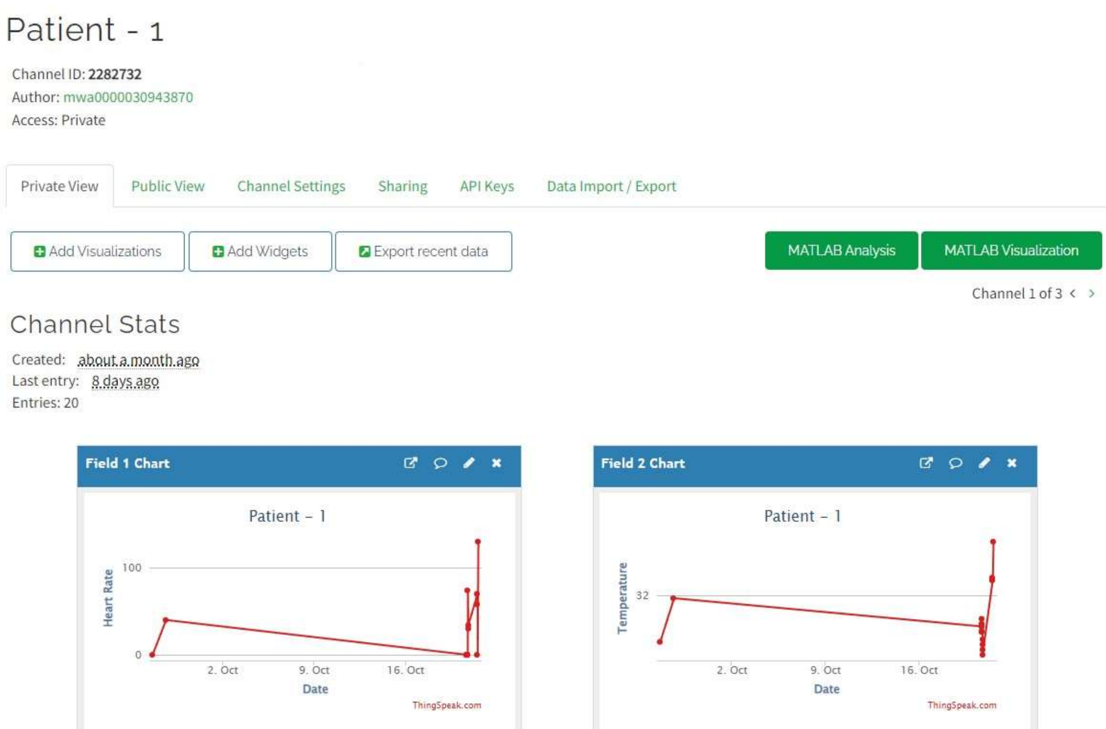


Fig. 29. Experimental Collected Data of Patient 1

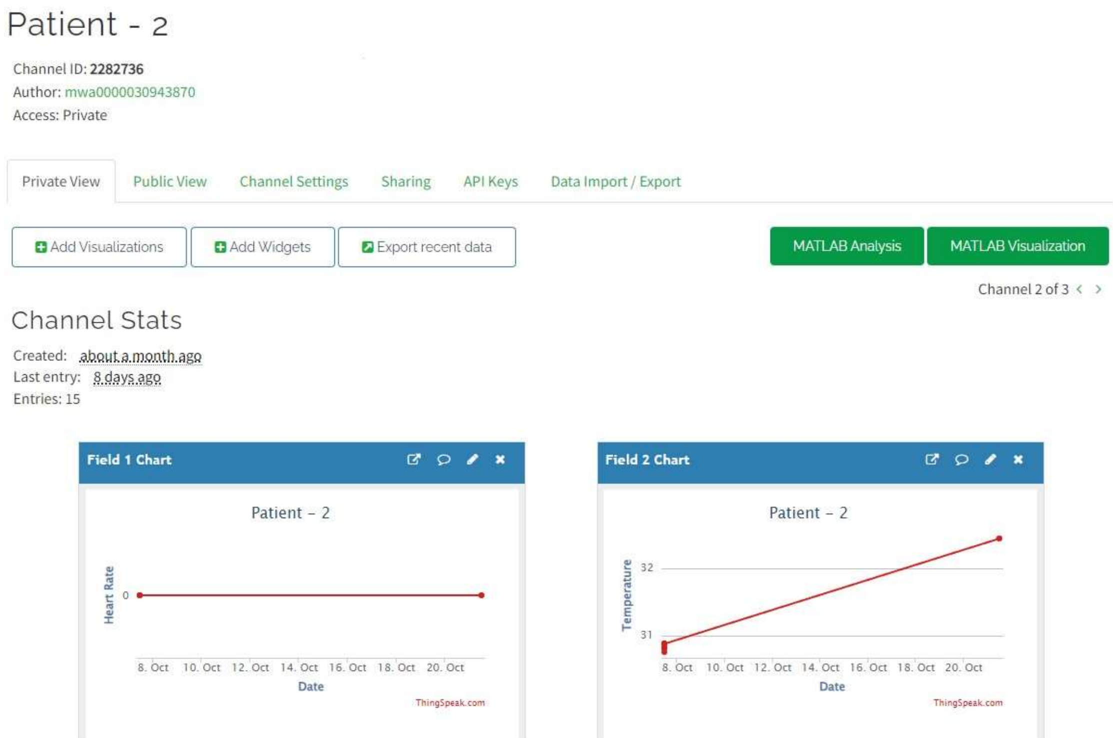


Fig. 30. Experimental Collected Data of Patient 2

