Design of a Low Cost Emergency Response Bot

Justin Rodriguez[1], Hunter Michko[2], Marcos Vila[3], Anthony Aguilar[4], Jong-Hoon Kim[5],

Discovery Lab, Florida International University, U.S.A.,

[1] jjrodr206@gmail.com, [2] hmich008@fiu.edu, [3] mvila040@fiu.edu, [4] anthonyj.aguil@gmail.com, [5] kimj@cis.fiu.edu,

(Tel: 1- 305-348-3751, Fax: 1-305-348-3549)

ABSTRACT

In the light of the Sandy Hook elementary shooting and the subsequent shootings that preceded the tragic event this paper explores robots of different designs and purposes followed by the proposal of an Emergency Response Bot (ERB). A robot designed to be an immediate first responder for small fires and attacks on school campuses while being developed inexpensively to be affordable for schools. The architecture for the Emergency Response Bot is described in detail, which makes use of a flexible wireless network connection between the robot and the user to enable full remote control of all the ERB's functions. Experimentation displays that the concept of the ERB's is feasibly possible as well as revealed some needed future improvements to its conceptual design.

Keywords

Low Cost Robot, Emergency Response

1. INTRODUCTION

On December 14, 2012 a tragic shooting at Sandy Hook Elementary in Newtown, Connecticut had taken place [5]. With the gun debate raging on and politicians refusing to touch the sensitive issue of gun control there have been suggestions of hiring or assigning police officers for increased campus security. However, with almost $3 billion being slashed from the education budget, there simply aren't the funds required for such a thing at every school in America [3].

So the question becomes is it possible to remedy the problem presented here? Is it possible to have greater security at our educational facilities while addressing two main concerns: avoiding the gun within the gun debate making the possible solution easier to consider and assuring the proposed solution is cheap enough for schools to afford. Yet, there is also an unspoken third concern. Is such a specialized robot truly justifiable in terms of cost? To put it into perspective, in 2004, a joint study between the Department of Education and the Secret Service puts the likelihood that a child between the 9th and 12th grades within the 7th and 8th percentile, 1 in 13 or 14 odds, of being threatened or harmed with a weapon in school. The odds a child is killed within school, 1 in 1 million [1].

A highly specialized machine built solely for such an emergency isn't justifiable in cost. So this machine would need to have a secondary purpose. Research from the National Fire Incident Reporting System (NFIRS) over the course of 2003 to 2005 have noted that yearly, schools experience an estimated loss of $85 million to the average of 14,700 fires a year [6]. It would be ideal to have a robot with a system to handle both emergency situations, and while such a robot could never replace a policeman or firefighter it can serve as an immediate first response to the situation at hand until our public service men and women arrive on scene. There have been robots built for emergency situations, however, these are usually for large scale disasters, the Emergency Response Bot (ERB), is designed to be inexpensive, capable of putting out fires and helping protect school campuses from attackers.

2. LITERATURE REVIEW

A robot developed by Boston Dynamics named Atlas is a humanoid robot whose task is to aid in disasters. This robot is currently being built in order to compete in the DARPA Robotics Challenge. The purpose of this challenge is to encourage the making of robots for emergencies. The robots should be able to climb stairs, use tools, drive vehicles, and aid in removing rubble. In addition to these functions, Atlas is also capable of walking on its two legs atop different types of terrain [2]. AIST (National Institute of Advanced Industrial Science and Technology) has also developed a series of humanoid robots known as the HRP (Humanoid Robotics Platform) series. These machines are capable of walking on different types of surfaces and inclines. They also have the capacity to grip objects and utilize tools using a 3-fingered hand design. The HRP robot is even capable of using its arms and legs in coordination with each other [8].

