RescueRobot: Simulating Complex Robots Behaviors in Emergency Situations

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Abstract. This paper aims at studying complex behaviors of search and rescue robots in emergency situations. We used as environment of the simulation NetProLogo in order to: i) build a simulated scenario with robots, humans beings, and emergency exits, ii) endow robots with reasoning rules, and iii) evaluate robots behavior on the basis of two search strategies. Preliminary results show that one search strategy reaches better performance. Next studies will cover more simulations and different scenarios.

Keywords: complex systems, rescue robots, reasoning

1 Introduction

Natural calamities such as fire, floods, earthquakes, hurricane, and tsunamis can cause loss of human lives, ecological disruption, and damage to infrastructures. Disasters typically occur suddenly and, with the same speed of the emergency, safety services should be put in place. However, the standard ability of the affected community is often not sufficient to deal with emergencies and humans rescues. External resources are then required for such chaotic and dangerous circumstances. For these reasons, mobile robotics in the domain of Search And Rescue (SAR) would be helpful [6]. The current challenges in SAR development are: robot design, simultaneous localization and mapping in the disaster area, and human beings detection. In a SAR task, a humanoid rescue robot would be designed, in the upper part, with two arms used to pick up humans, whereas the lower part would consist of two tracks for a better rough terrain mobility. Typically, they are equipped with sensors such as thermal camera, ultrasonic and microphone in order to detect human beings. The main purpose of the adoption of SAR robots is to help and facilitate the hardest operations of saving people from danger. Other benefits of SAR robots to these operations include reduced personnel requirements, and access to otherwise unreachable areas.

SAR robots are developed with specific abilities such as searching, reconnaissance, and mapping, removing or shoring up rubble, delivery of supplies, medical treatment, and casualties evacuation. Even with all these ideas coming about, there are still some technical challenges that remain. In fact, it is a hard task to plan how a SAR activity is conducted, by forecasting which difficulty robots may face, and analyzing complex phenomena that may evolve during a rescue. In this paper, we address such problems by modeling, analyzing and simulating a SAR activity conducted by robots. In a complex environment, different robots behaviors may emerge, depending on the reasoning processes held to accomplish a SAR activity. Will the robots cooperate? Or will they be in competition?. For these reasons, we developed:

1. the robot behavior to search for humans in danger and rescue them in a safety place;
2. the collective behavior of robots to perform this task in an efficient way, using the swarm robotics approach.

Swarm robotics is a recently developed approach to the coordination of multi-robot systems which consist of large numbers of mostly simple physical robots [7]. SAR robotics has received much attention in recent years and it is under investigation all over the world [4]. Lee et al. [3] propose a humanoid rescue robot characterized by two arms used for carriage of people in the upper part whereas the lower part consists of two track for better rough terrain mobility. Koch et al. [2] describe a SLAM approach applicable to multiple mobile robots.

The main research goal is that a desired collective behavior would emerge from the interactions between the robots and interactions of robots with the environment, as well as insects, ants and other fields in nature, where a swarm behavior occurs. This study aims at modeling complex behaviors of SAR robots depending on random setup of evacuations by running a simulation in emergency situations.

This paper is organized as follows. Section 2 presents an overview of the whole system. Section 3 describes the experimental setup and the preliminary results. Finally, conclusions are drawn.

2 RescueRobot

In this paper, we present RescueRobot, a multi-agent modeling environment for simulating complex systems. We developed a scenario in which robots (i.e., agents) have to search and rescue humans in the emergency situation of evacuation from a building on fire. In order to model and simulate this scenario we endowed the robots with reasoning rules. A reasoning rules system is a software system that infers conclusions from available knowledge using logical techniques such as deduction and induction. In order to simulate the complex robot behaviors in the proposed scenario we exploited NetLogo [8], and in particular the NetProLogo extension[1], that permits to run Prolog [1] inside NetLogo.

NetLogo is a multi-agent programmable modeling environment that enables exploration of emergent phenomena. It comes with an extensive models library including models in a variety of domains, such as economics, biology, physics,

[1] https://github.com/jgalanp/NetProLogo

chemistry, psychology, system dynamics. It is possible to use agents as turtles, links, patches and the observer. NetProLogo (NetLogo + Prolog) is a NetLogo extension that allows running Prolog code inside NetLogo in order to take advantage of Prolog features to provide NetLogo agents (turtles, links and patches, or the observer) with reasoning capabilities.

Prolog is a logic programming language used in artificial intelligence field. Prolog uses rules for the knowledge representation, and an inference engine to derive conclusions [5].

In this setting, a robot can help just one human per time. Hence, robots have to keep in safe humans by guiding them out of the emergency status. As general rescue strategy, robots exploit their internal stored map of the building to bring humans to the closest safety point. We then designed two search strategies:

1. search the nearest human first (NearS);
2. search humans on the basis of their gender and age first (ReasS).

In the former, robots act with no particular reasoning skills and just look for humans to rescue them as they find them. In the latter, robots should reason about what type of person safe first. Suppose that robots can recognize human characteristics by using face analysis algorithms. Hence, robots can infer gender and age rescue policies to determine a ranking based on the probability of humans to fend for themselves. The outcome of this reasoning, based on human characteristics, is the following ordered list:

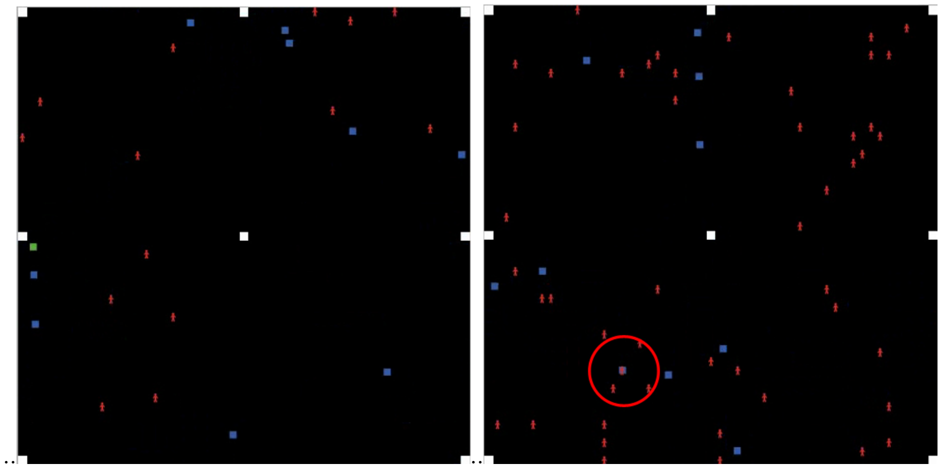
1. little girls;
2. little boys;
3. elder women;
4. adult women;
5. elder men;
6. adult men.

3 Results

Several simulations have been run using 10 robots and a different number of humans: 10, 20, 30, 50, and 100. Both search strategies have been evaluated according to the following metrics:

1. time elapsed;
2. number of total visited places;
3. number of saved humans;
4. number of robot single unit movements.

In the NetLogo graphical environment the robots are drawn in blue, the exits are represented in white, humans beings in red and robots that brings a human in green. In Fig. 1a and 1b are illustrated respectively two simulation with NearS and ReasS search strategies after 750 steps, with 10 robot, 100 humans and 8 exits. In particular, in Fig. 1b inside the red circle, it is possible to see a robot



(a) NearS (b) ReasS

Fig. 1: NearS and RearS search strategies. 750 steps, 10 robots, 100 humans, and 8 exits. Exits in white, robots in blue, humans in red, robot that brings a human in green.

on the same patch of a human. The robot does not bring the human because of the reasoning strategy.

In Table 1 results for NearS search strategy are provided. Moreover, in Table 2 results for ReasS search strategy are provided.

Table 1: Results of the simulation using the NearS strategy.

People to save	Time Elapsed (sec.)	Visited Places	Saved Humans	Robot single unit movements
10	8	759	100 % safe	177
20	34	1710	100 % safe	735
30	12	773	100 % safe	251
50	13	837	100 % safe	259
100	24	1520	100 % safe	549

From the results in tables 1 and 2, it is possible to note that when the number of humans is ≤ 10, the ReasS strategy performs better in terms of the number of visited places and number of robot single unit movements. On the other hand, as long as the number of humans to save increases, the NearS approach works better, assuring always that the whole number of humans rescues is accomplished in very few time.

Table 2: Results of the simulation using the ReasS strategy.

People to save	Time Elapsed (sec.)	Visited Places	Saved Humans	Robot single unit movements
10	11	446	100% safe	162
20	180	2600	100% safe	3693
30	317	2620	100% safe	6814
50	>500	3000	40% safe	>10000
100	>500	3000	20% safe	>10000

4 Conclusion

In this paper we presented a simulation of complex robots behaviors in emergency situations. We have tested two search strategies through several simulations and preliminary results. The simulations show that with a little number of humans, the ReasS approach outperform the NearS one, while, as long as the number of humans to save increases, the NearS approach works better. Since the nearest person strategy performs better than reasoning strategy in most of the tested cases, it is the recommended strategy to be adopted in big emergency situations.

As future works,other simulations will be performed and other strategies will be modeled using also a hybrid approach.

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