PROJECT REPORT
on

FIRE SEARCH AND RESCUE ROBOT USING ROBOTIC ARM

submitted by

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Academic Year : 2015-2016

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This is to certify that the Project Report Stage – II

"Fire Search and Rescue Robot using Robotic Arm"

Submitted by:

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Students of **Electronics and Telecommunication Engineering** have successfully completed their **Project Report Stage – II** required for the fulfillment of **SEM VIII as** per the norms prescribed by the **University of Mumbai** during the First half of the year 2016. The project report has been assessed and found to be satisfactory.

Internal Guide | **External Guide**

Head of Department | **Principal**

Internal Examiner | **External Examiner**

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DECLARATION

We hereby declare that this submission is our own work and that, to the best of our knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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ABSTRACT

Robot technology is emerging for applications in disaster prevention with devices such as fire-fighting robots, rescue robots, and surveillance robots. In this project, we suggest a portable fire evacuation guide robot system that can be thrown into a fire site to gather environmental information, search displaced people, and evacuate them from the fire site. This spool-like small and light mobile robot can be easily carried and remotely controlled by means of Bluetooth. It mounts a temperature sensor on it.. This robot system moves on a robotic car which will be controlled by Bluetooth of the phone. The sensors mounted on the robotic car are gas sensors for measuring CO gas concentration and an ultrasonic sensor to detect an obstacle. A camera unit is also installed on the car to capture the site. Laboratory tests were performed for evaluating the performance of the proposed evacuation guide robot system.

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ACKNOWLEDGEMENT

We would like to thank our project guide Prof. (Ms.) Mrunalini Ingle for her guidance and counsel. We would also like to show our gratitude towards Dr. Amit Deshmukh (Head of department) and also to the teaching and non-teaching staff of Electronics and Telecommunication Department for their support and motivation.

CHAPTER 1
INTRODUCTION

1.1 BRIEF IDEA ABOUT ROBOTICS

Robotics is the branch of mechanical engineering, electrical engineering, electronic engineering and computer science that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing.

These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, and/or cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics.

In recent years robots left controlled laboratory settings and started to address real world scenarios and situations. In order to tackle 'the wild', robots need to adapt their knowledge and their behaviour over time. Lifelong and online learning techniques are currently being established as one of the major research goals in mobile robotics. The rising interest in lifelong learning stems from the fact that all major mobile robot tasks, including mapping, navigation, manipulation, target tracking, planning or learning in general can be performed more accurately and more reliably when formulated and addressed as online learning problems. Given that modern mobile robot systems are being employed in highly dynamic environments such as cities, the capability of improving and refining the internal representation and performance of algorithms for mobile robots during their operation becomes a crucial requirement.

1.2 MOTIVATION

Until recently, robots have not been capable of understanding and coping with unstructured environments (like the ones humans work in) because their systems have relied on knowing in advance the specifics of every possible situation they might encounter. Each response to a contingency has had to be programmed in advance, and systems have had to rebuild their world model from sensor data each time they had to perform a new task.

This is one of the main reasons why, to date, robots have been mostly relegated to highly controlled and predictable environments like manufacturing plants, but have made few significant inroads into the human sphere. The human world is just too nuanced and too complicated to be summarized within a limited set of specifications. But what if robots could learn from their past experiences? And what if they could share their new-found knowledge instantaneously with their peers?

These are not hypothetical questions. Rapid development of sensor and networking technology is now enabling researchers to collect vast amounts of sensor data, and new data-mining tools are being developed to extract meaningful patterns. Researchers are already using networked "feed forward" approaches to make significant advances in machine-based learning systems.

Thus far, however, these smart feed forward systems have been operating in isolation from each other. If they are decommissioned, all that learning is lost. Even more disconcerting to researchers is the question: why are thousands of systems solving the same essential problems over and over again anyway?

1.3 OBJECTIVES

The theme of the ICRA 2011 conference is "Better Robots, Better Life", an expectation that the ever growing technology in robotics and automation will help build a better human society. But achieving this goal is not only a technical problem. Robotics research and applications are increasingly raising ethical questions, related to emerging interactions between robots and human beings, as well as to the closer interaction between robotics research and the biological and social sciences.

The application of ethics to machines, including robots and computer programs, has been mostly limited so far to the consideration that designers and operators should take full responsibility of the machines. However, in the near future, the robotics community will develop machines whose behavior will be an emergent and, to some extent, unforeseeable result of design and operation decisions made by humans and even by other machines.

Moreover, the interaction and the physical integration of human beings and robotic systems is increasing exponentially. The social, economic, psychological, philosophical, and even spiritual impacts of this research are still unclear, but certainly they require careful analysis and attention by the robotics research community.

Among the objectives of the workshop is the opportunity of developing rules for roboethical quality insurance, aimed at preventing unethical uses of robotics research products. Long-term objectives include the increase of robotics researcher's ethical awareness, in the context of the ever growing inter-disciplinarily that will characterize the new generation of robotics research.

1.4 IMPORTANCE OF ROBOTICS IN INDUSTRIES

If there is one technological advancement that would certainly make living easy and convenient, robot would be the answer. Robots are human like machines capable of doing tasks they are programmed to do. They have shown significance in decreasing human work load especially in industries.

Robots are mostly utilized in the manufacturing industry. The type of job that laborers encounter in this type of business is usually repetitive and monotonous. People who do the same thing for a long period of time tend to get bored and tired of what they are doing and might arrive in a position wherein he is unwillingly doing his job. The person who reached this point will not be as efficient and effective as when he first started working. Also, as human being, we get exhausted so the length of time that we can work is only limited. This is when the importance of robots is realized. They can be set to function for a long span of time producing the same quality product all throughout the production process. This resulted to an increase in the number of manufactured products and decrease in the production of defective goods.

It is the industries that gained a lot of benefits out of robotics. The company productivity has risen which made businesses achieve more profits. Also, company loss has been reduced because flawed products are trimmed down to almost none. On the contrary, the emergence of industrial robots brought disadvantages on laborers. Since the former are truly effective machines, industries prefer utilizing them rather than employing humans. As a result, unemployment rate goes high. Many underprivileged people become poorer while company owners which are only a few get richer.

The brain of robots where they receive set of instructions that make them perform tasks automatically is called artificial intelligence or AI. There have been stories showing that these machines have become intelligent enough to think and act independently and overthrow humanity. At present, this is nowhere near to happen since robots nowadays are not capable enough to do tasks without being controlled.

1.5 NEED IN FIRE RESCUE AREAS

According to the National Fire Protection Association, in a typical year, about 25 percent of firefighter line-of-duty fatalities are caused by heart attacks, including overexertion; 21 percent die trapped by fire; and 18 percent die from collapses and unrecoverable injuries resulting from fire-damaged floors and obstructions. There are also tens of thousands of strains, sprains, and other injuries every year, many from lifting hoses and carrying heavy objects. Many firefighters get cancer or other ailments from coming into contact with carcinogens or poisonous gases and chemicals. Many avenues for reducing firefighter deaths, injuries, and exposures are being explored. We are in the midst of a revolution in robotics technology. Now is the time for the fire service to take a more active role in evaluating the technology and shaping features that will be of value to firefighters.

The purpose of this article is to give insight into robotic technology already in existence or currently in development that might be useful to the fire service. The hope is to whet appetites for more information and stimulate leadership to take a more active role in setting requirements and working with robotics researchers. The fire services in several other nations are already collaborating with robotics researchers and manufacturers to implement firefighter-assistance robotics. It is time that we catch up.

The term robot is used here to refer to robotic machines that mechanically or otherwise assist humans. Think of technology like firefighter-guided robots designed to detect and handle dangers (like bomb-handling robots do for police) or mechanical mules designed to haul loads or sensors mounted on a mobile unit designed to improve situation awareness and not the autonomous humanoid robots like R2D2 from Star Wars that would replace firefighters.

1.6 DIFFICULTIES FOR IMPLEMENTATION IN FIRE AREAS

Recently, mobile robots capable of ubiquitous computing have become very popular; these robots can be used at all times under all conditions. They can be widely used in areas such as military, the medical profession, and in various industries. However, for the deployment of robot systems in fire environments, a number of unsolved problems remain. The most representative examples of such problems are as follows.

