A Device for Command and Control System for Military Communication

by

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Department of Electronic and Telecommunication Engineering
INTERNATIONAL ISLAMIC UNIVERSITY CHITTAGONG

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CERTIFICATE OF APPROVAL

The project entitled as **"A Device for Command and Control System for Military Communication"** submitted by **Sha Imran Ahmad**, bearing Metric ID. **T183028** of session **Spring 2022**, to the Department of Electronic and Telecommunication Engineering, International Islamic University Chittagong, has been accepted as satisfactory in partial fulfilment of the requirements for the degree of Bachelor of Science in Engineering and approved for the examination held on **15th July, 2023**.

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CANDIDATE DECLARATION

It is hereby declared that this work has been done by us and no portion of the work contained in this thesis/project has been submitted elsewhere for the award of any degree or diploma.

Sha Imran Ahmad

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Authors

ABSTRACT

The objective of this project is to create an advanced military M2M system that combines object and sound detection with command technologies. The system will use computer vision and audio processing to provide real-time information to military personnel in the field. Deep learning techniques, including CNNs, will be utilized by the object detection component to precisely detect weapons, vehicles, and other pertinent objects in real-time. A dataset of military objects will be used to train the object detection algorithm for improved accuracy and robustness in difficult conditions. The system will utilize signal processing algorithms to differentiate between different sounds, including speech, gunfire, and explosions. The system facilitates swift and precise identification of potential threats by military personnel, enabling them to respond accordingly. The M2M system can be remotely controlled by military personnel through the command system, which facilitates real-time situational awareness and swift response. The system will have a user-friendly interface and will be designed to function in challenging environments, including combat zones. The M2M system will be designed to endure challenging environments, including severe temperatures, dust, and impacts. The system's ability to function effectively in challenging environments and provide dependable information to military personnel will be guaranteed. A combined M2M system utilizing object detection, sound detection, and command technologies is expected to enhance military operational efficiency and personnel safety. The system enables military personnel to receive real-time information and respond quickly to potential threats.

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LIST OF ABBREVIATIONS

M2M Machine to Machine

LED Light Emitting Diode

SMS Short Message Service

USB Universal Serial Bus

IC Integrated Circuit

AC Alternative Current

DC Direct Current

LCD Liquid-crystal display

CHAPTER 1
INTRODUCTION

1.1 Introduction

The project is a significant step forward in terms of the advancement of technological capabilities for military defense. This novel system builds a robust communication and control framework between a commander and a soldier by utilizing the capabilities of ESP32 Audino microcontrollers and a complete array of components. Additionally, it integrates powerful object identification and sound detection functionalities. These elements improve situational awareness, operational efficiency, and the overall effectiveness of military operations, thereby solving important difficulties that are encountered on today's modern battlefield.

It is of the utmost importance to have the capability to detect and identify prospective threats in real time, as the landscape of combat is always shifting and changing. The suggested system includes an integrated object detection system, which enables the military unit to study its surroundings and identify potential ambush spots, as well as barriers, suspicious items, and other potential threats. The system is able to discern between normal items and possible dangers, such as improvised explosive devices (IEDs) or concealed armament, thanks to the utilization of cutting-edge sensors and complex algorithms [1]. This talent gives the soldier the ability to quickly react to impending threats, adjust their tactics as necessary, and keep a strategic advantage over their opponents. The technology improves the soldier's situational awareness by delivering information on the detection of objects in real time. This helps to ensure that the task is successful while also reducing the risk to troops [2].

One of the most important aspects of military operations is the sound detection system that was developed as part of this project. The system is able to record and evaluate the audio signals present in the surroundings since it makes use of a microphone with a high quality [3]. The sophisticated algorithms that are used are able to differentiate between distinct patterns that are connected with loud sounds such as gunshots, explosions, or the movement of armored vehicles. The sound detection system serves as an auditory early warning system, which provides the soldier with an early warning of potential dangers or impending hostilities. The soldier is able to take rapid defensive actions, coordinate with their leader, and swiftly modify their strategy to changing situations as a result of this aptitude. The technology assures the protection of people during high-stakes operations by utilizing sound detection, which allows for a considerable reduction in response times, an improvement in the soldier's ability to detect concealed foes, and an increase in the soldier's capacity to detect hidden adversaries [4].

The ability of the proposed machine-to-machine communication and control system to establish smooth coordination and efficiently carry out commands is the most important factor in determining the system's relevance. The commander is in charge of monitoring and directing the actions of the soldier. This responsibility requires the commander to have access to an ESP32 Audino microcontroller as well as a variety of integrated components. The commander's control interface includes essential orders, such as forward, backward, left, right, and hold, which enables exact movement and synchronization of the soldier unit. Other instructions include forward, backward, left, and right. Direct control over a soldier's movements may be maintained by the commander thanks to the instantaneous wireless transmission of commands that is made possible by the MP605 module. This facilitates improved strategic decision-making and reduces the likelihood of misunderstandings occurring. Even in very complex and ever-changing circumstances, the efficient carrying out of missions is ensured by the centralized command structure [5].

In addition, the incorporation of a specialized keypad interface tailored specifically for the commander improves usability and speeds up the process of order issuance. The commander is given the ability to express particular instructions in an easy and time-effective manner thanks to the keypad, which features a range of predefined commands. The keypad reduces the amount of mental strain placed on the commander by streamlining the process of command entry [6]. As a result, the commander is better able to concentrate on making vital decisions in quickly shifting circumstances. The commander and the soldier unit are able to communicate more clearly and more quickly as a result, which considerably reduces the risk of misunderstandings occurring and ensures the instructions are carried out in a timely and accurate manner [7].

The conclusion is that the project marks a paradigm shift in the development of military defense systems. This cutting-edge system improves the user's situational awareness, makes it easier for them to communicate with one another in a seamless manner, and guarantees that commands are carried out effectively by incorporating sophisticated object identification and sound detection capabilities into a comprehensive communication and control framework. This project will contribute to the security of military personnel, the success of missions, and the overall effectiveness of military operations in the face of emerging threats through the use of cutting-edge technology.

1.2 Motivation

The vital need to improve military defense systems and provide improved capabilities for object identification and sound detection in military operations is the impetus behind this project, which will be driven by those needs. The acknowledgment of the considerable obstacles faced by military personnel in modern conflict scenarios and the urgent need for advanced technology to successfully alleviate these challenges served as the impetus for the creation of this project. These challenges were recognized as the inspiration behind the creation of this project.

The accomplishment of a mission and the protection of the lives of military personnel are both directly dependent on the military defense systems that are in place. It is absolutely necessary to provide military forces with cutting-edge defense technologies in order to preserve their strategic advantage in light of the continually morphing threats and adversaries who employ complex strategies [8]. The machine-to-machine communication system that has been proposed provides a comprehensive solution that improves the efficiency of military operations as a whole. This is accomplished through the provision of seamless communication, accurate control, and increased awareness of the surrounding environment [9].

Object detection is an essential part of military operations because it permits the early identification of potential threats and dangers in the operational environment. This is why object detection is considered to be one of the most important aspects of military operations. Military personnel gain the capability to detect and evaluate things or barriers that may pose hazards to their safety or hamper mission progress by adding an object detection system into the proposed project. This enables the military people to better complete their missions. This skill enables for proactive decision-making, rapid adaptation to changing situations, and effective deployment of countermeasures. As a result, the vulnerability of military troops to surprise attacks and ambushes is reduced [10].

Due to the fact that auditory signals frequently convey crucial information about the presence of opponents, possible hazards, or major events, the detection of sound plays an essential part in the operations of military forces. The proposed project will improve the soldier's situational awareness by implementing a sound detection system. This will be accomplished by gathering and analyzing audio signals in real time, which will take place in the field. The capability of the system to recognize particular sound patterns associated with powerful sounds, such as gunfire or explosions, enables military troops to quickly react, take appropriate defensive actions, and efficiently coordinate with their commanders. When there is a high level of intensity in the conflict, the sound detection system provides an additional layer of defense, greatly cutting down on response times and significantly lowering the chance of civilian casualties [11].

The areas in which military operations take place are defined as being complicated and dynamic, and it is essential to make decisions in a split second and communicate effectively [12]. These issues can be overcome with the help of the machine-to-machine communication and control system that is being suggested for this project. This system will ensure that there is consistent and reliable communication between the commander and the troop unit. The incorporation of cutting-edge technology, such as the ESP32 Audino microcontrollers and the keypad interface, simplifies the process of command issuance, lowers the danger of misunderstandings, and guarantees that instructions are carried out in an effective manner. This system gives military troops the ability to tackle operational problems effectively by permitting precise maneuverability and synchronization. As a result, mission success rates are increased, and risks are reduced [13].

To summarize, the imperative requirement to improve military defensive systems with cutting-edge technology is the driving force behind the "Machine-to-Machine-Based Object Detection, Sound Detection, and Command Systems for Military Purposes" project. This project's name comes from the acronym for "Machine-to-Machine-Based Object, Sound, and Command Systems for Military Purposes." This project intends to improve situational awareness, enable real-time threat identification, and facilitate seamless coordination among military personnel by merging features for object detection and sound detection into a complete communication and control framework. This system intends to contribute to the safety, effectiveness, and success of military operations in modern combat by addressing operational issues and decreasing vulnerabilities. This will allow the system to solve operational challenges and reduce vulnerabilities.

1.3 Objective of this Project

The project's main goals are as follows:

1. To create an M2M-based system for military use that can detect objects, sounds, and respond to commands.

2. To improve conventional detection methods by utilizing sensors, CPU, and military resources in the implementation of the system.

3. To enhance the safety and effectiveness of military personnel by reducing their exposure to hazardous situations.

1.4 Report Outline

The project was planned and created with a focus on six distinct sections. The document provides an overview of the chapters and their respective content:

Chapter 1 (Introduction): In this discourse, we shall deliberate on the antecedents of this undertaking and the intended objectives thereof.

Chapter 2 (Literature Review): In this study, a review of the existing literature pertaining to this field was conducted.

Chapter 3 (Components): This chapter has provided a comprehensive coverage of the various components involved in this work.

Chapter 4 (System Design): This chapter outlines the methodologies employed to conduct the pivotal experiments for this investigation.

Chapter 5 (Implementation and Result): The next section will discuss the methodology employed in executing the project and its ultimate results.

Chapter 6 (Conclusion): This chapter provides a more detailed analysis of the overall scope of this undertaking. This study analyzes the prospects of the project, along with its potential benefits and advantages.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The current chapter, along with the pertinent material that will assist the investigation, will serve as an introduction to the inquiry that will be carried out for the project. This will be done in conjunction with the previous sentence. In addition to that, we gave a condensed summary of the problem statement that was associated with the detection of objectives, detection of sound, and command system. This article offers a condensed explanation of the significance of the system in question.

2.2 Review of the Previous Work

Machine-to-machine (M2M) technology has become increasingly widespread, which has made it easier for the military to capitalise on hitherto unexplored avenues of opportunity. M2M technology has the ability to completely transform military operations because to its integration of object recognition, sound detection, and command systems. The purpose of this literature review is to provide an overview of recent discoveries that have been derived from study and advancement in this specific field.

At a conference that took place not too long ago, a presentation with the title "Acoustic threat detection and direction finding system" was presented. The purpose of the project is to investigate both the positive and negative aspects of using ultrasonic technology into machine-to-machine communication for mobile robots. The research highlights the significance of having an object detection system that is accurate and effective while also doing an analysis of the technologies that are now accessible [14].

The article "Military operations: Wireless sensor networks based applications to augment future battlefield command system" includes a debate on Military M2M command systems. The title of the paper is "Military operations: Wireless sensor networks based applications to augment future battlefield command system." This study addresses the challenges that are associated with the design of the aforementioned systems, including the establishment of secure and dependable connections, as well as the implementation of intuitive and user-friendly interfaces. The most recent developments in this specific industry point to the possibility that Machine-to-Machine (M2M) command systems will be able to lend support to military endeavours in the years to come [15].

The academic study named "Obstacle Detection Utilising Ultrasonic Sensor for Mobile Robotics" investigates the use of machine-to-machine (M2M) technology in several aspects of the military. This article takes a look at the numerous techniques that can be used for real-time object identification in military operations. Particular attention is paid to the primary objectives of rapidity, precision, and resilience, as well as the demand for trustworthy procedures. According to the findings of the literature assessment, M2M-based object, sound, and command systems are becoming increasingly commonplace in the armed forces. According to findings from previous studies, the application of the aforementioned equipment has the potential to revolutionise military operations by elevating their level of precision and effectiveness [16].

An analysis of the relevant literature reveals that there is a rising interest in the research and development of M2M-oriented object recognition, sound detection, and command systems for military applications. Recent research has shown that these technologies have the potential to improve the accuracy and effectiveness of military operations. As a result, they have the potential to revolutionise the way that military operations are carried out. In spite of this, there are issues that have not been satisfactorily answered and require attention. These issues include the requirement for secure and dependable communication; the demand for detection algorithms that are accurate and effective; and the want for user interfaces that are nice to use and easy to understand.

2.3 Problem Statement

The analysis of the relevant literature reveals that there are various unanswered questions and obstacles to be overcome in the process of designing machine-to-machine (M2M)-based command, sound detection, and object detection systems for use in the military. The military use of machine-to-machine (M2M) technology faces a number of critical research gaps as well as obstacles in the integration of object detection, sound detection, and command systems. Even if there have been recent developments in this field, it is very necessary to solve the detailed issues in order to develop M2M-based object detection, sound detection, and command systems that are efficient and effective for use in military applications [17].

Real-time and accurate object detection: Existing approaches for object detection for military applications frequently have latency issues and lack the needed level of precision. Real-time and accurate object detection is a goal of this research. There are some limitations to the system's capacity to recognize and categorize things of interest in real-time military scenarios. There is a need for research to develop innovative algorithms that can considerably cut down on latency while yet keeping a high level of accuracy in object detection. This covers the investigation of cutting-edge computer vision techniques, deep learning methods, and productive hardware architectures [18].

Reliable and effective sound detection: Sound detection plays an important part in military operations because it permits the identification of essential auditory cues such as gunfire, explosions, or hostile communication. This is why sound detection is so important to the military. However, the creation of sound detection algorithms that are dependable and effective within M2M systems for use in the military is still an active research challenge. In order to improve the precision and effectiveness of sound detection systems, there should be a greater emphasis placed on the investigation of signal processing methods, acoustic modeling, and algorithmic approaches to machine learning [19].

Integration of command systems that is completely seamless The seamless integration of command systems into M2M technology for military applications needs careful consideration of a number of different elements. These capabilities include the capacity to handle complex command hierarchies, user-friendly interfaces, and secure communication routes. The currently available research does not produce complete answers that successfully address these difficulties. Additional research is required to develop command systems that support complicated command structures encountered in military operations, assure secure and reliable communication, and enable intuitive engagement with the M2M system. These characteristics must be present in the command systems [20].

Because of the wide range of sizes and complexities of military operations, it is necessary for M2M systems to be able to adjust to a variety of settings and circumstances. In the current body of research, there is a dearth of robust methodologies that are capable of scaling effortlessly and adapting to a variety of military environments. Additional research is required to build flexible architectures, modular designs, and adaptive algorithms that can support a variety of operational requirements, terrain conditions, and equipment configurations. These advancements can be made possible by modularizing designs and designs that are built on top of each other [21].

Military applications call for communication channels that are both safe and reliable in order to protect the integrity of sensitive information and maintain its confidentiality.

However, the special security issues that are connected with M2M-based systems in military situations have not been adequately addressed in the research that has been done thus far. In order to protect M2M-based systems from unwanted access, data breaches, and cyberattacks, further research is required to build effective security protocols, encryption techniques, intrusion detection systems, and authentication processes.

The filling of these research voids and the overcoming of these problems will result in the creation of cutting-edge M2M-based object recognition, sound detection, and command systems that are developed expressly for military applications. These devices will enable enhanced situational awareness, quicker decision-making, and improved mission results, all of which will considerably boost the efficiency, accuracy, and reliability of military operations.

2.4 Military Defense System

A military defense system is a complete framework that is designed to safeguard a nation, its territories, assets, and population against external threats and possible aggressors. These can come from within or from without the nation. It includes many different aspects, such as personnel, equipment, technology, plans, and tactics, all of which are coordinated to protect the safety of the nation as a whole.

The soldiers that make up a military defensive system are the system's most important asset. The cornerstone of effective defense capabilities is comprised of soldiers, officers, pilots, and other specialized units, all of whom have received extensive training and have a strong commitment to their jobs. They put themselves through grueling training in order to hone their skills in areas such as warfare, intelligence collection, logistics, and strategic planning.

Innovative hardware and armament are essential to the operation of today's military defense systems. This includes things like armored vehicles, fighter jets, naval vessels, artillery systems, missiles, unmanned aerial vehicles (UAVs), communication equipment, and observation and reconnaissance systems. The military now possesses both offensive and defensive capabilities as a result of these technologies.

The military's ability to defend itself effectively requires highly functioning command and control systems. These systems offer real-time situational awareness, make it possible to coordinate across the many branches of the military, improve communication, and give assistance for decision-making processes. They make use of cutting-edge information technology, various instruments for conducting intelligence analysis, and private communication networks.

The collection of intelligence is largely relied upon by military defensive systems in order to evaluate potential threats and track the activities of adversaries. Intelligence organizations utilize a wide variety of techniques, such as human intelligence (HUMINT), signals intelligence (SIGINT), imagery intelligence (IMINT), and open-source intelligence (OSINT), in order to gather and evaluate information that is vital to the country's security [22].

In this day and age, protecting a country's network against cyberattacks is a crucial part of any military defense strategy. Protecting vital information networks, defending against cyberattacks, and making certain that communication systems can withstand disruptions are of the utmost importance. When it comes to protecting against online dangers, cyber defense systems incorporate cutting-edge technologies such as encryption algorithms, firewalls, and intrusion detection systems.

When it comes to protecting against ballistic missile dangers, missile defense systems are an absolutely essential component. These systems are designed to detect incoming missiles, track them, intercept them, and destroy them before they can reach their intended targets. Technologies for missile defense include interceptors based on the ground, anti-ballistic missile defense systems, defense systems based on the sea, and observation and tracking systems located in space.

When it comes to protecting the airspace from hostile aircraft and missiles, air defense systems are absolutely necessary. These systems are able to identify, track, and destroy approaching aerial threats because they make use of fighter jets, surface-to-air missiles, radar systems, early warning systems, and air defense artillery. They offer defense against attacks from the air and make it possible to have superiority in the air [23].

