Expedients for Marsupial Operations of USAR Robots

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***Abstract*— This paper presents observations and suggestions for urban search and rescue (USAR) robot developers whose products may be involved in ad hoc marsupial operations at ground disaster sites. A marsupial operation can be defined as the delivery of robotic services through the explicit physical interaction of two or more robots employed cooperatively. These suggestions are presented from observations made at the second in a series of Response Robot Evaluation Exercises held by the United States Department of Homeland Security, the Federal Emergency Management Agency and various USAR teams, held at "Disaster City" at Texas A&M University.**

I. Introduction

The use of ground robots to assist first responders at disaster sites is a relatively new phenomenon. Various investigators who have attended disasters have reported at least some benefit from the use of purpose-built, research, and re-purposed robots for use in disaster situations [1-3]. Work has been done to improve the performance of USAR robots by providing appropriate test beds [4], and suggesting standards for describing and measuring human factors, sensing, mobility and manipulative ability. In addition, there is quite a lot of work attempting to automate at least some of the tasks an USAR robot might need to perform [5, 6].

II. Response Robot Evaluation Exercises

The purpose of the response robot evaluation exercises (RREX) is to introduce emerging robotic capabilities to emergency responders while providing valuable feedback to robot developers. Hosted by Texas Task Force 1, on the grounds of Texas A&M University, the second RREX was conducted by the Department of Homeland Security/Federal Emergency Management Agency with the cooperation of various emergency responders from around the United States and Canada. While the scenarios were simulated the human-robot, human-human and robot-robot interactions were real and many lessons were learned from them.

III. Marsupial Operation

This paper discusses one aspect of this exercise—the ability of robots to participate in ad hoc teams during marsupial operations. We present preliminary findings stemming from observed interactions between responders, robot vendors, and simulated disaster scenarios prescribed by experienced first responders. This paper departs from previous work in that we will suggest simple modifications to existing robotic systems that may improve certain aspects of marsupial operation performance in USAR environments.

The use of multiple robots in "teams" for USAR has been variously reported [7-9]. The term "Marsupial" was first suggested in [10] between "mother" and "daughter" robot teams deployed in support of simulated USAR activities. This concept was expanded in [11].

A marsupial operation can be defined as a cooperative robotic deployment used to deliver SAR assets via the explicit physical interaction of two or more robots to exploit their individual strengths and overcome individual weaknesses. The relationships between humans and robots working in teams can be quite varied and are discussed at some length in [12]. We will consider only a marsupial operation that implies a team of humans issuing individual commands to individual robots.

IV. The Robots

Various vendor-provided robots were invited to participate in the exercise. Responders were encouraged to interact with the robots in roughly defined scenarios and to create their own disaster situations using the extensive facilities available. Five robots were employed in scenarios that might benefit from some form of marsupial interaction between robots. Of the five, only one robot was explicitly designed to support marsupial interaction.

The BomBot was developed by the West Virginia High Technology Consortium (WVHTC). A small, low-cost, four-wheel drive, remote-controlled truck that has been equipped with a pan-tilt camera and a dispensing mechanism similar to that of a dump truck, the bombot has the benefit of speed but limited cross-country ability. In this exercise, the BomBot was repurposed from its original Explosive Ordinance Disposal (EOD) role of delivering and dispensing high explosive charges for the destruction of improvised explosive devices.

Throwbots are small wireless robots with limited mobility and sensing intended for use for local reconnaissance and deployable by dropping or throwing into an area of interest. The version employed on this exercise was the Toughbot manufactured by Omnitech Robotics. The Toughbot provided a small yet mobile audio and video surveillance device. In addition, the Toughbot is equipped with a wire "tail" that provided an obvious lifting and grasping point.

Figure 1 Toughbot showing "Tail"

The Matilda robotic platform was developed and is sold in many variants by Mesa Robotics. The basic platform consists of a highly versatile tracked, radio-controlled, base vehicle that can be augmented with the addition of many optional components. The Matilda robot employed during the exercise was equipped with a manipulator arm and end effector. The Matilda is being used in many roles including reconnaissance, breeching, inspection with military and law enforcement variants.