1) Presently available robots are not able to function at high temperatures of over 1500°C, which occurs after flashover, and in the presence of water supplied by fire trucks, which would prevent

firefighters from entering the site if a robot is being used. This implies that an evacuation robot needs to be equipped with temperature protection, waterproofing, and impact resistance mechanisms.

2) In general, when a fire or some other disaster is reported, firefighters are sent to the site in order to cope with it as soon as possible. Therefore, the evacuation robot also needs to be not only light weight but also easy to carry for rapid emergency response. Moreover, it is important that the firefighter can safely withdraw the deployed robots, because the efforts for withdrawing include additional dangerous activities in fire sites.

3) Due to the poor information regarding indoor space at fire sites, it is very difficult to decide when or how should firefighters enter a building. Therefore, the robot employed for evacuation purposes should be able to not only monitor the situation at fire sites but also report the gathered information to remote firefighters by using a manipulator.

4) In addition to the above drawbacks, there can be other unexpected problems that need to be addressed, such as poor vision in smoke-filled areas and limited RF communication Channels. In order to resolve these unsolved problems, many applications that use caterpillar and fire extinguisher equipment have been proposed. However, they have several limitations due to their large sizes and high cost of maintenance. Therefore, the firefighters cannot easily carry or operate such robots in emergency situations.

1.7 SCOPE OF THE PROJECT

Here, we report the design and development of a portable evacuation guide robot with various sensing systems that can monitor indoor disasters such as fire, and it can also be used for victim detection and atmosphere observation. In addition, by using a LED guidance lamps, the robot can help in rescuing the victims. In order to cover large fire areas, several robots can be organized into a group, and they can transmit gathered information to the firefighter's controller at a remote site.

In the prototype, a robotic arm is mounted on the robotic car. Various sensors have been used to measure the temperature, gas concentration and the range of the obstacle. An application has been built for Android based mobile phones to control the robotic arm and the robotic car. The communication between the prototype and the mobile phone is done using Bluetooth. A camera is also installed on the car to send the live images of the scene to the mobile handset.

CHAPTER 2
CURRENT ADVANCEMENTS

2.1 CURRENT TECHNOLOGY

Some robots are already available for the fire service to use, other robots can be modified, and many more are in the development stage. One tack being taken in the military research is to develop robots that imitate animal capabilities, such as carrying large payloads (300-plus pounds) while maintaining mobility and stability over rough terrain; climbing and crawling rapidly while remaining agile; and locating and alerting to the presence of people. Other military research has developed robots that can remove obstructions, break doors, and investigate hazardous conditions. Most of these robots can be controlled remotely from hundreds of meters away and can transmit video and navigational data to the user to assist with monitoring dangers ahead. The robots are potentially capable of assisting firefighters with carrying equipment, clearing areas, removing obstructions, ventilating rooms, locating victims, and extinguishing fires—abilities with the potential to save lives and prevent injury to firefighters and to civilians.

2.2 ASSISTING URBAN FIREFIGHTERS

Examples of robots with the capability to aid urban firefighters with a wide variety of tasks are shown in Table I. Each robotic technology is compared to existing methods used for a firefighting task. Robots have the potential to assist urban firefighters with searching and finding victims within a structure, using water to extinguish flames, removing debris and knocking down obstacles, and removing people from hazardous situations. Most of the robots are prototypes and are still in the R&D phase. We cannot know for sure if any particular technology will be useable in the long run, but collectively they demonstrate the potential the technology has to offer. Each prototype is expected to improve with subsequent generations.

Table I: Potential Robotic Technology for Structural Fires
(These are examples of existing technology. Although we cannot vouch for the effectiveness of any one technology, collectively these technologies illustrate state of the art capabilities.)

Task	Risks	Current Technology	Sample Robot Technology
Size-up • Situation awareness • Game plan	• Reality does not always match prefire plans. • Must carry many tools and personal protective equipment (PPE) to prepare for unknown situations • Lack of necessary resources • Hazardous areas (highway accident, toxic chemical plant, etc.)	• Preincident plan • Personal Protective Equipment (PPE) • Self-Contained Breathing Apparatus (SCBA)	**iRobot's *510 Pacbot* to survey building interior and detect levels of oxygen, carbon dioxide, and combustible gases (U.S. military)** • Thermal imaging capability • Easy maneuverability through narrow and confined spaces • Breaching capability that includes expandable toolbar with wire cutters, spade and other tools • Advanced dexterous manipulator to pick up small objects and turn doorknobs • Double-wall cooling system to work in extreme temperatures. • Remote-control capability to investigate the interior of a fire area and relay real-time data to user
Locate • Find fire hot spots • Find hazards	• Smoke inhalation • Heat exposure • Blocked entries (time delay) • Unknown source of ignition or fuel • Poor visibility	• Thermal imaging cameras • Pike poles (to search ceiling and walls for fire)	**InRobot Tech Ltd. *FFR-1* to obtain environmental information without line of sight (Israel)** • Sensors for humidity, chemicals, biological detection, and radiation • Provides real-time data to remote user without line of sight
Access • Tear down walls • Breach entrances • Access from outside	• Reactivation of fire • Flashover • Backdraft • Smoke inhalation • Extreme heat exposure	• Halligan tools, K-tool, fire ax for breaching) • Fire ladder	**Boston Dynamic's *Big Dog* to carry loads (U.S. military)** • Carry up to 350 lbs. of equipment • Front and rear-leg attach points for balance and self-recovery • High intensity lighting to navigate during day or night • Battery-recharge station • Remote-controlled Possible Modifications: • Gait modification to carry victims • Climbing up stairs (currently travels up 30° incline)
Ventilate • Vertical (roof, floor) • Horizontal (windows, walls)	• Reactivation or worsening of fire • Flashover • Backdraft • Utilization of dangerous tools (saws, axes, etc.)	• Positive-Pressure Ventilation (PPV) fans • Hydraulic pumps • Smoke ejection	***Rechner's LUF60* to ventilate area remotely from up to 1,000 feet away (Austria)** • Water beam fog with a hydraulically driven PPV ventilation fan to clear a path up to 1,000 feet away • 360° high-pressure nozzles for Class A & B foam • Withstands extreme heat
Extinguish	• Lack of adequate water supply • Burns from steam or fire • Smoke inhalation • Utilities not shut off (gas explosion, electrocution, etc.)	• Ladder, pumper, and tanker trucks • Fire hose/foam dispenser • Fire extinguisher	**SINTEF's *Anna Konda* to apply water (Norway)** • 20 hydraulic joints with hydraulic cylinders that can withstand pressures up to 1450psi, which provides movement like a snake. • Navigates up stairs and through tight spaces • Can travel alongside firefighter or be steered remotely
Search • Rapid search • Detailed search	• Extreme heat • Difficulty breathing	• Infrared cameras	**Hoya Robot Company's *Firefighters Assistance Robot* to transmit environmental data back to user (South Korea)** • Fits in palm of hand and weighs 3 lbs. • Capability for remote-control deployment from 50 yards away • Remote collection of image, sound, temperature, smoke, and gas data to assist firefighters to locate victims • Withstands temperatures up to 320°F
Rescue • House • Building • Vehicle accidents	• Unconscious, disoriented, or immobile victims • Elderly, pregnant, disabled, or child victims • Victims in multiple locations • Hazards and obstacles blocking access • No clear escape route • Structure collapse hazards/falling	• Hydraulic rescue tools • Multipurpose tool (ax, sledge-hammer, and ram combination)	**Vecna Robotics' *HG2* robot to extract and carry victims, and remove obstacles up to 500 lbs. (U.S. military)** • Hydraulic-based dexterous "hand" to extract and lift victims up to 500 lbs. outdoors/indoors, up/down stairs, and in structurally unsound buildings • Long-distance carrying capacity • Lifting capacity (hand): 360 lbs. • Lifting capacity (finger): 120 lbs. Possible Modification: • Sensors to ensure that victims are removed with appropriate care
Overhaul	• Falling, burning, and sharp debris • Dangers of collapse • "Hidden" fires/hot spots • Rekindled fire • Water/ice slip danger	• Pike poles • Halligan tool • Sledgehammer • Power saws • Shovels/water vacuum	**iRobot's *Dirt Dog* robot to pick up debris autonomously (U.S.)** • Low-cost, commercially available robot picks up light or heavy debris using powerful high-speed brushes • Size and weight of robot: 13.5-in diameter, 3.5-in" thickness, and 6.5 lbs. • "Smart Technology" to navigate around obstacles and focus on dirty areas • Newest model in the Roomba series which vacuums floor area for dust and ash Possible Modification: • Capability to haul away large-sized debris

There are several examples of robotic technology already used internationally to assist the fire service. For example, a South Korean robot called Firefighters Assistance Robot, which weighs less than five pounds, can enter a fire scene; provide data on temperature, smoke conditions, and gas levels from 50 yards away; and transmit images. The data provide firefighters with information on the fire situation before they enter a burning building. The robot not only can withstand temperatures up to 320°F but also can be easily carried into a building. Firefighters can deploy the robot to search for trapped victims and locate safe escape routes. As of October 2009, 50 fire stations in South Korea have received 100 units to test.