The protection of territorial seas, coasts, and maritime commerce routes are the primary focuses of marine defense systems. In order to monitor and secure sea routes, prevent piracy, put an end to smuggling activities, and provide defense against potential naval threats, the military makes use of naval vessels, submarines, coastal defense systems, and maritime patrol aircraft.

There is typically a role for military defense systems in the process of ensuring border security. This entails keeping an eye on and guarding national borders, controlling immigration, thwarting attempts to traffic illegal goods, and fending off transnational dangers. Efforts to secure the border are aided by elements such as border patrol forces, surveillance systems, and border control checkpoints.

The effectiveness of military defense systems frequently depends on the formation of strategic alliances with other countries. Mutual defense pacts, collaborative defense agreements, information sharing, combined military drills, and intelligence sharing all contribute to increased collective security and serve as a deterrent to potential aggressors. These agreements improve the capabilities of the armed forces and contribute to the maintenance of regional stability.

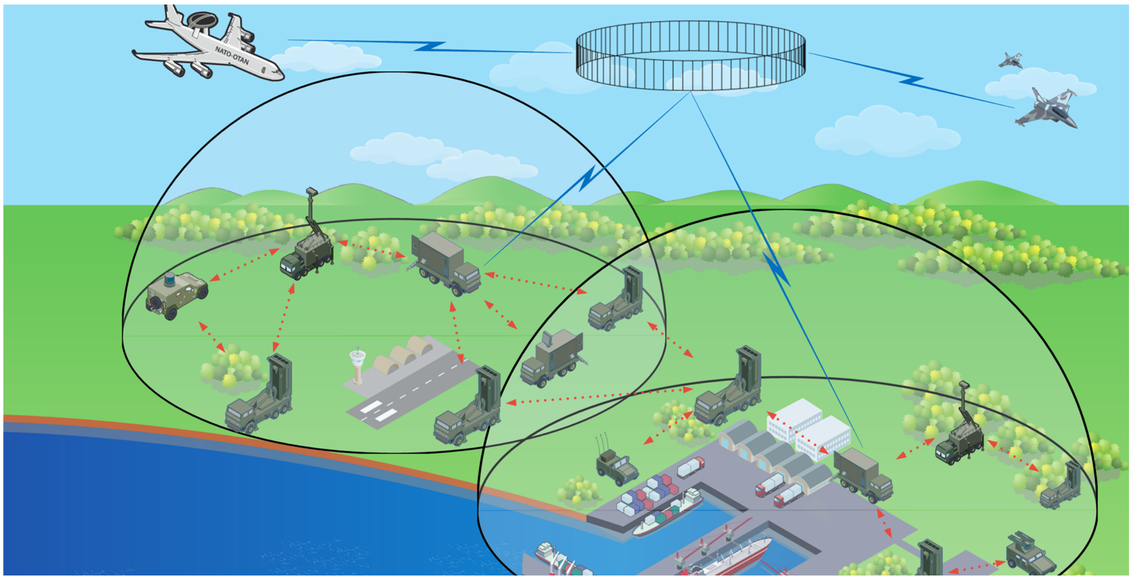

Fig. 2.1 Military Defense System [24]

In a nutshell, military defense systems are all-encompassing frameworks that protect a nation's security by including manpower, equipment, technology, plans, and tactics. The purpose of effectively integrating these components into military defense systems is to achieve the goals of deterring aggression, maintaining national sovereignty, and protecting citizens and assets from foreign threats.

2.5 Machine to Machine Communication in Military Defense System

The term "machine-to-machine" communication, or M2M for short, is used in the context of military defence to refer to the process of exchanging data and information between different autonomous or semi-autonomous systems without the involvement of humans. It enables equipment and platforms that are connected to one another to work together, share information, and coordinate activities, which in turn improves the efficacy and efficiency of military operations.

Communication between machines (M2M) makes it possible to integrate a wide variety of military equipment, including as sensors, vehicles, unmanned platforms, weapons systems, and command centres. These interconnected systems are able to communicate with one another and share data, commands, and status updates, so establishing a networked environment for the collaborative sharing of information in real time [25].

Communication between machines, also known as machine-to-machine or M2M, is especially helpful for autonomous or semi-autonomous systems, which are systems that run alone or with limited involvement from humans. Robotic systems and autonomous sensors are two examples of unmanned systems. Others include unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs). These systems are able to share situational awareness, coordinate activities, and exchange information, which enables more effective decision-making and the carrying out of missions.

M2M communication facilitates the construction of sensor networks, which allow many sensors to share data and collectively improve their situational awareness. These networks can be placed in a variety of different locations. Sensor networks can be utilised for a variety of purposes, including surveillance, reconnaissance, target acquisition, and early warning systems. This results in improved threat detection capabilities as well as comprehensive coverage [26].

The integration of command and control (C2) systems with a variety of military platforms and sensors can be simplified with the help of machine-to-machine (M2M) communication. It permits real-time information interchange, which in turn enables commanders to monitor and operate many assets concurrently, which in turn enhances situational awareness and facilitates rapid decision-making.

Communication between machines makes it possible to combine information obtained from a variety of sources, such as sensors, platforms, and intelligence systems. This enables a more thorough and accurate study of the operating environment, which in turn supports better-informed decision-making and the prompt reaction of new hazards.

Communication between machines makes it possible to run tasks in a distributed and decentralised manner, in which multiple units or platforms can work together but also independently. This capacity increases flexibility, adaptability, and resilience because it enables units to coordinate and alter their activities based on the shared situational awareness and the objectives of the operation [27].

Through the automation of certain activities and the offloading of decision-making to interconnected systems, machine-to-machine (M2M) communication helps minimise the cognitive strain that is placed on human operators. Because of this, operators are given the opportunity to concentrate on higher-level strategic and tactical decisions, while the M2M network takes care of regular chores and data processing.

The use of machine-to-machine (M2M) communication in military defence calls for the implementation of stringent security measures to safeguard the availability, integrity, and confidentiality of data. In order to stop unauthorised access, manipulation, and disruption of M2M communication, encryption, authentication procedures, and secure communication routes are put into place.

M2M communication systems are built with redundancy and resilience in mind to ensure ongoing functioning even in demanding or hostile circumstances. This is accomplished through the use of several communication channels. To ensure that connectivity and data transfer capabilities are maintained at all times, failover procedures, backup servers, and redundant communication links have been built.

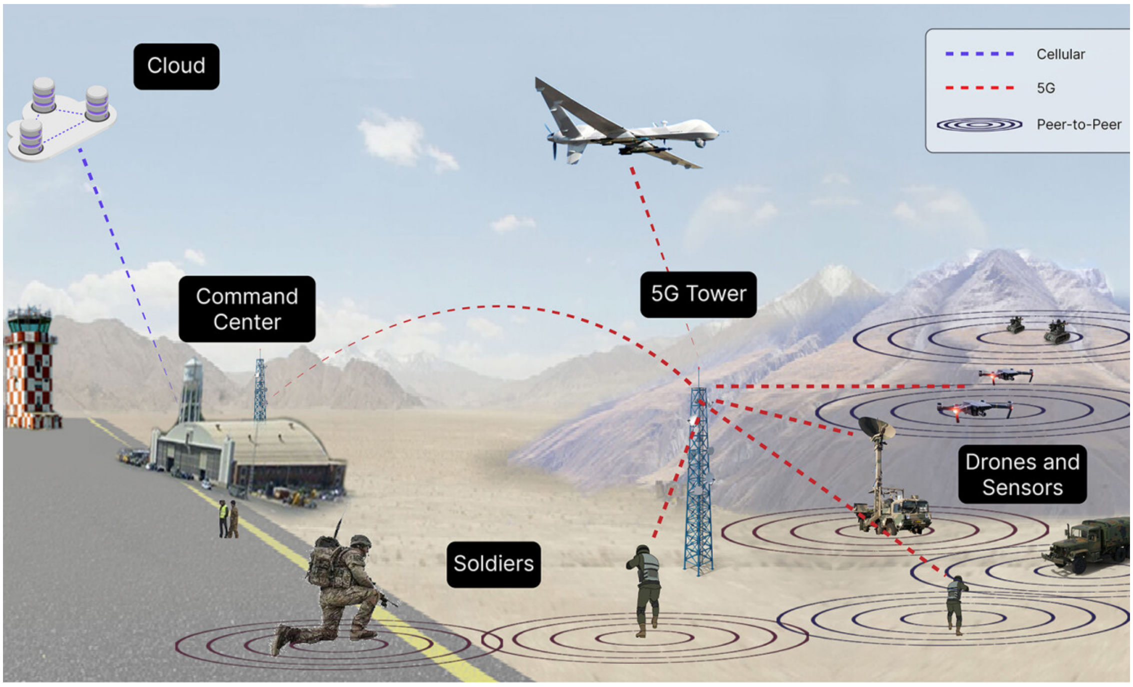

Fig. 2.2 Machine to Machine Communication in Military Defense System [28]

The advancement of artificial intelligence (AI), machine learning (ML), and edge computing technologies are driving the continued progress of research and development in the field of machine-to-machine (M2M) communication for military defence. The employment of artificial intelligence algorithms for autonomous decision-making, enhanced data analytics for predictive capabilities, and the integration of machine-to-machine (M2M) communication with emerging technologies like 5G networks and Internet of Things (IoT) devices could be among the potential developments in the near future [29].

In a nutshell, the use of machine-to-machine communication in military defence makes it possible for interconnected systems to work together, share information, and coordinate actions in an autonomous or semi-autonomous manner. M2M communication improves the efficacy, efficiency, and flexibility of military operations. This, in turn, contributes to the completion of missions successfully and the preservation of national security.

2.6 Object Detection System in Military Defense

A significant contribution that object detection systems provide to the improvement of situational awareness, threat detection, and target identification can be made in the context of military defense. These systems make use of cutting-edge technology in order to recognize and keep tabs on a wide variety of targets, such as vehicles, soldiers, weapons, and possible dangers.

Object detection systems used in military defense make use of a wide variety of sensor technologies to locate and follow the movement of objects. Radar systems, electro-optical/infrared (EO/IR) cameras, LiDAR (Light Detection and Ranging) systems, acoustic sensors, and sonar systems are all examples of the types of sensors that fall under this category. Every available sensor technology offers a number of benefits and can be utilized successfully in a variety of military contexts and settings [30].

The military defense sector makes extensive use of radar as a technology for the detection of objects. Radio waves are utilized in order to detect and track objects, which results in the provision of precise information regarding the distance, speed, and direction of the items being tracked. Radars used by the military might be ground-based, airborne, or naval systems. These radars can perform a variety of functions, including surveillance, target acquisition, and fire control.

EO/IR systems are able to detect and track things based on their thermal signatures as well as their visual appearance by utilizing optical and infrared sensors. These systems are efficient during both daytime and nighttime operations, delivering detailed imaging as well as thermal signatures that can be used to identify targets. It is normal practice to employ them for purposes of surveillance, reconnaissance, and target acquisition.

Laser technology is utilized in LiDAR systems in order to measure distances and generate comprehensive three-dimensional maps of the surrounding area. LiDAR systems can be integrated into ground-based or aerial platforms with the purpose of providing accurate capabilities for object detection, mapping, and terrain analysis in the context of military defense. LiDAR is especially helpful in locating items in surroundings that are particularly complicated or chaotic.

Acoustic sensors are used for both object detection and tracking in military operations that take place on the ground as well as those that take place underwater. These sensors analyze the sound waves and vibrations produced by an object or activity in order to determine what it is. Examples of such things include submarines, ships, automobiles, and footsteps. Applications such as maritime security, anti-submarine warfare, and perimeter defense can all benefit greatly from the information that acoustic sensors can provide.

Data fusion and processing methods are frequently utilized in object detection systems utilized by the military with the purpose of improving detection accuracy and decreasing the number of false alarms. Combining the data from several sensors and running it through processing algorithms helps improve object tracking, cuts down on clutter, and extracts information that is useful for danger assessment.

Automated target recognition, or ATR, algorithms can be incorporated into object detection systems in order to examine sensor data and classify objects according to specified patterns or features. Algorithms based on ATR can identify possible threats or targets of interest in a short amount of time, which enables military operations to make decisions and react more swiftly.

It is common practice to link object detection systems with command and control (C2) systems in order to give real-time situational awareness to military personnel and to facilitate the sharing of object information with them. Integration with C2 systems provides the rapid transmission of object detection data, which in turn improves coordinated reactions and makes decision-making processes easier [31].

Applications for object detection systems can be found in many different areas of military defense, such as border security, perimeter defense, surveillance, reconnaissance, target acquisition, missile defense, and counter-drone operations. During military operations, these systems contribute to the detection of threats, early warning, force protection, and successful completion of missions.

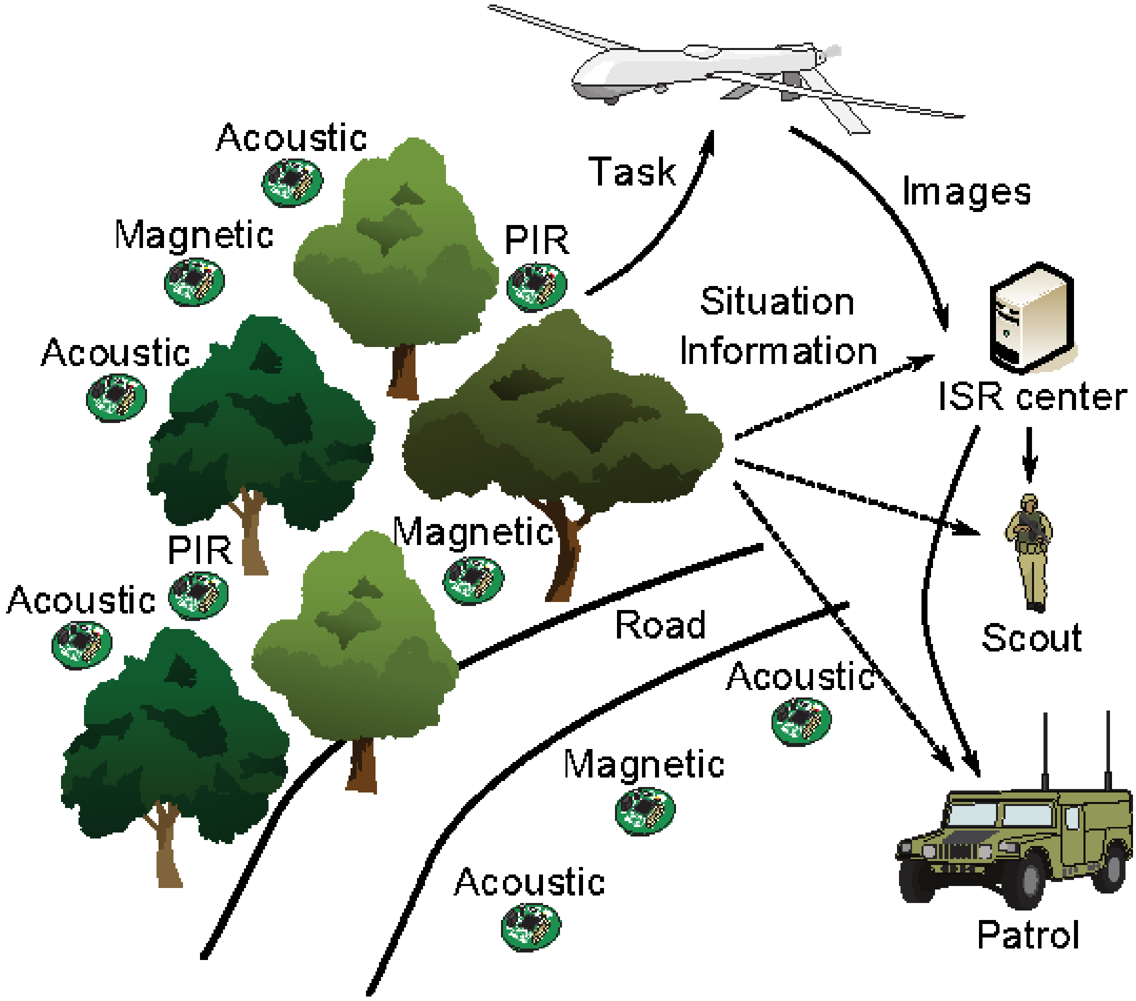

Fig. 2.3 Object Detection System in Military Defense [32]

The evolution of sensor technologies, artificial intelligence (AI), machine learning (ML), and computer vision are driving continuing research and development efforts in object detection systems for military security. These efforts are driving the industry forward. The employment of AI algorithms for object detection in real time, multi-sensor fusion for greater accuracy, and the integration of autonomous platforms for enhanced surveillance capabilities are all possible future developments.

When it comes to military defense, object detection systems are essential components that provide the ability for military personnel to detect, track, and identify items of interest or possible threats in a variety of operational contexts. These devices contribute greatly by enhancing users' awareness of the surrounding environment.

2.7 Sound Detection System in Military Defense

The detection and identification of acoustic signatures associated to potential threats, such as gunshots, explosions, and enemy communication, is an extremely important function that is performed by sound detection systems that are used in military defense. These devices make use of cutting-edge technology to record and analyze sound waves, thereby enhancing the military personnel's situational awareness and maybe saving their lives.

Sound detection systems are built on a foundation of acoustic sensors as their primary components. These sensors were developed to capture sound waves and turn them into electrical signals that can then be analyzed further. Microphones, hydrophones (which are used for operations underwater), and specialized directional sensors are examples of acoustic sensors that are utilized in military defense. These sensors are able to detect noises coming from particular angles or directions.

In order to evaluate collected acoustic signals and extract meaningful information from them, sound detection systems make use of highly complex signal processing algorithms. In signal processing, algorithms are used to filter out background noise, improve signal quality, and identify specific sound patterns that may indicate the existence of potential dangers or activities of interest.

In terms of military defense, one of the most important applications of sound detection systems is the detection of gunfire. These technologies have been developed to instantly identify and locate the source of gunfire, delivering real-time alerts to military troops in the process. The auditory characteristics associated with gunshots are analyzed using gunshot detection algorithms, which enables a quicker response and a better awareness of the surrounding environment.

The employment of sound detection systems allows for the detection and identification of explosion sounds, such as those created by improvised explosive devices (IEDs), landmines, or artillery rounds, amongst other potential sources. These systems are able to provide early warning by evaluating the distinct acoustic signatures of explosions, which helps in the process of threat assessment and response.

In military defense, sound detection systems also include underwater acoustic sensors for the purpose of detecting operations that take place underwater, such as the movement of submarines or the discharge of torpedoes. Hydrophones and specialized sonar systems are used to catch and analyze underwater acoustic waves. This provides maritime security and anti-submarine warfare operations with important information that may be utilized to improve their effectiveness.