While a humanoid robot certainly would be an effective choice of design for the Emergency Response Bot there are major issues with proceeding with this type of structure. Firstly, humanoid robots are extremely complicated to construct. Implementing fully functional limbs, making sure the upper torso is constantly balanced, these functions take years to develop and refine. The HRP series were developed over a span of 8 years, from 2002 to 2010, spanning 4 generations of robot prototypes [8]. This increase in investment of time and money would return in the form of high costs for the intended users of the robot, schools. Secondly, while having all the capabilities of a human being would be convenient, it would ultimately serve no purpose for the ERB. The ERB's purpose is to be a first response to contain small fires and defend against lethal attacks on campus; this can be accomplished without the need of human-like functionality. All of these seemingly optional functions would simply result in the ERB being too expensive for schools to even consider.

Another robot being developed for DARPA is the CHEETAH. Its purpose is to handle difficult terrain at high speeds. The CHEETAH has four legs and can reach speeds up to twenty-eight mph. Its legs are what gives its advantage over tracked and wheeled robots [4]. However, trying to imitate a living organism's limbs requires more thought and calculation in comparison to just placing wheels on a machine and having it roll on the ground, and it is this same difficulty that must be considered as well, when considering a similar quadruped design for the ERB. In this essence, designing the robot to function similarly to an animal comes with the same issues as with using the humanoid design. While the ability to traverse over different types of obstacles would certainly be a function to consider for the Emergency Response Bot, it is possible to accomplish this by other means that do not result in increased development time and cost.

Following the nuclear disaster at the Fukushima Power Plant, Toshiba had designed a nuclear emergency response robot to aid in the effort. Another four legged machine just like the above mentioned CHEETAH bot, it allows workers to assess the damages at a nuclear facility at a safe distance with its ability to be remote controlled with the use of six cameras, and with a dosimeter to gauge the radiation levels [7]. There is also a class of robots known as Ant Bots. As their name suggests, they are a class of robots that specialize in group operations of lifting and transporting objects in large numbers [11]. Once again, like with the CHEETAH bot the maneuverability, while absolutely necessary for the situations at a nuclear facility, isn't really necessary for traversing a school, besides the possibility of stairs. In order to accomplish this without increasing production time or cost a tank style design could be considered enabling a similar range of maneuverability for the ERB without the complications. The Ant Bots present a possible need for joint operations; the ERB may need to work with another ERB on two different floors, however, despite being inexpensive as well as designed for group functionality the Ant Bots are primarily designed to merely lift payloads.

A remote-controlled fire-fighting robot has also been implemented using a multi-functional crawler and hydraulic excavator as a base model. Capable of climbing obstacles up to the height of 22mm this robot uses a large cylindrical arm to aim a fire hose at its intended target. Temperature sensors are installed in case the allowed temperature limit is breached the robot is notified to save itself [10]. Lastly, for the purpose of exploration and inspection a four-flipper robot was designed. Designed with ability to display video and audio feedback to the person controlling it, it is was created for the purpose of surveying surrounding areas to help locate people in accidents or find potential dangers caused by fires, natural, and non-natural disasters. Maneuverability is handled by four tracked flippers that enables the robot to climb over any type of terrain, stairs included. It also comes with the capability of using add-on to transport goods or people [9]. The fire-fighting robot design has a problem of being solely designed for the purpose of fire-fighting with no defensive capabilities. Meanwhile, the four flipper exploration bot explored many various designs from wheeled, tracked, to flipping tracks. Its high maneuverability and inexpensiveness is what makes it look so attractive in design and the ability of additional add-ons only furthers that. It is a robot designed strictly for surveying yet the tracked design similar to a mini tank could serve as the basis for the Emergency Response Bot's design. In addition, the tank archetype could also be designed in a manner that enables the robot to function regardless of vertical orientation.

3. ERBot ARCHTECTURE

The architecture of the Emergency Response Bot revolves around being able to construct a machine that can either defend against attackers or put out small fires over a wireless network. The architecture of the robot's hardware is divided into two main cores, the Communication and Controller Cores. The Controller Core consists of a microcontroller with six power out pins, four connected to motors that handle movement and the last remaining pins connected to a solenoid that triggers the fire extinguisher and the airsoft gun. Output control for all six is handled by each being connected to a motor controller.

