Autonomous Mobile Platform for Enhanced Situational Awareness in Mass Casualty Incidents

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Abstract— **To enhance the efficiency of the search and rescue process of a Mass Casualty Incident, we introduce a low cost autonomous mobile platform. The mobile platform motion is controlled by an Android Smartphone mounted on a robot. The pictures and video captured by the Smartphone camera can significantly enhance the situational awareness of the incident commander leading to a more efficient search and rescue process. Moreover, the active RFID readers mounted on the mobile platform can improve the localization accuracy of victims in the disaster site in areas where the paramedics are not present, reducing the triage and evacuation time.**

I. Introduction

Mass Casualty Incidents (MCI), whether caused by humans or nature, can cause significant loss of human life and property. These disasters are impossible to accurately predict or avoid. So how to effectively handle a mass-casually incident is one of the greatest challenges the emergency medical community can face.

In general, when an MCI occurs the incident site is usually in a chaotic situation. Although emergency medical technicians (EMTs) are well trained and can offer efficient rescue and control of the incident area, there are still many limitations. For example, in some cases, there may not be enough EMTs to cover large number of victims and/or large disaster sites leading to delays in the triage and evacuation procedures. Moreover, given the paper triage process currently in place the incident commander does not have a visual interface that provides the location or triage level of each patient in the disaster area. Lack of such information will slow down the triage and evacuation process in the critical stage of disaster recovery.

We have introduced the Dynamic Information Collection and Resource Tracking System for Disaster Management (DIORAMA) system that provides situational awareness in the disaster site [1]. DIORAMA system provides location and injury level of each patient in the disaster site as well as the location of responders. We have shown that the DIORAMA system significantly decreases the triage and evacuation time, improving the survival chances of patients.

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In DIORAMA, the localization of patients is obtained by tagging each patient with an active Radio-frequency identification (RFID) tag. Each responder carries an Android Smartphone and an active RFID reader. The active RFID reader collects the signal strength readings of the active tags. These readings along with the responder GPS coordinates are sent through the phone's 4G network to the DIORAMA server, which computes the location of each responder. Since the localization infrastructure is mobile (active RFID readers are carried by the responders) the localization is opportunistic, i.e., localization can occur only if the responder is at a reasonable distance from the patient (closer than 60 feet).

To enhance the disaster management we developed a mobile platform with the following functionality:

1. The mobility functions and sensors of the mobile platform along with the communication between the platform and remote site are controlled by an Android Smartphone
2. The platform can move autonomously to a designated location
3. The incident commander or responders can remotely control the motion of the mobile platform and determine its destination
4. The platform carries an active RFID reader used to increases the localization coverage in remote areas
5. The camera of the onboard Android phone can take pictures and videos and transmit them to the server - it increases the situational awareness of the incident commander by providing pictures and videos of specific point of interest

The use of robots in disaster search and rescue has caused great interest among researches. A coordination procedure for a multi-robot rescue system that performs real-time exploration of disaster areas is introduced in [2]. Autonomous robotic strategies for urban search and rescue, which use map-based semi-autonomous robot navigation and fully autonomous robotic search are described in [3]. In [4] the authors introduce a robot-integrated system, SENEKA, which networks various robots and sensor systems used by first responders. Autonomous mobile robots that deploy a wireless sensor network to be used in disasters is introduced in [5]. To the best of our knowledge this is the first paper that introduces an Android phone controlled robot for disaster management that can be remotely controlled by an Android device.

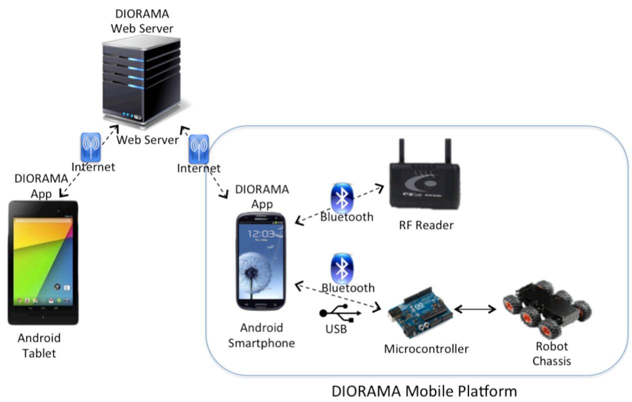


Figure 1. System Architecture

The paper is organized as follows. In the next section we introduce the system architecture, which includes the system architecture, the hardware and software platforms. In Section 3 we describe the testing procedures and results and Section 4 concludes the paper.

II. System Architecture

The overall architecture of the robot integrated disaster management system is shown in Fig. 1.

