1. Project description

1.1 RoboCup Rescue Robot overview
The Rescue Robot competition is organized by RoboCup – an international organization based in Sweden. Their goal is to promote robotics and agent technology world-wide. The goal of the Rescue Robot competition is to create a friendly, competitive environment for prototype robots to be tested against each other in a variety of tasks that simulate real world disaster scenarios. Urban search and rescue is the main focus in these arenas, and robots have to be able to operate without assistance. The operators of the robots have to rely on a remote interface to the robot and cannot directly see the robot or its surroundings.

There are a variety of tests that the robots have to perform as part of the competition. None of these tests involve human subjects and so there are no ethical problems to deal with. Human victims are simulated by dummies with realistic skin colouring and heat signatures. Other tasks have no victims at all and are simply stress tests. These include navigating an unstable environment made up of many small cubes stacked on top of each other. These blocks have a tendency to fall out from under the robot and cause it to fall over. If the robot is unable to continue it is disqualified. The robot must also be able to perform certain computer vision tasks as separate tests, such as detecting hazardous materials (hazmat) signs and also detecting the letter ‘E’ at various orientations (“rolling E test”).

1.2 Honours Project overview
For this Computer Science Honours project, three students will be working as a team to produce parts of the software system for a robot developed and constructed by the Agents and Robotics lab in the Mechanical Engineering department of the University of Cape Town. The focus of this project will be to create modular software components that can be re-used and improved upon in future years by the robotics team. The parts to be created by each student will cover three important components of the final system. These parts can be developed independently, although there is interdependency between them for the final product. The parts to be developed are:

1. Robot graphical user interface (Zwivhuya Tshitovha)
2. Robot control interface (Jaco Colyn)
3. Robot visual system (Jonathan Dowling)
2. **Problem statement**

2.1 **Research question**

The main research questions of this project fall under the three categories of the sub-tasks.

- How can an effective system be built to automatically detect human victims, hazmat signs and the rolling E’s using the normal an IR cameras available on the robot and applying computer vision techniques to extract the features?
- How can a graphical user interface be built that is decidedly easier to use than current generation interfaces available by hiding irrelevant information, preventing sensory overload and using participatory design?
- How can an intuitive and easy-to-use robot control system be created by mapping the robots functions onto a game console controller so that minimal training is required for operators?

3. **Social impact and importance of research**

Rescue robots are a very valuable avenue of research from the societal perspective. Disaster relief workers risk their lives in order to save the lives of disaster victims. These individuals have a very dangerous job and the largest danger arises from having to go into many situations blind, with limited knowledge of the hazards and risks that have emerged. In addition, there is often no longer a reliable map of the disaster area and so the relief workers have to piece together a mental map on-the-fly. In some situations the disaster area completely prohibits sending relief works, as in nuclear reactor meltdowns.

This situation is ideal for robots that can automatically map their surroundings and locate victims. Robots can even be fitted to furnish victims with supplies and communication with the outside. The robots thus lay the groundwork for a more efficient and effective rescue operation with a reduced risk to the lives of rescue workers.

Robots not only provide valuable intelligence about the disaster area but can also be fitted to perform repairs and many other important tasks in situations such as the Three Mile Island and recent Japanese nuclear disasters.

4. **Deliverables**

Stephen Marais is acting as a co-supervisor and client for the project. He is the head of the Agents and Robotics lab of UCT and has overseen the construction of the robot’s hardware. Stephen will make sure that the software is able to perform the tasks required by the RoboCup and would also like the robot to be able to eventually perform in real disaster scenarios in South Africa, such as mine disasters.

The deliverables required for this project are:

- A visual system for the robot to be able to pass the “rolling E’s” test
- Hazardous material signs detection
- Human victim detection
- Easy to use interface for controlling the robot via a game console controller
- Intelligent graphical user interface that highlights only important information to the operator

5. Procedures and methods

5.1 Systems

5.1.1 Computer Vision

The computer vision system, to be used to detect the various symbols such as the hazmat signs, will be developed by taking an input stream of video from the robots on-board cameras. The robot contains a Bosch video recorder which transmits the video stream through the robot’s on board wireless communications system. This video stream will then be read to the remote computer system through the provided Bosch SDK. Once the video is received, it will be processed in order to detect the various hazmat, rolling “E” and human body parts. The image processing will be done with the help of the OpenCV software system. The general procedure is to transform the image’s data into a simpler representation and then apply a machine learning algorithm onto the transformed data to detect features. The framework for the symbol detection system will possibly be provided by a software suite known as Robot Operating System, or ROS.