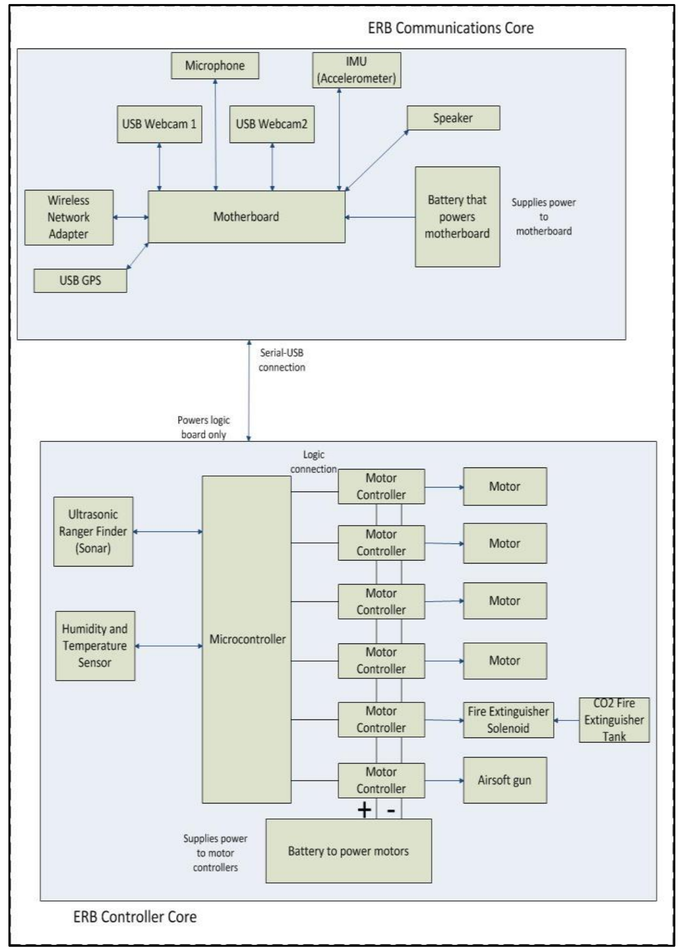

Figure 1. ERBot Hardware Architecture

In the future, a sonar module will be added to detect any surrounding objects the ERB currently cannot and a humidity and temperature sensor to measure temperature readings. The Controller Core receives power from its serial connection to the motherboard in the Communications Core. However, this power is mainly for the logic board within and not the pins. To address this, the output pins are powered by its own separate battery to enable functionality.

The Communications Core consists of a motherboard which receives video input from two USB webcams. Audio input is handled by a microphone, while audio output is handled by a speaker attachment. An IMU that takes accelerometer readings to determine the ERB's vertical orientation and a GPS to determine the robot's position in the build are also attached to the motherboard. The motherboard is powered by its own battery. The Controller and Communications Cores are connected to each other to control of all the power out pins (Fig. 1). Using a wireless network adaptor connected to the motherboard within the

Communications Core, the Emergency Response Bot receives and retrieves information through the use of a wireless network.