In Norway, a three-meter-long experimental robotic fire hose named Anna Konda uses hydraulic motors to slither like a snake up stairs, following alongside firefighters to the fire source and spraying water from its front end ("mouth") at a pressure of 1,450 pounds per square inch (psi). The robot also can be remote-controlled to go to a designated location. Subsequent generations will likely increase its water capacity, which is currently too low for most fire tasks, but it is a fascinating display of potential.

In Austria, scientists developed a wireless-controlled robot named LUF60 that uses a high-capacity positive-pressure ventilator and "water-beam fog" to clear a path through smoke, heat, and toxic gases. It can be controlled from up to 1,000 feet away. A barrel-like container mounted on top of LUF60 carries Class A and Class B foam. It allows firefighters to clear a path to the seat of the fire and rescue victims safely.

Many situations require firefighters to carry heavy equipment such as fire hoses, entry tools, and extinguishers into buildings and up staircases. A mule-like robot named Big Dog was developed for the U.S. military to carry up to 350 pounds of gear, climb up hills, and travel over different types of terrain (e.g., a street filled with hoselines). It can walk in snow or on ice. Researchers are currently working to modify it to climb stairs and to increase its carrying capacity. Firefighters could use such a mechanical mule to reduce stress, move faster by transferring their payloads to the mule, and have a wider variety of equipment and tools available than they now can carry.

2.3 WILDLAND AND OUTDOORS FIREFIGHTING

Fighting forest fires, like fighting urban fires, is high risk. Wildfires often occur in remote areas, and firefighters often have to travel long distances with heavy equipment. In Israel, researchers developed a construction equipment-based robot (RMP400F) to assist with creating fire breaks by digging large quantities of dirt and removing obstructions and rubble. The next prototype is expected to be capable of applying 10 gallons of water per second using a remote-controlled water cannon. In Germany, scientists have developed a robot named OLE that can go to a GPS-designated location, provide visual and auditory capabilities to identify pockets of fire, and disperse powdered fire extinguishing agents or water at approximately 10 gallons per second. Unstaffed aerial vehicles (UAVs) already are used for long-range detection and surveillance of wildfires. The UAVs can be modified to set backfires; some can hover and fly themselves to the ground. Additional wildfire-related robot technologies are described in Table II.

2.4 MONETORY ISSUES

Many argue that robots are too expensive to buy, especially in difficult financial times such as these. Some robotic technology may have a high cost up front, but the technology is often cost-effective in the long run. Preventing one career-ending back injury can save hundreds of thousands of dollars. Large-scale use of robotic technology will produce economies of scale that make it more affordable. IR cameras, once considered prohibitively expensive at a cost of $40,000 per camera, are available now for $7,000 or less. When firefighters witnessed how IR cameras helped locate victims and identify hot spots of fires, hundreds of fire departments purchased them. Now, IR cameras are commonplace in fire departments and have become part of the National Institute for Occupational Safety and Health (NIOSH) list of recommended standard equipment.

Robots are disposable; human life is not. Robots can serve to protect the firefighters so that the firefighters can perform their duties with less risk of injury. Robotic technology can do hazardous and strenuous tasks without the need for rest.

The majority of robots are semiautonomous. Most need to be controlled by a user but do not have to be tethered to a power cable. Robotic technology is not yet advanced enough to deal with unexpected events or to make fast judgments. A firefighter is needed to make rapid decisions based on changes that occur during an emergency situation. However, firefighters with more information and physical capability at their disposal can function more safely and efficiently. Robotics will not put firefighters out of a job, but they can change the nature of the job, improve safety, and increase capability.

Table II: Robotic Technology for Wildfires

Task	Risks	Current Technology	Potential Robot Uses
Size-up	• Underestimating extent/behavior of flame • Sending firefighters for ground containment in high-risk areas with fast fuel ignition or multiple spot fires • Unpredictable winds make it difficult to plan safe areas	• Database software to track weather, fire danger, and fuel moisture observations	**Quinetiq's *Talon* robot to rapidly transport large amounts of water and equipment (U.K.)** • Four color cameras: standard, night vision, thermal, and zoom option • Capability to lift heavy payloads such as equipment, water, and foam • Transport equipment over large distances rapidly • Long battery life
Locate	• Fire whirls and plumes leading to dangerous fire exposure and difficulty identifying fire sources from the air and ground • Rapid spread of fire makes it difficult to plan fire breaks and increases danger of fire exposure • Smoke plumes that hover over fire	• IR sensors • Range sensors • Satellite data, aerial imagery, and GPS to detect plume locations	**General Atomics' *Predator UAV* to locate fire sources (U.S.)** • Can fly 22,000 feet over forest fire • Real-time data processing to alert firefighters on the ground (satellite data link system) • Geo-registered image capture capabilities for rapid mapping • Two-color video cameras and a forward-looking infrared (FLIR) camera as well as a synthetic aperture radar (SAR) to detect hot spots through smoke and haze
Contain • Firebreak • Clear brush	• Flanking and backing fire fronts • Short and long distance spotting or jumping • Heat stress and burns when digging and clearing brush • Crown, plume fire, fire whirls, firebreak jumping.	• Pulaski ax • Chainsaws • Brush hook • Wildfire torch • McLeod tool	**Northeast Forestry University's *Logging Harvester* robot to remove dead wood and clear brush to contain fire (China)** • Mechanical arm and a felling head that has clipping claws, two driving rolls, two measuring rolls, a pair of delimbing knives, and a chain saw to remove brush and create firebreak • Flexible felling head with 10 degrees of freedom for wide range of motion to remove all types of brush- manipulator rotation, inner boom rising and falling, outerboom extending and retracting, felling head pitching, felling head rotation, clipping claws opening and closing, driving roll rotation opening and closing, chain saw cutting and swinging • Can remove dead wood that has a diameter of up to 30cm and remove brush from 4 -10.5m around itself
Search	• Exposure to smoke • Impaired vision • Irritated throat and lungs from forest/environment, smoke, and debris	• Unmanned Aerial Vehicles (UAV) with thermal imaging technology	**University of Florida's *CRASAR* robot to locate victims (U.S.)** • Capability to locate victims in areas that are inaccessible or difficult to see • "Mother" robot can deploy "baby" robots to expand search and access hidden areas • 100 feet of robot tether cable • Omnidirectional and IR cameras (thermal and imaging) for locating victim • Two-way audio for rescue worker located remotely to communicate with victim
Rescue	• Fire entrapment • Burning • Respiratory problems due to smoke	• Rope • Fire shelter to delay full fire exposure	**Sandia National Labs' *M2* robot extracts victims with manipulator arm (U.S. military)** • 5-foot, 600-lb. robot rolls on treads around obstacles • Tethered with control of arms that extend 6 meters out and lifts 8 meters high • Capability to use tools such as pipe shears, saw, wrench, plasma torch, water jet • Dexterous to reach into awkward places and apply force to drills and screwdrivers • Position memory to affix tools at the right height and depth • Self-monitored for temperature condition and replacement of parts status • Auditory and 20-camera visual capabilities Possible Modifications: • Optimize to extract victims instead of dismantling bombs • Change remote deployment tools to rescue-based hand tools • Reduction of weight for mobility
Extinguish	• Inhalation of on-fire oxygen or carbon monoxide poisoning	• Halotrun tanks • UAVs or helicopters with fire retardant or water • Utility Terrain Vehicles (UTV) with large water storage	**New iteration of Segway Robotics' *RMP400F* to apply 10 gpm of water (Israel)** • Four-wheeled, 240-lb. robotic platform originally designed for riot crowd control • Rapid speed (travels 18 mph) • Water cannon fires 10 gallons per second (gps) • Can remove rubble to create fire breaks (to assist with containment)
Mop-Up	• Cindered earth • Flying embers • Residual odors from chemical contamination (households, pesticides, etc.)	• Mop-up wand • Cordova equipment • Fire broom • Infrared cameras • Chainsaws	**University of Magdeburg-Stendal *OLE* robot to locate hot spots (Germany)** • Fire-resistant ceramic-fiber coating that can withstand up to1850°F • Speed of 10-20 kilometers per hour and equipped with GPS • Visual and auditory capabilities so user controller can observe pockets of fire • Disperses water and foam • Infrared and heat biosensors to detect fire sources