Many times, algorithms for sound classification and identification are incorporated into sound detection systems so that different acoustic signatures can be distinguished from one another. The system is trained to distinguish certain noises of interest, such as vehicle engines, airplanes, or human voice, which enables rapid assessment of potential threats. Machine learning and pattern recognition techniques are applied.

Typically, sound detection systems are included into command and control (C2) systems, which enables the real-time dissemination of acoustic data to military personnel. Integration with C2 systems improves situational awareness, makes decision-making easier, and bolsters coordinated responses to sounds that are detected [33].

Sound detection systems also have the ability to provide information regarding the location of sound sources as well as their mobility. These systems are able to estimate the location of sound-emitting objects and monitor their progress by performing an analysis of the time delay that occurs between the arrival of sounds at various sensor locations or by utilizing specific array processing algorithms.

Fig. 2.4 Sound Detection System in Military Defense [34]

For the purposes of counter-surveillance and intelligence gathering, sound detecting systems are utilized in military defense operations. These systems contribute to the collecting of actionable intelligence and enable effective countermeasures by detecting and analyzing adversary communication or other acoustic signals. This can be done using a variety of acoustic signals.

Research and development efforts pertaining to sound detection systems for military defense are making steady progress. These developments are being driven by advancements in sensor technology, signal processing methods, and machine learning strategies. The incorporation of artificial intelligence (AI)-based algorithms for real-time sound recognition, greater sensor downsizing for deployable and mobile applications, and improved localization accuracy are all potential future developments that could be made.

In military defense, sound detection systems are essential components that improve situational awareness, threat identification, and response capabilities. These systems provide vital information to military troops by capturing and analyzing acoustic signals. This enables them to make informed decisions and effectively manage possible threats in a variety of operational circumstances.

2.8 Command System in Military Defense

A command system in military defence is an essential component that ensures efficient communication, coordination, and control of military troops in operational contexts. This is accomplished through the use of radios and other forms of electronic communication. It makes it easier for military personnel to communicate commands, information, and situational awareness to one another, which in turn enables more effective decision-making and the carrying out of tasks.

The military has a hierarchical framework for its command structures, with multiple levels of command ranging from the strategic to the tactical. This hierarchical organisation promotes efficient communication and decision-making across multiple echelons of command, which helps to ensure that all military units are working together cohesively and in collaboration with one another.

In order to ease the dissemination of information and commands, command systems are dependent on a communication infrastructure that is both robust and secure. This ensures that there are channels of communication that are both dependable and encrypted between command centres, headquarters, and the forces that are deployed. This includes secure networks, radio systems, satellite communications, and data connectivity.

Integration of data from a variety of sources, including sensors, intelligence reports, and surveillance systems, gives command systems the ability to provide real-time situational awareness to their users. Because of this, commanders are able to have a thorough picture of the battlefield, which includes the location of both friendly and enemy forces, as well as elements of the terrain and potential dangers.

The incorporation of decision support tools within command systems, including as data analytics, simulations, and visualisation technologies, provides commanders with the assistance they need to make educated judgements. The efficacy and efficiency of decision-making processes can be improved with the use of these tools, which assist in the analysis of complex information, the prediction of outcomes, and the evaluation of potential courses of action.

The creation and distribution of commands and messages across the entirety of the military organisation are both made possible by command systems. This includes communicating mission commands, tasking orders, intelligence reports, and coordination messages to all of the different units in order to ensure that they are all in sync with the overall mission objectives and operational plans.

The planning of missions is facilitated by command systems, which supply the necessary tools for operational planning, resource allocation, and mission analysis. They lend a hand in drafting operational plans, delegating responsibilities to subordinate units, and keeping tabs on how missions are being carried out, among other responsibilities. Because of this, commanders are able to successfully synchronise their forces and resources to accomplish the goals of their missions.

Command systems make it easier for individual military units to work together and coordinate their efforts by easing the sharing of information, the coordination of activities, and collaborative planning. They make it possible for commanders, staff officers, and units located in different geographical areas to work together in real time, which ensures coordinated and synchronised activities are carried out in a smooth manner.

Cybersecurity and information assurance are given high priority in command systems in order to secure critical military information from being accessed, manipulated, or disrupted by unauthorised parties. The data that is sent through the command system is protected by stringent security mechanisms, such as encryption, authentication protocols, and intrusion detection systems. These safeguards are in place to ensure that the data's integrity and confidentiality are maintained.

During joint operations, the goal of interoperability across various military units and partner nations is to be achieved by command systems. This will make it possible to communicate and work together more effectively. In order to guarantee compatibility and an efficient flow of information between the many different military systems, standardisation, protocols, and data formats are agreed upon and implemented.

In order to lessen the harm that can be caused by system failures or disruptions, command systems are built with redundancy and resilience in mind. Even in tough or hostile circumstances, backup communication links, redundant servers, and contingency plans are put into place to retain command and control capabilities.

Fig. 2.5 Command System in Military Defense [35]

In a nutshell, the infrastructure, tools, and capabilities that facilitate effective communication, coordination, and control of military troops are provided by the command systems that are part of military defence. These technologies improve the efficacy and efficiency of military operations by making it easier to remain aware of the surrounding environment, come to decisions, and carry out missions. This helps to ensure that missions are completed successfully and that national security is maintained.

CHAPTER 3
COMPONENTS

3.1 Introduction

The production of a valuable output within a project is challenging when the constituent elements lack superior quality.The process of selecting suitable components is a crucial yet demanding task. Firstly, let us commence our discussion on the construction materials that shall be employed for our undertaking. The objective of this section is to furnish a thorough exposition of hardware, encompassing its constituent elements, their respective functions, block diagrams, and additional pertinent details.

3.2 List of components

The subsequent enumeration comprises the constituents that are employed in this endeavor:

1. ESP32 Microcontroller
2. MPU6050 Accelerometer and Gyroscope Module
3. Ultrasonic Sensor
4. Sound Sensor
5. LCD 16×2 display
6. I2C Module
7. Keypad
8. Veroboard
9. Wire

3.2.1 ESP32 Microcontroller

The SP32, a low-cost System on Chip (SoC) Microcontroller, has been developed by Espressif Systems, the same entity that was responsible for the creation of the widely recognized ESP8266 System on Chip (SoC). The SP32 microcontroller was developed by Espressif Systems [36]. The ESP32 System-on-a-Chip is a subsequent iteration of the ESP8266 and is offered in single-core and dual-core versions of Tensilica's 32-bit Xtensa LX6 Microprocessor, which includes integrated Wi-Fi and Bluetooth capabilities. The software is accessible in configurations of both 32-bit and 64-bit. Additionally, this chip provides support for the ESP8266 System-on-a-Chip (SoC). The ESP32, akin to the ESP8266, confers an advantage in the form of integrated RF components. The aforementioned RF components are integrated and comprise a Power Amplifier, Low-Noise Receiving Amplifier, Antenna Switch, Filters, and RF Balun. The ESP8266 is endowed with this particular functionality, among other similar ones. As a result of this, the process of constructing hardware based on the ESP32 can be achieved with considerably less exertion, as illustrated in the **Fig. 3.1**. The reason for this is that the ESP32 requires only a restricted number of external components.

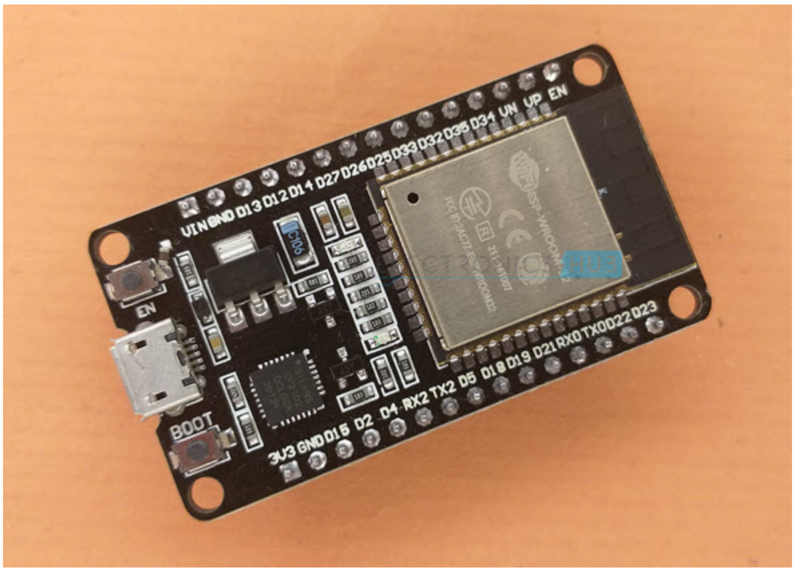

Fig. 3.1 ESP32 Microcontroller [37]

The SP32 is a low-cost microcontroller by Espressif Systems, maker of the ESP8266 System on Chip (SoC). The ESP32 System-on-a-Chip, a successor to the ESP8266, features Tensilica's 32-bit Xtensa LX6 Microprocessor with integrated Wi-Fi and Bluetooth. It comes in single-core and dual-core versions. It supports the ESP8266 SoC such the ESP8266, the ESP32 includes RF components such a Power Amplifier, Low-Noise Receive Amplifier, Antenna Switch, Filters, and RF Balun. ESP8266 has this feature. The ESP32 lends itself to simplified hardware design, as depicted in **Fig. 3.1**, due to its minimal external component requirements.

3.2.1.1 Layout of ESP32 Microcontroller

The board is outfitted with a total of thirty pins, with fifteen pins located on each side. There exists a disparity in the number of pins between various boards, with some possessing a total of 36 pins and others exhibiting a substantially lower count. Therefore, it is advisable to thoroughly examine the pins prior to establishing any connections or activating the board's power [38]. The ESP32 Board is comprised of the following components:

- ESP-WROOM-32 Module
- Two rows of IO Pins (with 15 pins on each side)
- CP2012 USB – UART Bridge IC
- micro–USB Connector (for power and programming)
- AMS1117 3.3V Regulator IC
- Enable Button (for Reset)
- Boot Button (for flashing)
- Power LED (Red)
- User LED (Blue – connected to GPIO2)
- Some passive components

3.2.1.2 Specification of ESP32 Microcontroller

The specifications of the ESP32 microcontroller are presented in **Table 3.1**.

Table 3.1 Specification of ESP32 Microcontroller [39]

No	Features
1	Single or Dual-Core 32-bit LX6 Microprocessor with clock frequency up to 240 MHz
2	520 KB of SRAM, 448 KB of ROM and 16 KB of RTC SRAM.
3	Supports 802.11 b/g/n Wi-Fi connectivity with speeds up to 150 Mbps.
4	Support for both Classic Bluetooth v4.2 and BLE specifications.
5	34 Programmable GPIOs.
6	Up to 18 channels of 12-bit SAR ADC and 2 channels of 8-bit DAC Serial Connectivity include 4 x SPI, 2 x I2C, 2 x I2S, 3 x UART.
7	Ethernet MAC for physical LAN Communication (requires external PHY).
8	1 Host controller for SD/SDIO/MMC and 1 Slave controller for SDIO/SPI
9	Motor PWM and up to 16-channels of LED PWM.
10	Secure Boot and Flash Encryption.
10	Cryptographic Hardware Acceleration for AES, Hash (SHA-2), RSA, ECC and RNG.

3.2.2 MPU6050 Accelerometer and Gyroscope Module

The MPU6050 is a commonly utilized integrated circuit for measuring acceleration and rotation rates, possessing a measurement accuracy of 16 bits and detecting six axes of motion, as illustrated in **Fig. 3.2**. Due to its affordability and high precision, this product has garnered significant attention within the DIY community. The MPU6050 is commonly integrated into various commercial products. In general, Inertial Measurement Units (IMUs) consist of accelerometers and gyroscopes [40].

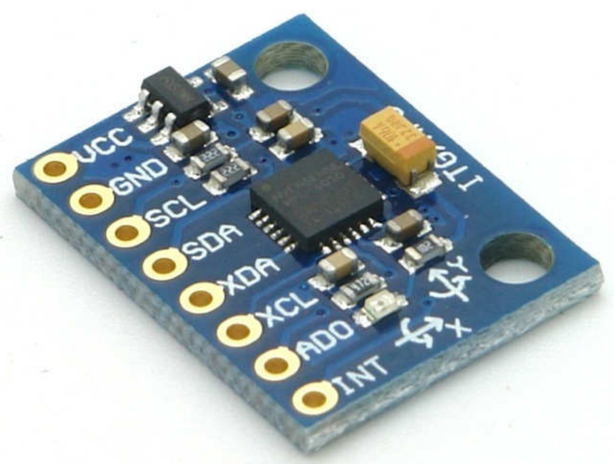

Fig. 3.2 MPU6050 Accelerometer and Gyroscope Module [41]

In a wide range of applications, including but not limited to mobile phones, tablets, satellites, spacecraft, drones, UAVs, and robots, IMU sensors are employed. Various applications such as motion tracking, orientation and location detection, and flight control rely on the utilization of these devices.

3.2.2.1 Working Principle of MPU6050

The MPU6050 Inertial Measurement Unit (IMU) amalgamates a triaxial accelerometer and a triaxial gyroscope onto a solitary microchip. The gyroscope is capable of measuring the rotational velocity and the rate of change of angular location over time along the X, Y, and Z axes. The measurement process employs microelectromechanical systems (MEMS) technology in conjunction with the Coriolis effect. For further elucidation on this topic, kindly refer to my dedicated lesson on the operational principles of MEMS sensors. Given that the gyroscope readings are denominated in degrees per second, determining the angular position necessitates solely the integration of the angular velocity [42].

In contrast, the MPU6050 accelerometer employs a similar approach to the one explicated in the preceding video for the ADXL345 accelerometer sensor to detect acceleration. In summary, the device has the capability to track gravitational acceleration across three axes, and through the application of fundamental trigonometric principles, we can ascertain the orientation of the sensor. Consequently, the fusion or integration of data obtained from the accelerometer and gyroscope can yield significantly accurate insights into the sensor's orientation. Due to its six outputs—three accelerometers and three gyroscopes—the MPU6050 IMU is called a six-axis motion tracking device or 6 DoF gadget. Because the device can move along six axes, it's called "six degrees of freedom."

3.2.2.2 Pin Configuration of MPU6050

The pin configuration of the MPU6050 is presented in **Table 3.2**.

Table 3.2 Pin Configuration of MPU6050 [41]

Pin No.	Pin Name	Description
1	Vcc	Provides power for the module, can be +3V to +5V. Typically +5V is used
2	Ground	Connected to Ground of system
3	Serial Clock (SCL)	Used for providing clock pulse for I2C Communication.
4	Serial Data (SDA)	Used for transferring Data through I2C Communication.
5	Auxiliary Serial Data (XDA)	Can be used to interface other I2C modules with MPU6050. It is optional.
6	Auxiliary Serial Clock (XCL)	Can be used to interface other I2C modules with MPU6050. It is optional.
7	AD0	If more than one MPU6050 is used a single MCU, then this pin can be used to vary the address.
8	Interrupt (INT)	Interrupt pin to indicate that data is available for MCU to read.

3.2.2.3 Features of MPU6050

- MEMS 3-aixs accelerometer and 3-axis gyroscope values combined
- Power Supply: 3-5V
- Communication : I2C protocol
- Built-in 16-bit ADC provides high accuracy
- Built-in DMP provides high computational power
- Can be used to interface with other IIC devices like magnetometer
- Configurable IIC Address
- In-built Temperature sensor

3.2.3 Ultrasonic Sensor

Ultrasonic sensors, a type of electronic device, have the capability to ascertain the distance to a target through the emission of ultrasonic sound waves and subsequent conversion of the received signals into electrical ones. The velocity of ultrasonic waves surpasses that of audible sound waves. The transmitter and receiver are regarded as the two fundamental components that are deemed essential. The acoustic signal is generated by the transmitter through the utilization of piezoelectric crystals. Subsequently, the signal propagates towards the intended target and subsequently reflects back towards the reception component [43].

3.2.3.1 Ultrasonic Sensor Pin Diagram

The schematic representation of the pin configuration for an ultrasonic sensor is depicted in **Fig. 3.3**.

Fig. 3.3 Ultrasonic Sensor [44]

The following chart depicts the pin-out of an ultrasonic sensor:

- **Vcc:** This pin has to be connected to a power supply +5V.
- **TRIG:** The Arduino board sends command signals using this pin. The little prong there is the sensor's input trigger
- **ECHO:** The transmission of signals to the Arduino board is facilitated through a specific pin, following which the Arduino undertakes the computation of distance by analysing the pulse duration. The pin in question serves as the outlet for the ECHO signal emitted by the sensor.
- **GND:** This pin has to be connected to the ground.

3.2.3.2 Working Principle of Ultrasonic Sensor

The ultrasonic sensor is comprised of two essential components, namely a transmitter and a receiver. The compactness of this configuration results in a propagation of sound waves that follows a linear trajectory between the origin and destination points without any deviation. The diminution of the distance between the transmitter and receiver results in a decrease in computational errors. The amalgamation of the transmitter and receiver functions within a solitary package has led to the common reference of these devices as ultrasonic transceivers [45].

The sensor in question exhibits characteristics akin to a burst signal, wherein it is disseminated for a finite duration. Following a communication, a period of silence ensues, commonly referred to as the reaction time, during which no verbal utterances are made. The temporal gap in the response implies a state of patient anticipation for the arrival of the reflected waves. It is imperative to evaluate the beam angle and spread as the shape of the acoustic waves emitted from the transmitter bears resemblance to that of laser light. The detection area exhibits an omnidirectional expansion as the acoustic waves propagate away from the source. The specification of coverage in terms of beam angle and beamwidth is necessitated by the non-standard detection area, as opposed to the conventional detection area.

For optimal outcomes, it is recommended to observe the beam angle pattern of the sensor, which may include the entire beam angle or the beam angle of variation that corresponds to the straight line formed by the transducer. Typically, a narrower beam angle results in an increased detection range, while a wider beam angle leads to a decreased detection range. It is possible that there could be an impediment to the transmission of either visual or auditory stimuli. When an obstacle is encountered, the acoustic wave undergoes deflection. The term utilised to describe a reflected signal of this nature is commonly referred to as a "echo." The entity that obtains the reflected signal is referred to as the receiver.

Upon undergoing either amplification or attenuation, the incoming signal is transformed into a digital representation. The determination of the distance between the ultrasonic system and the obstruction can be achieved by measuring the time interval between the transmission and reception of sound waves.

3.2.3.3 Ultrasonic Sensor Specifications

Facilitating comprehension of precise estimations of distance measurements can be achieved through access to the specifications of an ultrasonic sensor, as depicted in **Table 3.3**.

