The Scarab Project

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***Abstract*— Urban Search and Rescue (USAR) is an active research field in the robotics community. Despite recent advances for many open research questions, these kind of systems are not widely used in real rescue missions. One reason is that such systems are complex and not (yet) very reliable; another is that one has to be an robotic expert to run such a system. Moreover, available rescue robots are very expensive and the benefits of using them are still limited.**

In this paper, we present the Scarab robot, an alternative design for a USAR robot. The robot is light weight, human-packable and its primary purpose is that of extending the rescuer's capability to sense the disaster site. The idea is that a responder throws the robot to a certain spot. The robot survives the impact with the ground and relays sensor data such as camera images or thermal images to the responder's hand-held control unit from which the robot can be remotely controlled.

I. INTRODUCTION

Beginning with the World Trade Centre disaster in 2001, rescue robots have been increasingly deployed into disaster areas. However, although many solutions have been suggested and designed, rescue robots have never become commonplace in rescue operations.

Various rescue robots have been designed each having varying levels of success. One robot's performance was described as "no better than could be achieved with a simple human operated pole camera" and had trouble with traction [1]. Other robots had trouble with tether management and a high robot to operator ratio. While large sized robots have the ability to navigate over rough terrain, their complexity and high cost have led to to a low market penetration. A companion paper [2] elaborates on various rescue robots and their ability to operate in a rescue environment. In this paper a case was presented for a general purpose, low cost robot. The conclusion reached was that a low cost robot that is rugged and simple to operate could be integrated into all areas of rescue teams and could become instrumental in providing rapid deployment of rescue robots at disaster sites. The idea of integration is to ensure that each city, fire department and/or police station has at least one rescue robot available.

In 2002, Murphy, Blitch and Casper proposed the most basic level of robots for AAAI/RoboCup as "Robust teleoperation with basic mixed-initiative capabilities". These robots would be teleoperated and able to handle rubble and confined spaces. Mapping and planning would all be carried out manually by the operator, whose "user interface is visual and capable of displaying multiple sensors simultaneously." These sensors "[. . .] should be able to detect the basic affordances of a survivor: heat, motion, sound, and color." [3] Any rescue robot should adhere to these specifications and the actions of rescue operators should not be swayed by the fear of losing the robot. In order to achieve this the robot must be considered to be "expendably cheap".

In order to make the robot both affordable and rugged it has to be simple in design. In order for the robot to navigate through small voids it has to be as compact as possible. With both of these considerations in mind the Robotics and Agents Research Group at the University of Cape Town designed the Scarab. The design intent for the Scarab was to create a small, rugged, cost-sensitive robot with a very simple user interface.

II. FEATURES OF SCARAB

Currently rescue operators have many options of-off-the-shelf rescue robots. Scarab differs from these offerings in the following ways. Firstly, the cost is substantially lower and this impacts rescuers decision making. The fear of losing or damaging the robot should never impact a rescue operation. Secondly, Scarab allows multiple and different sensors to be connected to the same mechanical housing in the internal sensor payload. As long as each sensor is rated to 150G, Scarab remains throwable and able to withstand falls up to 3m. Additional differences to commercial products include the in-field charging and the very simple user interface (see [2] for more details). Another difference is the possibility for any university or researcher to adjust the internal sensors to their specific requirements, as long as they obey a simple power and communications interface.

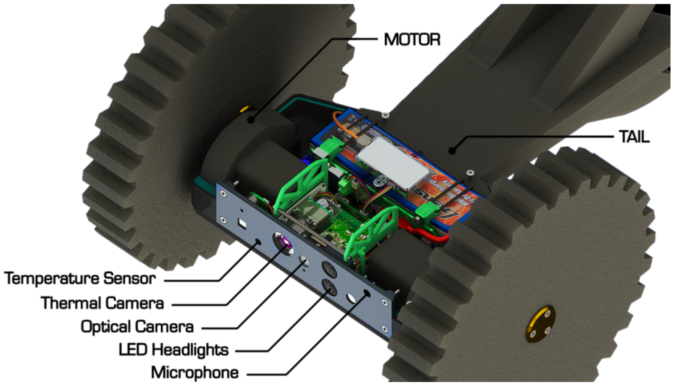

Fig. 1. The Internal Design of the Scarab

Fig. 2. The Controller of the Robot

Fig. 3. The Robot inside the Man Packable Vest

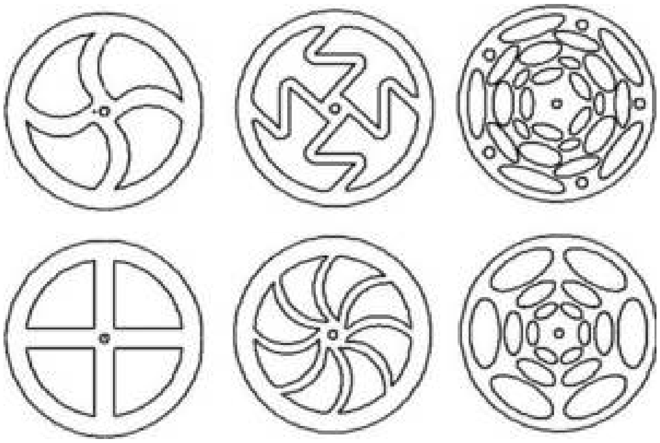

Fig. 4. Different Wheel Designs

III. THE SCARAB

The Scarab is designed to be rugged, low cost and man packable. It is approximately the size of a shoebox, 3kg in mass and is designed to withstand a drop from up to 3m. The embedded tail not only acts as an aerodynamic surface to stabilise the robot during flight, but also as the grip for the throwing action. It is a two-wheeled robot with independent drive where the tail drags along the ground and constrains the pitch of the body. The robot is designed to be deployed by being thrown in to a building and its navigation strategy is to tumble from higher floors to lower ones. Further design decisions and detailed designs can be seen in a companion paper [4].