5.1.2 Human Robot Interface

The Graphical User Interface (GUI), through which the robot operator will be given information from the robots on-board instruments, such as its cameras, will be developed in an Object Oriented Programming language such as C++. It is intended that the Scaleform GUI kit will provide a framework through which to develop the GUI for the robot control interface. Scaleform provides a vector graphics rendering engine used to display Flash-based user interfaces, HUDs, and animated textures for games, and operates on Microsoft Windows, Mac OS-X and Linux operating systems. By using a GUI library used in the games industry, the robot interface will be condensed into a single heads-up-display (HUD) that displays only the relevant information to the operator. This will help to prevent overloading the operator with the entire robot’s sensor data as only relevant information is displayed in situ.

5.1.3 Robot Control Interface

The robot control interface is intended to be developed in a modular approach in C++ as to let separate components, to be swapped out individually to be tested and improved upon. The robotic control interface will send all commands to the robot via TCP/IP socket messages passed over the wireless network, where the primary control system on the robot will interpret these messages and forward them to their respective sub-systems on the robot. The individual robot-system messages, such as “drive forward at half-speed”, will be sent to the various subsystems on the robot via various communications standards, such as serially through the RS-232 communications standard.
Many of the commands entered by the user controlling the robot will be received via a game controller, such as a PlayStation or Xbox game-console controller, which is plugged into the base station PC/Laptop showing the GUI. The base station, which will be a regular computer system, will receive inputs from the controllers and process them in the robot control interface.

5.2 Procedures

5.2.1 Computer Vision

For the computer vision and image detection system, the first requirement would be to receive sample image or video sets from the hardware on the robot. As the format of this raw data is part of the challenge for a computer to detect various features, the original pixel data must first be transformed in some way to help pick out generalizable features later.

A method for this transformation, such as generating histograms of gradients (HoG), must then be decided on, factoring in the format of the raw data and the requirements of the system.

Once the data has been transformed it can be fed into a feature recognition engine to detect and classify the various symbols required for the RoboCup Rescue project. The feature recognition engine can revolve around using a machine learning algorithm, linear or polynomial support vector machines (SVM) or a neural network.

As the HoG method in addition to the linear SVM approach can be used for both human recognition and hazmat sign recognition, it would be likely to use these methods with modifications for the separate parts of the computer vision system in order to save on time and complexity.

5.2.2 Human Robot Interface

To develop an effective robot control and graphical user interface (GUI), an iterative and incremental software engineering approach will be used. Interface development will be user centered. A participatory design workshop will be held and attended by the test subjects as well as the client: Stephen Marias.

The participants of the workshop will be given the floor to voice their opinions on the functionalities expected by the interface based on the commands they expect to give and the responses they expect to receive. After all possible functionalities of the interface have been pointed out; a GUI definition session will be held. The operators will be given a white board to sketch their ideas and appearance of graphical interface they would prefer.

Based on the interface defined, a paper prototype will be developed. Pre-defined scenarios will be given to the operators and must carry out tasks to solve those scenarios. Based on their experience during the session, changes will be made and this will be used to develop a high level prototype. The same approach will be used for following incremental prototypes. Carrying out this approach will increase the probability of a usable and effective interface.

Various challenges and limitations, including those in hardware and software, are present when developing any new system, some of which are known before the planning phase has even
started, and can be planned for in immediately, but some limitations are not obvious and will only appear after a usable prototype has been created and tested. For this reason we will use an iterative and incremental prototyping-testing development approach for all parts of the system.

6. Testing

6.1 Robot Control and GUI

The Robot control interface and GUI will be tested after using a user centered design approach. It is expected that qualitative and quantitative results and feedback can be generated from test subjects after they have been asked to complete specific tasks using the interface. The tasks evaluated during the testing phase would be the same tasks expected of the controller during an actual RoboCup Rescue competition.