As shown in Fig. 1, DIORAMA mobile platform includes a robot chassis, a microcontroller, an Android phone running DIORAMA application and an active RFID reader. The microcontroller controls the movements of the robot chassis. An active RFID reader is mounted on the robot to receive RF readings from the surrounding RFID tags attached to each patient. The Android phone onboard the mobile platform has the following functions: 1) to communicate between the DIORAMA web server and the mobile platform using either 4G or WiFi, 2) to collect all the information necessary from the RF reader and internal sensors on the phone (e.g. GPS, compass, accelerometer, camera) and 3) control the onboard microcontroller which in turn controls the platform movements.

The location of the mobile platform is obtained from the phone GPS module and its bearing is given by the compass on the phone. The platform location is continuously uploaded to server, ensuring that the commander application gets real time updates on the platform location.

The robot hardware and software are described in Section 2.1. We have developed an onboard *robot monitor application* (Section 2.2) that runs on the onboard phone and interacts with the Arduino microcontroller and with the *robot commander application* (Section 2.3.) that runs on the incident commander or responder devices (Smartphone and/or tablet). All the information transmitted between the commander application and the monitor application is via DIORAMA web server.

2.1.Mobile Platform

To enable the platform use during disasters the chosen platform needs to meet the following requirements:

a. powerful motion system along with speed control system;

b. move smoothly on all kinds of terrain surfaces;

c. high extensibility, i.e. it can be easily modified or mounted with other sensors and devices;

d. robust and capable to carry some weight;

e. low cost and light weight.

The Wild Thumper Mobile Chassis meets all these requirements [6]. As shown in Fig. 2，the robot chassis features six powerful DC motors with large spiked tires, and a unique “super-twist” suspension system that keeps each wheel in contact with the ground for maximum traction, even when driving over uneven or bumpy surfaces. The suspension can be adjusted to suit different loads and conditions.

As shown in Fig. 2, the chassis consists of two levels. On the bottom level, six motors are connected with the microcontroller and the battery. On the upper level we have an Android smartphone which is mounted on a servo and an RF reader.

We chose an Arduino microcontroller [7], which is an open source platform with simple and clear programming environment as well as compatible with a large number of sensors. The Arduino microcontroller is also connected to a Bluetooth communication module. The communication channel between the Bluetooth module and the Android smartphone is used to transmit both control commands and sensor information.

The motion of the platform is directly controlled by the Arduino microcontroller. By providing different electric currents to motors on each side, we realize the following mobility functions:

- advance() -- Control the robot to move forward
- back() -- Control the robot to move backward
- turn_L() -- Make a left turn
- turn_R() -- Make a right turn
- stop -- Stop all movements, waiting for command

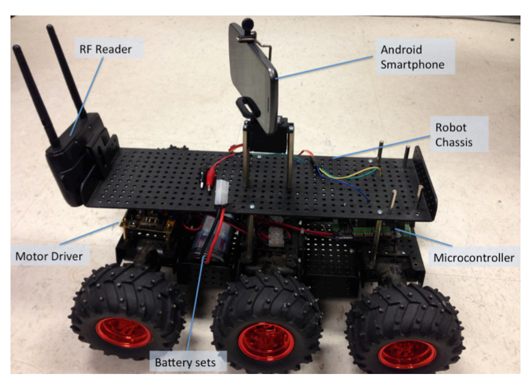


Figure 2. Mobile Platform

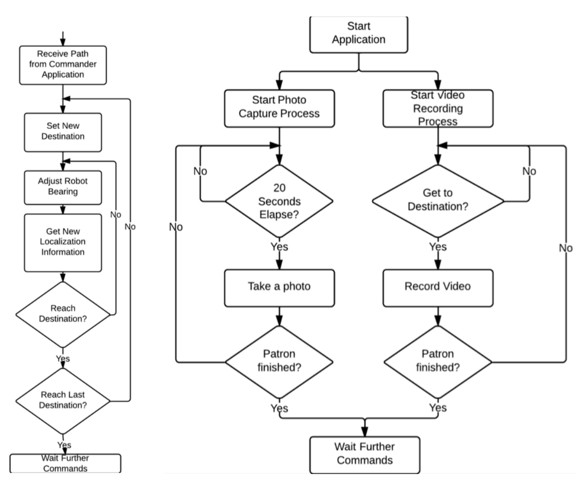
2.2.Onboard Monitor Application

The *monitor application* which runs on the onboard Android phone has the following functionality:

- Send motion control commands to microcontroller (see Fig. 3a);
- Get sensor information from microcontroller;
- Get robot's real time localization information from GPS and compass;
- Collect Radio Frequency readings from patients active RFID tags
- Take pictures and capture video- Image and video are captured autonomously by the robot while it is moving. Images of surrounding area are taken every 20 seconds. Videos are recorded as soon as the robot reaches its destination (see Fig. 3b).

As soon as the application gets the patrol command from the *commander application*, a series of destinations retrieved from the web server will be stored locally to generate the robot's moving path. A proximity alert is utilized to determine whether the robot has reached its destination. The distance between the platform current location and the destination is calculated using Haversine distance. The platform orientation control is based on the triangle relationship among three points: the robot current location, destination location and magnetic north pole. A feedback control strategy is applied to ensure the robot maintains correct bearing while moving.

