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Swarm Robotics for Bomb Disposal

(S.R.B.D)

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❖ ABSTRACT

Swarm robotics is one of the most fascinating and new research areas of recent decades, and one of the grand challenges of robotics is the design of swarm robots that are self-sufficient. This can be crucial for robots exposed to environments that are unstructured or not easily accessible for a human operator, such as the inside of a blood vessel, a collapsed building, the deep sea, or the surface of another planet.

In this report, we present a comprehensive study on hardware architecture and several other important aspects of modular swarm robots, such as self-reconfigurable, self-replication, and self-assembly. The key factors in designing and building a group of swarm robots are cost and miniaturization with robustness, flexibility, and scalability. In robotics intelligence, self-assembly and self-reconfigurable are among the most important characteristics as they can add additional capabilities and functionality to swarm robots. Simulation and model design for swarm robotics is highly complex and expensive, especially when attempting to model the behavior of large swarm robot groups.

LIST OF ABBREVIATIONS AND TERMS

Abbreviations	Meaning
PSO(1)	Particle Swarm Optimization.
CGSR(2)	Cluster Head Gateway Switch Routing.
AI(3)	Artificial Intelligence.
SR(4)	Swarm Robotics.
ATR(5)	All Terrain Robots.
PTZ(6)	Pan–tilt–zoom.
IOT(7)	Internet Of Things.
UIDs(8)	Unique Identifiers.
AV(9)	Anti-vehicle.
AP(10)	Anti-personnel.
S/D(11)	Self-destruct mines.
R/D(12)	Remotely delivered or scatter able mines.
SEU(13)	Swarm-Enabling Unit.

1. INTRODUCTION

Swarm robotics is the study of how to coordinate large groups of relatively simple robots through the use of local rules. It takes its inspiration from societies of insects that can perform tasks that are beyond the capabilities of the individuals.

1.1 What is the problem?

The problem is the mine problem and its detection and removal methods.

1.2 Why is it interesting and important?

The strategies for humanitarian demining using low-cost robotic units. These strategies are focused on the construction of a suitable setup of robots for demining, and what technologies these robots should incorporate. The goal is to construct a simulation tool able to show the robots demining under various types of missions and find out if the setup, created in the work for this thesis, fulfills the detection requirements

1.3 Why is it hard? (Why do naive approaches fail?)

The need to adapt to changing environments has always been associated with the need for fault tolerance. In many systems, e.g. swarm robotics, the operational environment is often dynamic and unpredictable. Thus, the operation of these systems is often also affected by the environment in which they are deployed. In operation, these systems may experience undesirable behaviors, or more precisely anomalies, for a variety of reasons. These can be caused by faults in the system or be due to interactions with the environment. Therefore, the ability to tolerate failures as well as the interference from the environment is a sought-after feature in most systems.

1.4 Why hasn't it been solved before?

In swarm robotics, a robot swarm has always been characterized as having built-in fault tolerance capabilities due to the redundancy of robots in the system. However, with work has demonstrated that there are cases when redundancy alone is insufficient, in particular with partially failed robots in the system. Therefore, there is a need to provide an additional level of fault tolerance on top of those provided through redundancy. In addition, tolerance to interference from the environment should also be considered.

1.4.1 Types of mines:

1- The anti-personnel land mine:

“Anti-personnel (AP) [10] mine means a mine designed to be exploded by the presence, proximity or contact of a person and that will incapacitate injure or kill one or more persons.” (Mine Ban Treaty definition)

2- Anti-vehicle land mines:

An Anti-vehicle (AV) [9] mine is a device designed to detonate by more than 100 kilograms of pressure. The mine cannot distinguish between a tank and tractor and is as such just as dangerous as the AP mine.

3- Developments in land mine technology:

The development in land mine technology has made detection and removal of the land mines more and more difficult. Land Mines produced today are mostly in one of the following categories:

- Plastic mines.
- Remotely delivered (R/D) [12] or scatter able mines.
- Anti-handling devices.
- Self-destruct (S/D) [11] mines.

2. BACKGROUND RESEARCH AND RELATED WORK

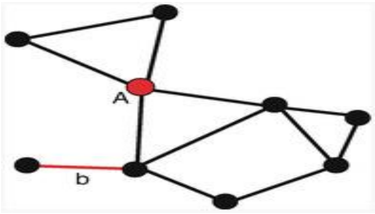
Comparison of swarm robotics and other systems:

	Swarm robotics	Multi-robot system	Sensor network	Multi-agent system
Population Size	Variation in great range	Small	Fixed	In a small range
Control	Decentralized and autonomous	Centralized or remote	Centralized or remote	Centralized or hierarchical or network
Homogeneity	Homogeneous	Usually heterogeneous	Homogeneous	Homogeneous or heterogeneous
Flexibility	High	Low	Low	Medium
Scalability	High	Low	Medium	Medium
Environment	Unknown	Known or unknown	Known	Known
Motion	Yes	Yes	No	Rare
Typical applications	Post-disaster relief Military application Dangerous application	Transportation Sensing Robot football	Surveillance Medical care Environmental protection	Net resources management Distributed control

2.1 Importance of swarm robotics:

There are three advantages of swarm robotics the first one is **Robustness**:

Robustness is defined as fault tolerance and fail-safety and it is achieved by massive redundancy and the avoidance of single-point-of-failures. An example for robustness in the next figure that obtain the interconnection between point A & B with the other points so if node A had failed the other points will be still connected to each other and they depend on themselves so there are a good redundancy also in swarm robotics system.



The second advantage is **flexibility**:

Due to quasi-homogeneity there is no specialization in terms of hardware. Each robot is able to complete the task of any other. The robots overcome limits in their capabilities by cooperation. Too weak actuators are compensated by the collective transport of objects, too low signal intensities are compensated by forming multi-hop communication lines of robots.

The third advantage is **scalability:**

can maintain its function while increasing its size without the need to redefine the way its parts interact because It’s not needed to do a control by algorithms in every robot because each of them depend on their neighbors locally. For example, incoming service requests might need to be registered at a central machine. As a consequence response times do not stay constant with increasing number of users and they also do not scale linearly but exponentially.

2.2 Most of similar projects:

- **Robot for Abandoned Mine**
  Super Droid Robots built the platform to carry camera equipment and an array of other sensors to get feedback from underground. The platform was waterproof up to 50 feet.
- **Tethered Fiber-Optic Robot**
  This robot was built to be sent hundreds of feet down a mineshaft. Since it has to travel such long distances, fiber-optic cable was used for minimal signal degradation. This robot is a modified version of IG42 SB Enclosed ATR (5) (All Terrain Robots) with 10" tiller tires, a pan-and-tilt system with a zoom camera, and a custom roll cage. Also built a spooler that would feed the fiber-optic cable on and off the spool.
- **Mine Inspection Robot**
  This robot was built to inspect potentially dangerous areas of a mine before sending humans in. It features a full HD video system with a PTZ (6) (Pan–tilt–zoom) camera, 10" tiller tires, and a custom wireless tablet interface with thumb joysticks.
  Hint: our project is combination of these three system and do an almost function but advanced.

2.3 Why our project is difference:

we used artificial intelligence and swarm robotics to have ability in detecting mines by using three robotics one main and two slavers , the main will detect the area of ground and to distinguish between metals and mines then order the other two slavers for crossing the clean area where there are no mines. In addition to increasing the level of human safety.

Our specific goals:

1- The ability to scan a land and detect its mines and surface bomb.
2- The ability to distinguish between metals and mines.
3- Ability to disposal the mine.

- We have designed it as a Swarm robots to the bomb disposal but there are a number of other applications of this robots. It can be **used by**:
  - ✓ **Police:** In hostage situations.
  - ✓ **Military:** For reconnaissance missions.
  - ✓ **Fire:** To provide video feedback of the site for analysis.
  - ✓ **Nuclear:** For handling hazardous or radioactive materials.

3. NOVELTY

3.1 Application scopes of swarm robotics

The study of robotics application in target search has grown substantially in the recent years. It is more preferable for the dangerous or inaccessible working area. The problems involved in swarm robotics research can be classified into two classes. One class of the problems is mainly based on the patterns, such as aggregation, cartography, migration, self-organizing grids, deployment of distributed agents and area coverage. Another class of problems focuses on the entities in the environment, e.g.

Searching for the targets, detecting the odor sources, locating the ore veins in wild field, foraging, rescuing the victims in disaster areas and etc. Besides these problems, the swarm robotics can also be involved into more sophisticated problems, mostly hybrid of these two classes, including cooperative transportation, demining, exploring a planet and navigating in large area. Several potential application scopes of swarm robotics which are very suitable are described below

3.2 Cooperative algorithms

Research on swarm robotics so far is still quite simple. Most of the algorithms are designed for every encountering application, but an algorithm with high usability has been undiscovered. A main reason for such situation is that there is still not a common and standard definition for swarm robotics system and application problems. The problems abstracted in swarm robotics research are in a wide variety with different problem definition and setups, and it's hard to provide a uniform description for all the problems. No benchmark test has yet been proposed. Therefore, different researching works can provide little experience to each other and these different algorithms cannot compare to each other easily. Thus the whole progress of swarm robotics research is still quite slow.

3.2.1 Features of swarm robotics algorithm

A swarm robotics algorithm must fit and make full use of the features of swarm robotics. The algorithm should explore the cooperation between robots and share some features with swarm robotics system. For example, Stirling et al. studied a swarm of flying robots searching in an indoor environment containing rooms and corridors. They introduced a strategy that saves energy significantly, i.e. the robots move one by one while all other robots pin to the roof to save energy. However, the swarm is required to transit the whole environment with very poor time efficiency. Since only one robot is moving at a time, the cooperative advantage of the swarm can hardly bring into play. It is hard to be classified as swarm robots algorithm in this case. Five features of swarm robotics algorithm are specially emphasized in this section: simple, scalable, decentralized, local and parallel.

3.3 Design of Swarm Robotics

Designing and analyzing self-organizing systems such as robotic swarms is a challenging task even though we have complete knowledge about the robot's interior. It is difficult to determine the individual robot's behavior based on the swarm behavior and vice versa due to the high number of agent–agent interactions. A step towards a solution of this problem is the development of appropriate models which accurately predict the swarm behavior based on a specified control algorithm. Such models would reduce the necessary number of time-consuming simulations and experiments during the design process of an algorithm.

4. METHODOLOGY

4.1 Project Description

It is well known that landmines are one of the biggest problem their wicked nature makes it extremely difficult, and in some cases impossible, to locate them using traditional sensors. In addition, landmines are typically placed in hard-to-navigate environments, to avoid risk the robotics intervention in mine detection

The main categories of operations that have been taken into consideration for a possible **introduction of robots are:**

- Surface preparation and marking.
- Actual detection.
- Mine removal or neutralization.

So we'll use the robot swarm the particle swarm this approach was inspired from the biological study of ants another insect of demeanor of collective migration and interaction with their surroundings. These insects coordinate using decentralized control and self-organization. The robot swarm consists of one robot (master) and three slaves This application deals with the detection of mines in an unfamiliar environment The master draws a map on a Simulation that locates mines After detecting the mine, they record its position and send its position to all other slaves robots which are in the network, so that they may also avoid those mines, This avoids repetitive detection and position updating of a particular mine.

A table for the recorded position is created having the coordinate positions of detected land mines. Different robots are given different target positions to reach and in the course of their navigation whenever they come across a particular land mine, updating process of position starts. Their coordinating approach minimizes the overall effort of robots since they do not have to cover whole area of navigation, which being another advantage of multi robots. They thus can explore wider area simultaneously with detection. If the thing in the earth is a metal or anything other than a mine, one of the slaves has given a signal to the rest of the robots that this place has been searched and there is anything other than a mine so that they do not approach this place again. If a mine is given a warning

4.2 Architecture

In this section, we present an architecture where multi-robots will be coordinating and communicating to perform a task efficiently. Where multiple coordination and communication algorithms are compared on the basis of their performance, time and space complexes we have concluded that CGSR[2] and PSO[1] for communication and coordination are respectively better than other approaches.

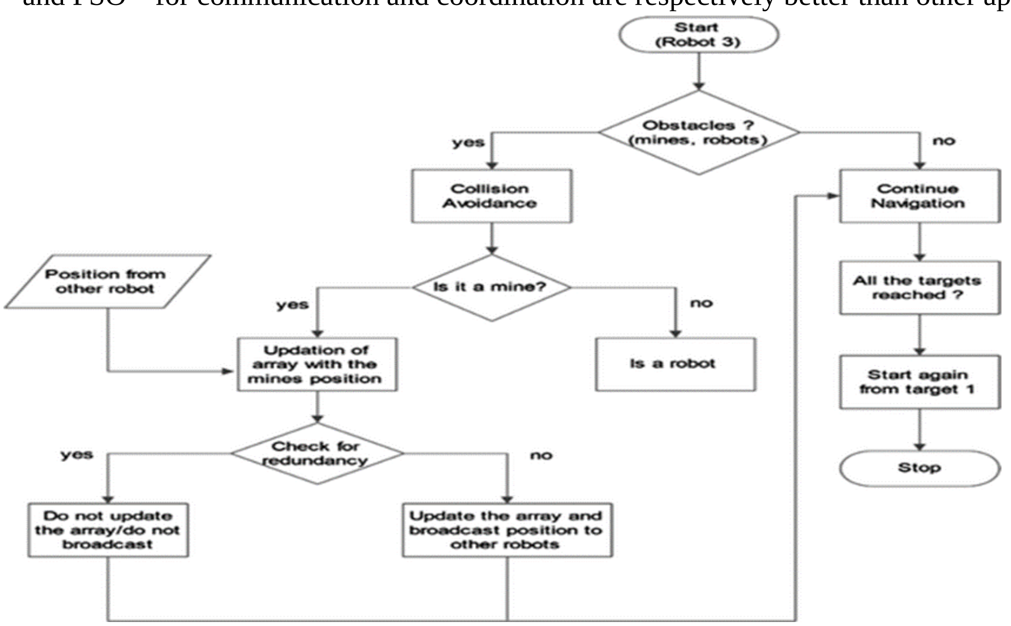


Fig. 1 Flow diagram depicting the working of application

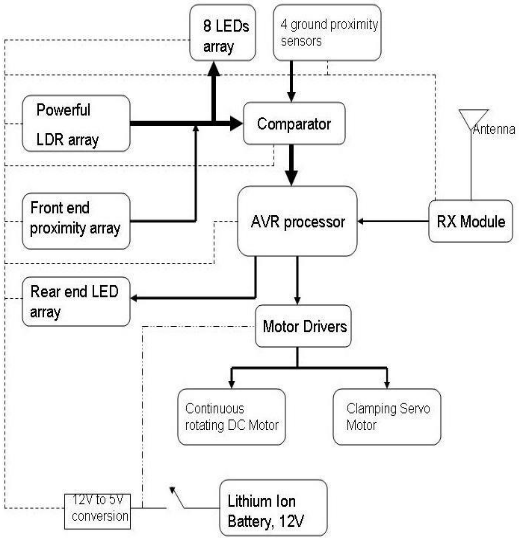


Fig 2 Control System at the Master-bot end

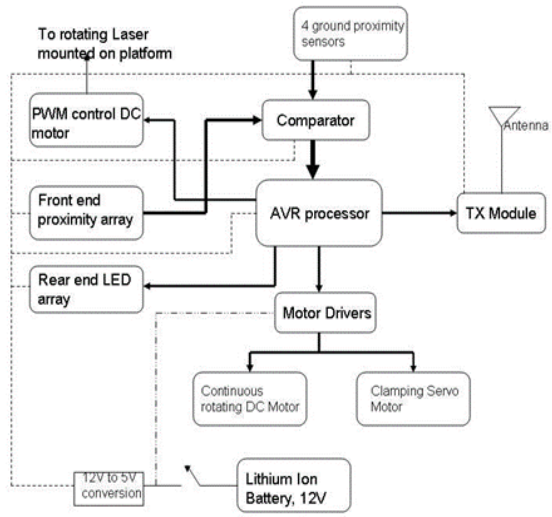


Fig 3 Control System at the Slave-bot end

Note: These are just examples and we have not actually implemented those (Architecture & Algorithm)

4.3 Algorithm

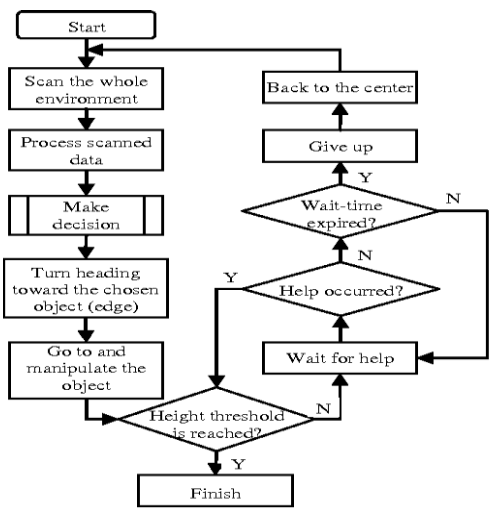


Fig 4 Working algorithm of each robot

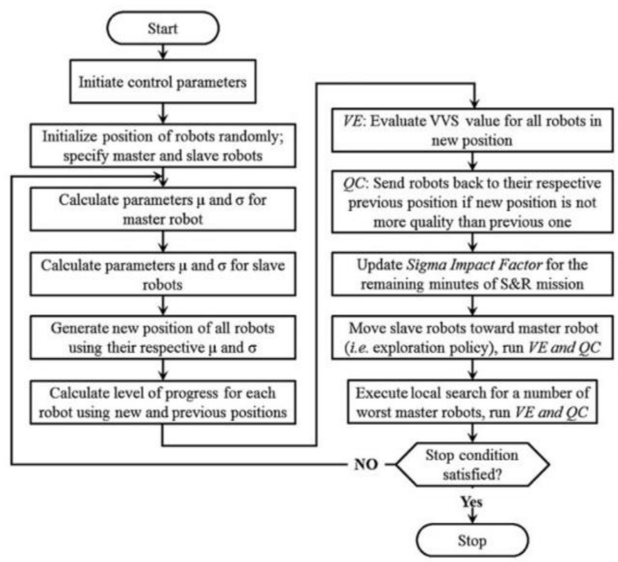


Fig 5 Flow chart SRSR algorithm

4.4 Error Analysis

Given the fact that there is no single sensor to determine the location of any type of landmines There are two possible solutions: one is the installation of all the necessary sensors on one vehicle, while the less conventional use is the use of several vehicles, each equipped with one sensor since the use of one sensor calls for a smaller, lighter and simpler robot, while completing the task requires cooperation between several units, which in turn poses issues of information exchange.

4.5 Special Case

A special case here is that we use the Robotics Squadron as its basic idea of nature to solve a problem in nature through artificial intelligence and self-learning of the robotics.

4.6 Technologies

4.6.1 AI (Artificial Intelligence)

AI (artificial intelligence) is the simulation of human intelligence processes by machines... These processes include learning (the acquisition of information and rules for using the information), reasoning (using the rules to reach approximate or definite conclusions) and self-correction.

Types of artificial intelligence:

• Narrow AI[(3)]

• General AI[((3)]

4.6.2 Embedded System

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system.

4.6.3 The Internet of Things

The internet of things, or IOT[(7)], is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs)[(8)] and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

5. HIGH LEVEL ARCHITECTURE OF THE SYSTEM

To enable swarming, it is essential to achieve distributed communication and decentralized decision between a particular robot and the swarm and is composed of a communication module and a processing unit running code using the marabunta module. At the software level, each Slave is composed of three elements.

First, the “body” interacts with the robot to control its movement and gather information from its state and sensed environmental data. Second, the “network” interacts with the communication module to broadcast the current state of the agent to the swarm and to gather information from other agents’ state. Third, the “behavior” contains the cooperative control strategy. In its most elementary form, the behavior is implemented by an update rule that defines the movement of the robot for a certain time window, given the current state of the robot and these data gathered from the body and the network

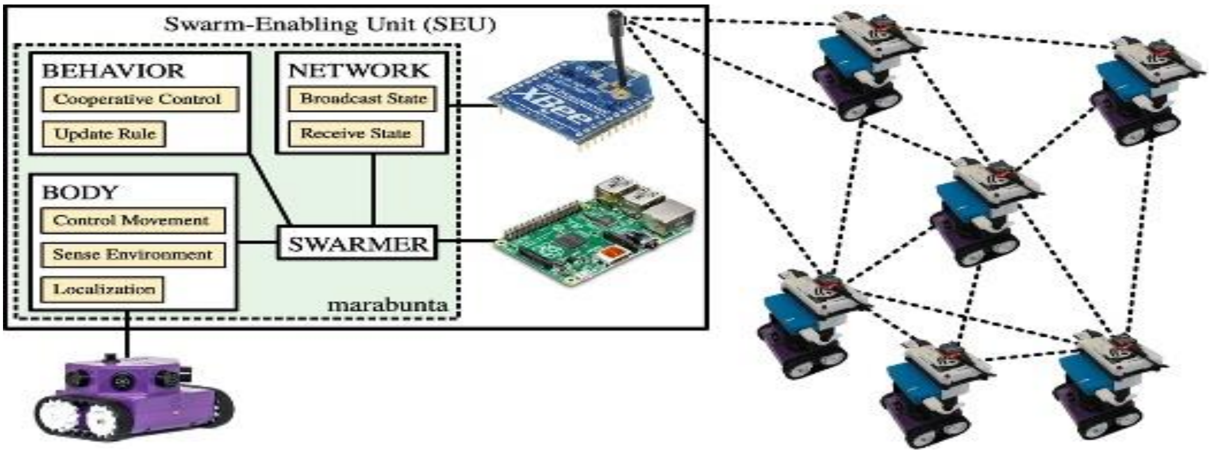


Fig. 6. The Hardware Block diagram of the swarm-enabling unit (SEU [(13)]).

Swarm robotics contains wireless connections that rely on Wi-Fi custom-design between master and slave, as well as an overhead position tracking system. The software stack extends from robot-specific firmware to the back-end server software, which consists of the simulation infrastructure and interface components (APIs that allow users to write their algorithms in higher languages) and server application coordination.

Swarm robotics includes components that are performed locally on the basic swarm architecture the remaining components deal with user administration using AI.

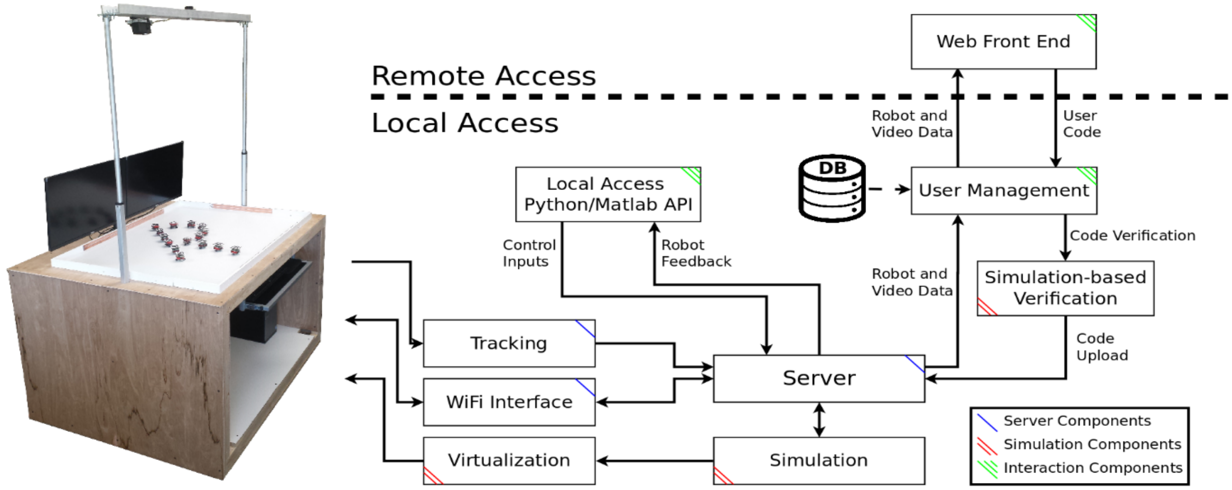


Fig. 7 System architecture overview

Note: These are just examples and we have not actually implemented

6. RESOURCES

Most swarm intelligence researches are inspired from how the nature swarms, such as social insects, fishes or mammals, interact with each other in the swarm in real life. These swarms range in size from a few individuals living in the small natural areas to highly organized colonies that may occupy the large territories and consist of more than millions of individuals.

The group behaviors emerging in the swarms show great flexibility and robustness, such as path planning, nest constructing, task allocation and many other complex collective behaviors in various nature swarm. The individuals in the nature swarm shows very poor abilities, yet the complex group behaviors can emerge in the whole swarm, such as migrating of bird crowds and fish schools, and foraging of ant and bee colonies.

It's tough for an individual to complete the task itself, even a human being without certain experiences finds it difficultly, but a swarm of animals can handle it easily. So we thought about this project and in this idea to reduce the problem of mines and bombs with less cost, more accuracy and less time.

7. TEST AND RESULTS

In our project, we have tried to solve the problem of mines in a new and more effective way than the existing ones. We have turned to the new theories and methods used in technology. Where we used a group of robots consisting of the Master and Slaves to form an organization called Swarm Robotics, where the Master survey of a piece of land after lifting the space and divided into squares to facilitate the search, and the main task of the Master is to mapping a specific land where the presence of any kind of Minerals, and task batches complemented by slaves where they take the information and analyze it and identify the safe paths they will take to clear the ground again to determine if this point is a mine or just a piece of metal.

After each of the Slaves determine a point and have the information that this point is a mine or just a piece of metal that publishes information between him and the Master and Slaves, so as to accelerate the completion of the task in a safe and effective and higher accuracy and a less faulty. The final result is a map of the minefields with high accuracy, so that the Slaves can then dismantle and destroy the mines.

In our Project:

We will help gas and oil companies, Agriculture, tourism, and etc.

Our project will help all countries not only Egypt to overcome of the Ghost of mines to increase the investment projects that develop the economy and the Investment projects that disrupt the work due this problem and of course to saving the lives of people.

At present, this idea has not been tried because we are still working on it at the moment.

8. PRODUCT FEATURES

- That our application has many uses which will be useful to the community where the swarms of robots can do many tasks using the technique of artificial Intelligence to detection underground mine and surface bomb.
  - The discovery of underground landmines and surface bombs and know their type and the ability to deal with them and dismantle them.
  - This project can be used in mineral exploration and gold mining operations, where in Egypt a lot of land full of mines and impeding investment of these lands in mineral prospecting and gold and oil and gas and invest in construction and industry and agriculture. And there must be an innovative solution to that problem.
  - Civil protection forces can use our app in the rescue from fire accidents and earthquakes and people under rubble.
  - Army Special Forces can uses our project in combat operations and reconnaissance operations by up to assist them in their tasks and provide them with adequate information for the success of the process and to secure the lives of soldiers during these operations.
  - The police can use secure ambushes that are held on ways to avoid accidents and terrorist attacks against police forces in bombing ambushes and killing their members and can also be used by police special forces in the insurance operations or hostage rescue operations or reconnaissance operations.
  - From the main applications that we will work in the future is an area of discover space, where we want development in our project becomes probes launched into space to explore the planets and space but with new technology called swarms of probes.
- I think with the potential requirements will produce a unique product able to change many things and will be a great thing to work and development of the project like this to benefit society and the people in all fields to by a new innovation way and different.

9. PRACTICAL DEPLOYMENT

Autonomous artificial swarms of robots could enable new approaches for search and rescue missions, construction efforts, environmental remediation, and medical applications. Our project is a new and innovative idea that helps people know where mines are located without jeopardizing them, which are useful in hard to reach environments. It is implemented by Internet objects, industrial automation, and artificial intelligence and embedded systems.

Swarm technique it is possible to develop a robotic structure and algorithm, depending on how the octopus works. Instead of working as slaves in the head, technology is used in the development toolkit based on the five principles of intelligence of the swarm: awareness, independence, rigidity, expansion and flexibility.

Can be developed according to environment and market needs. For example, if in the desert it is possible to change the wheels with the strongest wheels to withstand heights. The main robot can be replaced by drones that scan the ground site, locate mines and send data to slaves. This includes higher accuracy in the location of the mines and the speed of implementation. The sensors can be developed inside the robot based on the function used.

