Firefighter Assistance Robot

Lewis Riches  
School of Built Environment, Engineering and Computing  
Leeds Beckett University  
Leeds, UK  
l.riches6426@student.leedsbeckett.ac.uk

Dr Mark Judge  
School of Built Environment, Engineering and Computing  
Leeds Beckett University  
Leeds, UK  
m.s.judge@leedsbeckett.ac.uk

Abstract—This work sets out to explore the supporting role an intelligent robotics system might play in gathering and processing the initial data from fire incidents. Initial findings from this developing project indicate that having a continually updating map of internal conditions improves accuracy of route planning and potentially the ability of crews to reach casualties and stabilise the building with increased efficiency.

Index Terms—Firefighting Robot, Field Robotics, Planning, Mapping, Simulation

I. INTRODUCTION

Cognitive load theory suggests that too much stimuli offered at one time can cause key information to be missed [1]. The maximum capacity of the short-term memory has now been found to be only 4±1 pieces of information at one time [2]. Fire incidents are complex environments at which it is essential for crews to have as much information as possible, including during approach and upon arrival at the scene. Duty of care to preserve life (both crew and casualties) is the overriding priority, along with considerations for the environment and building. Existing protocol [3] states that, when a major fire incident is declared, a human command structure can be set up. Such a structure allows for the decision making and processing of stimuli to be spread across a large body of personnel reducing cognitive load on an individual. Along with a command structure, the technique of sectorisation can be used to divide large buildings into smaller sections, further reducing the amount of stimuli one team or individual needs to process. However, there is limited information and preparation opportunities whilst the crews are en route. UK Government statistics show the average response time to a fire incident, within the UK, is 8 minutes and 49 seconds [4]. Thus, the time after arrival is used to formulate a plan to tackle the incident, often using paper maps and further witness testimony. By creating supportive intelligent robotic systems, containing layout, construction and internal hazard information, the 8 minute response time could be better used to develop and evaluate a plan(s) for the incident.

II. COMPUTER SIMULATION

Whilst there is much work taking place in the field of physical firefighter assistance robotics [5][6][7], due to the scale of such projects, together with the COVID19 global-pandemic situation, it was decided that all initial research work would be conducted using computer simulation software. Simulation software allows for the generation of digital models of real-world objects and environments. These digital models provide researchers the ability to change any detail of the model allowing for full flexibility of the environments to make them as realistic and accurate as possible and create any scenarios of the environment required. To enable this realism the software requires a physics engine to apply real world physics to the models generated [8].

Table I summarises the main requirements of the simulation software to be used for this project, along with optional requirements of supporting C++ or Python. The packages considered for this work were: Webots [9], Gazebo [10] and CoppeliaSim [11]. In order to determine the most appropriate of these, Multiple Criteria Decision Analysis (MCDA) [12] was used. Table II shows the results of the analysis, leading to the use of Webots for this work.

III. IMPLEMENTATION

As an initial proof of concept, the A* algorithm [13] was chosen as the search method to be used since it employs a heuristic based search. A* was chosen over other algorithms such as simultaneous localisation and mapping (SLAM) [14] due to its capacity as an informed search approach, which allows it to analyse a map and plot the quickest route. For this research, the system will be provided with an initial structural outline of the building, which will be given in the form of a binary occupancy map [15]. Real world implementation could
use CCTV [16], drones [17], ad-hoc networks interacting with smart devices [18] or building information modelling [19] to generate the occupancy map but for this research this was provided using a graphical user interface to mark the outline on a grid. Initial route planning was performed on this occupancy map. Once the system was following the planned route, it was able to use LiDar [20] and distance sensors to update the map with potential hazards encountered, replanning to avoid obstacles. When the system reaches its target location it then provides a final updated version of the binary occupancy.

A straightforward robotics test system was modelled and used in this first phase of the project. To sense the external environment the system uses four distance sensors. Their trajectories are shown by the red lines in figure 1. Additionally a 360 degree lidar sensor was used. For internal sensing, the system has two motor encoders one for each wheel along with inertial units for sensing roll, pitch, and yaw.

IV. EXECUTION AND RESULTS

Each scenario was completed in Webots and all files and maps provided were generated ahead of time and were not included in the execution speeds recorded. As this is early-stage work, 3 simple scenarios have been executed. Each scenario defined a start (green square) and target point (red square) with obstacles (black square) and available space (white square). Each scenario was given the initial map shown in Fig2 A and the final updated maps are shown in Fig 2 A, B and C with the robot’s path shown by the yellow path.

Definitions of the three scenarios are also shown below.

- Scenario 1 – Static environment, no obstacles (Fig2 A).
- Scenario 2 – Static environment, one obstacle (Fig2 B).
- Scenario 3 – Static environment, two obstacles (Fig2 C).

Early findings (Table III) suggest a continually updating map of an internal structure and hazards could expedite decision making, locate trapped civilians, identify fire sources, potential hazards and structural defects by passing this information to inbound fire crews. Execution times show the robot can quickly move to its target location while simultaneously mapping its environment and re-planning its route when required. To further analyse the benefit this robot could provide, further simulation testing will be completed in realistic environments. Interrogation of simulation results can provide evidence of whether the system can efficiently map a large complex environment but also complete the mapping before fire crews arrive on the scene (8 minutes and 49 seconds).

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V. CONCLUSION AND FUTURE WORK

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