As the platform moves in the disaster area with many potential obstacles we have developed strategies for obstacle avoidance and handling cases where the platform is stuck. We use an infrared sensor for detecting surrounding obstacles. When an obstacle appears within a preset distance scope, the obstacle avoidance strategy will be applied and the platform will generate and take an alternative path to its current destination. If the platform location remains the same for more than 3 seconds and the accelerometer reading on the smartphone is less than the preset threshold value, then the



(a) (b)

Figure 3. (a)Platform Motion Flow (b) Picture and Video Capture

robot will recognize by itself that it is stuck. In order to get out of stuck, a predefined moving pattern is utilized by robot. Based on the nature that the robot chassis always generate more power when moves forward or backward. So in this specific moving pattern, the robot first moves backward, trying to use its greatest power to get out of stuck. After this, the GPS or the accelerometer readings will indicate that the robot has been unstuck and return its common movement.

2.2.Robot Commander Application

The robot *commander application* is installed on an Android tablet or Android phone. Both the incident commander and the responder can use this application to deploy and control a robot and get information from the robot. This application provides the following features:

- Friendly user interface
- Indication of robot's real time location
- Remote control functionality
- Picture and video retrieval from server

The robot commander user interface is depicted in Fig. 4. We use Google Maps to display the disaster area. A marker on the map shows the current geographical location of the platform. As the platform moves, the position of the marker changes accordingly. Marker with letter "D" is the platform destination, which is set by the incident commander through a single click on the map. A series of these markers indicate the robot has to reach multiple destinations in a specific order. A marker with letter "T" specifies robot's next destination. This gives the commander a better understanding of where the robot is heading. The marker will change to flag-like marker after the position has already been reached. At this time, a short video of the surroundings of the current robot location will be sent back. The incident commander and responders can retrieve these videos through a single tap on the video marker.

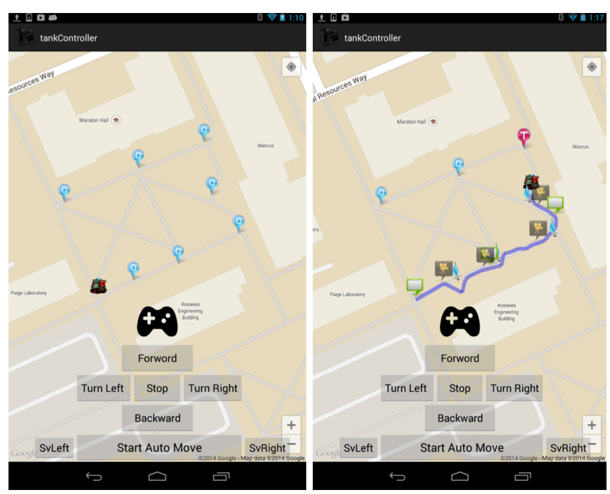


Figure 4. Robot Commander User Interface

III. Tests

As shown in Fig. 5 the test area includes both grass and pavement. There are also benches and streetlights, which could possibly block the robot's movement. The ground surface is not flat, it has ridges between the pavement and the grass, which may challenge the robot smooth movement.

Figure 5. Test Area

A sample test is presented in Fig. 6. A human rescuer first sets up the path of the mobile platform by determining the destinations. The robot reached all the destinations and at its last destination it displays the captured image and video.

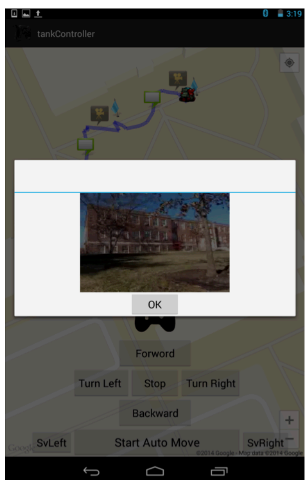


Figure 6a: Robot reaches all destinations

Figure 6b: Image and video

After multiple successful tests we conclude that the robot:

- moves smoothly on both pavement and grass
- receives and follows commands from the commander application, e.g. the robot moves to desired destinations determined by the incident commander or responder reports current location to the server
- collects RFID readings while moving and transmits them to the server
- takes pictures and videos and sends them to the server

IV. Conclusion

In this paper we introduced a mobile platform that we plan to integrate in a disaster management system. Using sensors on the onboard Android phone, the robot can move smoothly on various terrain surfaces and collect information of the disaster area. Such information includes RFID signals, pictures and videos which improve situational awareness of the disaster site, decreasing the triage and evacuation time as well as making rescue efforts safer. Our next steps will be to test the robot in a simulated disaster which will include a large number of obstacles, rough terrain, large areas as well as many possible destinations.

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