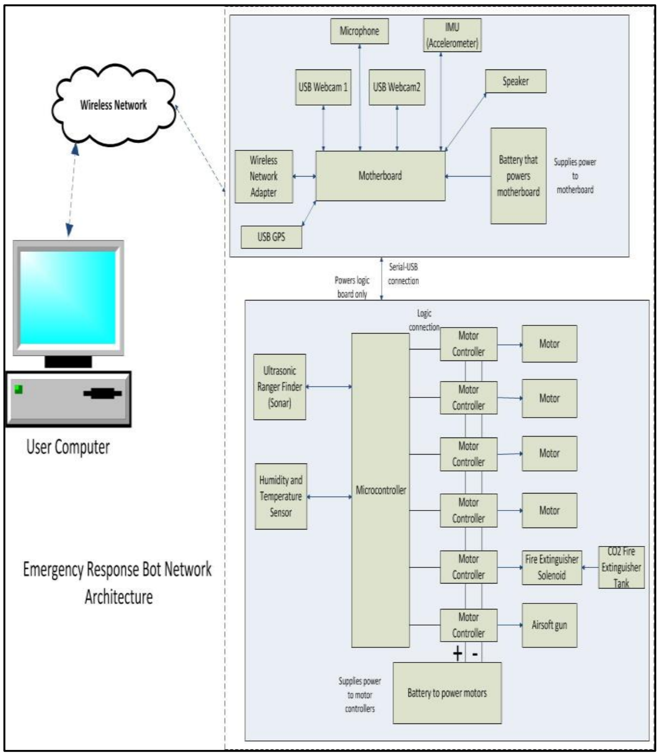

Figure 2 ERBot Network Architecture

The network architecture consists of merely the robot and the user's computer. The use of this network allows the robot to receive its commands and display feedback to the user (Fig. 2).

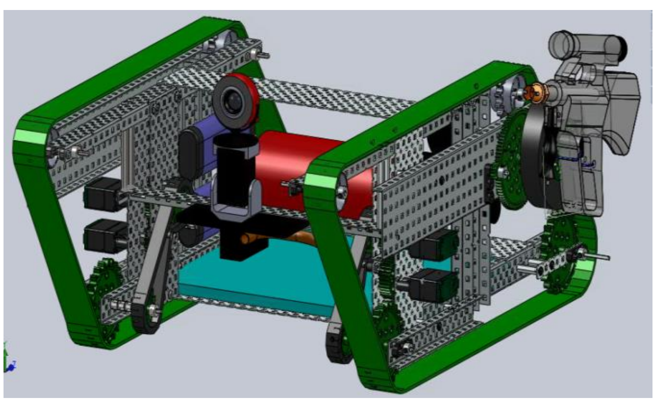

Figure 3 ERB Prototype Concept Design

The prototype of the ERB is a robot with a tank-like shape. The first prototype design, shown in figure 3, consists of a drive train, shooting mechanisms, and a camera. The drive train of the ERB would consist of tank threads powered by a four motor system. The robot would be equipped with an airsoft gun and a fire extinguisher that shoot from the side and the front respectably. Finally, the camera at the front of the robot possesses two degrees of motion allowing for a full visual range.

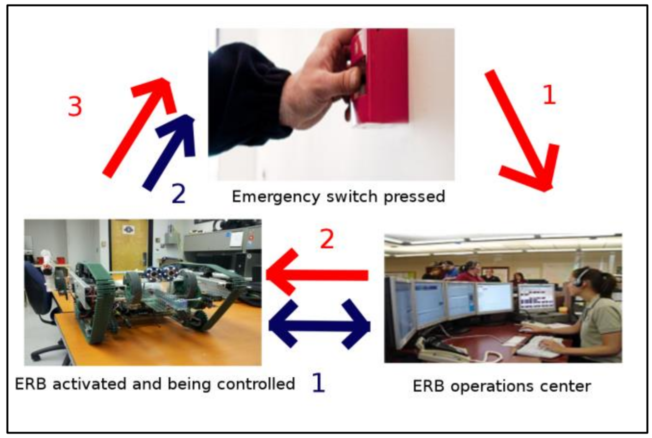

Figure 4 Illustration of the two operation scenarios for the ERBot

There are two methods of which the Emergency Response Bot can be integrated and deployed within schools. As shown in figure 4, someone could trigger a distress beacon by pressing an emergency switch activating the robot and sending an alert to personnel at the ERB's operation center who would then take control of the activated ERB and maneuver it to the source of the emergency. The other method would be to have the robot function similar to a security drone. The robot would be constantly active and patrol the halls of the schools until either an alert is sent or the ERB discovers a problem