Table 3.3 Specification of Ultrasonic Sensor [46]

No	Features
1	The sensing range lies between 40 cm to 300 cm.
2	The response time is between 50 milliseconds to 200 milliseconds.
3	The Beam angle is around 5^0.
4	It operates within the voltage range of 20 VDC to 30 VDC.
5	Preciseness is ±5%.
6	The frequency of the ultrasound wave is 120 kHz.
7	Resolution is 1mm.
8	The voltage of sensor output is between 0 VDC – 10 VDC.
9	The ultrasonic sensor weight nearly 150 grams.
10	Ambient temperature is -25^0C to $+70^0$C.
11	The target dimensions to measure maximum distance is 5 cm × 5 cm.

3.2.4 Sound Sensor

The sound sensor module is tasked with the responsibility of monitoring and detecting diverse sound signals such as speech, claps, snaps, knocks, among others. It is occasionally denoted as a sound detector or an acoustic sensor in academic literature. Deployed across diverse domains such as security systems, monitoring systems, radios, telephones, mobile phones, computers, home automation systems, consumer electronic products, and analogous applications. The figure depicted in **Fig. 3.4** illustrates a sonar sensor.

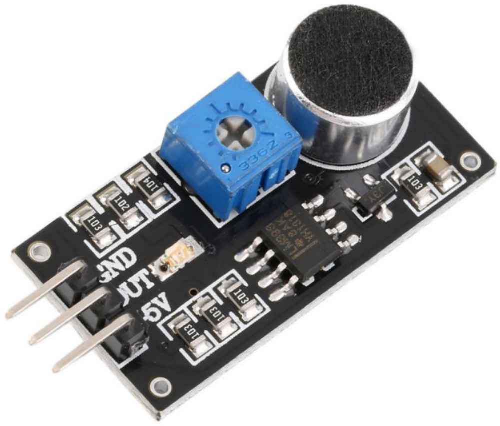

Fig. 3.4 Sound Sensor [47]

The device is outfitted with a power amplifier, a microphone, and an output actuator. The microphone serves as an input sensor that captures the sound signal and subsequently transforms it into an electrical signal. Subsequently, the signal undergoes amplification via the power amplifier, and the amplitude of the signal is gauged through employment of the peak detector. The amplified electrical signal is transformed into an auditory signal by the output actuator, which operates in a manner analogous to that of a loudspeaker.
The frequency range of the sound sensors is between 3,000 and 6,000 hertz (kHz), and their operational voltage is in the range of 3.3 to 6 volts of direct current. The auditory system is capable of perceiving sound waves within this particular range. This sensor is characterised by its compact size and provides a high level of cost-effectiveness [48].

3.2.4.1 Pin Diagram of Sound Sensor

Presented below is an illustration of the pin configuration for the sound sensor module:

- **Pin 1 (VCC):** This pin is used to give a positive power supply of 3.3V to 6V.
- **Pin2 (GND):** This pin is used for common ground connection.
- **Pin3 (Analogue output A0):** The pin mentioned above fulfills the function of obtaining the analog output signal that originates from the module. In the course of interfacing, the connection is established with the analog pin of the microcontroller or Arduino.
- **Pin4 (Digital output D0):** The aforementioned pin serves the purpose of acquiring the digital output signal from the module. Upon detection of the signal, the sensor

will trigger a response whereby the D0 output will be either in a high state or a low state.

3.2.4.2 Sound Sensor Working Principle

The sound sensor is equipped with a condenser microphone, which serves as its internal audio receptor. This particular type of microphone comprises of a pair of electrically charged plates, wherein one of the plates is commonly known as the diaphragm. These plates exhibit characteristics that resemble those of a capacitor. When sound signals, such as claps, snaps, knocking, or alarms, propagate through the air and make contact with the diaphragm of a microphone, the vibration of the diaphragm causes a shift in the distance between the two charged plates. This phenomenon takes place when acoustic or audio signals propagate through the medium of air [49].

Consequently, the alteration in the capacitance between the plates gives rise to the generation of the electrical signal output. The magnitude of the output signal is in direct proportion to the intensity of the input acoustic signal that was captured by the microphone. Subsequently, the signal emanated by the amplifier undergoes amplification and digitization to enable the quantification of the magnitude of the incoming acoustic signal.

3.2.4.3 Specifications of Sound Sensor

The specifications for the sound sensor module are presented in **Table 3.4**.

Table 3.4 Specification of Sound Sensor [47]

No	Features
1	Wide operating voltage of 3.3V to 5V DC.
2	Operating current of 4mA to 5mA.
3	The voltage gain of 26dB.
4	The high sensitivity of 1KHz.
5	Microphone's dB level of 52 to 48dB.
6	The impedance of the microphone is 2.2-kilo ohms.
7	The frequency of the microphone is 16KHz to 20KHz.
8	The signal-to-noise ratio is 54dB.
9	LM393N comparator with threshold present is used.
10	The induction distance is 0.5 meters.

3.2.5 LCD 16×2 display

The electronic display module is a ubiquitous component found in a diverse range of applications. The aforementioned applications encompass a diverse array of circuits and devices, such as but not limited to, cellular phones, electronic calculators, personal computers, and television receivers. Furthermore, these applications encompass a diverse array of other commodities [50]. The installation of these displays is expected to yield the greatest advantages for light-emitting diodes featuring multiple segments and displays that incorporate seven segments. The module in question offers a notable advantage in that it does not impose any limitations on the display of custom characters, unique animations, and similar features. Additional benefits of this technology include its cost-effectiveness, programmability, incorporation of animations, and absence of any discernible limitations. The LCD depicted in **Fig. 3.5** is an acronym for "liquid crystal display."

Fig. 3.5 16×2 LCD Display [51]

3.2.5.1 LCD 16×2 Pin Diagram

The specifications of a 16x2 liquid crystal display (LCD) are presented below:

- **Pin1 (Ground/Source Pin):** The GND pin present on the display serves the purpose of establishing a connection between the display and either the GND terminal of the microcontroller unit or the power supply.

- **Pin2 (V_{cc}/Source Pin):** The supply pin designated for the display's voltage serves the purpose of connecting to the power source's supply pin.
- **Pin3 (V_0/V_{EE}/Control Pin):** The aforementioned pin serves the purpose of facilitating the connection of a modifiable POT that has the capability to furnish a voltage range of 0 to 5V. Its primary function is to regulate the disparity between the two displays.
- **Pin4 (Register Select/Control Pin):** The aforementioned pin serves the purpose of establishing a connection between a pin of the microcontroller unit and acquiring a binary value of either 0 or 1. The binary value of 0 signifies the data mode while the binary value of 1 signifies the command mode. The device has the capability to alternate between the command register and the data register.
- **Pin5 (Read/Write/Control Pin):** It's possible to toggle between reading and writing on the display by connecting this pin to a 0 or 1 output pin on the microcontroller device. 0 is shorthand for "write," while 1 is shorthand for "read."
- **Pin 6 (Enable/Control Pin):** In order to execute the Read/Write process, it is necessary to set the logic of the pin that is continuously connected to the microcontroller unit to high.
- **Pins 7-14 (Data Pins):** The aforementioned pins are utilized for the purpose of transmitting information from the computing device to the display monitor. In order to establish a connection between said pins, two-wire modes, such as the 4-wire and 8-wire modes, are employed. The 4-wire configuration entails the connection of solely four pins, specifically 0 through 3, to the microcontroller unit. When operating in the 8-wire mode, all eight pins, ranging from 0 to 7, establish a connection with the microcontroller unit. When operating in 4-wire mode, the microcontroller is restricted to reading numerical values within the range of 0 to 3 [52].
- **Pin15 (+ve pin of the LED):** This pin is linked to the +5V supply.
- **Pin 16 (-ve pin of the LED):** This pin is linked to the GND terminal.

The pin configuration for a 16x2 LCD is depicted in **Fig. 3.6**.

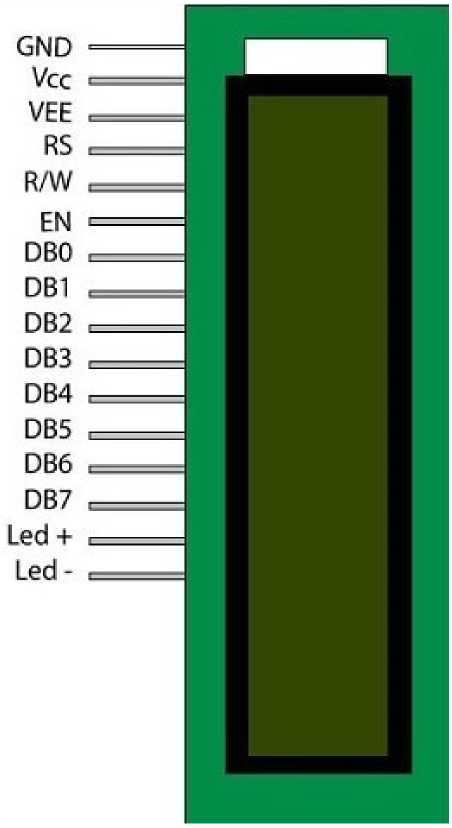

Fig. 3.6 LCD 16x2 Pin Diagram [51]

3.2.5.2 Features of LCD 16x2

The key features of the liquid crystal display (LCD) under consideration are delineated in **Table 3.5**.

Table 3.5 Features of LCD 16x2 [53]

No	Features
1	This LCD has a voltage range of 4.7V-5.3V for its operational voltage.
2	It consists of two rows, with each row having the capacity to create 16 characters.
3	When there is no backlight, the amount of electricity drawn is 1 mA.
4	Every character may be constructed using a box that is 5 by 8 pixels.
5	LCDs that display both alphabets and numbers are alphanumeric.
6	Is the display capable of operating in two modes, such as 4-bit and 8-bit.
7	These are available in both blue and green backlight colors.
8	It shows a few characters that were produced.

3.2.6 I2C Module

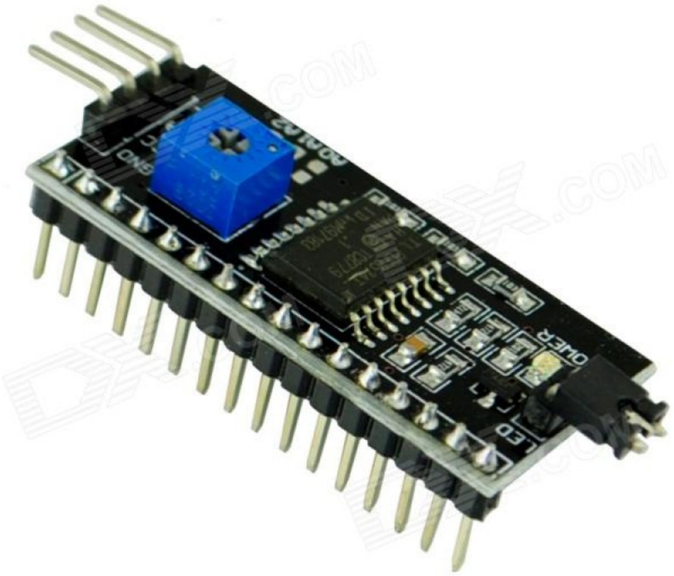

Fig. 3.7 I2C Module [54]

The limited number of available pins may pose a challenge in regulating an LCD display through a microcontroller or central processing unit. The operational process is streamlined through the utilization of serial-to-parallel converters, which possess the capability to function with only a pair of pins. The I2C serial interface adaptor module, which is based on the PCF8574, serves as a suitable illustration of this category of device, as depicted in **Fig. 3.7**. The serial interface adapter features a pair of signal output pins, namely SDA and SCL, that facilitate communication with a microcontroller or CPU. The I2C Module utilizes the PCF8574 I2C chip to facilitate the conversion of serial I2C data into parallel LCD data, which is then displayed on a 16x2 LCD. The default I2C addresses for these modules are either 0x27 or 0x3F, contingent upon the input provided. The identification of the module version can be determined by examining the black I2C adapter board located at the base of the device. The pre-assigned location for three distinct sets of pads denoted as A0, A1, and A2 is 0x3F. A machine lacking any input/output devices will utilize the hexadecimal address 0x27. A contrast adjustment dial is located on the posterior aspect of the screen, situated immediately inferior to the region where the thumb is positioned. Calibration is a necessary step to ensure legibility of text on a screen [55].

3.2.6.1 Features of I2C Module

Presented below is an enumeration of the functionalities of the I2C Module. The most important attribute of this module is illustrated in **Table 3.6**.

Table 3.6 Features of I2C Module [56]

No	Features
1	Operating Voltage: 5 volts.
2	The brightness of the lighting and the contrast may both be adjusted using a potentiometer.
3	Management of an LCD display using PCF8574's serial I2C interface.
4	Includes two IIC ports, each of which may connect to the device using the Dupont Line that is supplied or a separate IIC dedicated line.
5	Compatibility with LCDs measuring 16 by 2.
6	One more fantastic IIC/I2C/TWI/SPI serial interface.
7	With the help of this I2C interface module, it will be possible to show information with a minimal amount of wires.

3.2.7 Keypad

In most cases, input values for projects are obtained through actions such as key presses, button clicks, or switch toggles. In order to establish a connection between a key, button, or switch and a microcontroller, it is necessary to allocate one GPIO pin from the microcontroller. However, in the event that we intend to establish a connection between a multitude of keys such as 9, 12, or 16, a significant number of GPIO pins from a microcontroller will be necessary, resulting in the forfeiture of numerous GPIO pins [57].

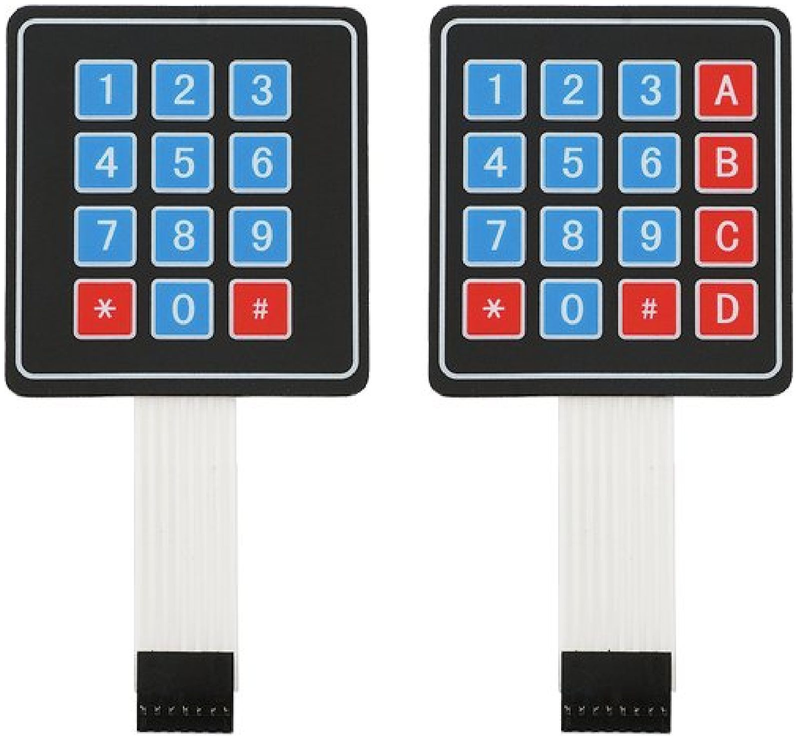

Fig. 3.8 Keypad [58]

The 4x4 matrix keypad is an input device, as depicted in **Fig. 3.8**. Its principal purpose in a given project is to furnish input values. The device comprises a set of sixteen keys, thereby signifying its capacity to accommodate sixteen distinct input values. Perhaps the most intriguing aspect is the utilization of only 8 GPIO pins on a microcontroller.

The keypad modules are composed of a membrane material that possesses characteristics of being thin and flexible. The 4 by 4 grid keypad module comprises 16 keys arranged in a matrix of rows and columns. A conductive pathway interconnects all of the aforementioned switches, enabling them to establish communication with one another. Typically, there is no interconnection between rows and columns. Depressing a key on a keyboard results in the contact between a specific row and column.

3.2.8 Veroboard

To effectively construct the necessary circuit utilizing veroboard, as depicted in **Fig. 3.9**, it is imperative to position the components in the correct orientation and connect them to the conductors in a manner consistent with other types of stripboards. This guarantees the successful construction of the circuit. This ensures that the circuit will function precisely according to its intended design. The complexity of the circuit can be heightened through the inclusion of gaps in the tracks, typically located in proximity to perforations. This will lead to a more intricate arrangement. The presence of gaps within the strips results in the creation of numerous discrete electrical nodes, thereby facilitating the augmentation of complexity [59].

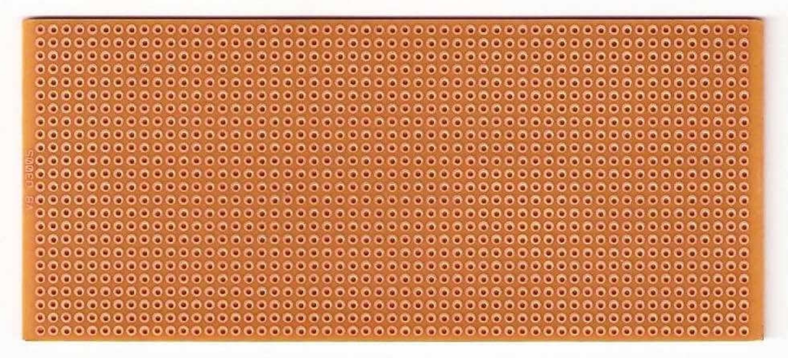

Fig. 3.9 Veroboard [60]

3.2.9 Wires

A jump wire is an electrical conductor, or a set of conductors within a cable, featuring a connector or pin at each terminus (or occasionally lacking one, being "tinned"). Its primary function is to establish interconnections between the constituents of a breadboard or other experimental or testing circuit, either internally or with additional equipment or components, without the need for soldering. This task can be accomplished either utilizing the breadboard in isolation or through the utilization of supplementary equipment or components. A jumper, alternatively referred to as a jumper wire or a DuPont wire, is a common component in electronic circuits. Alternative designations for jump wires encompass the following [61].

Fig. 3.10 Wires [62]

The process of connecting individual jump wires involves the insertion of "end connectors" into designated slots on a breadboard, header connector of a circuit board, or a piece of testing equipment. This facilitates the interconnection of the jump wires. The figure depicted as **Fig. 3.10** displays several instances of jump wires.

