POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Formal Analysis of Search-and-Rescue Scenarios

Project for Formal Methods for Concurrent and Realtime Systems course

Authors: **Alberto Nidasio, Federico Mandelli, Niccolò Betto**

Advisor: Prof. Pierluigi San Pietro
Co-advisors: Dr. Livia Lestingi
Academic Year: 2023-24

Abstract

This document presents a formal model implemented with Uppaal of search-and-resque scenarios. Inside a rectangular map of arbitrary size, civilians have to be brought to safety by either reaching an exit or being assisted by first-responders. Drones surveys the area and coordinate the rescue efforts by instructing civilians on what to do. The model then undergoes formal verification to highlight key behavioral aspects and identify optimal configurations for maximizing civilian safety.

1 High Level Model Description

The model adopted for the search-and-resque mission involves 3 different types of agents: Civilians, First-responders and Drones. They are placed in different numbers inside a rectangular map, where exits (i.e. safe zones reached by civilians to get to safety) and fires are fixed in placed from the beginning of the scenario.

The key characteristics of the agents are:

- **Civilians**: Can be in 3 different states, depending whether they find themselves near a fire or if they are following instructions
  - **In-need** (i.e. near a fire): They cannot move and needs to be assisted. After T_v time units near a fire, they became a casualty
  - **Busy**: The civilian is following an instructions and can be either assisting directly or contacting a *first-responder* to get help
  - **Moving**: When civilians are not near a fire or busy enacting some instruction, they can move towards an exit to get to safety following a some *moving policy*
- **First-responders**:
  - **Assisting**: When a civilian *in-need* is withing a 1-cell range, the *first-responder* will assist them for T_{fr} time units. After that, the assisted civilian is considered safe
  - **Moving**: When free from other tasks, the *first-responder* can move following some *moving policy*
- **Drones**: They survey their surroundings, limited by the field of view N_v of the sensors, and follow a pre-determined path moving 1 cell at each time step. When two civilians, one *in_need* and one free, the drones can assign instruct the free civilian to either assist directly or contacting a *first-responder*

2 Model Description and Design Choices

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut postea variari voluptas distinguique possit, augeri amplificarique non possit. At etiam Athenis, ut e patre audiebam facete et urbane Stoicos irridente, statua est in quo a nobis philosophia defensa et collaudata est, cum id, quod maxime placeat, facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et.

```
// Map cell status enumeration
const int CELL_EMPTY =      0;
const int CELL_FIRE =       1;
const int CELL_EXIT =       2;
const int CELL_FIRST_RESP = 3;
const int CELL_SURVIVOR =   4;
const int CELL_ZERO_RESP =  5;
const int CELL_IN_NEED =    6;
const int CELL_ASSISTED =   7;
const int CELL_ASSISTING =  8;

typedef int[0, 8] cell_t;

// Map array
cell_t map[N_COLS][N_ROWS];
```

2.1 Civilian

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut.

2.2 First-responder

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut.

2.3 Drone

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut.

2.4 Design Choices

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut postea variari voluptas distinguique possit, augeri amplificarique non possit. At etiam Athenis, ut e patre audiebam facete et urbane Stoicos irridente, statua est in quo a nobis philosophia defensa et collaudata est, cum id, quod maxime placeat, facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et.

3 Properties

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut.

4 Conclusion

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim aeque doleamus animo, cum corpore dolemus, fieri tamen permagna accessio potest, si

aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut.