DERRT: Disastrous Emergency Response Robot Team for Cooperative Rescue

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***Abstract*—Even though different technologies have been invented to predict natural disasters, we cannot avoid people getting injured or dying. Every time, after a natural disaster, although lots of rescue teams from different parties have been involved in relieving the victims, there are still so many casualties. Therefore, we have proposed a cooperative rescue robot system, called Disastrous Emergency Response Robot Team (DERRT). DERRT is a team of cooperative robots integrated with a great variety of equipment for the sake of saving lives. Basically, our team consists of 4 types of robots, named as "Coordinator", "Crusher", "Saver" and "Lifter". They work collaboratively, which depends on the kind of situation that they face. In this positioning paper, applied technologies, limitations as well as possible extensions of the system are fully discussed.**

***Index Terms*—cooperative robots, disaster rescue, robot, common core curriculum**

I. Introduction

WITH the advanced development in the recent two centuries, our living standard has no doubt improved a lot. When we enjoy the fruits of technology, we also, meanwhile, create a spite of adverse impacts on our living planet. In response to human's activities, our Mother Earth brings us more and more catastrophic disasters such as severe flooding, stronger typhoons and more extreme weather. Apart from these, even though so many precise devices have been invented to predict other natural disasters like earthquake now, we cannot avoid people getting injured or dying. Every time, after a natural disaster, although lots of rescue teams from different parties have been involved in relieving the victims, there are still so many casualties. Therefore, different robots had been developed for rescue purposes [1]–[10].

In order to save as many casualties as possible, we have proposed a cooperative rescue system, called Disastrous Emergency Response Robot Team (DERRT). Its major job is to assist rescue teams to revive more victims lives. DERRT is a team of robots integrated with a great variety of equipment for the sake of saving lives from different natural disasters. Basically, our team consists of 4 types of robots, which can combine together to deal with different scenarios, named "Coordinator", "Crusher", "Saver" and "Lifter". All of them carry different equipment and serve different purposes. They can also work individually, which depends on what kind of situation that they face.

In this positioning paper, Sections II, III and IV describe the system features, technical implementation concerns and possible future developments, respectively. Finally, limitations of the current system are discussed in Section V.

II. Features and Benefits of DERRT

DERRT can change their equipment base on different adverse scenarios. For example, when there is a blaze, some of the robots will carry more water or fire extinguisher. With regard to other cases like a ship sinking accident, they may use the same space to change their equipment into water vacuole to make them float instead. Descriptions of the robots are as follow.

A. Coordinator

"Coordinator" acts as the brain of the team. It has an advanced AI system and sensors so that it can operate the analysis of the entire situation itself. For example, it has a vibration sensor to monitor the magnitude of earth movement and the vibration due to the wind all the time and provide updated information for themselves and other rescue team as well. Meanwhile, an infra-red sensor and sound detector will be also included so as to locate all the victims inside the collapsed structure. Then, it will coordinate the other three robots to choose the easiest way to save the victim.

B. Crusher

As its name stated, "Crusher" is to clear all the obstacles that it encounters and provides a smooth pathway for others to get deeper to the debris. First of all, several cameras in different directions will be installed on the "Crusher" to let people monitor the situation. It is also equipped with small but powerful drills, saws and welding equipment which can cut the obstacles in pieces. In addition, if the pathway is too narrow, "Crusher" is also equipped with some pistons along its body. These pistons act as a hammer to expand the route so that other robots and also people can have enough space to pass through.

C. Lifter

Since not all the pathways of "Crusher" created are stable, some extra supports are required to hold the route. As a result, its major functions are to act as a small column to support the unstable point and lift up some heavy things in order to allow others to pass through. Therefore, its main body will serve as a storage tank which stores a variety of supporting gears.

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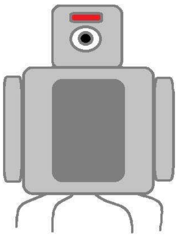

Fig. 1. Robot “Coordinator”.

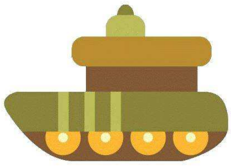

Fig. 2. Robot “Crusher”.

D. Saver

“Saver” is the most complex robot which has lots of sensors, equipment and an AI system to operate. First and foremost, it has AED (Automated External Defibrillator) to revive victims who are almost dead or just stop breathing. Additionally, respirators and sensors monitoring human pulse will be added to this robot. If it detects that someone has weak pulse, it will send a request to “Coordinator” in order to rescue the victim first. Then, the “Coordinator” will provide detailed information to the base station and let the station officer make a decision.

Aside from these, a small storage tank with high energy food, like chocolate, and water will be one of the components of the robot. When the robot discovers a victim from the scene, food can be delivered directly. More importantly, it is equipped with communication devices so the victims can communicate with their relatives and gain spiritual support from them. Meanwhile, the rescue team can know more about the situation. Apart from these life-maintaining devices, “Saver” can add some devices optionally. If there is a fire near the victim, it can be equipped with a small fire extinguisher to put out the fire in order to minimize the danger imposed on that victim.

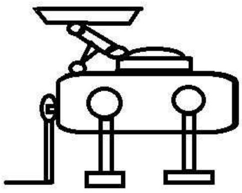

Fig. 3. Robot “Lifter”.

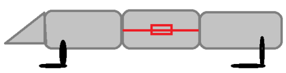

Fig. 4. Robot “Saver”.

III. Applied Technologies

A. Wireless Nested Network System (WNNS)

A typical robot team has four robots and they are all connected via Bluetooth or other wireless communication technology, where “Coordinator” will serve as a brain in the team. By using this technology, the robots can exchange the data with each other. For example, the “Coordinator” can use this technique to receive different kinds of information gathered by others robots. After the analysis, “Coordinator” can transfer the commands it generates back to the other robots in the team in order to complete their missions. At the same time, other robots in the team can communicate with each other to execute the commands.

A control center (mother ship) with a proton computer can be developed to coordinate all the “Coordinators”, gather and analyze all the information from different teams and give a general view of crisis. The control center will analyze and give different commands to different teams. Each “Coordinator” of the teams can share the information and form a giant nested network system which looks like a spider web. This system can help us to deal with a large area of disastrous emergency such as earthquake or tsunami in a more effective way with a large number of teams.

B. Artificial Intelligence (AI)

AI is a technology that studies and develops the intelligent decision system which involves a lot of technical aspects. At the present stage, AI in DERRT can be mainly divided into two types, “Central AI” and “Peripheral AI”. “Central AI” is a primary goal of AI which allow the objects to act like human beings. It enables objects to think, communicate and move to complete different tasks. Meanwhile, “Peripheral AI” is a specific AI technology aspect that will let the objects to perform some actions with analysis, but basically not intelligent as human beings. In our team, we will use “Central AI” as the central processing unit of the coordinator as it has to act as a brain of the team while the other robots will own a “Peripheral AI” which offers them the ability to complete some tasks.

1) Coordinator: The “Central AI” will provide the coordinator with abilities to integrate and summarize the information received from other robots. It has stored a large variety of commands in order to deal with different situations. Based on different information, for example the images recorded from the camera or the vibration recorded from the vibration sensor, the coordinator will find the most suitable cooperative rescue solution and command for the other robots to take action. However, this solution is only a general direction for the robots to perform. For example, the coordinator has detected there is a survivor under the collapsed structure. It then analyzes the situation with different information and come up with a rescue plan. After that a general direction of goal will be given to the robots. For instance, the coordinator will only give a command *“Crush down the block”* to Crusher, but not a command *“Use hammer to crush down the block”*. The way to execute the command will be the duty of other robots.

Moreover, the “Central AI” enables the coordinator to define what to do first. It can set different goals and put

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them into different priority by sorting. This can make the rescue mission more effective.

2) Crusher: The “Peripheral AI” has stored some commands that fit into solving specific problems. The “Peripheral AI” of “Crusher” will analyze the command given by the “Coordinator”, which is the general direction of the missions. It then generates the most suitable strategy and executes the command in the way the AI suggests. For example, the “Coordinator” has detected there is a survivor under the collapsed structure. It then gives a general command *“Crush down the block”* to the “Crusher”. “Crusher” will collect the information of the block by its sensor and analyze the situation. After that, “Crusher” will generate a command *“Use the hammer to crush down the block”*. The path is then clear and the team can proceed on the next mission.

3) Lifter: Similarly, the “Peripheral AI” of “Lifter” will analyze the command given by the “Coordinator” and executes the command in the way the “Peripheral AI” suggests. For example, after the “Crusher” has crushed down the block, there are some heavy things on top of the survivor. The “Coordinator” will then command “Lifter” to *“lift up the heavy things”*. “Lifter” will then analyze and execute the command *“Use the machine arm to lift up the heavy thing”*. The survivor will then feel more comfortable and the next goal of rescue can be performed.

4) Saver: Similarly, the “Peripheral AI” of “Saver” will analyze the command given by the “Coordinator” and executes the command in the way the “Peripheral AI” suggests. For example, after the “Crusher” has cleared the path and the “Lifter” has lifted up the collapsed structure, the “Coordinator” will give a command *“Save the person”* to the “Saver”. “Saver” will then obtain the information by scanning the situation of the person and find that the person is going to die. It then analyzes all the information and gives a command *“Use the AED to save the person who is almost dead”*. Thus, the person will get the immediate rescue and own a higher chance to survive.

C. Global Positioning System (GPS)

GPS has been implemented in our robots which gives information of the time and location of the robots over the satellite. As the robots can detect the survivors and give them emergent help, the location of survivors can be recorded at the same time which can allow the rescuer to go there without doing much effort to search for survivors. The rescue mission is then become more effective.

In a rescue mission, there exists a lot of dangerous situation such as aftershock. Our robots may get damaged in those dangerous situations and lose their contact with the base. If our robots suddenly lose contact with the base, GPS can provide the last record of their location and the time, which can let us find the remains back or to check what has happened by using a satellite telescope in order to avoid more loss and give a quick response to the situation.

D. Augmented Reality (AR)

AR is a technology which can provide an over view of the situation. It is useful when it combines with the future development of WNNS. As long as the robots are moving, the camera on robots will record the environment and the image will be grouped and be shown in the center in a 3-D projection. This can help the people in the center to get into the situation faster and a better coordination among every aspect can be done. For example, there are some workers trapped in the coal mine after the explosion. Since the coal mine may consist of many branches and people may be separated in different places, it is hard for the rescuer to search. DERRT can help to give an overview of the coal mine as long as they are getting deeper and record the environment and the situation of the survivors. Therefore, the rescuer can locate and save the survivors in a more efficient way.

E. Life Detect and Record System (LDRS)

LDRS is a system that people can use to detect and record the symptom of life of the survivors. Life detection will mainly be performed by the “Coordinator” as it has the most computational power. We can implement the Infra-red thermography (IRT) which is a technology to detect the radiation in the infrared range of spectrum. The infrared sensor (thermographic camera) will be the primary sensor to detect whether there is any survivor by reading the measurement. The system will also record the visual representation of pulse, heart beat rate and other symptoms of life detected by different sensors from the robots. Those symptoms will be analyzed and a survival rate will be generated. This survival rate is the indicator which a person has the chance to survive onward. This can help the rescuer to find out who is the one that needs most immediate support and improve the rescue efficiency.

F. Case Study: Applications of DERRT in the Earthquake Rescue

There is no doubt that the application of DERRT can be very extensive as long as there is any disaster occurring Ranging from a blaze to a super typhoon, DERRT can always serve as an alternative.

Take Sichuan earthquake as an example. After earthquake, although hundreds and thousands of rescue workers rushed into the disaster area, the majority of the roads were blocked by giant rocks. It took several hours to open the route to let people pass through. During that period, if DERRT had been invented, more lives would have been saved. Since they are not too big and heavy, the air force can drop DERRTs from air without seriously defect. Then, they can work automatically.

At the beginning, once DERRTs arrived, they would divide themselves into different groups. Each group would still have those four robots. The “Coordinator” started to use its built-in system and apparatus to analyze the region and find out where all the victims locate continuously. Consequently, it would give some basic command to the other three robots and send all the data to the rescue team such that they could establish a comprehensive plan to rescue as many people as possible.

Afterwards, the other three robots would follow the information and the instructions given by the “Coordinator” to work separately. First, “Crusher” followed by “Lifter” would create a suitable path for “Saver” to provide first-aid treatment to the victims. And then, they would find another victim and repeat the same process until the victims are saved.

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G. Problems to Be Solved

We have used lots of advanced technologies on DERRT in order to perform its main goal. However, some of the technologies have not been fully developed and thus our DERRT is still a conceptual idea. To make our robot team come to reality, there is still something we need to solve.

- To make the WNNS work, we need to enlarge the working distance of wireless communication.
- To make the robots perfectly run, advanced AI is indispensable. We need to develop AI that can perform different goals in a faster way than now.
- AR is probably a new technology which has not been fully developed yet. But it is essential to the control of the situation by human beings and it can make our WNNS being more concrete.
- To enable the robots to withstand the harsh condition of mission, some hardware has to be developed. This will be discussed in Section IV.

These problems are not in our project scope. However, some of these technologies are being researched. We hope that we can see DERRT come to reality in the near future.

IV. Further Extension

A. Extension for Robots

1) Coordinator: Accuracy of coordination is our main concern. We want to minimize the deviation which the local environment in the scenario made. An efficient computation platform is then expected to lower the chance of deviation. The platform muse be reliable such that the coordinator can work accurately.

2) Crusher: Rock stiffness identifying equipment can help judge the hardness of the rocks. In particular, the equipment should identify the water, material and mineral content of the rock in front of it and then automatically match up with the content in the database to take the best action.

3) Lifter: Multiple lifting hands and self-scarification are being looked forward to. Multiple lifting hands can deal with more than one situation once. In reality, situations do not come on their own, but with series of problems following concurrently. Multiple lifting hands have the ability to deal with more than one situation whenever they happen. A self-scarification model should be included in the lifter system. A motion sensor should be included to calculate forces and speed whenever there is an accidental structure collapse. It can scarify itself to protect the supporting point form being destroyed which may cause even a higher degree of disastrous events.

4) Saver: The main purpose of a saver is to maintain lives before they are rescued. But then, there are problems for transporting the supplies to people who are in need with a tiny little body of a saver. Therefore, a compacted saving kit should be able to contain a one-day-basic supply for a normal people with water, energy and oxygen.

B. Extensions for the System

DERRT has two biggest challenges, which are robot energy sources and distance limitation of wireless communications.

1) High-Performance Battery: With the functions mentioned, lots of energy is dissipated. As a result, a high energy support is essential to maintain the operation of all robots. Therefore, we need to use a high-performance battery, with small size, to tackle the problem. A long usage time is essential for the robots to take up their missions as they are mostly likely serving 24 hours each and every time.

2) Long-ranged Wireless Communications: Long-ranged wireless communication technologies can help in tackle the distance limitation for robots to contact. This idea could help DERRT in a stable service status without any disconnecting risking lives of people.

3) Robots with New Functionalities: In terms of technological design, DERRT would be expected to increase its team members, serving even more purposes under the original system. Flexible joints are designed on each robot in DERRT, and this sets no limit on the usage of each kind of robot as most newly invented parts are suitable for every robot to carry. Different scenarios could be fit to different featured DERRT.

C. Applications of DERRT in Other Situations

In terms of usage, DERRT is expected to serve the whole world whenever there are disastrous events. We expect that when robot technologies are mature enough for mass production, the whole world would rely on them to deal with difficult cases, for example, rescuing lives in remote areas which vehicles can hardly approach.

Moreover, we expect that the robot do not only serve the rescuing purpose, but also discovery. DERRT is initially equipped with four team robots which help locate objects, and this feature can be used in various aspects. Apart from different kinds of sensors and networking, DERRT can be a very flexible team which can equipped with other features such as rock collecting equipment. The new advanced feature parts are expected to help discovered nowadays unreached lands, like the deep sea, underground or even the space. We could use DERRT with space-oriented equipment to examine landscapes, climate, organic or lives activities or even its resources on Mars, for instance.

V. Limitations and Suggestions

The theoretical DERRT is no doubt perfect in facing any difficult situations. To tackle various adverse scenarios, DERRT will equip with different useful tools. For example, “Saver” may be distributed while earthquake to search for any victims alive. “Crusher” maybe used to drill rock into breccia for emergency exit. “Lifter” can be used for sustaining the unstable point and lift up heavy things besides cracking them. Nevertheless, when they are put into practice, constraints would appear and the operation of DERRT may be restricted.