In the front of the robot is an interchangeable sensor payload which allows for increased sensor flexibility by accommodating any number of purpose-built sensor payloads. For initial testing, two sensor payloads are being used. The basic sensor payload contains a temperature sensor, optical camera, LED, microphone and IMU. If further sensor capability is desired, the advanced payload includes the above-mentioned sensors and adds a thermal camera, gyroscope and magnetometer. In order to keep both size, cost and complexity to a minimum, small internal embedded controllers have been used. Although this eliminates the possibility of complex on-board functionality such as mapping and image recognition, these could be done off-board on the operator's side. The Scarab is symmetrical and has no right side up. The sensor payload is able to flip the camera image and controls appropriately no matter which way up the Scarab lands.

The Scarab's internal components with the advanced sensor payload on-board can be seen in Figure 1.

As rescuers need to be highly mobile in dangerous and unstable environments, the Scarab can either be clipped to a belt, or mounted in a tactical vest. When mounted in the tactical vest, the Scarab's internal batteries recharge. This allows the operator to perform multiple missions without becoming concerned about battery levels. The tactical vest and Scarab mounting are seen in Figure 3.

Scarab is controlled with a small sized handheld controller. All the buttons are designed to be operated by the hand holding the controller and are large and rugged enough to be operated even when wearing gloves. Sensor information such as battery percentage, temperature and GPS coordinates are displayed onscreen. The operator is able to modify these settings should they desire. Additionally, the on-board display can be sent to a pair of FatShark goggles that will give the user a first person view of the rescue scenario.

Because the deployment and navigation strategy could lead to the robot falling a full storey, the robot needs to be able to survive drops up to 3m without incurring sensor damage. To simplify the design, impact reduction is achieved with impact absorbing wheels. In order to empirically evaluate the effect of different materials and geometries, multiple wheels were designed and tested, some of which can be seen in Figure 4. All of the wheel designs are made up of laminated laser-cut sections of expanded polyethylene foam. Testing with the current wheel design limited the impact deceleration of the internal electronics to 150G. This is achieved without the suspension bottoming out; i.e the chassis does not touch the ground. The most sensitive electronic component was the thermal camera, which had an absolute maximum G rating of 250G.

The total cost of the hardware for the Scarab is USD 500, more than 15 times less then a similar commercial product. It is estimated that with assembly and mass manufacture the cost will remain under USD 1000. This lower cost allows rescue workers to make decisions based on rescue need and not be constrained by the risk of losing the robot.

IV. CONTROL AND ROS DRIVERS

For offering an open programming interface for the Scarab, we decided to provide ROS drivers for the Scarab. The Robot Operating System (ROS) [5] is one of most-widely used open source middlewares in the robotics research community today. As a robotics middleware, ROS supports the development of robotic applications by offering an interprocess communication infrastructure, debugging and visualisation tools and integrating a 3D physical simulation with Gazebo [6], to name just a few features. It is in particular interesting to develop Scarab's application software in ROS as the research community has accepted ROS and it is developing to a standard robot middleware. This results in numerous off-the-shelf packages for robotic applications such as robot drivers, mapping tools, localization and path planning modules.

We therefore aim at fully supporting ROS for the Scarab platform. We currently implement low-level drivers and develop for the motor controller and the sensor payload. Furthermore, a simulation model for the Gazebo simulation environment is being developed. While ROS has some issues with real-time support etc, the step of offering a ROS integration will allow users to benefit from the ROS toolchain to develop their own application with the platform more easily. Since the internal controller does not allow advanced functions such as mapping to be done by the robot itself, a ROS interface at the operator station could implement these functions, provided there is a stable and reliable communication link.

V. FUTURE WORK AND TESTING

Further work is being undertaken to refine the mechanical design, to improve the control of the Scarab and increase the functionality of the user interface. Basic operational testing is also underway. Future work will increase the ground clearance of the chassis such that higher falls can be survived, with decreased G-loading on the internal components.

We envision to evaluate the proposed robot concept in two directions. We plan to deploy the robot with our team participating in the RoboCup Rescue Robot League [7]. In this competition robot concepts as well as teleoperated and autonomous control strategies are evaluated in an artificial disaster where the robot is used to explore the environment and to locate victims. The test arena is based on the standard test methods for robots developed by the National Institute for Standards and Technology (NIST)[8]. This evaluation is directed to the open scientific questions.

We have good experiences to deploy robots in real disaster response exercises [9], [10]. Such events performed together with first responders are crucial to evaluate a proposed technology or system for its usefulness in the field. We plan to integrate the robot in the upcoming drills. Although, these exercises were mainly done in Europe so far we will work on building up the contacts with African responder to interest them into such technology and evaluate the usefulness for the African context.

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