3.2.9.1 Types of Wires

There exist numerous discrete variations of jumper wires that are commercially available for procurement. While certain cables lack the same type of electrical connection on both ends, others possess this feature and utilize it to establish a connection [63]. The subsequent instances are illustrative of prevalent associations.

- **Solid tips:** These constituents are intended for employment in conjunction with a female header on a breadboard or analogous apparatus. Breadboards facilitate a higher density of component and jump wire mounting without the risk of short circuits, owing to the design of their elements and the ease of insertion. Jump wires of different sizes and colors are utilized to denote various types of operational signals.
- **Crocodile clips:** These devices are utilized for the swift and effortless attachment of sensors, buttons, and other prototype items to components or equipment through a diverse range of connectors, cables, screw terminals, and similar means.
- **Banana connections:** These are commonplace on DC and low-frequency AC signal testing equipment.
- **Registered Jack (RJ):** Phones use (RJ11) versions of this jack, while computers utilize (RJ45) versions for networking.
- **RCA Connections:** Shielded cables are frequently utilized for composite audio and video transmissions with low frequencies.
- **RF Connections:** These tools are utilized for the objective of evaluating equipment, establishing connections between circuits, and linking antennas.
- **RF Jumper Cables:** Corrugated wires, which exhibit reduced dimensions and enhanced flexibility, are employed for interconnecting antennas and other network nodes. Jumpers are utilized in these regions to establish a connection between the antennae of radio equipment and the base stations. Typically, a 1/2-inch-diameter jumper wire is considered to be the most adaptable option.

CHAPTER 4
DESIGN METHODOLOGY

4.1 Introduction

The segment in question represents the most pivotal element of any project report. As a constituent of the design methodology of the project, the forthcoming will encompass the exhibition of a block diagram, a flow chart, and a circuit diagram, accompanied by concise explications of the roles of each.

4.2 Block Diagram

To enhance comprehension of this undertaking, a block diagram was devised. The ESP32 microcontroller has been utilized by our team.

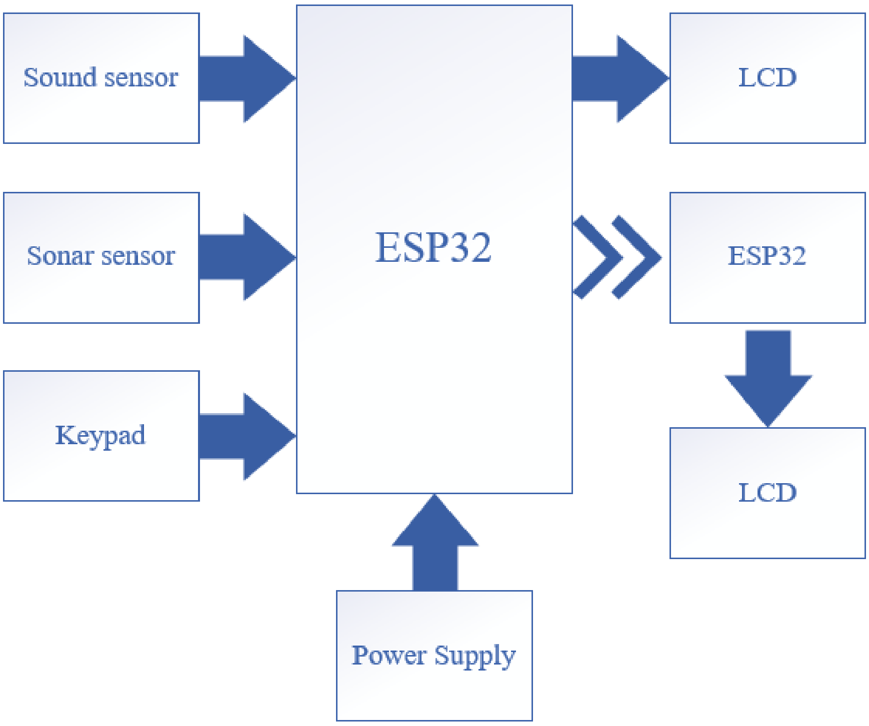

Fig. 4.1 Block Diagram of the Project

The diagram under consideration is presented in **Fig. 4.1**. The system comprises two ESP32 microcontrollers. The operational framework is governed by a pair of micro-controllers, one of which functions as the commanding unit while the other serves as the subordinate unit. The ESP32 microcontroller, under the commander's ownership, is linked to various components including an MPU 6050 module for soldier movement control, a sound sensor and an ultrasonic sensor for detection of loud sounds and obstructions, respectively, and a keypad for the commander's issuance of orders to the soldier. The ESP32 microcontroller, which is under the purview of the commander, serves as the central hub connecting all of these components. The ESP32 microcontroller possessed by the commander is linked to each of these distinct components in a certain manner.

The ESP32 microcontroller, which is constantly carried by the soldier, is linked to an LCD display. The display serves as a platform for presenting the information conveyed by the commander to the soldier. The unidirectional machine-to-machine communication between the commander and the soldier has a variable range of 500 to 700 meters in both directions.

The commander possesses five distinct controls that enable them to maneuver the unit in any of the following directions: forward, backward, left, right, or hold on command. It is reasonable to assume that the soldier has been apprised of the instructions, as they were transmitted through the appropriate communication channel. Upon detection of a high decibel sound or obstacle by the sound or ultrasonic sensor respectively, the soldier shall receive prompt notification. This admonition shall not be postponed.

Through the utilization of the keypad, the commander is capable of issuing diverse orders to the soldier, and each of these directives will be displayed on the LCD screen of both the commander's and the soldier's devices. This enables the commander to establish effective communication with both factions. The commander's helmet will house a microcontroller that will serve as the primary means of issuing instructions, while the soldier's primary responsibility will be to execute said commands.

4.3 Flowchart

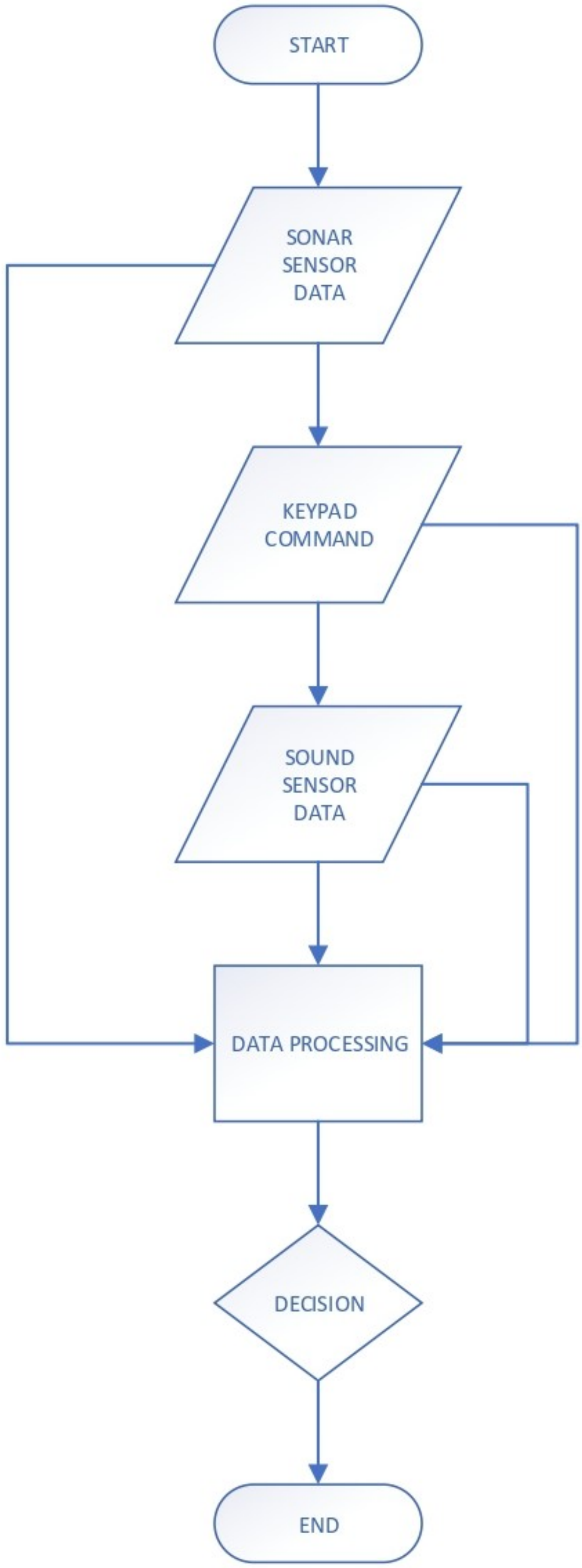

Fig. 4.2 Flowchart of the Project

The flowchart pertaining to the project has been depicted in **Fig. 4.2**. The operational features of the flow chart are segmented in the subsequent manner:

- Initially, the algorithm of the program will be started.
- Subsequently, the ultrasonic sensor acquires a measurement of the object and transmits the data to the processing unit.
- In addition, the commander has the ability to transmit instructions for obtaining data from the ultrasonic sensor through the utilization of keypad commands.
- The auditory sensor will identify any unidentified auditory stimuli and transmit the data to the processing unit.
- The entirety of the data will be transmitted to the ESP32 microcontroller assigned to the soldier for the purpose of making a determination.
- The soldier will be presented with all the aforementioned information through the utilization of a 16x2 LCD display.

4.4 Circuit Diagram

4.4.1 Commander

During the project's execution, the commander circuit diagram depicted in **Fig. 4.3** was constructed utilizing the Proteus software.

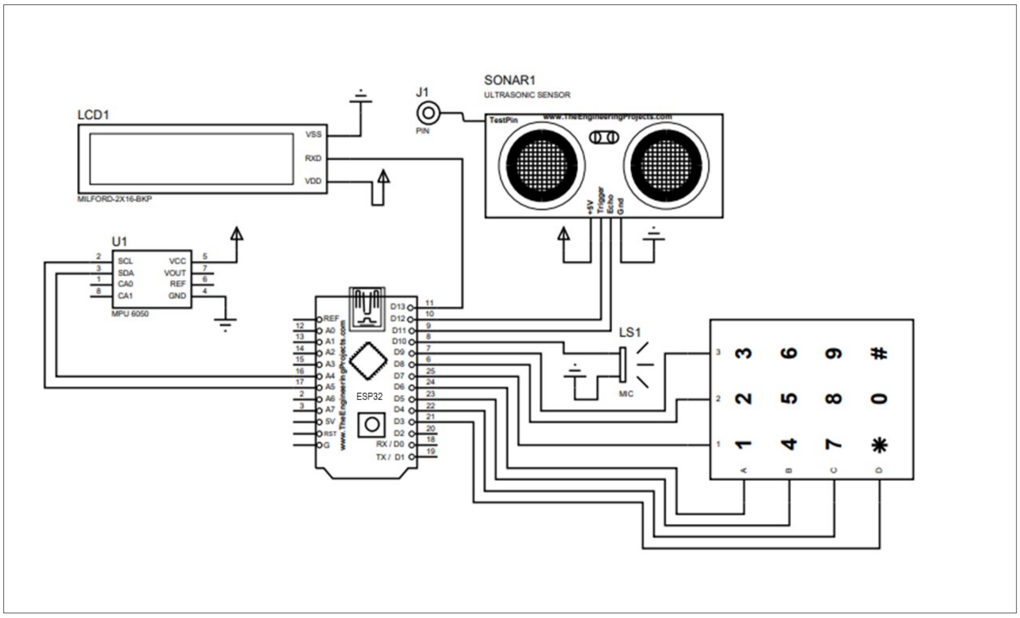

Fig. 4.3 Commander Circuit Diagram of the Project

4.4.2 Soldier

The soldier circuit diagram depicted in **Fig. 4.4** was constructed utilizing the Proteus software.

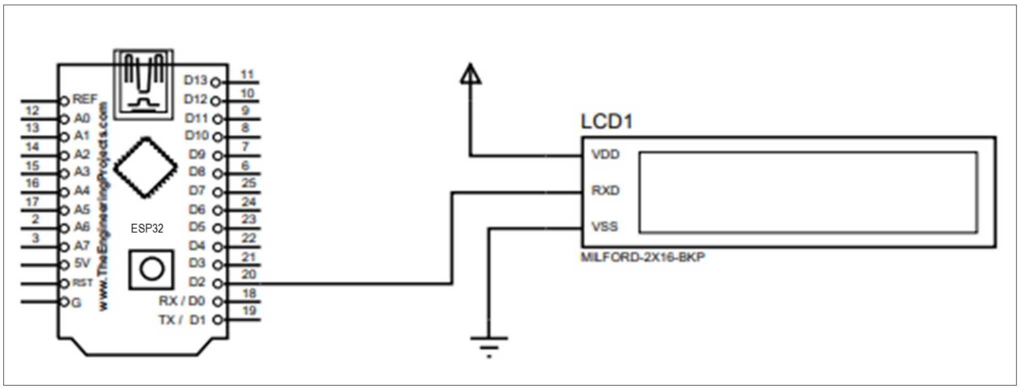

Fig. 4.4 Solider Circuit Diagram of the Project

4.5 Pin Connection of the Project

To facilitate programming of an ESP32 microcontroller, the requisite connections are established between the power supply, ground, and programming pins of the controller. The SDA and SCL pins of the ESP32 microcontroller are connected to the corresponding pins of the MPU6050 module in the commander circuit. One of the general-purpose input/output (GPIO) pins of the ESP32 microcontroller is connected to the output pin of the sound sensor. The ultrasonic sensor's trigger pin and echo pin have been linked to the GPIO pins of the ESP32 microcontroller. The output pins of the keypad are connected to the general-purpose input/output (GPIO) pins of the ESP32 microcontroller.

The ESP32 microcontroller's power supply, GND, and programming pins have been connected to the soldier circuit to facilitate controller programming. The GPIO pins of the ESP32 microcontroller are connected to both the display data pins and control pins of the LCD display, serving as a general-purpose input/output interface.

CHAPTER 5
IMPLEMENTATION AND RESULTS

5.1 Introduction

The goal of this initiative is to gather recommendations on where to place sensors, computer systems, and other military hardware. This will involve interaction with military experts to ensure the system is tailored to the specific needs of the military. The testing and evaluation step involves putting the M2M-based system through its paces in a mock military environment to gauge its efficacy, reliability, and accuracy.

5.2 Implementation

A solid board is utilized as a means of assembling all of the components and moving parts of the system. The ESP32 microcontroller is equipped with various components such as the MPU6050 module, ultrasonic sensor, sound sensor, LCD display, and keypad. Connectors are utilized for the purpose of linking individual hardware components to the ESP32. Furthermore, the kit comprises both female and male pin headers intended for the LCD display, alongside a 16x2 LCD display and a power switch.

5.3 Overview

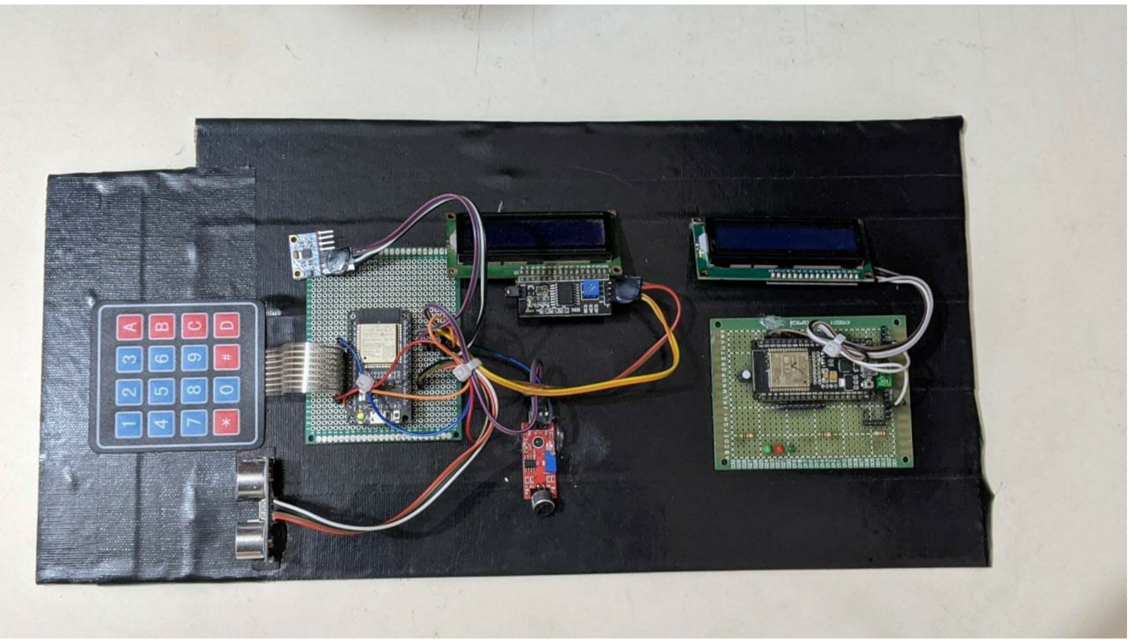

Fig. 5.1 Total Overview of the System

The schematic denoted as **Fig. 5.1** provides a comprehensive depiction of the system. The project was comprehensively mapped out and a circuit diagram was generated using

Proteus software to visually represent the interconnections among the various hardware components. The present study employed a veroboard, an ultrasonic sensor, a sound sensor, an LCD display, an MCU6050 module, and multiple cables to interconnect the diverse components.

5.4 Performance of the System

Initially, we will establish a programming interface to link a personal computer with an ESP32 device to facilitate the downloading of software. Subsequently, the program shall be initiated through the provision of requisite energy. The ESP32 Arduino, along with its accompanying components, will be controlled by commander, while the display will function in a comparable capacity. The Commander will use MPU6050 accelerometer and gyroscope module to execute commands for forward movement, reverse movement, left or right turning, as well as maintaining a stationary position. The solider will receive the command imminently. The device is equipped with a sound sensor and ultrasonic sensor that serve the purpose of detecting noises and obstacles, respectively. Upon detection, microcontroller will send message to commander as well as to soldier to alert them. The commander will issue orders to the troops via a 4×4 keypad. By activating a control pad, the commander is able to promptly communicate orders that are promptly conveyed to both the commander and the troops. By tapping the appropriate keys, the commander can issue orders such as "Connect to H.Q.," "Divide into two groups," "Fire," etc. The M2M communication system will relay these orders to the soldier. The 16x2 LCD display will be utilized to provide the commander and soldier with the aforementioned information.