4. IMPLEMENTATION

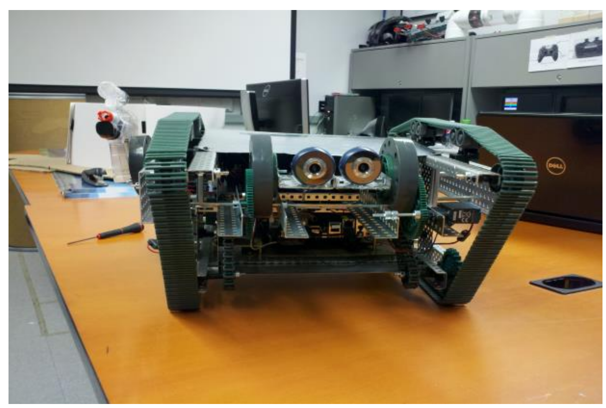

Figure 5. Proof of concept Emergency Response Bot

The ERB's proof of concept design is a parallelogram like frame with tank treads along opposite sides depicted at figure 5. These treads remain uncovered when the robot is upright in order for the ERB to have the ability to function regardless of vertical orientation. The robot operates by wirelessly connecting to a user's desktop and streaming video and audio feedback. This is accomplished via the use of two USB web cameras. Current design and prototyping has them connected to an Intel I5 motherboard running Ubuntu 12. The treads are set at an angle in order allow traversing of any type of terrain as well as provide a tight turning radius.

Figure 6. ERBot Components

Figure 6 is showing in-depth look at the ERB and its components: 1. the LPC1768 Mbed board, 2. the I5 Intel Motherboard, 3. the 800 psi CO2 tank and solenoid with the 12 and 7V battery packs, 4. the BB gun, 5. the aluminum cover, 6. the parallelogram aluminum frame.

This first prototype was constructed through the use of Vex Robotics parts. The robot is one foot in height, two feet long and 15 inches in width. An I5 motherboard functions using the Ubuntu v12 operating system which runs the ERB's program on the robot's side. Four Vex motors, two 393s and two 269s handle the prototype's movement capability. The two 393 motors enable the ERB to move in whatever direction the user chooses while the 269 motors handle aiming the defense system and the robot's ability to look vertically. These motors are controlled by the Mbed LPC1768 microcontroller.

Within the ERB's Mbed board is a series of libraries and a single main program that enables the board to be controlled through a Java based program on the motherboard. Besides the motors connected to the Mbed board, there is a BB gun and a solenoid that triggers dispersal of CO2 from 800 psi tank.

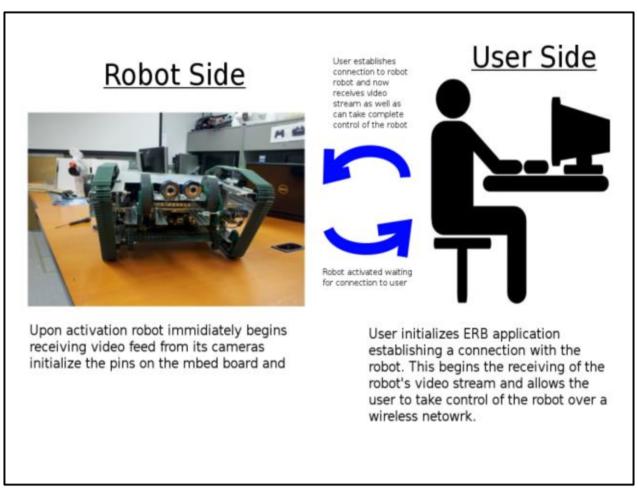

Figure 7 How the communication between the user and the Emergency Response Bot is established.

Communication between the Emergency Response Bot and the user is accomplished by first having the robot listen and establish a wireless network connection between it and the user as described at Figure 7. During this waiting period the robot assigns all the pins on the Mbed board their designated functions through Java. Once the user connects to the robot over the network, he/she can take full control over its functions. Video streaming is handled via two webcams managed by Ubuntu's Motion application and displayed to the user by accessing the specific thread on the ERB. The outer covering is a cut out 19 inch sheet of aluminum to protect the internal components. A 6.2 V nickel–metal hydride (NiMH) and a 12.4 V Lithium Iron (LiFePo4) power the robot.