10. VALUE

- The Value of our Project is Reduce human losses and benefit from the huge natural resources development revenues in those areas that are currently held hostage by mines, exploitation of mineral, petroleum resources, and a number of lands suitable for agricultural development and reclamation of arable land.
- Where we are developing **SWARM ROBOTS** operating in a variety of situations, low cost and energy saving.

10.1 Market Size

10.1.1 Target Segments

1. Armed Forces.
2. Mining Companies.
3. Gold Factories.
4. Petroleum Companies.
5. Countries that Contaminated with Land Mines and Bomb.

10.1.2 Number of Target Customers

- Landmines pose a threat to more than **80** countries, there are estimated to be around **110** million anti-personnel mines in the ground and another **100** million stockpiled around the world and there are a lot of Mining Companies all over the World.

10.1.3 Calculating potential sales

- We are confident that the sales rate of the product will be significantly increased due to the product's benefit to the entire world.
- Size of consumer Robotics Market is projected to reach Billions, 2020-2025.

- So the project price is likely to be from **160.000** L.E to **200.000** L.E and this is depending on market needs.

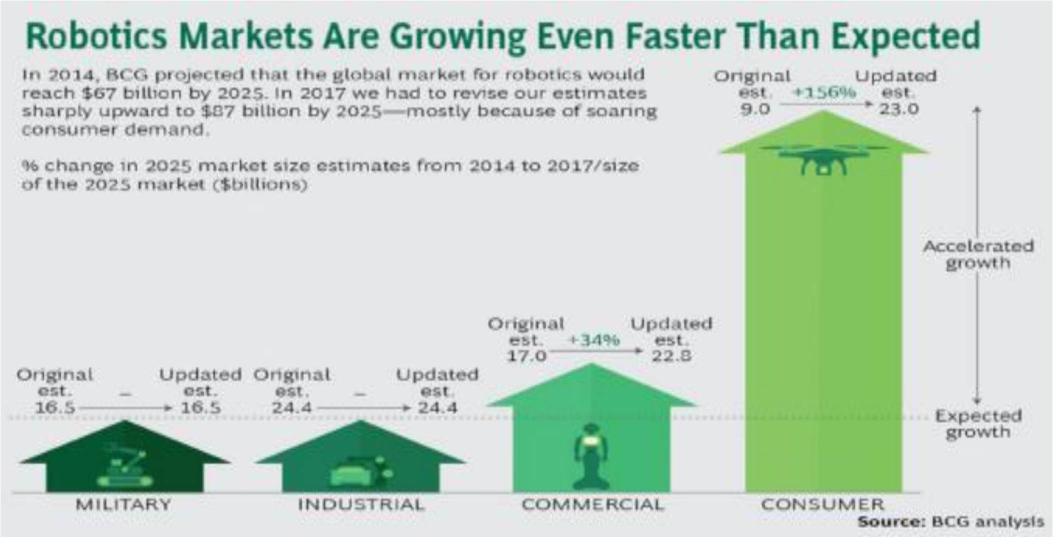


Fig.8 Robotics industry growing faster than expected

10.1.4 Cost Structure

- After conducting a feasibility study for the project, we expect the total cost of the project to be from 60,000 LE to 80,000 LE, It is also possible that it may actually cost less money.

❖ CONCLUSION

Robots go where humans fear to tread. They have many applications, bomb disposal is one of the most dangerous application where the risk of death lurks with every move. We have many bomb disposal robots but what make our project more intelligent and creative we added two main ideas that made the project more powerful than ever. We used AI[(3)] – SR[(4)].

So we have the idea which is one single robot that controlled by human and we give it the location that it will treat or face a bomb in. but in our project we have Swarm robots that will do scanning and treating with area without interfacing of human with AI. In addition using the technique of Swarm Robotic and Artificial Intelligence make the project can be used in many cases and much better in speed and accuracy than the single robot.

In our project we used swarm robots so we can dispose many bombs in the same time and we can also secure a specific area that we doubt if this a bomb or just a normal metal. At the end, we’ve been in this research through how we could create swarm robots with Artificial Intelligence that we could use them in our project much better than single robot without AI[(3)].

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