5.5 Demonstration and Result of the Project

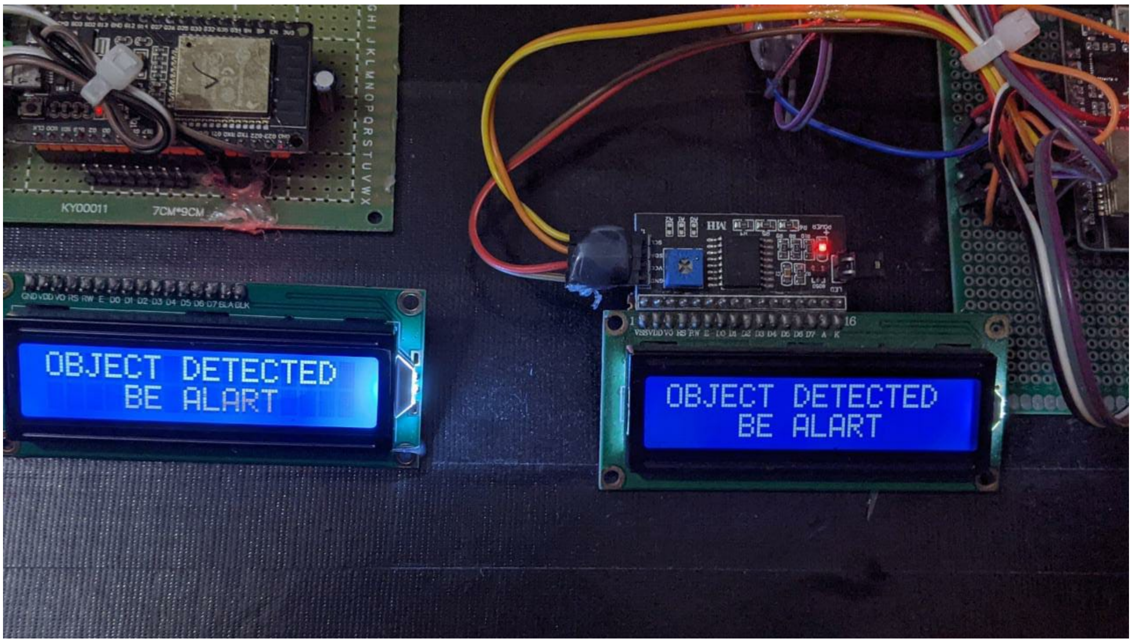

Fig. 5.2 Unknown object detected

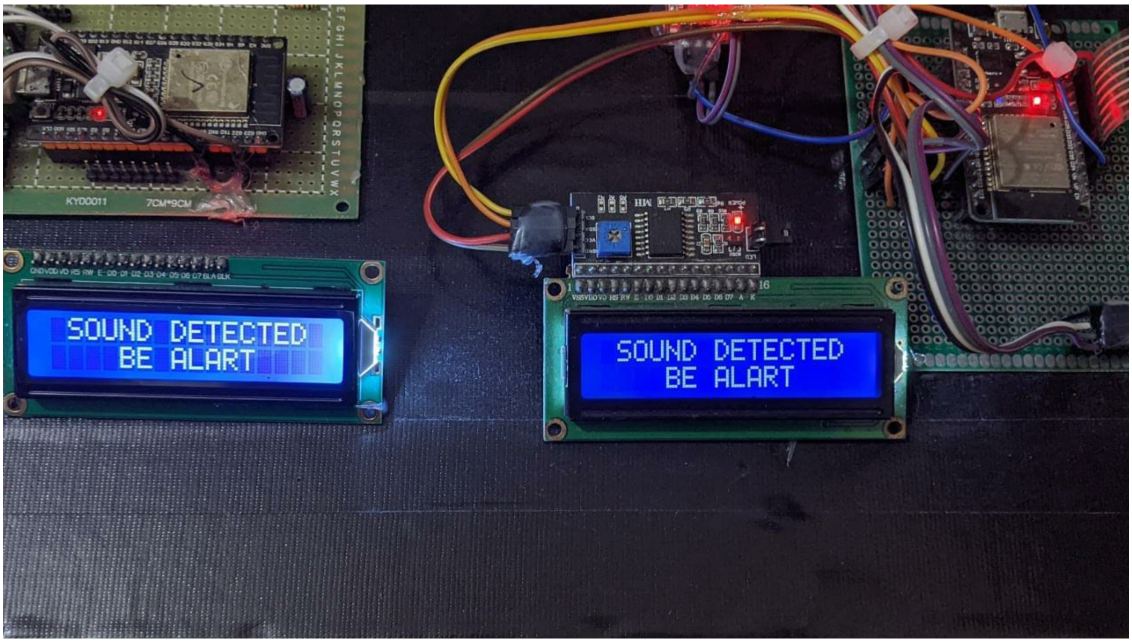

Fig. 5.3 Anonymous sound detected

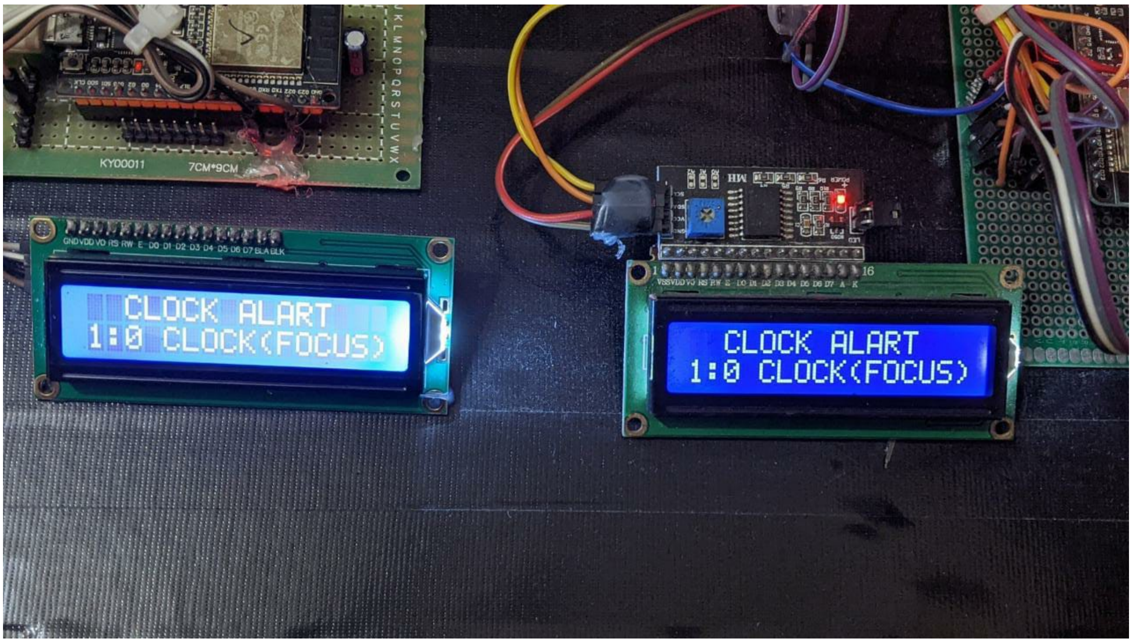

Fig. 5.4 A specific location alert (Clock alert)