5. EXPERIMENTAL EVALUTATION

Initial tests of the ERB prototype were first conducted upon the discharge time of the 6.2 V motor battery under two different conditions: with and without any load. The purpose of which was to determine the optimal continuous run time of the robot's motors, 22 minutes, in comparison to how it would perform when placed on the ground, 15 minutes, which in this case is a 31 percent difference. The motherboard discharge time, however, was 1 hour and 15 minutes. Following which, a speed test was conducted over a course of 10 feet, which the ERB covered in 10 seconds, revealing its speed to be 1ft/s. Unfortunately, when tackling inclines the ERB drained all its power trying to reach the peak of 30 degree incline, but couldn't climb over it. The cameras' allowed vertical view is able to be adjusted anywhere between 75 and -35 degrees, while the BB gun could be rotated 360 degrees. The ERB was also capable of being driven while flipped over with no change in performance (see figure. 8).

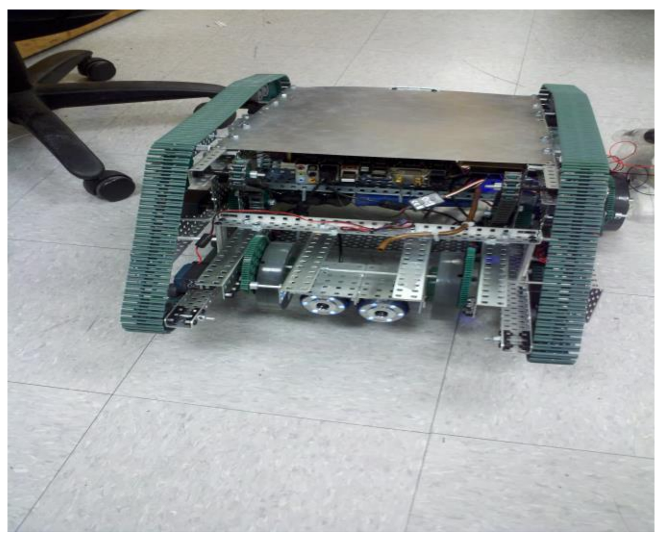

Figure 8 ERB functioning while flipped over

Tests for the network connectivity of the user and ERB were done on by running duplicate programs on separate local desktops over a LAN network. The socket connections were able to be established and the acting server was able to receive data from the user. With remote connection possible this same network code was applied to the ERB where a connection was established, enabling the user to send commands to the robot. Once connection was proven possible command response time was measured.

Swapping between actions was seamless. The robot was capable of moving, shooting BBs or CO_2, adjusting aim or vision all within a .1 second of response time and showed the ability of carrying out these functions at the same time.

The results of these tests indicate a number of possible revisions for the second prototype of the Emergency Response Bot. Little over an hour of operation time is acceptable as far as the motherboard is concerned, however the motor battery's performance by comparison is a problem. A possible reason for these complications maybe due to the batteries slowly deteriorating due to not being completely emptied of power prior to being charged, resulting in a decline in operation times. When the robot was made to climb the incline the robot had succeeded in climbing up till it had reached the peak afterword the robot had ceased its movement and couldn't climb any higher, yet it was capable of climbing back down. This alludes to two possible problems preventing the robot from overcoming the incline: the batteries clearly do not have enough power to enable the motors such a steep climb or the motors used for this prototype simply lacked the power to make the climb. Both the battery power and the incline issue can be addressed with the replacement of the NiMH batteries with Lithium Ion batteries would enable the robot to function longer and more efficiently without fear of the batteries deteriorating as a result of not being entirely drained of their stored charged, and more powerful motors with the addition of suspension to aid in traversing different obstacles and inclines.