2.5 ACTION NEEDED

The U.S. fire service has an important opportunity to guide the development of robots to support specific firefighting needs. There are robotic technologies in development that can reduce the risks to firefighters. The fire service must be willing to work with engineering teams to develop this technology to assist with firefighting needs.

There are three important steps to push this idea forward. First, the fire service needs to be informed about current robotic technology and its potential applications. Second, the fire service needs to provide insight as to the changes needed to refine and develop robotic capabilities to meet fire department requirements. Third, once the requirements have been understood and acted on by R&D firms, the fire service will need to work with robotic engineers to provide feedback to optimize the technology. The new developments in robotics have the potential to revolutionize the way firefighters combat fires, deal with hazardous materials incidents, and reduce firefighter casualties. The technology development can be sped up if we act now.

CHAPTER 3
DESIGN, IMPLEMENTATION AND INSTALLATION

3.1 WORKING PRINCIPLE

The working principle of the project is explained here. The codes written on the Arduino boards serve to perform the desired actions of the arm and robotic car. The movements of the arm are controlled using the Bluetooth module by giving the feedback to the Arduino to perform the desired action. The movements of the car are controlled using the Bluetooth module by giving the feedback to the Arduino to perform the desired action. The temperature, CO concentration and the images of the site are displayed on the mobile phone. The readings of the ultrasonic sensor is fed to the Arduino which takes the appropriate actions as required.

3.2 BLOCK DIAGRAM

The block diagram shown in Figure 3.1 shows the basic working of this project.

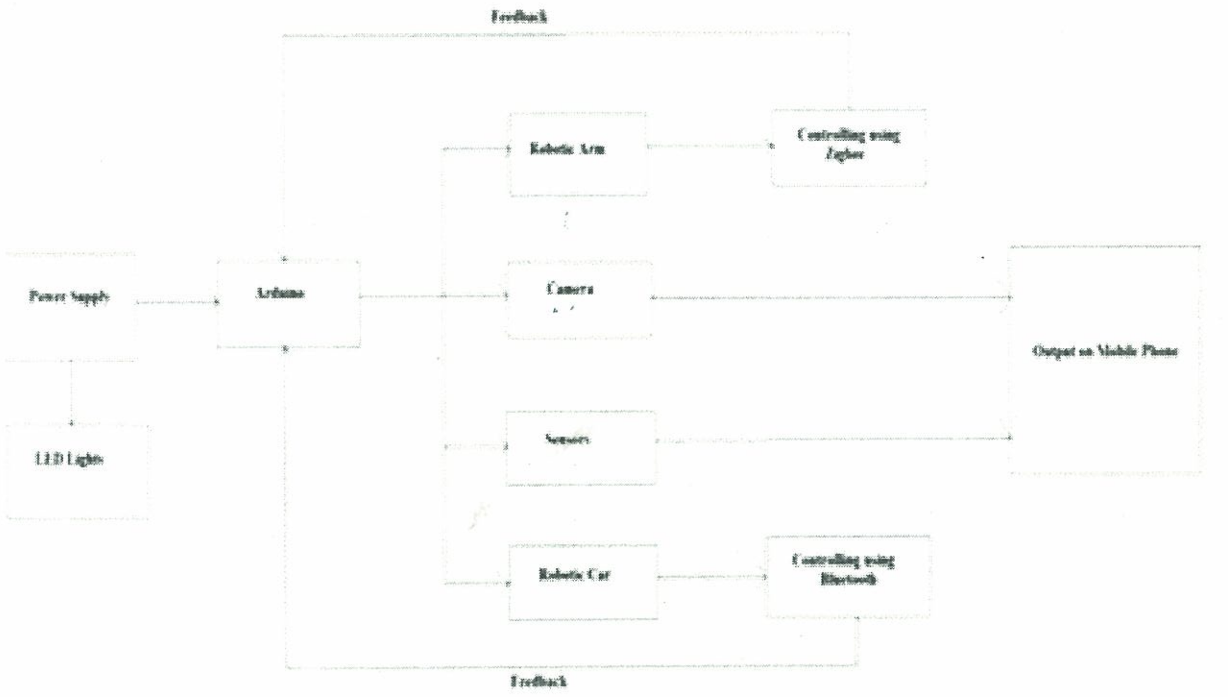

Figure 3.1: Block Diagram

3.3 Components overview

The components used in the project include Arduino, Bluetooth, temperature sensor, CO concentration sensor, camera, ultrasonic sensor, servo motor, DC motor, LED display and power supply. The robotic arm requires 6V 3A for powering it while the robotic car requires 9V 1A for it's working.

3.3.1 Arduino

rduino is an open-source computer hardware and software company, project and user community that designs and manufactures microcontroller-based kits for building digital devices and interactive objects that can sense and control the physical world.

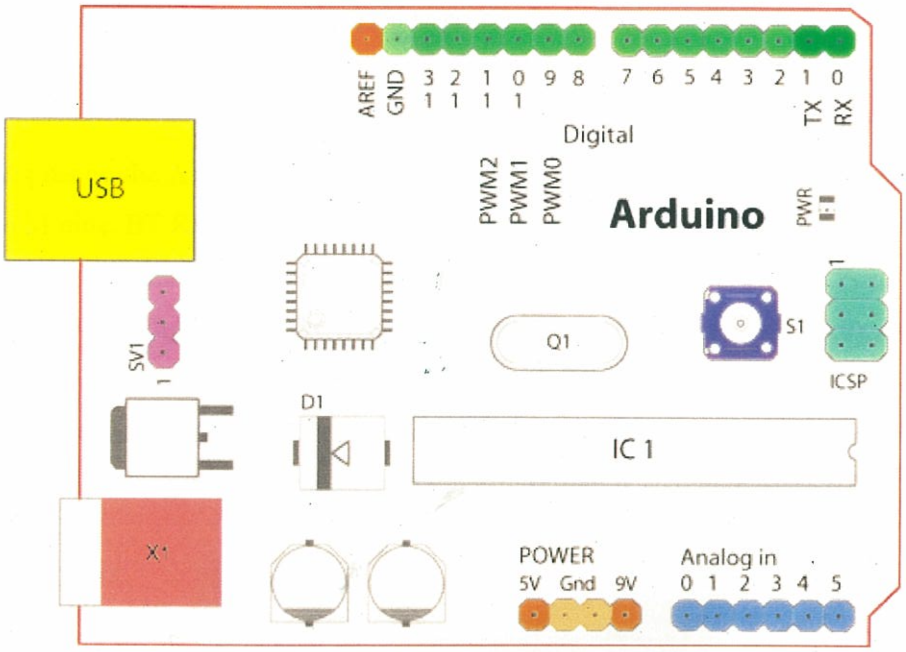

Figure 3.2: Different components on the Arduino Board

The main components present are:

1. Analog Reference pin
2. Digital Ground
3. Digital Pins 2-13
4. Digital Pins 0-1/Serial In/Out - TX/RX
5. Reset Button - S1
6. In-circuit Serial Programmer
7. Analog In Pins 0-5
8. Power and Ground Pins
9. External Power Supply In (9-12VDC) - X1
10. Toggles External Power and USB Power (place jumper on two pins closest to desired supply) - SV1
11. USB (used for uploading sketches to the board and for serial communication between the board and the computer; can be used to power the board)
12. Microcontrollers (Atmega 48)

Some of the pins on the Arduino board are Digital Pins, Serial TX and RX pin, External Interrupt 2 and 3, PWM pins, BT Reset, LED Pin 13, Analog Pins, Power and GND pin, AREF and Reset pin. Some of the pins of Atmel 48 microcontroller are VCC, GND, Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2, Oscillator, Oscillator amplifier, Port C (PC5:0), PC6/RESET, Port D (PD7:0), AVCC, AREF, ADC7:6 (TQFP and QFN/MLF package only). The above-mentioned pins play an important role in Arduino circuit board as it helps to define whether a pin is analog, digital or a transmission pin. The pin configuration is shown in Figure 3.4.