Talon robots, developed and sold by Foster-Miller, are small tracked vehicles that are widely used in many roles including military, law enforcement and rescue. The variant used in the exercise was equipped with a manipulator arm and end effector.

Sneaky, by M-bots, is a low-cost, compact, lightweight and rugged security robot that is intended for use in security, reconnaissance and surveillance applications. While the robot is not intended to have good cross-country performance, its low profile makes it applicable for tasks like under-vehicle inspections.

V. The Scenarios

Three scenarios were created that would support the use of ad hoc teams of responders, vendors and robots. The scenarios were created by responders who used area facilities to create working environments that might benefit from the use of two or more robots working together.

The scenarios are described in the table below.

Table 1 The Scenarios

Scenario	Description and Goal	Operators and Robots
1) House of Pancakes	Partially collapsed structure with a sloping roof in contact with the ground and a precipitous drop into a void. Mother to insert daughter into void	Responders operating Talon and Toughbot
2) Single Family Dwelling	A family home provided with a breech entrance, internal debris hinders exploration. Robots to explore interior rooms.	Vendors operating Matilda and Sneaky responder coordinated
3) Rubble perimeter	Perimeter of a rock and concrete rubble pile blocked by a contaminated trailer. Complete perimeter survey.	Responders operating Bombot and Toughbot observed by vendors

Operators were sited in close proximity to each other, could communicate with one another and could see, and in some cases, hear the output of both their own controller and that of the other robot operator. In scenarios 1 and 2 the robots were not visible but the robots could be directly observed in scenario 3. The emergency responders were male, between the ages of twenty and fifty and had many years of experience in disaster response. A scene from the first scenario is depicted below.

Figure 2 Talon Inserting Toughbot

VI. OBSERVATIONS

Operators related similar cognition problems reported elsewhere [13] but also experienced difficulties associated with the ad hoc nature of the interaction between the robots and the operators. Operators and observers in scenarios 1 and 2 repeatedly reported difficulty in determining the orientation of the daughter robots when relying solely on the video feed they had available to them. There were many instances where the operators of the robots needed to confer on the orientation of the daughter robot. This was especially prevalent when the camera feed was narrowly focused on a small part of the robot.

The figure below is an image taken by an observer of the interaction of the robots Sneaky and Matilda in scenario 2. Due to a sudden gust of wind, the Sneaky robot was flipped upside down. Even though the operator of the Matilda robot was observing the Sneaky robot through the video window of his console, the flipping was not observed by the operator who had focused one of the arm cameras on a particularly small portion of Sneaky's body.

While Sneaky's operator was aware that the robot had flipped, there were a few moments of confused interaction between the two operators until Sneaky's Orientation could be established by Matilda's operator.

Figure 3 Sneaky and Matilda

The figure below is the console view of the Matilda robot after the operator had zoomed out to get a better view of the situation. While Sneaky can be clearly seen, its orientation is not obvious.

Figure 4 Sneaky Via Matilda's Console

A recurrent physical problem was the lack of any obvious place that could be used to manipulate the daughter robots by the mother robots. When situations occurred that caused a daughter to become stuck or flipped, the mother's operator was forced to experiment with gripping wheels or attempting to grasp features on the body of the daughter. While this worked on many occasions, it caused the partial loss of a wheel on one occasion and the video feed of the daughter robot was obscured while the daughter's camera housing was being used as a lift point.

However, the ad hoc nature of the marsupial relationship of these robots also proved to be beneficial in at least one case. The fact that the Bombot could carry a smaller robot, deliver it quickly to a release point and deposit it and stay nearby to provide a different camera angle on the operation, made the bombot a far more useful robot than if it were operating independently.