For example, a user could be asked to drive the robot through a sample “obstacle” course where they would have to stay within certain marked bounds, the number of times the robot deviates from the course and crosses over the marked boundaries can be counted and used as a qualitative test result. After such a test, qualitative test results could be obtained by interviewing the user which would then be asked to raise any concerns they have with the system, such as whether or not the GUI effectively allowed the user to see where the robot was going, and whether or not the control interface controlled the robot in the intended manner.

6.2 Computer Vision

The robots ability to detect various symbols such as hazmat signs, human body parts, and the rolling “E” can be determined through performance measurements and quantitative results from simulation testing. Initially a snapshot or photo of a scene containing one or many of the required symbols could be fed into the system to determine if they are detected, after this the robot could be driven through an example course where there would be various amounts of these symbols present in known locations, while the detection system receives streaming input from the cameras on the robot.

The number of symbols detected, as well as the accuracy in detecting these symbols would be recorded and used to give an indication of how effective the robot’s vision system would be. Various parameters can also be tuned to determine in which cases the robot vision system is effective at detecting the symbols, for example in bright light vs. dim or no light.

7. Ethical, Professional and Legal Issues:

The robot that is being developed will be used in the Robocup competition. It requires robots to demonstrate their capabilities in mobility, sensory perception, planning, mapping, and practical operator interfaces, while searching for simulated victims in unstructured environments. This means that no real victims are used at the competition and therefore when the robot is being
tested for victim detection a dummy will be used. Thus no ethical issues are involved concerning harming victims.

The sections that require user testing is the Human robot interface and robot control sections. Since the hardware that is used for the robot is quite expensive, no external users will be used to test the software.

Masters students will be the test subjects of any user centered tasks and techniques to be carried out. Ethical clearance will be obtained from the department of mechanical engineering. The expected tests will be clearly explained to the subjects, and they will be notified that information gathered will be kept confidential.

8. Related Work

8.1 Team Description Papers

Team RoBrno [4] developed a remotely operated robot with help of visual telepresence. The robot mobility is controlled by a joystick. Their interface provides transparent overlays on the video screen that gives more information to the operator about the state of the robot and the surrounding environment.

8.2 Robot vision

Mikolajczyk et al [2] investigated a novel method for human detection in single images which can detect full bodies as well as close-up views in the presence of clutter and occlusion. They use robust part detection since humans are modeled as flexible assemblies of parts. They used AdaBoost for system training.

8.3 Robot Control

Richer et al [3] suggested that ideas and interfaces for HRI should be taken from successful video games, as these games are essentially little more than its interface. He said that games require players to understand where important objects are in a 3D environment and undertake fast-paced activities that require efficient interaction, these problems and tasks are similar to those when remotely controlling a robot.

8.4 Human Robot Interface

Adams [1] investigated the considerations for Human-Robot Interface Development. He defined situation areas that should be taken into consideration while designing a robot interface. He said that human decision-making, situation awareness, vigilance, workload levels, and human error are the areas to be considered during design. Therefore in order to develop a usable and efficient interface, design principles and user centered design techniques are essential and will thus be a great focus for this project.
9. **Anticipated Outcomes**

9.1 **System**

The robot will be able to detect victims’ limbs, hazmat sighs, chemical waste and rolling E set. The objects detected will be clearly highlighted on the interface and the user can go into detail if required. As the robot moves in an environment a map will be generated automatically and an operator would be able to view and print the generated map.

The user interface to be developed will be 3D game inspired. It will be intuitive and will not subject the user to sensory and information overload. The interface will only display the selected video streams and what is core to operating the robot. Minimal but informative data will transparently overlay a selected video stream. Other data will only be brought when requested. The system will be more graphical than textual in order to decrease operator cognitive and mental workload. The interface will be able to incorporate information fusion by switching between modes; that is the thermal image will be overlaid on the actual image.

Once the project is completed a user will be able to control robot base, robot sensor payload and robot arm by using a joystick and the interface developed. Robot base control involves controlling the motion of the robot that is forward, back, turn, as well as the flipper positioning. This will include the speed that the robot moves at. Robot arm control is the control of position of the arm and the operation of the manipulator and robot sensor payload control is the control and selection for the different sensors.