As a result, limitations must be found out in advance, in order to minimize the operational risk when DERRT is run in reality. In the following, suggestions are figured out so as to improve the system of DERRT.

A. Coordinator

As mentioned, “Coordinator” has a vibration sensor to supervise the extent of earth movement. For instance, it must be fixed at a position which experiences no change of magnitude of earth movement. Otherwise, it will provide unreal data for themselves to identify earthquake or tsunami disasters. Also, it is equipped with wind sensor so it needs to be located at a position with obvious wind variation. Indeed, the selection of location is very important and this affects much to the accuracy of predications and coordinations.

On the other hand, the infra-red sensor and sound detector are installed in it. The distance measured between the "Co-ordinator" and the victims should be accurately calculated. Different equations related to heat and distance must be taken into account to estimate the distance. For the sound detection, for example in an earthquake condition, the reflection of sound inside the rocks will create interference. Even though victims emit sound to call for help, the sound will be deflected or disturbed and clear sound cannot be heard by the "Coordinator".

B. Crusher

"Crusher" equipped with drills, saws and welding tools can divide obstacles into small pieces. In reality, materials consist of wide range of hardness. Only for rock, the stiffness and hardness differ a lot with various species. It will be difficult for "Crusher" to identify the rock type. Although it is installed with cameras, rock cannot be analyzed due to the dark situation. Even the cameras are equipped with flashlight, the rock type may not be identified every-time.

As a result, wrong hardness of drill may be used to crack unknown type of rock. This will highly increase the probability of damage of drills. Therefore, it is suggested that diamond which is the hardest material in the world should be used to clear all the obstacles. However, it may not be cost-effective.

C. Lifter

Loads are applied to provide extra support to hold the route. This is the main duty of "Lifter". Mechanical arms provide forces to sustain the lifting. However, in a tiny robot, what is the maximum force that can be generated? Actually, different varieties of supporting gears are installed inside the "Lifter". The force generated and the force required for supporting the unstable point must be calculated in advance.

D. Saver

Since "Saver" is the most complex robot with lots of equipment, considerations should be taken into account to ensure its smooth operation. Firstly, AED (Automated External Defibrillator) will help to revive victims without enough oxygen to breathe. For a tiny robot, how much oxygen can it carry? Is the amount of oxygen enough for an adult to breathe while waiting for the other rescue team? We can observe that the oxygen bottle carried by a fireman is large and heavy. How can a tiny robot passing through gaps of rocks carry such a large bottle? A possible solution can be compressing the oxygen into liquid to minimize the occupied space. Also, GPS can be used for the transmission of message between "Saver" and "Coordinator".

In addition, the same problem occurs when the robot stores food and water. As mentioned above, high energy food like chocolate and energy bar will be carried. It is suggested that the robot should bring high energy but tiny size food. Besides water, drinks for sports can replace it for providing more energy and glucose for the victims. In order to enhance the survival probability of victims, basic necessity of living should be provided by robots: oxygen, energy and water.

E. DERRT System

There may be some misconception on DERRT that they will eventually take over all the human rescue operations. In fact, they will not. On the contrary, they will only be utilized when some scenarios are too dangerous that the threat imposed on the rescuer outweigh the chance of saving the victims. Besides, the existence of DERRT is to buy some extra time for rescues to save lives rather than saving wounded people by themselves. For instance, one of the victims trapped in debris of a building after earthquake, the only thing that DERRT can do is to locate him and provide him with some basic needs. But, the task of taking him out of the debris is still the job of rescuers.

VI. Conclusion

In this positioning paper, we have proposed a cooperative rescue robot system, called Disastrous Emergency Response Robot Team (DERRT). DERRT is a team of different robots integrated with a great variety of equipment for the sake of saving lives. Undoubtedly, DERRT will be useful, which can make the world be a better place with less sadness but more happiness. It is so hard to imagine how the disastrous area will become without DERRT. Therefore, DERRT will always act as an essential role to rescue victims in the future.

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