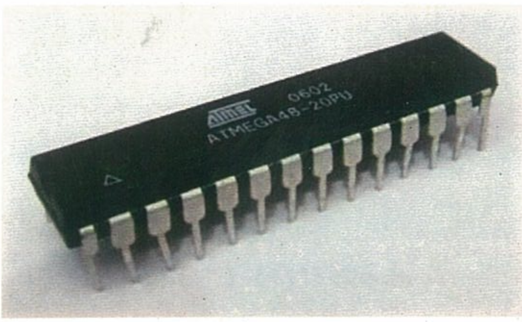

Figure 3.3: ATMEL48 IC

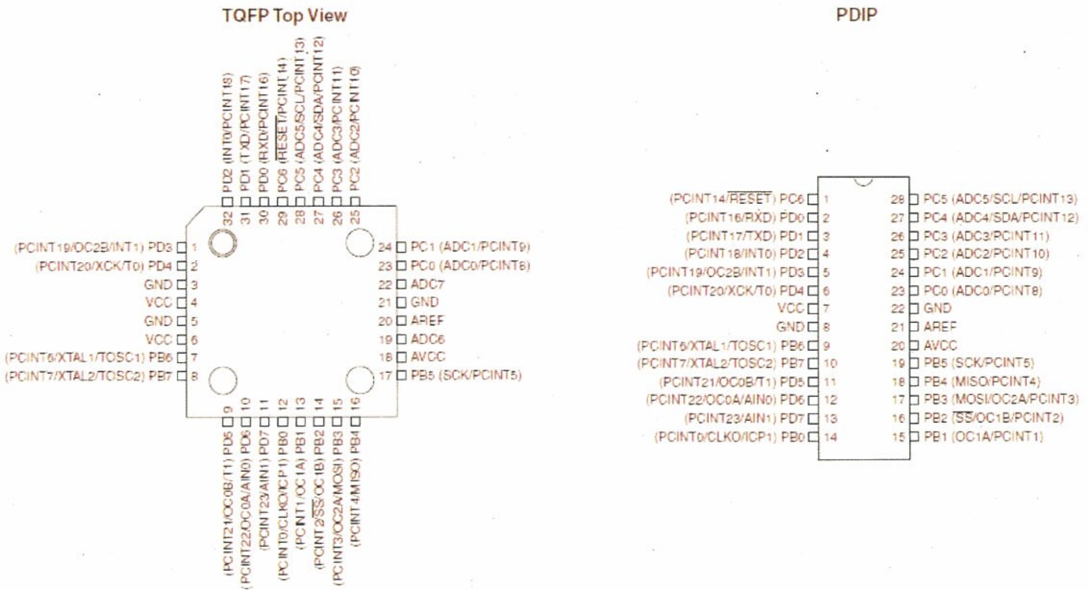

Figure 3.4: Pin Configuration of ATMEL48

3.3.2 Sensors

The various sensors used in the prototype are –

1. LM35 TEMPERATURE SENSOR
2. MQ-6 GAS SENSOR
3. HC-SR04 ULTRASONIC RANGING MODULE

Let us discuss the one by one.

3.3.2.1 Temperature Sensor – LM35

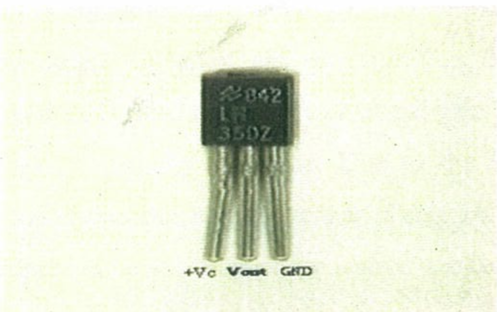

Figure 3.5: LM35 Sensor

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly- proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient centigrade scaling. The diagram of LM35 is shown in Figure 3.5. The LM35 device does not require any external calibration or trimming to provide typical accuracies. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. Pin Description is given in Table III.

Pin No	Function	Name
1	Supply voltage; 5V (+35V to -2V)	Vcc
2	Output voltage (+6V to -1V)	Output
3	Ground (0V)	Ground

Table III: Pin Configuration of LM35

3.3.2.2 GAS SENSOR MQ-6

For measurement of different gases, we use MQ-6 gas sensor. Sensitive material of MQ-6 gas sensor is SnO2, which with lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is higher along with the gas concentration rising. Convert change of conductivity to correspond output signal of gas concentration. MQ-6 gas sensor has high sensivity to Propane, Butane and LPG, also response to Natural gas. The sensors can be used to detect different combustible gas, especially Methane. Due to the low cost, it is suitable for different application. Figure 3.6 shows the MQ-06 sensor. Table IV and V show the standard working conditions and environmental conditions of the sensor respectively.

Figure 3.6: MQ-06 gas sensor

Symbol	Parameter Name	Technical Condition	Remarks
VC	Circuit voltage	5V±0.1	AC or DC
VH	Heating voltage	5V±0.1	AC or DC
RL	Load resistance	20Kohm	
RH	Heater resistance	33Kohm±5%	Room temperature
PH	Heating consumption	Less than 750mW	

Table IV: Standard Working Condition of MQ-06

Symbol	Parameter Name	Technical Condition	Remarks
TO	Operating Temp.	-10°C-50°C	
TS	Storage Temp.	-20°C-70°C	
RH	Relative Humidity	<95%	
O2	Oxygen Concentration	21%(standard condition) Oxygen concentration can affect sensitivity	Minimum value is 2%

Table V: Environment Condition of MQ - 06

3.3.2.3 HC-SR04 ULTRASONIC RANGING MODULE

HC - SR04 is shown in Figure 3.7. It is used for measurement of the distances between the sensor and the object. It provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work depends on using IO trigger for at least 10us high level signal, sending eight 40 kHz and detect whether there is a pulse signal back and if the signal is back, the Test distance is given by (high level time×velocity of sound (340M/S)) / 2. We have also used a camera module, which captures the images at the site and sends it to the mobile, which is used by the person controlling. Table VI shows the HC-SR04 Specifications.

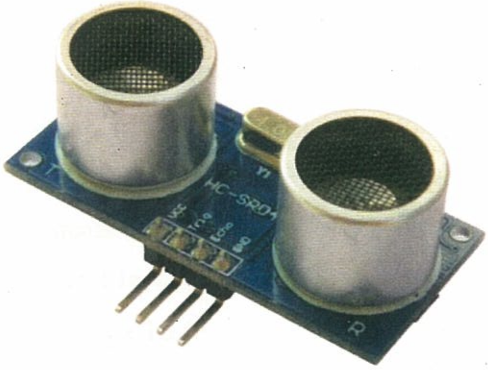

Figure 3.7: HC-SR04 Ultrasonic Sensor

Working Voltage	DC 5V
Working Current	15mA
Working Frequency	40Hz
Max Range	4m
Min Range	2cm
Measuring Angle	15 degree
Trigger Input Signal	10μS TTL pulse
Echo Output	Signal Input TTL lever signal and the range in proportion
Dimension	45 * 20 * 15mm