Figure 5 Toughbot Carried by Bombot

Figure 6 Toughbot Deployed Under Trailer

VII. Conclusion

Three lessons were learned as these scenarios played out. The first was that ad hoc marsupial relationships formed between heterogeneous robots provided functionality beyond what either robot could deliver individually. The ability to mutually support each other's onboard resources provided clear benefit in proceeding with each search task.

The second lesson is that there is a clear need to provide strong, end-effector-friendly and obvious lift points on USAR robots. These can be provided in a number of simple ways including pop-riveting or gluing rough metal grip points onto the body of existing robots and painting them in a high-contrast colour. While this will not alleviate problems concerning visual acuity and camera placement on the mother robots, it may serve to reduce the cognitive load of operators seeking such points. It may be necessary to standardize the size and shape of these lift points as part of the voluntary consensus standards being developed for USAR robots.

Figure 7 Sneaky with no Obvious Lift Points

Finally, it would be very helpful if robots being employed in a USAR role were provided with orientation labels. Labels could be provided in sticker form and applied to indicate important features. A potentially useful set of stickers is depicted in the figure below.

Figure 8 Label for Top Centre of Robot

Figure 9 Label for Bottom Centre of Robot

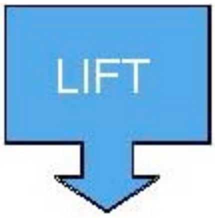

Figure 10 Label to Indicate Lift Point

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References

[1] A. Davids, "Urban search and rescue robots: from tragedy to technology," IEEE Intelligent Systems and Their Applications, vol. 17, pp. 81-83, 2002.

[2] J. Casper and R. R. Murphy, "Human-robot interactions during the robot-assisted urban search and rescue response at the World Trade Center," IEEE Transactions on Systems, Man and Cybernetics, Part B, vol. 33, pp. 367-385, 2003.

[3] R. R. Murphy, "Trial by Fire (Rescue Robots)," in IEEE Robotics & Automation Magazine, vol. 11, 2004, pp. 50-61.

[4] A. Jacoff, E. Messina, B. A. Weiss, S. Tadokoro, and Y. Nakagawa, "Test arenas and performance metrics for urban search and rescue robots," presented at IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, 2003.

[5] R. Wegner and J. Anderson, "Agent-based support for balancing teleoperation and autonomy in urban search and rescue," International Journal of Robotics and Automation, vol. 2, 2006.

[6] J. Scholtz, J. Young, J. Drury, and H. A. Yanco, "Evaluation of human-robot interaction awareness in search and rescue," presented at IEEE International Conference on Robotics and Automation, 2004.

[7] R. R. Murphy, "Human-robot interaction in rescue robotics," IEEE Transactions on Systems, Man and Cybernetics, vol. 34, pp.

138-153, 2004.
[8] I. R. Nourbakhsh, K. Sycara, M. Koes, M. Yong, M. Lewis, and S. Burion, "Human-robot teaming for search and rescue," IEEE Pervasive Computing, vol. 4, pp. 72-79, 2005.
[9] E. Kadioglu and N. Papanikolopoulos, "A method for transporting a team of miniature robots," presented at Proceedings of the 2003 IEEE/RSJ Int. Conf. on INtelligent Robots and Systems, 2003.
[10] R. R. Murphy, M. Ausmus, M. Bugajska, and T. Ellis, "Marsupial-like Mobile Robot Societies," ACM Autonomous Agents, 1999.
[11] R. R. Murphy, "Marsupial and shape-shifting robots for urban search and rescue," IEEE Intelligent Systems and Their Applications, vol. 15, pp. 14-19, 2000.
[12] H. A. Yanco and J. Drury, "Classifying human-robot interaction: an updated taxonomy," presented at IEEE International Conference on Systems, Man and Cybernetics, 2004.
[13] J. Casper and R. R. Murphy, "Workflow study on human-robot interaction in USAR," presented at IEEE International Conference on Robotics and Automation, 2002.