9.2 **Expected impact**

Should our project be successful we expect that the system will be used for a rescue robot that is developed by the Robotics and Agents Research Laboratory, Department of Mechanical Engineering, UCT. They will use the system while they participate in the Robocup competition.

9.3 **Key success factors**

9.3.1 **Robot vision**

Success factors for the robots vision will be to measure how accurately and how quick the system can detect and recognize victims, Hazmat sighs and rolling E set. This also includes the measure of how much features the system can extract from a detected object. The objects to be used during the test will be placed in different disastrous environments and the system must be able to detect and recognize those objects. For the system to be regarded as a good image recognition system it must classify the images in wrong categories the least and the detection should be done the shortest amount of time.

9.3.2 **Robot interface and control**

Success factors for the interface will be the measure of usability and efficiency of using the system. This requires measuring the time and effort it tasks an operator to accomplish a desired job or task. A successful interface will be one where the operator has modest movement of hands, eyes and, equally importantly, focus of attention. This will require carrying out user-
centred design (UCD) techniques with the operators. Success factors for robot control will be the measure of propagation delay of command from the operator to the robot and responsiveness of the robot to a command. A success will be when the robot takes the least about of time to receive and respond to a command based on a benchmark. The success factors of robot control are directly affected by how usable and effective the robot interface is.

10. Project plan

10.1 Risks

10.1.1 Accessing the robot

Risk: This is the risk that the robot will not be available for software testing on it due to construction and maintenance.

Effects: Unable to test the success or failure of the software.

Like hood: Low

Mitigation: The engineering department has developed a marine robot which has some same features as the rescue robot. The marine robot can be used to carry out any test.

10.1.2 Robot hardware damage

Risk: While the software is being tested, software bugs may cause irregularities to the robot and the robot may damage its hardware.

Effects: Unable to test the success of failure of the robot control software due to unavailability of the robot. The department might not allow the software being used on the robot because the hardware is expensive.

Like hood: Medium

Mitigation: Thorough unit testing of each component before it is integrated and tested on the robot. Whenever a test is carried out, there should be supervision present.

10.1.3 Missing project millstones

Risk: Due to time constraints, expected deliverables may not be met.

Effects: May have an effect on all the preceding tasks that need to be done because less time will be available to carry them out, which may cause an overall project failure.

Like hood: Medium
**Mitigation:** A constant review and analysis of availability of time to meet the deadlines. Make sure that all the team members are aware of the deadlines and the amount of work required from each of them.

10.2 **Timeline**
See Gantt chart in Appendix A.

10.3 **Resources required**

10.3.1 **Hardware**
- 19 inch wide screen: To display the graphical interface.
- Robot: To be able to test our systems.
- Xbox Play station Controller: For controlling the robot.

10.3.2 **Software**
The required software is as follows:

- OpenGL Libraries
- OpenCV: Open Computer Vision library for image processing and image detection.
- Bosch SDK: For displaying camera data
- Integrated Development Environment
- ROS: Robot Operating System, platform for running the system
- Scaleform: Vector rendering engine used to display flash based interfaces
- Unreal development kit: Contains scaleformGFx library for GUI development

10.4 **Deliverables**
The project deliverables are as follows:

- Project proposal
- Project Proposal Presentation
- Project web presence
- Project webpage
- Project poster
- Project report
- Project Software

10.5 **Milestones**
10.6 Work allocation to team

Due to the scale of the project the work has been divided accordingly amongst the group members based on experience and expertise of the research area. Though some parts of the project will be worked on collaboratively to prevent absolute separation of the whole project. For the project to be successful and on time, each of the group members sections’ has to be completed.

10.6.1 Group members
The following tasks will be carried out collaboratively:
- Feasibility study
- Project report
- Testing and Verification of system on robot

10.6.2 Zwivhuya Tshitovha

Z Tshitovha is responsible for the implementation of a user friendly, usable and efficient graphical interface that will be used by operators and all related tasks.

10.6.3 Jaco Colyn
J Colyn’s responsibility lies on the robot control. This requires giving the operator the ability to remotely control the robot efficiently.

10.6.4 Jonathan Dowling
J Dowling is responsible for the computer vision of the robot. This involves implementing image recognition system to detect various objects located in the video stream.
11. References


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