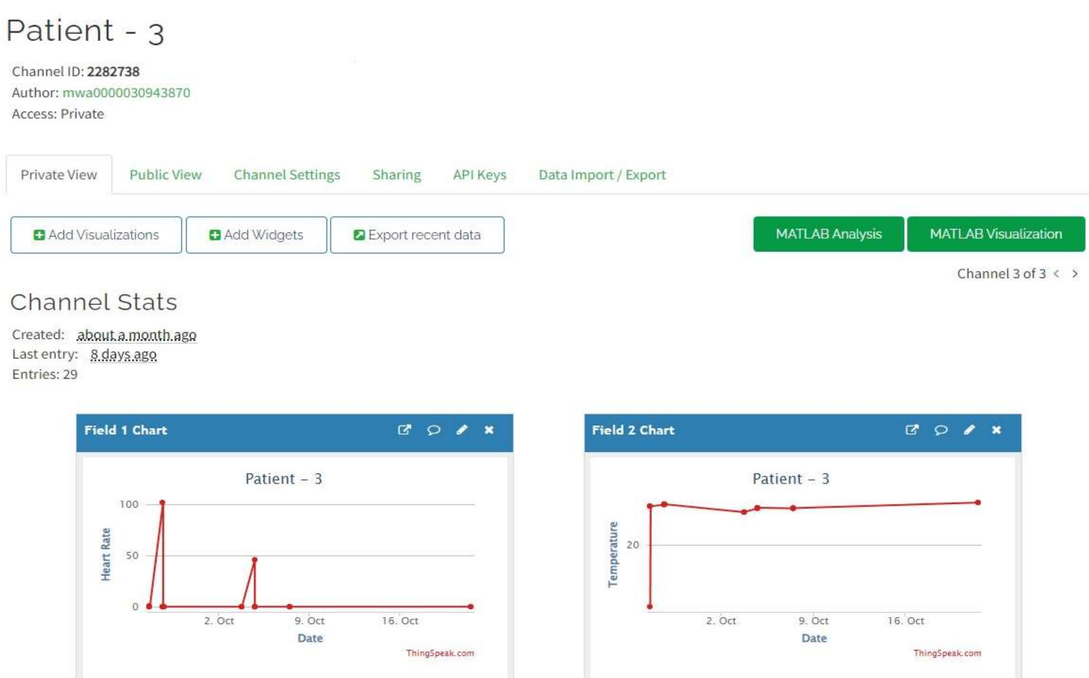


Fig. 31. Experimental collected Data of Patient 3

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