Table VI: HC-SR04 Specifications

3.3.3 COMMUNICATING MODULE: BLUETOOTH

3.3.3.1 BLUETOOTH TECHNOLOGY

Bluetooth is a specification for short-range RF-based connectivity for portable personal devices. It is a short-range wireless data exchange protocol designed for a small variety of tasks, such as synchronization, voice headsets, cell modem calls, and mouse and keyboard input. The specification began as a de facto industry standard; more recently, IEEE Project 802.15.1 developed a wireless PAN standard based on the Bluetooth v1.1 Foundation Specifications. The IEEE 802.15.1 standard was published in 2002. Bluetooth is directed principally to the support of personal communication devices such as telephones, printers, headsets, and PC keyboards and mice. The technology has restricted performance characteristics by design; hence, its applicability to WSN is rather limited in most cases. For these same environments, ZigBee is probably a better solution; however, given the popularity and longevity of the standard, it is given some coverage here. As part of its effort, the IEEE has reviewed and provided a standard adaptation of the Bluetooth Specification v1.1 Foundation media access control (MAC) (L2CAP, LMP, and baseband) and the physical layer (PHY) (radio). Also specified is a clause on service access points (SAPs), which includes a LLC–MAC interface for the ISO/IEC 8802-2 LLC. A normative annex that provides a protocol implementation conformance statement (PICS) proforma has been developed. Also specified is an informative high-level behavioral ITU-T Z.100 specification and description language (SDL) model for an integrated Bluetooth MAC sublayer . The Bluetooth specification defines a low-power, low-cost technology that provides a standardized platform for eliminating cables between mobile devices and facilitating connections between products. The system uses omnidirectional radio waves that can transmit through walls and other nonmetal barriers. Unlike other wireless standards, the Bluetooth wireless specification includes both link layer and application layer definitions for product developers. Radios that comply with the Bluetooth wireless specification operate in the unlicensed, 2.4-GHz ISM radio spectrum, ensuring communication compatibility worldwide. Bluetooth radios use a spread-spectrum, frequency-hopping, full-duplex signal. While point-to-point connections are supported, the specification allows up to seven simultaneous connections to be established and maintained by a single radio. AFH (adaptive frequency hopping), available with newer versions, allows for more.

The signal hops among 79 frequencies at 1-MHz intervals to give an acceptable degree of interference immunity between multiple Bluetooth devices and between a Bluetooth device and a WLAN device (at least in the case where not all the available frequencies are used by the WLAN—this is probably the case in a SOHO environment, where only one or two access points are used at a location). To minimize interference with other protocols that use the same band, the protocol can changes channels up to 1600 times per second. If there is interference from other devices, the transmission does not stop, but its speed is downgraded. Bluetooth version 1.2 allowed a maximum data rate of 1 Mbps; this results in an effective throughput of about 723 kbps. In late 2004, a new version of Bluetooth known as Bluetooth version 2 was ratified; among other features it included enhanced data rate (EDR). With EDR the maximum data rate is able to reach 3 Mbps (throughput of 2.1 Mbps) within a range of 10 m (up to 100 m with a power boost). Older and newer Bluetooth devices can work together with no special effort. Because a device such as a telephone headset can transmit the same information faster with Bluetooth 2.0þEDR, it uses less energy, since the radio is on for shorter periods of time. The data rate is improved by more efficient coding of the data sent across the air; this also means that for the same amount of data, the radio will be active less of the time, thus reducing the power consumption. Newer Bluetooth devices are efficient at using small amounts of power when not actively transmitting: for example, the headset is able to burst two to three times more data in a transmission and is able to sleep longer between transmissions. Noteworthy features of Bluetooth core specification version 2.0þEDR include:

- Three times faster transmission speed than that of preexisting technology
- Lower power consumption through a reduced duty cycle
- Simplification of multilink applications due to increased available bandwidth
- Backwardly compatible to earlier versions
- Improved bit-error-rate performance

Hardware developers were shifting from Bluetooth 1.1 to Bluetooth 1.2 in the recent past; Bluetooth 2.0 products were being introduced at press time. To be exact, version 2.0 devices have a higher power consumption; however, the fact that the transmission rate is three times faster (thereby reducing the transmission burst times) effectively reduces consumption to half that of 1.x devices. Devices are able to establish a trusted relationship; a device that wants to communicate only with a trusted device can authenticate the identity of the other device cryptographically. Trusted devices may also encrypt the data that they exchange over the air. A Bluetooth device playing the role of ''master'' can communicate with up to seven devices playing the role of ''slave'' (groups of up to eight devices are called piconets). At any given instant in time, data can be transferred between the master and one slave; but the master switches rapidly from slave to slave in a round-robin fashion. (Simultaneous transmission from the master to multiple slaves is possible but is not used much in practice.) The Bluetooth specification also makes it possible to connect two or more piconets to form a scatternet, with some devices acting as a bridge by simultaneously implementing the master role in one piconet and the slave role in another piconet. The Bluetooth SIG recently established a road map for future improvements to Bluetooth. Priorities for 2005 included quality of service (QoS), security, and power consumption; priorities for 2006 were to include multicast, additional security, and long-range performance. The Bluetooth SIG is also working with developers of UWB to ensure backward compatibility with the new standard. UWB is a short-distance wireless protocol capable of transmitting up to 100 Mbps of data a distance of about 10 m; Bluetooth is only capable of 1 to 3 Mbps over the same distance. It is conceivable that Bluetooth could be supplanted by this faster technology, so the Bluetooth SIG is working to make sure that UWB is backwardly compatible with current Bluetooth devices (at present, two groups are competing for their technology to be ratified as the UWB standard). Depending on the usage cases, technologies such as ZigBee and UWB can be either complementary or overlapping. It is hypothetically possible that Bluetooth wireless technology and UWB could converge, but work and agreements will need to take place to make this happen. The immediate problems for UWB—the two competing standards and the lack of the international regulatory approval—need to be resolved for the idea of convergence to be interesting for Bluetooth wireless technology.

3.3.3.2 HC-05 BLUETOOTH MODULE

It is a class-2 Bluetooth module with Serial Port Profile , which can configure as either Master or slave. A Drop-in replacement for wired serial connections, transparent usage. It can be used simply for a serial port replacement to establish connection between MCU, PC to an embedded project and etc. Its specifications are mentioned in Table VII. Its applications include in computer and peripheral devices, GPS receiver, Industrial control and MCU projects.

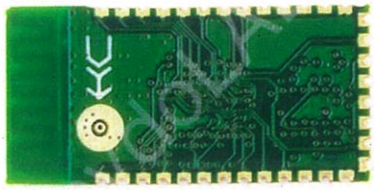

Figure 3.8: HC-05 Bluetooth Module

Bluetooth protocol	Bluetooth Specification v2.0+EDR
Frequency	2.4GHz ISM band
Modulation	GFSK(Gaussian Frequency Shift Keying)
Emission power	≤4dBm, Class 2
Sensitivity	≤-84dBm at 0.1% BER
Speed	Asynchronous
2.1Mbps(Max) / 160 kbps, Synchronous	1Mbps/1Mbps
Security	Authentication and encryption
Profiles	Bluetooth serial port
Power supply	+3.3VDC 50mA
Working temperature	-20 ~ +75Centigrade
Dimension	26.9mm x 13mm x 2.2 mm

Table VII: HC-05 Specifications

3.3.4 SERVO MOTORS

Servomotors have been around for a long time and are used in many applications. They are small but pack a big punch and are very energy efficient. Because of these features, they can be used to operate remote-controlled or radio-controlled toy cars, robots and airplanes. They are also used in industrial applications, robotics, in-line manufacturing, pharmaceutics and food services.

The servo circuitry is built right inside the motor unit and has a positional shaft, which usually is fitted with a gear (as shown below). The motor is controlled with an electric signal, which determines the amount of movement of the shaft.