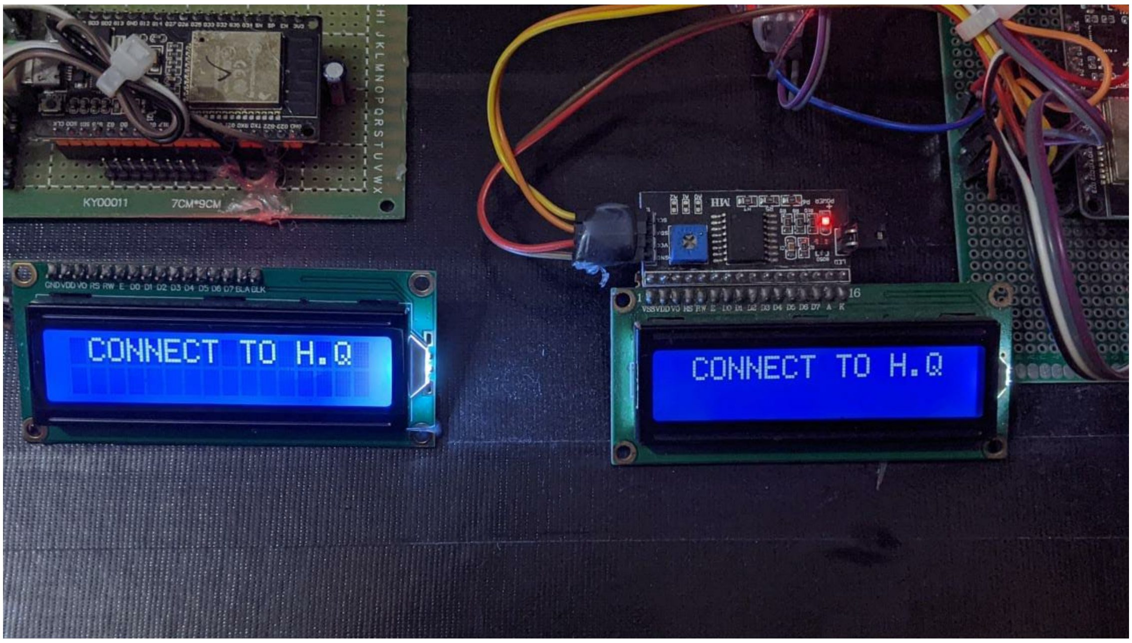

Fig. 5.5 Order to the soldier to connect to headquarter

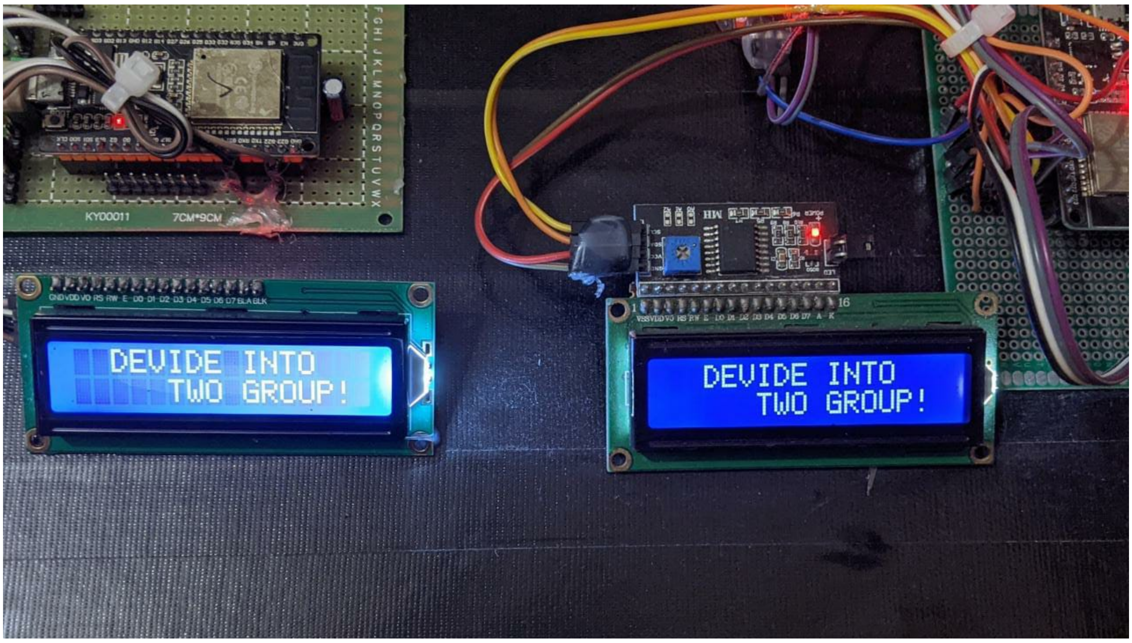

Fig. 5.6 Order to the soldier to divide in two group

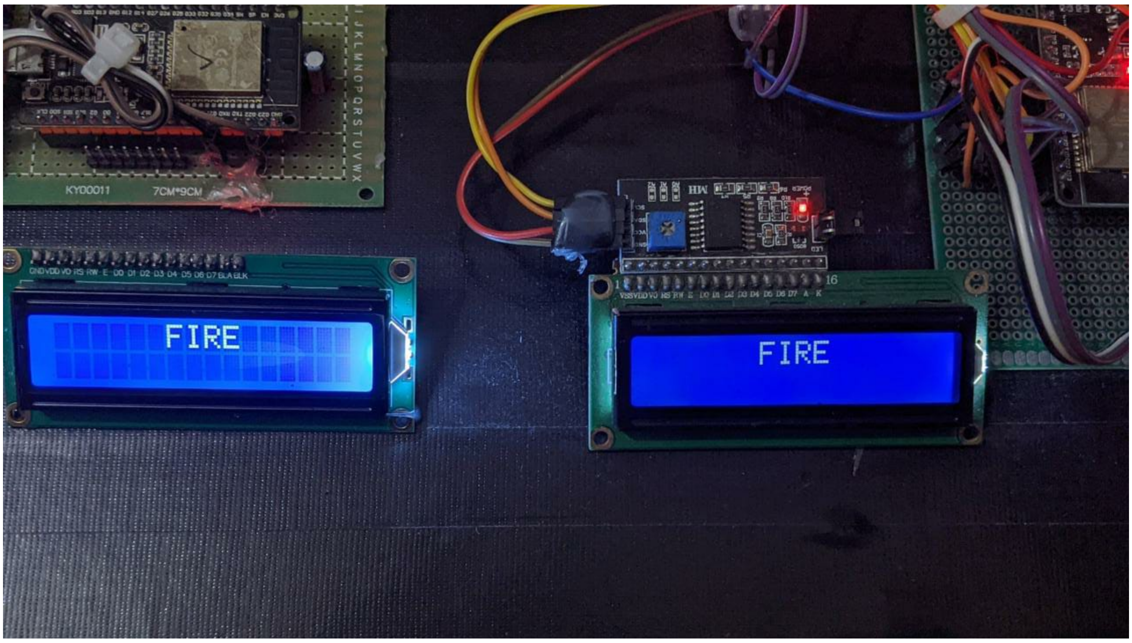

Fig. 5.7 Order to the soldier to fire on the target

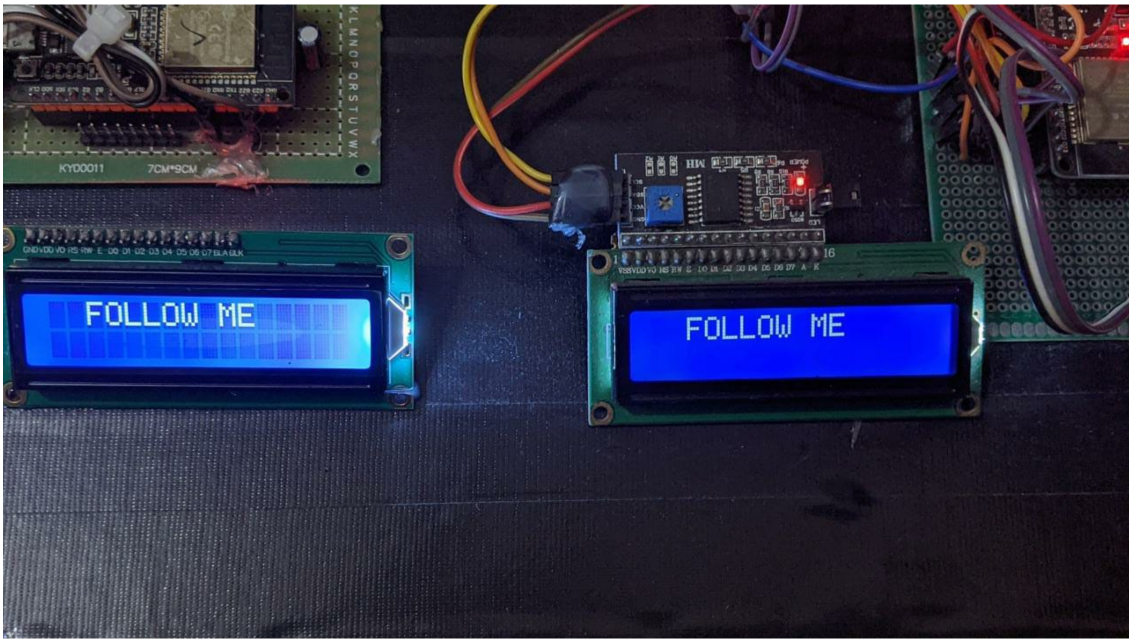

Fig. 5.8 Order to the soldier to follow the commander

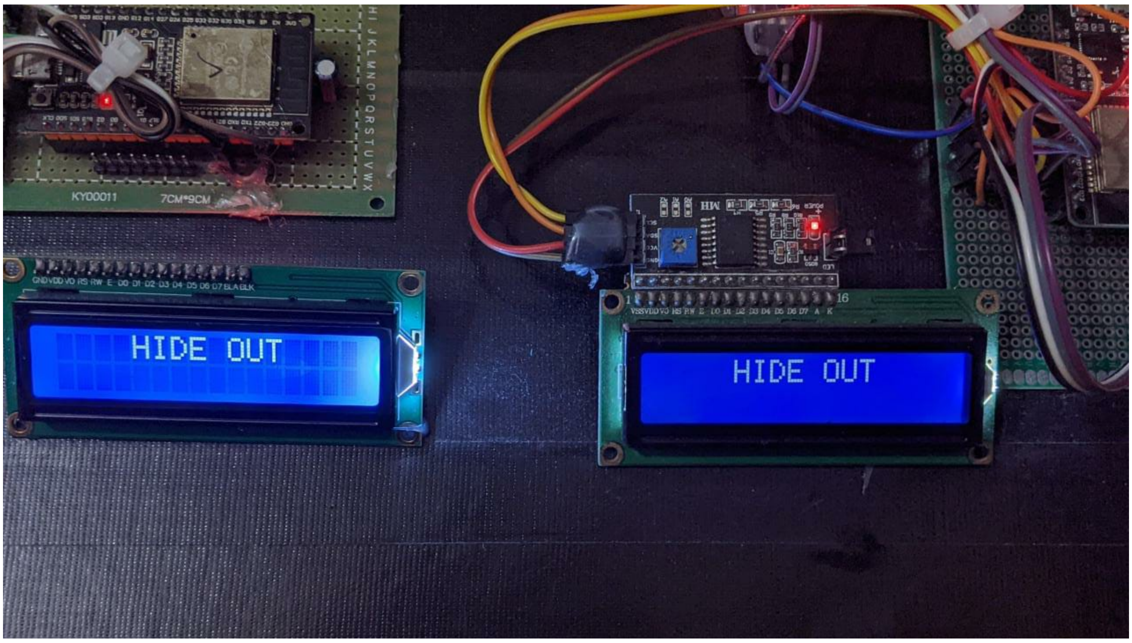

Fig. 5.9 Order to the soldier to hide out

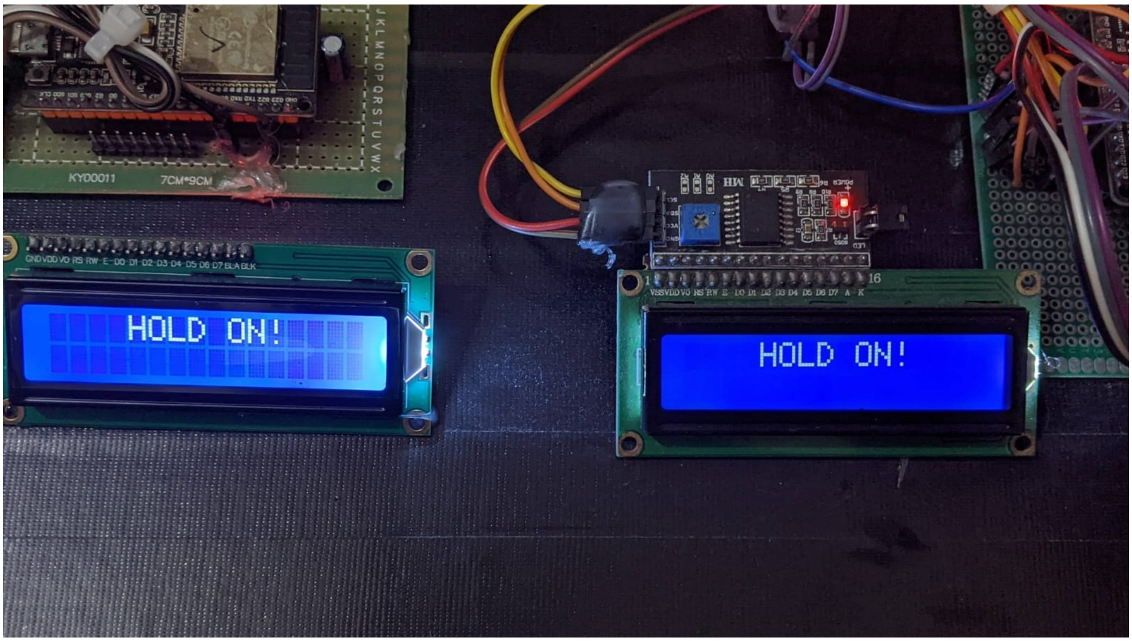

Fig. 5.10 Order to the soldier to hold on

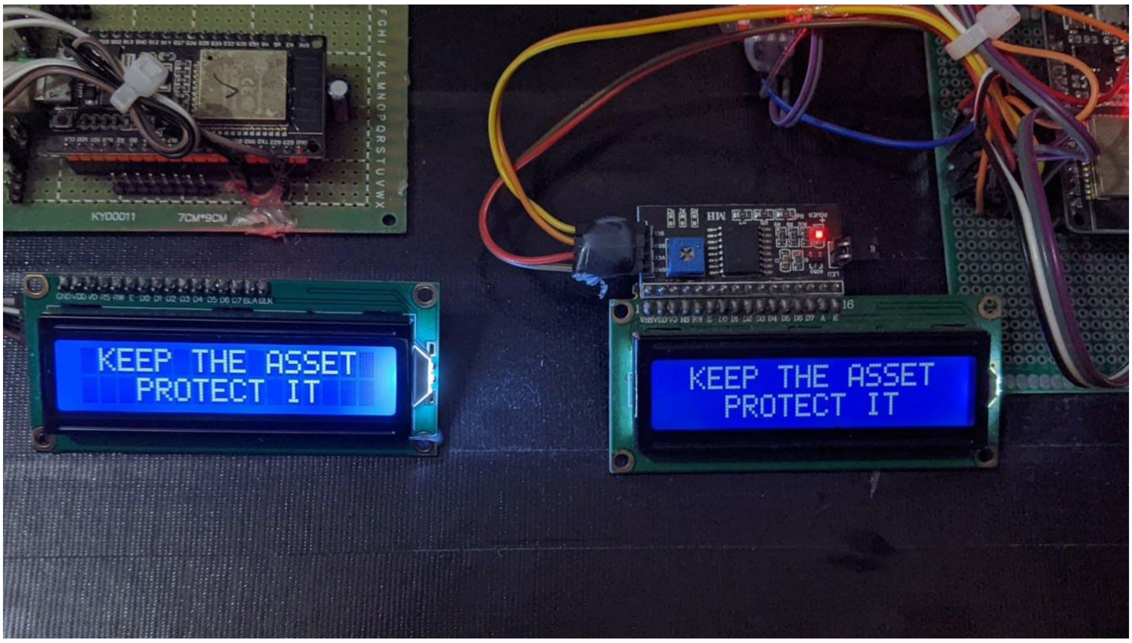

Fig. 5.11 Order to the soldier to keep the asset protect

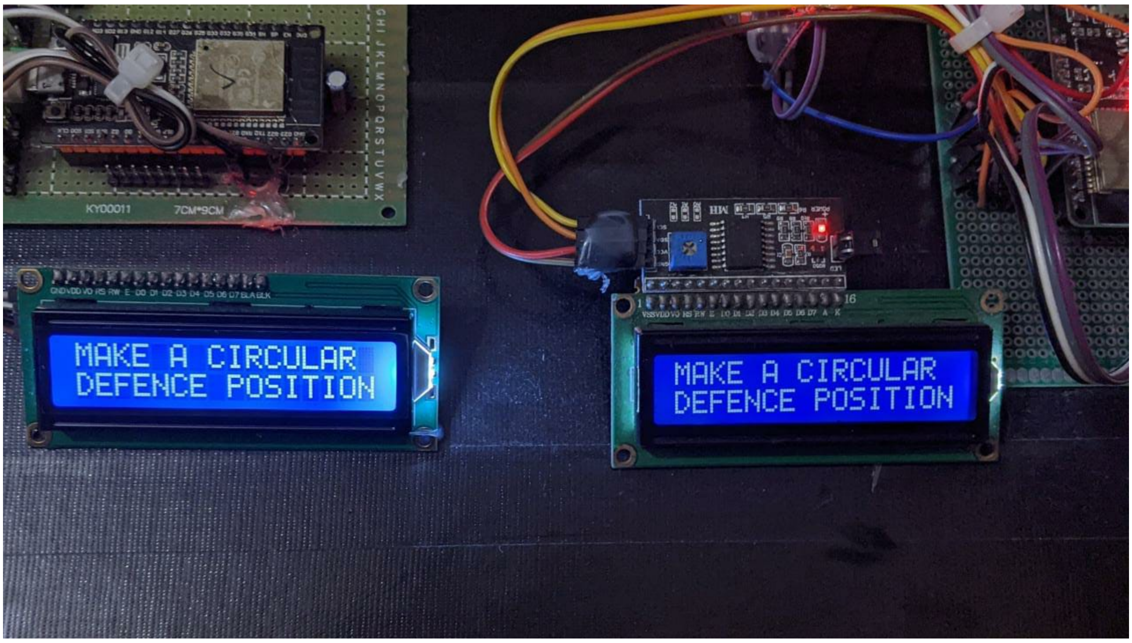

Fig. 5.12 Order to the soldier to make circular defense

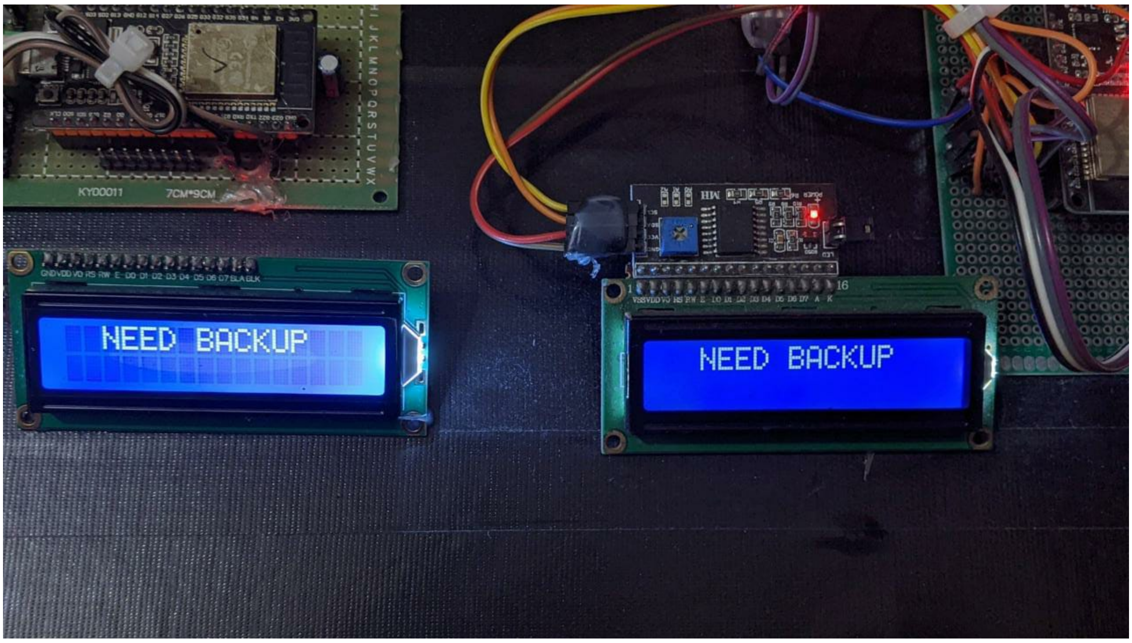

Fig. 5.13 Send message for backup

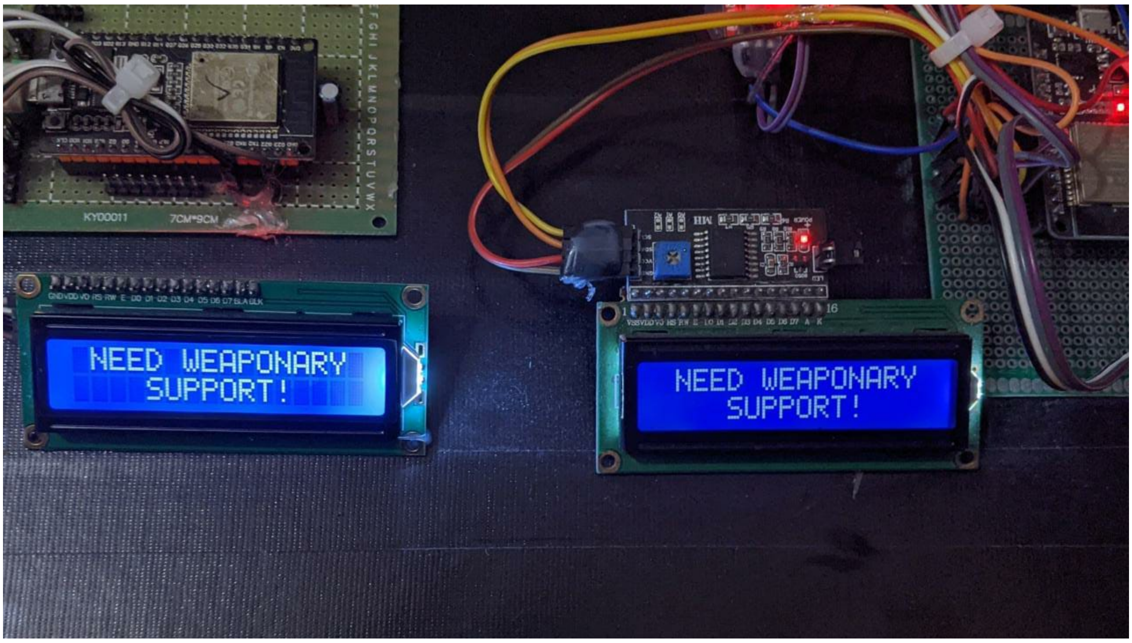

Fig. 5.14 Send message for weapon support

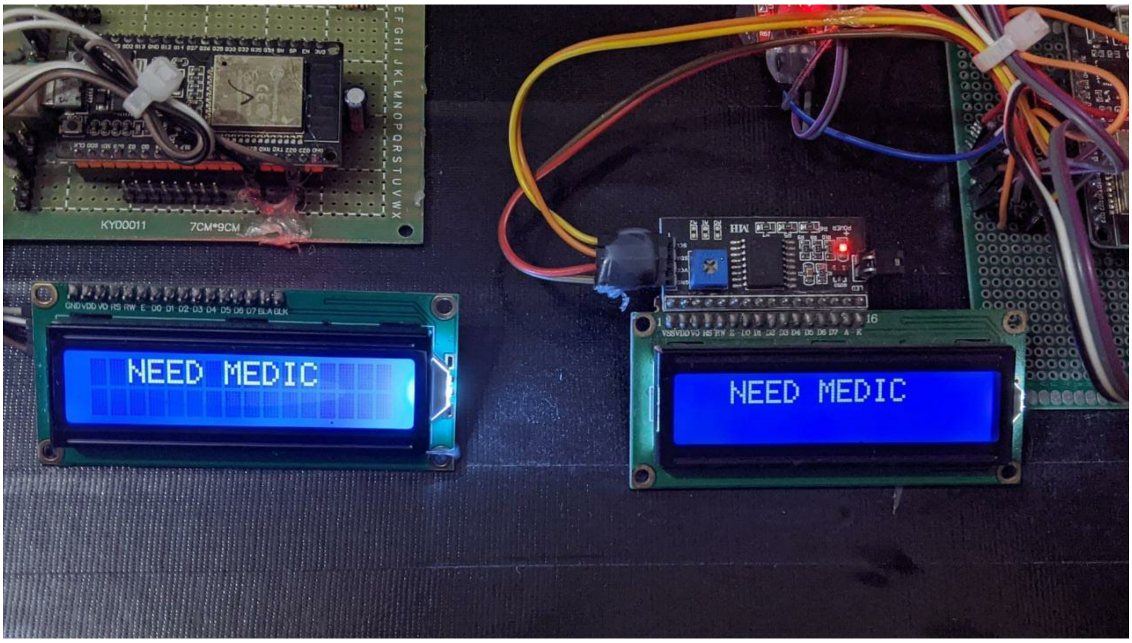

Fig. 5.15 Send message for medicine

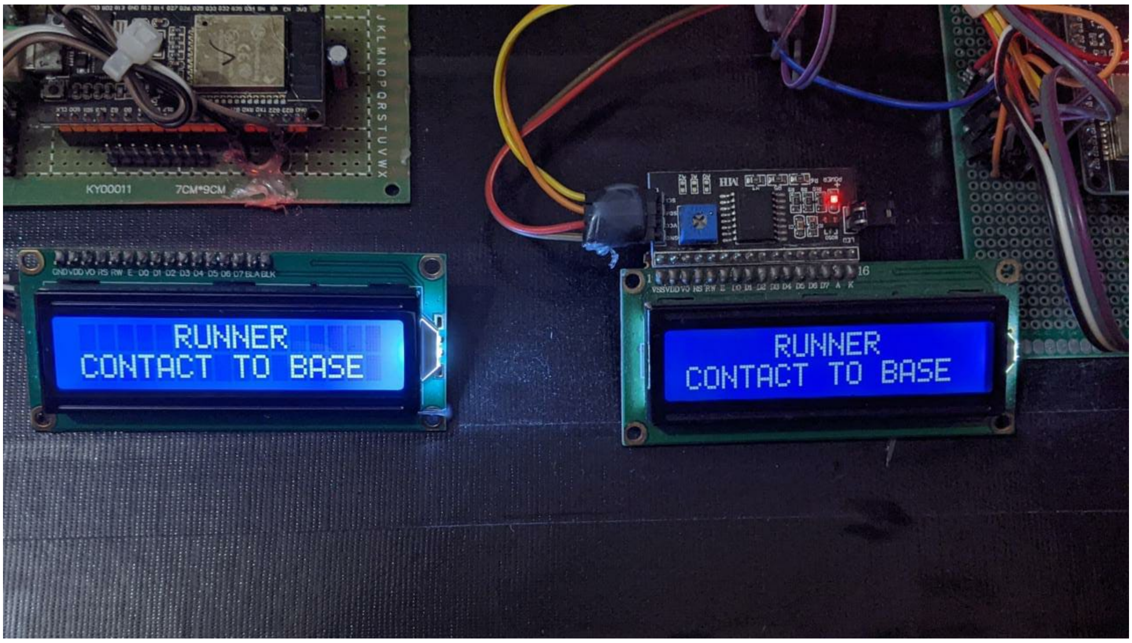

Fig. 5.16 Order to the runner Contact to base

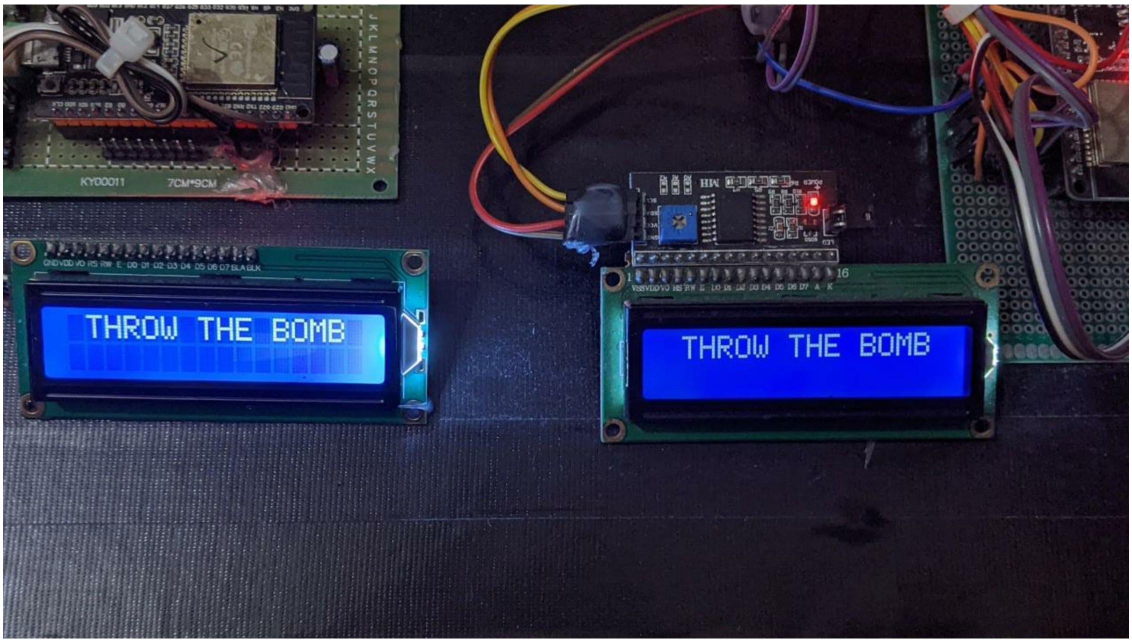

Fig. 5.17 Order to the soldier to throw the bomb

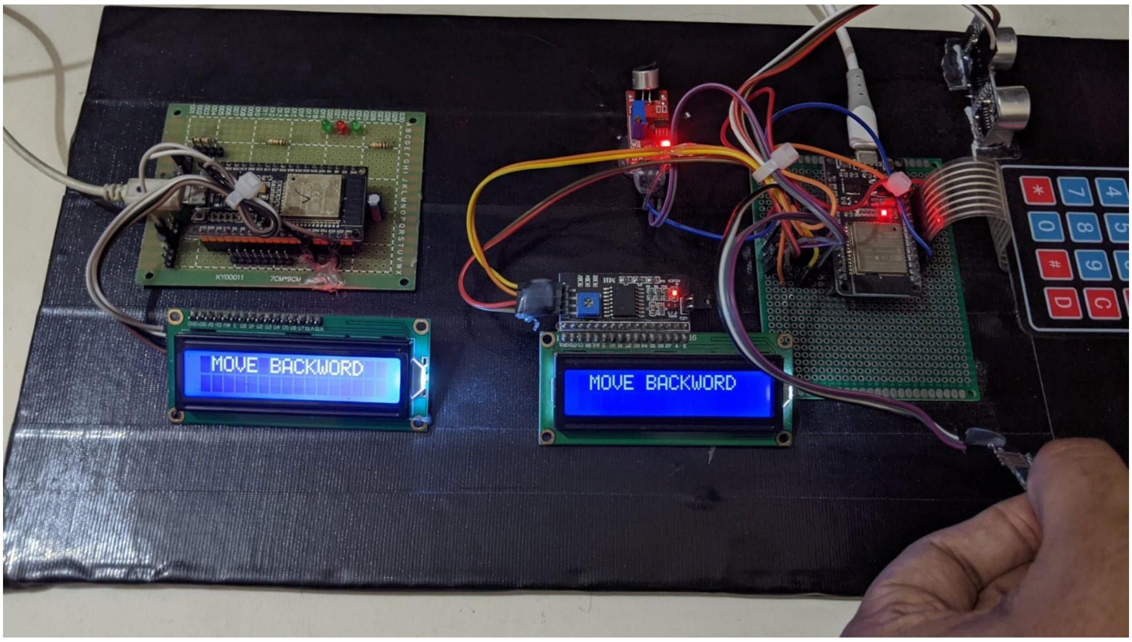

Fig. 5.18 Order to the soldier to move backward

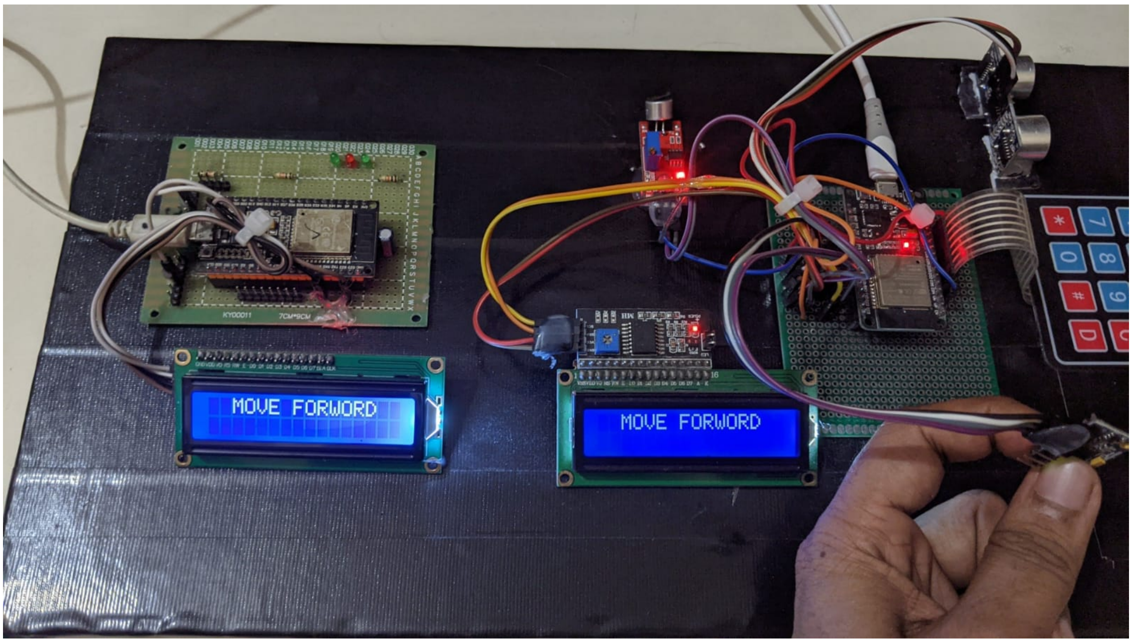

Fig. 5.19 Order to the soldier to move forward

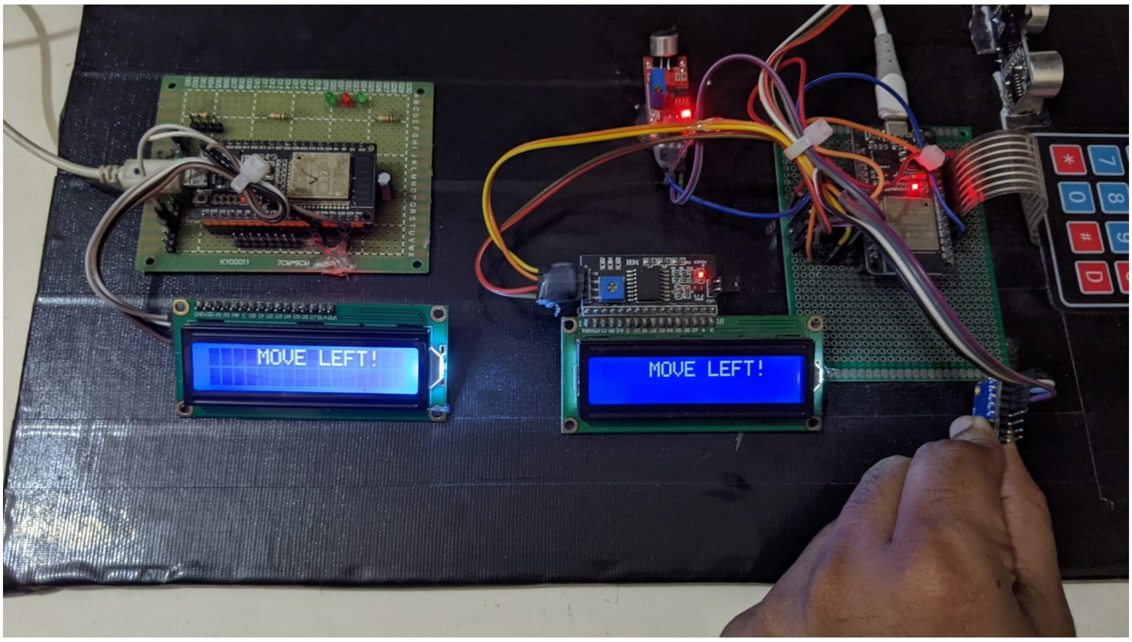

Fig. 5.20 Order to the soldier to move left

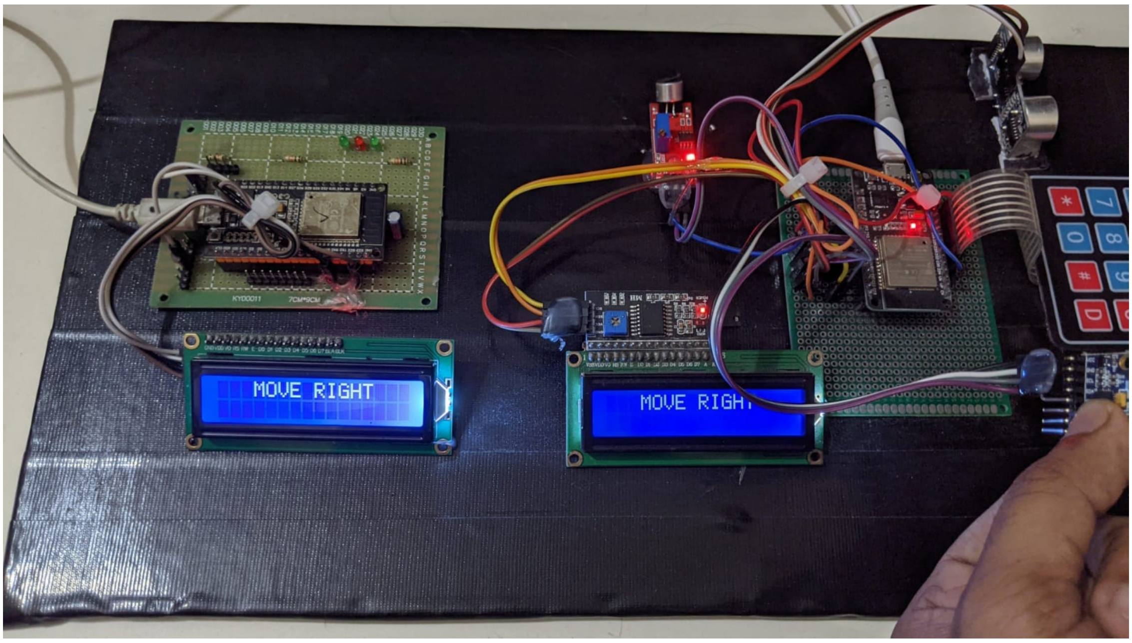

Fig. 5.21 Order to the soldier to move right

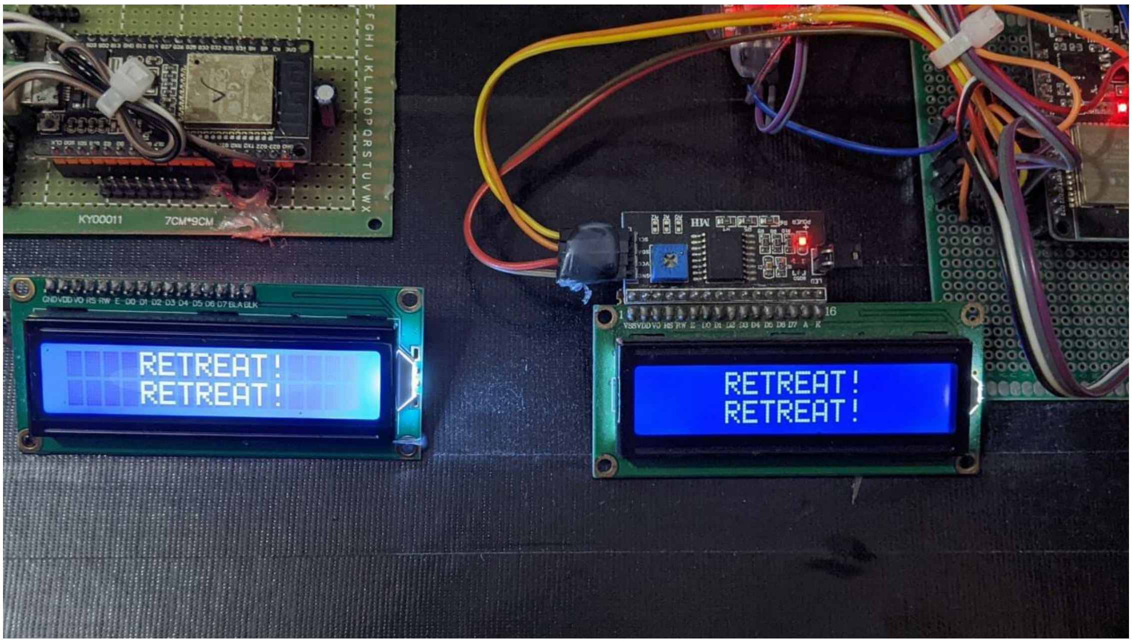

Fig. 5.22 Order to the soldier to retreat

5.6 Cost Analysis

Table 5.1 Total Cost of the project

No	Component Name	Quantity	Price (BDT)
1	ESP32 Microcontroller	2	1100/=
2	MPU6050 Module	1	500/=
3	Ultrasonic Sensor	1	100/=
4	Sound Sensor	1	90/=
5	Keypad	1	100/=
6	LCD 16×2 display	2	360/=
7	I2C Module	2	200/=
8	Veroboard	2	100/=
9	Wire	-	75/=
Total			**2,625/=**

The total amount necessary to finalize this project is **BDT 2,625**. In order to reduce costs, it may be necessary to either replace or reduce the quantity of certain pieces of equipment. However, this would result in a decrease in the overall efficacy of the project. The comprehensive breakdown of expenses pertaining to this undertaking is explicated in **Table 5.1**.

5.7 Comparative Study

This project was compared with other projects that were conceptually and practically analogous through the use of a comparative research study. According to the findings of the research, this undertaking is superior to other undertakings of a similar nature in the following respects:

- **Range:** This project's M2M communication system can cover a distance of between 500 and 700 meters, which is significantly further than the range of other projects of its kind. Because of this improvement in range, military forces are now able to carry out operations over a wider region and with more effectiveness.
- **Object Detection:** This project's sound and object detection system makes use of a microphone as well as sonar in order to identify loud sounds and obstructions. When compared to other initiatives of a similar nature that simply use a single kind of sensor, our system is more precise and efficient.
- **User Interface:** The keypad interface utilized in this project makes it possible for the commander to send a variety of commands to the soldier in a straightforward manner. This interface is simpler and easier to use than those utilized by comparable projects that use different interfaces.
- **Integration:** This project incorporates separate detection methods, including sound detection, object detection, and command systems, into a single complete infrastructure. Other projects of a similar nature might just concentrate on a single facet of the system, which would make them less effective overall.
- **Testing:** We are going to put this plan into action and put it through its paces to see if it can satisfy the requirements of military operations. There is a possibility that the efficacy of other programs very comparable to this one has not been tested or reviewed.

  In conclusion, the project is superior than other projects of a similar nature due to its enhanced range, accuracy, user-friendly interface, comprehensive integration, and testing for the system's performance. This project has the ability to improve both the success rate of military operations and the capabilities of military personnel.

CHAPTER 6
CONCLUSION

6.1 Introduction

This chapter marks the conclusion of the project report. The present chapter will center on the culmination of the project that has been the subject of our prior discussions. Furthermore, the limitations of the project will be discussed, along with potential advancements, applications, and benefits that may arise from it.

6.2 Conclusion

