ResQbot: A Mobile Rescue Robot for Casualty Extraction

Roni Permana Saputra*
Robot Intelligence Lab. - Dyson School of Design Engineering
Imperial College London
London, United Kingdom
r.saputra@imperial.ac.uk

Petar Kormushev
Robot Intelligence Lab. - Dyson School of Design Engineering
Imperial College London
London, United Kingdom
p.kormushev@imperial.ac.uk

ABSTRACT

Performing search and rescue missions in disaster-struck environments is challenging. Despite the advances in the robotic search phase of the rescue missions, few works have been focused on the physical casualty extraction phase. In this work, we propose a mobile rescue robot that is capable of performing a safe casualty extraction routine. To perform this routine, this robot adopts a loco-manipulation approach. We have designed and built a mobile rescue robot platform called ResQbot as a proof of concept of the proposed system. We have conducted preliminary experiments using a sensorised human-sized dummy as a victim, to confirm that the platform is capable of performing a safe casualty extraction procedure.

CCS CONCEPTS

• **Computer systems organization → Robotics**; **Robotic components**; **Robotic control**; **Robotic autonomy**; **Sensors and actuators**;

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1 INTRODUCTION

Extensive research studies have been conducted in the areas of robotic search, exploration, and monitoring, specifically with applications of search-and-rescue (SAR) scenarios [4]. However, only a little attention has been given to the physical rescue mission, including loading and transportation of the victim (a.k.a. casualty extraction) to a safe zone for further treatments. In many rescue scenarios, fast response for on-site human intervention may not be possible due to the high potential life risks for the rescue workers. A multi-storey building fire disaster—such as the recent Grenfell Tower inferno in London, United Kingdom—is an example of a such scenario [3]. Therefore, employing rescue robots with the capability to perform a safe casualty loading and transportation procedure is essential.

Our aim in this study is to develop a mobile rescue robot system that is capable of performing autonomous casualty extraction procedures, including loading and transportation of victims in a smooth fashion, essential for ensuring victim's safety. As a proof of concept, a novel mobile rescue robot platform called ResQbot has been designed and built, as it can be seen in fig. 1.

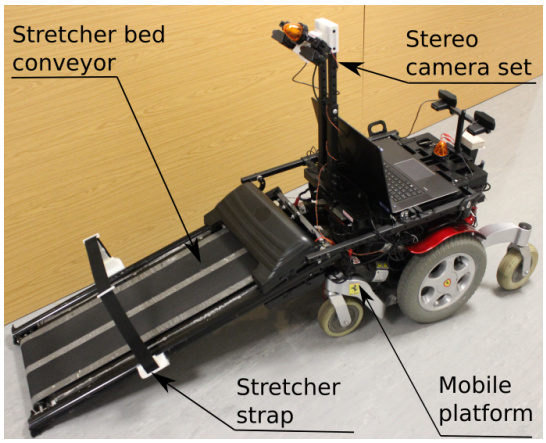

Figure 1: ResQbot robot platform comprising a motorised stretcher bed conveyor attached to a differential-drive mobile base, a stretcher strap module and a stereo camera rig.

2 CASUALTY EXTRACTION VIA LOCO-MANIPULATION APPROACH

In order to perform the casualty extraction routine, we apply a loco-manipulation approach—that can implicitly achieve the manipulation objective of loading a victim onto the robot through a series of locomotion manoeuvres. This procedure involves several major phases, including:

(1) *Relative pose adjustment*: The robot aligns its relative pose with respect to the victim in preparation for performing the loco-manipulation routine.
(2) *Approaching*: The robot gently approaches the victim safely and make contact with the victim's head for initiating the loading.
(3) *Loading*: Using a balance between the locomotion of the base and the motion of the belt conveyor, the robot smoothly loads the victim on-board.
(4) *Fastening*: After the victim is fully on-board, the strapping mechanism fastens the victim using a stretcher strap mechanism in preparation for safe transportation.

*Also with Research Center for Electrical Power and Mechatronics - Indonesian Institute of Sciences, LIPI.