Figure 3.9: Hitec HS-322HD Standard Heavy Duty Servo

3.3.4.1 SERVO COMPONENTS

Inside the servo is a pretty simple set-up:

1. A small DC motor,
2. Potentiometer and
3. A control circuit.

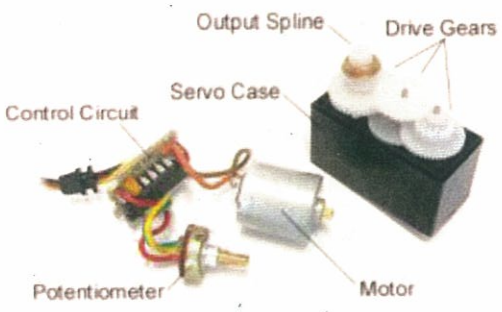

Figure 3.10: The guts of a servo motor (L) and an assembled servo (R)

The motor is attached by gears to the control wheel. As the motor rotates, the potentiometer's resistance changes, so the control circuit can precisely regulate how much movement there is and inwhichdirection. When the shaft of the motor is at the desired position, power supplied to the motor is stopped. If not, the motor is turned in the appropriate direction. The desired position is sent via electrical pulses through the signal wire. The motor's speed is proportional to the difference between its actual position and desired position. So if the motor is near the desired position, it will turn slowly, otherwise it will turn fast. This is called proportional control. This means the motor will only run as hard as necessary to accomplish the task at hand.

2. DC - DC servos are not designed for high current surges and are usually better suited for smaller applications.

Generally speaking, DC motors are less expensive than their AC counterparts. These are also servo motors that have been built specifically for continuous rotation, making it an easy way to get your robot moving. They feature two ball bearings on the output shaft for reduced friction and easy access to the rest-point adjustment

3.3.4.4 SERVO MOTOR APPLICATIONS

There are various applications of the servo motors in various fields. Some of them are as follows-

1. Servos are used in radio-controlled airplanes to position control surfaces like elevators, rudders, walking a robot or operating grippers. Servo motors are small, have built-in control circuitry and have good power for their size.
2. In food services and pharmaceuticals, the tools are designed to be used in harsher environments where the potential for corrosion is high due to being washed at high pressures and temperatures repeatedly to maintain strict hygiene standards.
3. Servos are also used in in-line manufacturing, where high repetition and precise work is necessary.

3.4 MAKING OF THE APPLICATION USING AI2-APP INVENTOR

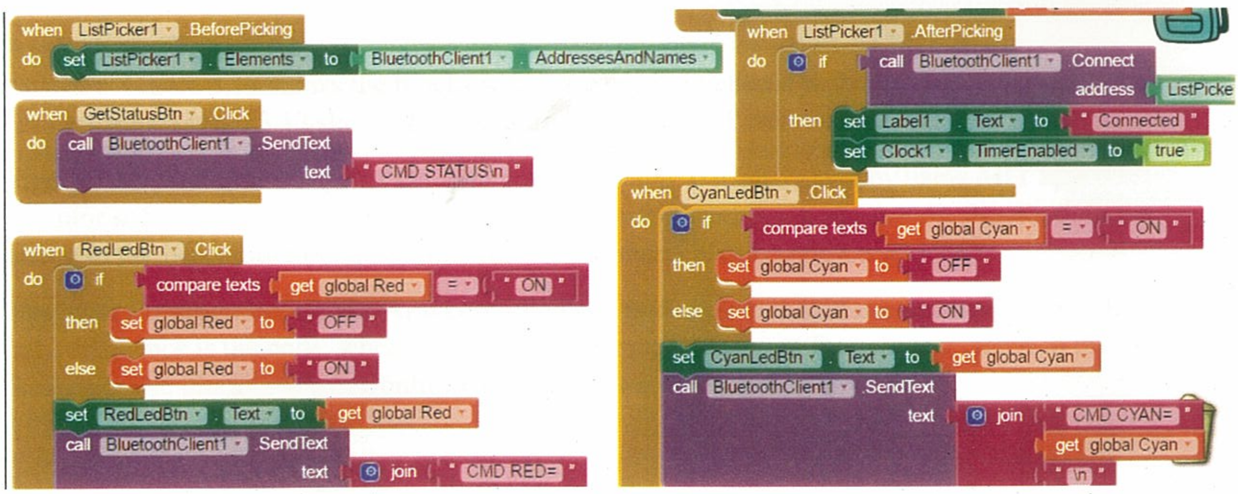

Figure 3.12: Blocks of Car controlled App

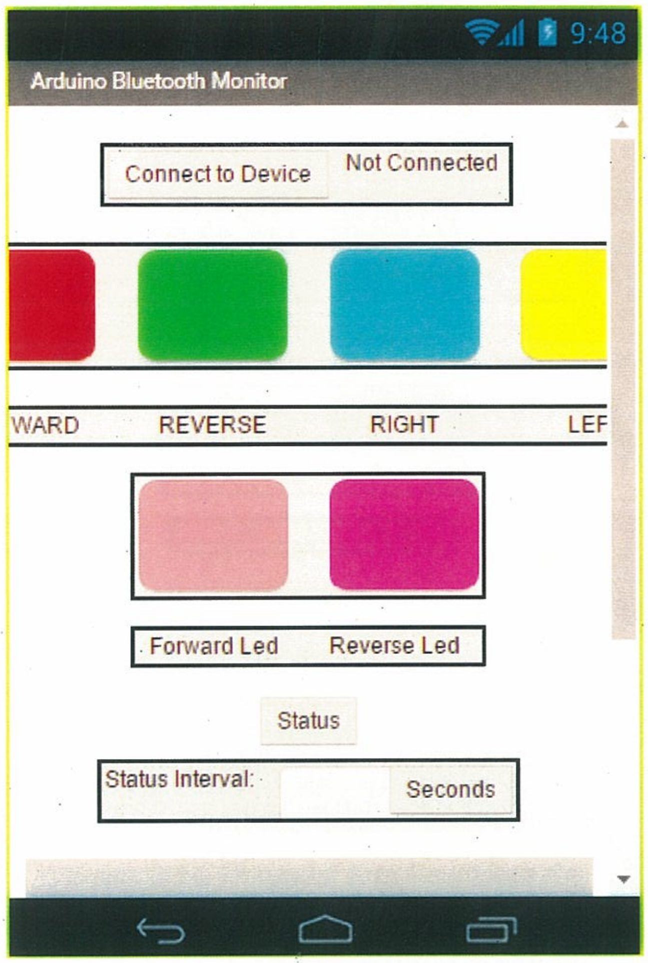

Figure 3.13: Design of Car Controlled App

As shown in Figure 3.12 and Figure 3.13, we have designed an app using MIT app inventor software. Figure 3.12 shows the blocks which are used to define a particular function which the car performs. Figure 3.13 shows the design and placement of each button.

Figure 3.14 shows the design of the Arm controlled app. It is also made by using MIT app inventor software. The app is connected to the Arduino board using the in-built Bluetooth in the phone to the Bluetooth module connected in the Arduino board.

The logic for programming the Arm controlled app is similar to that of car controlled app. The only difference is the code, where each button performs a different function compared to that of the other. The blocks of Arm Controlled app is shown in Figure 3.15.