The implementation of a machine-to-machine (M2M) system that incorporates object detection, sound detection, and command capabilities for military purposes represents a significant advancement in the modernization of military operations. A proposal has been put forth for the development of a system of such nature. The utilization of M2M technology has the potential to surpass the limitations of traditional detection systems, enabling real-time monitoring, precise decision-making, and reduced risks to human life. The project's main objectives, encompassing the development of a customized, proficient, and streamlined detection mechanism, the mitigation of human intervention in hazardous scenarios, the assessment and validation of the system's efficacy, and the generation of knowledge for future exploration and enhancement, have been comprehensively tackled. The proposed M2M-based system for object detection, sound detection, and command has the potential to offer real-time response and detection capabilities for military applications. The aforementioned capabilities have the potential to enhance the decision-making abilities of military personnel in situations that may pose a threat to their safety, resulting in expedited and precise decision-making. The system has been designed with the aim of providing a more efficient detection mechanism that could potentially overcome the limitations of current methodologies. This is achieved through the utilization of contemporary sensors. The implementation of M2M technology could potentially reduce the necessity for human involvement in situations that pose a risk to safety, thereby mitigating the hazards encountered by military personnel. The efficient functioning of the system possesses the capability to preserve human lives and mitigate hazards that jeopardize human survival.

The project's insights possess the capacity to facilitate further research and development in the domain of machine-to-machine (M2M) technology and its utilization in the military. The successful implementation of this project may lead to the deployment of comparable systems in analogous military endeavors. The implementation of this measure is expected to enhance the effectiveness and efficiency of military maneuvers, while concomitantly reducing the risks to human safety. Overall, the planned project has achieved its objectives and has the potential to significantly improve military operations in the future.

6.3 Application

The proposed employment of a machine-to-machine (M2M) system for object detection, sound detection, and command in military operations presents a wide range of possible applications.

- The system exhibits a broad spectrum of potential applications and can be employed for diverse purposes such as monitoring, gathering intelligence, and safeguarding national boundaries, among other functions.
- The utilization of the system can be extended to areas where conventional detection systems exhibit limited efficacy, such as the detection of stealth aircraft and submarines.
- Measurement of temperature and humidity in the gas tank.
- The utilization of technology enables instantaneous monitoring and analysis, potentially aiding military personnel in expediting and enhancing their decision-making processes. This could ultimately result in the preservation of human lives and the mitigation of associated risks.

6.4 Advantages

The proposed system utilizes M2M technology, which offers several advantages over traditional detection systems. This may potentially mitigate the limitations that are inherent in the utilization of traditional methodologies.

- The system's real-time monitoring and analysis capabilities facilitate prompt and precise decision-making in situations that may carry inherent risks.
- Additionally, the implementation of the system has the potential to mitigate the necessity for human involvement in situations that pose a potential threat to personnel in the military, thereby resulting in a decrease in associated risks.

- A detection system that utilizes contemporary sensors and algorithms has the potential to enhance its effectiveness and efficiency.

6.5 Limitation

All entities present in the universe are subject to certain limitations imposed by the laws of nature. There exist certain limitations associated with the execution of this project. Individuals have the alternative of replacing any fluid other than gas during the process of weight measurement. Due to its simplistic nature, this undertaking is deemed unsuitable for execution within the corporate domain.

6.6 Future Improvement

The M2M-based system proposed for object detection, sound detection, and command has significant potential for future development and improvement. The potential for improving the accuracy and reliability of a system can be further augmented through the utilization of artificial intelligence (AI) and machine learning techniques. To achieve a more comprehensive detection system, it may be advantageous to integrate this system with other military resources, such as unmanned vehicles and drones, to optimize its efficacy. Furthermore, the system exhibits adaptability for implementation in non-military contexts, including safeguarding national borders and responding to natural calamities. Ongoing research and development in this domain may potentially improve the system's effectiveness and efficiency, while also facilitating continuous innovation in the realm of machine-to-machine (M2M) technology and its applications.

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