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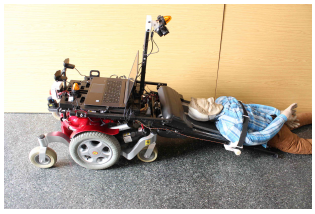
(a) Relative pose adjustment

(b) Approaching

(c) Loading



(d) Fastening

Figure 2: Sequence of images showing the progress of the casualty extraction task in the simulated rescue mission scenario in our experiments.

3 EXPERIMENTAL SETUPS AND RESULTS

A mock rescue scenario was conducted to evaluate the proposed platform. This scenario involved loading of a human-sized dummy from the ground and transportation of the dummy away from the disaster scene. We used a human dummy with approximate weight 40 kg (representing a victim). This dummy was sensorised with an Inertial Measurement Unit (IMU) to capture its behaviour (i.e. 6 degree of freedom acceleration) during the experiment at 100 Hz sampling frequency. In this preliminary experiment, ResQbot was teleoperated by human operators in order to execute the mock rescue scenario. Ninety series of trials, in total, were conducted, including 45 series for each expert and naive operators—that have no experience operating this robot—with the same setup of the victim—i.e. its relative position and orientation with respect to the ResQbot. In general, we achieved successful completion of the casualty extraction objective in all trials. Figure 2 demonstrates the sequential screenshot illustrating the procedure of casualty extraction operation by ResQbot based on the loco-manipulation technique.

Two extreme cases among the trials– which were the largest and the smallest maximum instantaneous acceleration—were selected for safety evaluation. We call these two cases as smooth and rough operations, respectively. Based on the IMU sensor data, we investigated several parameters, including maximum acceleration, maximum speed, maximum head displacement, and impact force applied to the dummy's head. Table 1 summarises the evaluated parameters in two selected extreme cases during the trials. We compared these parameters with several thresholds—which were reported in literature possible to cause head or neck injuries to the victim [1, 2]. According to the figure 3, it can be seen that all evaluated parameters in the experiments are relatively small and below the threshold. Even though it is not conclusive yet, this preliminary result shows a high safety promise of the proposed platform for casualty extraction procedure, and thus it motivates to a more elaborated safety evaluations for the practical deployment.

Table 1: Experiment summary

	Smooth	Rough
Max. instant acceleration (m/s^2)	≈ 0.154	≈ 4.042
Max. speed during first contact (m/s)	≈ 0.015	≈ 0.16
Victim's head displacement (m)	≈ 0.004	≈ 0.051
Max. impact force (N)	≈ 23.63	≈ 41.12

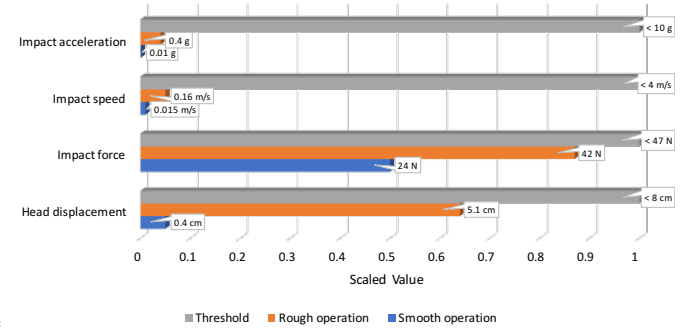


Figure 3: The measured instantaneous acceleration during the loading procedure for two extreme cases.

4 CONCLUSION AND FUTURE WORK

In this paper, we presented a proposed mobile rescue robot system that has been capable of performing casualty extraction using a loco-manipulation approach. We designed and built a mobile rescue robot platform called ResQbot. We conducted preliminary experiments to evaluate that the proposed platform could perform a safe casualty extraction procedure. Based on the conducted experiments, the platform demonstrated the capability to perform loading and transportation of the victims smoothly, so that it was possible to use this platform as a great promise of a safe platform for rescuing human victims.

Ongoing work has been focused on design and development of the mobile rescue robot for the research platform. We are currently developing autonomy for several phases of the casualty extraction procedure.

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