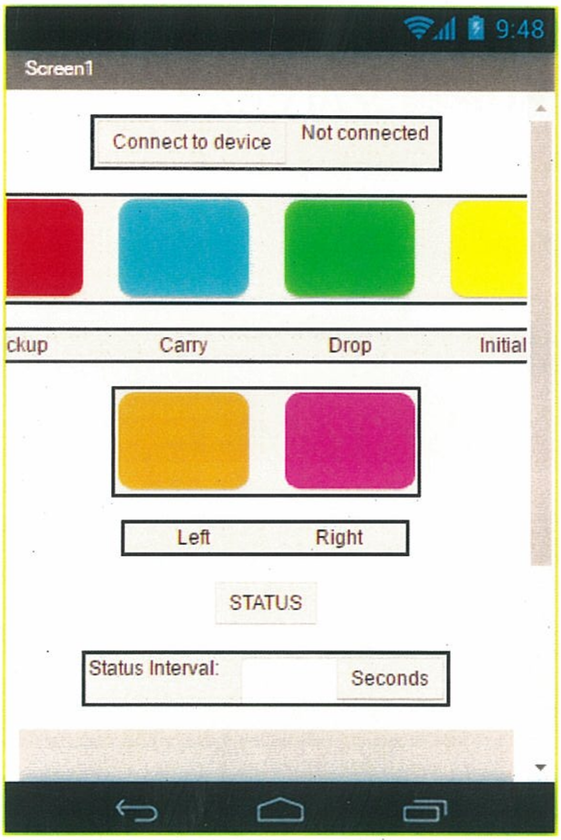

Figure 3.14: Design of Arm Controlled App

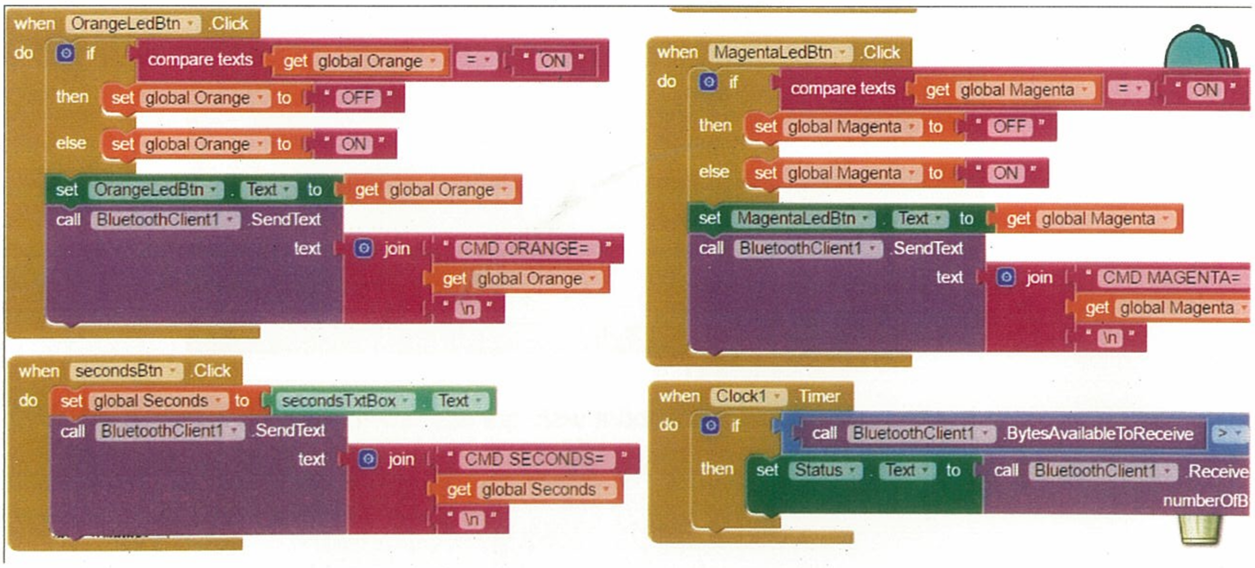

Figure 3.15: Blocks of Car controlled App

CHAPTER 4
RESULTS AND DISCUSSION

The final implementation of the car is shown in Figure 4.1. Figure 4.2 shows the top view of the car fitted with robotic arm.

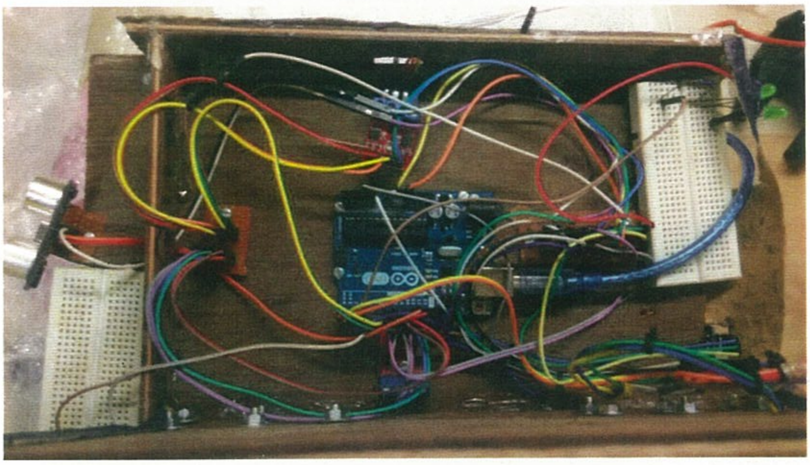

Figure 4.1: Implementation of the car

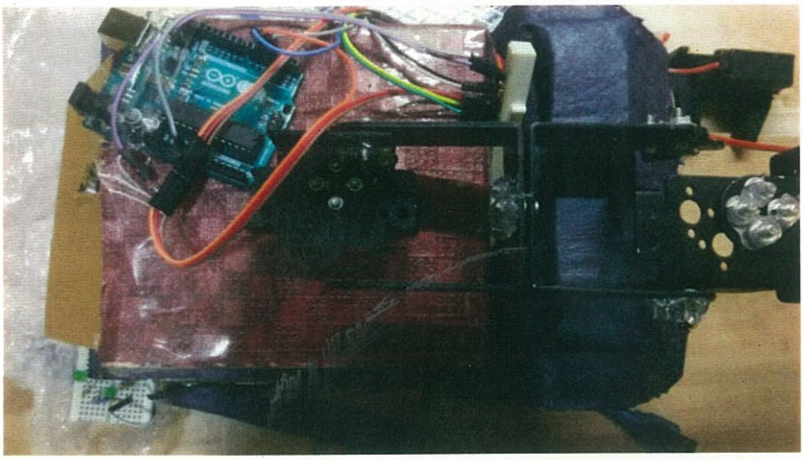

Figure 4.2: The top view robotic car with the arm

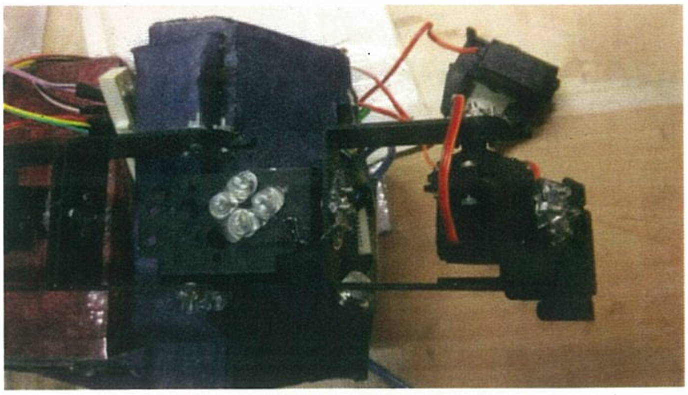

Figure 4.3: The robotic arm

Figure 4.4: Side view of the car

Figure 4.3 and Figure 4.4 show the robotic arm and side view of the car respectively.

CHAPTER 5
APPLICATION AND FUTURE SCOPE

5.1 APPLICATION OF THE PROTOTYPE

The robotic arm can be used in many military and industrial applications. The robotic arm can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. For example, robot arms in automotive assembly line perform a variety of tasks such as wielding and parts rotation and placement during assembly.

In space, the space shuttle Remote Manipulator System, have multi degree of freedom robotic arms that are used to perform a variety of tasks such as inspections of the Space Shuttle using a specially deployed boom with cameras and sensors attached at the end effector.

The robot arms can be autonomous or controlled manually and can be used to perform a variety of tasks with great accuracy. The robotic arm can be fixed or mobile (i.e. wheeled) and can be designed for industrial or home applications. Robotic hands often have built-in pressure sensors that tell the computer how hard the robot is gripping a particular object. This keeps the robot from dropping or breaking whatever it is carrying. Other end effectors include blowtorches, drills and spray painters, which can improve their performance.

In medical science: "Neuroarm" uses miniaturized tools such as laser scalpels with pinpoint accuracy and it can also perform soft tissue manipulation, needle insertion, suturing, and cauterization.

In search and rescue operations, the armcanpick up the saviors and transfer them to a safe place. It can be used to clear the path of debris or any other object obstructing the path for rescuers.

5.2 FUTURE SCOPE

- One of the major drawbacks is the robot cannot reach high places or cannot move through heavy debris. This can be overcome by converting the bot into a quad copter. This will help the bot to fly in places where the bot can't reach by driving.
- Other scope is to make it self-sufficient by adding solar powered batteries or by generating the power through the heat being generated inside the fire.

- As the arm cannot handle heavy weight, the design of arm should be considered. Instead of using normal servo motor, high torque generating and high durability motors should be used.
- The arm and the car should be designed using heat resistant materials as the flames from the fire can harm it. Special care should be taken while designing the electrical components as the fire can harm the components which may hamper the working of the robot.

CHAPTER 6
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