Also, while being able to travel 1ft/s may not seem like the blistering pace needed for an emergency response, to put it into perspective with a max distance of 48 ft until the current motors and battery are forced to rest for 2 mins the ERB could cover at least an entire hall way to reach and disable an attacker or put out the fire out well before emergency responders just within the first 48 seconds of the emergency's occurrence. Despite the problems, the concept of building a robot that was both affordable yet efficient with defense capabilities for assailants as well as fire combating technology had been proven. This first prototype was created under a budget of merely a thousand dollars, the individual parts totaling roughly $980. The system could actively swap between the two systems with the simple pressing of a different button to engage either the BB gun or the fire extinguisher.

6. CONCLUSION

There have been robots built for emergency situations. Sophisticated robots built in a manner where some can emulate human functions, scout surroundings, lift heavy payloads, and put out fires. However, these machines prove to be either expensive or just not adept enough to be used for security as well as fire safety in schools. In this paper we have discussed the proposal, architectural design, implementation, and experimentation of the ERB. A robot designed primarily as an inexpensive yet efficient first responder for the purpose of defending schools from on campus attacks and fires. Being designed around this concept it uses inexpensive off the shelf materials that could be quickly assembled into a preliminary design prototype while maintaining a limited research budge. With this in mind the starting design will need many improvements in order to be ready for actual field work.

Future development will revolve around the refinement in the ERB's structure: designing a proxy server component to allow both the robot and user to connect to a remote server and increasing performance values through the use of better motors and batteries. Lastly as the project continues to refine itself the airsoft gun will be replaced with ballistic Taser shells and a pepperball gun to test the actual stopping power of the ERB. Adjustable nozzles for the fire extinguisher will also be added to enable the dispersed CO_2 to be aimed more directly at a fire.

7. ACKNOWLEDGMENTS

Authors acknowledge the sponsorship of FIU's Discovery Lab in the contribution and development of this project and the contribution of Carmela Vallalta for providing the Solidwork images of the for the concept models of the Emergency Response Bot

REFERENCES

[1] Bloom, Molly. "Tragic But Rare: Odds of Dying in a School Shooting, as in Chardon, About One in a Million." stateimpact.npr.org. NPR, 27 Feb. 2012. Web. 15 Aug. 2013.

[2] Bray, Hiawatha. " Teams vying to give brawny robot a brain." bostonglobe.com. 5 Aug. 2013.

[3] Web Article (http://www.nea.org/home/52610.htm), "Impact of Sequestration on Federal Education Programs - State-by-State." , March 1, 2013

[4] Mlot, Stephanie. "DARPA's Cheetah Bot Breaks Human, Robot Speed Records." pcmag.com. 7 Sept. 2012 Web. 19 Aug. 2013

[5] Web Article, "Sandy Hook shooting: What happened?." CNN.com. 15 Aug. 2013.

[6] "School Fires." Topical Fire Research Series Aug. 2007: 8. (https://www.usfa.fema.gov/downloads/pdf/tfrs/v8i1.pdf).

[7] Strange, Adario. "Toshiba unveils nuclear emergency robot to aid Fukushima recovery." dvice.com.. 21 Nov. 2012.

[8] Kaneko, Kenji. "Towards Emergency Response Humanoid Robots." Mecatronics-REM (2012): 504-11..

[9] Brkic, K., M. Cukon, Z. Kovacic, D. Miklic, A. Mutka, I. Rajkovic, G. Vasiljevic, and F. Vuglec. "Design and Control of a Four-flipper Tracked Exploration & Inspection Robot." 21st Mediterranean Conference on Control & Automation (MED) (2013): 7-12. .

[10] Dai Cheng, and Weichun Zhang. "Development of A New Remote Controlled Emergency-handling and Fire-fighting Robot." World Congress on Computer Science and Information Engineering (2009): 239-243..

[11] Bay, John S.. "Design of the 'Army-Ant' Cooperative Lifting Robot." IEEE Robotics &Automation Magazine Mar. 1995: 36-43.