Reactive Search and Rescue Planning

0515575

Abstract

This paper looks at a generic natural disaster scenario where a number of survivors are scattered over a geographical area requiring a coordinated helicopter search and rescue effort. It aims to show that an Empirical Modelling approach to coordinating this is appropriate due to the scenario being dynamic (i.e. reports of new survivors) and changes can be unexpected (e.g. a building collapse requiring some survivors to be high priority) requiring human intervention to the model. Such changes should affect the search and rescue strategy accordingly. The suitability of dependency for affecting these changes is investigated.

1 Introduction

Strens and Gardner (2006) specify a challenge for artificial intelligence in which there has been an earthquake over a large urban area requiring a search and rescue effort to be coordinated, with the stipulation that the area of interest is only accessible from the air using a number of search and rescue helicopters. As many survivors as possible must be viewing manually from the air to identify those in most need of immediate rescue. The rescuers periodically get the location of a percentage of the survivors through the civilian mobile phone network, which should inform the best course the helicopters should take over the area. Such a scenario would require constant modification to the helicopters' courses to be most effective. It is believed that a strong solutions to this scenario would benefit from an Empirical Modelling perspective, firstly as Empirical Modelling is well suited to modelling changing observables, secondly as it provides a powerful mechanism for changing behaviour based upon changes to these observables, and lastly human interaction with the model can be easily incorporated; both in viewing the helicopter strategy and in reacting to changing variables in the scenario (e.g. a building collapse, a phone call from a survivor or an aftershock resulting in some survivors needing priority).

The complexity of the scenario outlined in Strens and Gardner (2006) is beyond the scope what can be done with this project, so the aim is to tackle a simpler toy problem involving survivors and helicopter coordination to demonstrate the previously described strengths of an Empirical Modelling approach.

2 The Model

2.1 Survivors

The model constructed consisted of 20 randomly positioned survivors over a 900m x 900m grid. Survivors are numbered on the model to identify them for the purpose of manually referring to them (i.e. for moving a survivor manually in tkeden). Survivors can have one of three states:

- Unknown – the position of the survivor is unknown to search and rescue, so this survivor should not have any bearing on the rescue strategy.
- Known – the position of the survivor is known about, but still needs to be identified by a helicopter.
- Identified – the position of the survivor is known, and a helicopter has indentified the survivor.

At the start of the simulation approximately a third of the survivors start in the 'known' state while the rest start 'unknown'. The aim of this model is for the helicopters to transition all survivors to the 'identified' state. The rules for state transition are:

- Unknown -> Known – occurs with a 1% chance each tick for all unknown survivors, reflecting the possibility of the survivor making a phone call, and with a 20% chance if a helicopter is within 150m, reflecting the possibility of a lucky sighting by the crew (e.g. survivor using a light or flare)

- Known -> Identified – occurs when a helicopter is within 30m of a survivor. Reflects the crew being close enough to verify a survivor is at the position, and determine their priority for later rescue (out of scope of this model).

2.2 Helicopters

Two helicopters performed the search and rescue, taking off from two separate bases. These bases can be moved in the model (e.g. heliPadOne = cart(X, Y);) resulting in a change in the helicopters starting position. By default, the bases are both at the bottom of the grid, 300m apart. This close proximity allows to model to demonstrate some dependency in the helicopters' strategies.

The helicopters move at a variable speed each tick. The default is 10 metres per tick, however this can be changed by a scout interface provided with the model. Fuel is used up as the helicopters move. There is a linear relationship between speed and fuel consumption. The helicopters start with enough fuel for 2000 metres travel. The consumption of the fuel can be seen on the model by the fuel gauges on the right. Helicopters can refuel by returning to one of the helicopter bases.

The flight paths of the helicopters are determined by a greedy strategy – the helicopters move to the nearest survivor in the 'known' state. Before a helicopter moves towards a new target it checks the other helicopter isn't currently heading to that survivor. If it is, the second-closest survivor is chosen as the new target in order to prevent the two helicopters following the same path. When a helicopter only has enough fuel to reach one of the bases, it returns to that base to refuel.

The greedy strategy of the helicopters can be overruled by human intervention by making one of the survivors a priority target. Due to time constraints this can only be done through an EDEN definition in the tkeden window. This definition is priorityTarget = x; where x is the number identifying the survivor. When this definition is changed, the nearest helicopter to that survivor immediately changes target to move to the priority. Once the priority target is identified the helicopter carries on with a greedy strategy.

3 Limitations

In this section I investigate some of the weaknesses of my model, and consider where further work could improve upon these weaknesses.

3.1 Limitations of the model

The model has a number of huge simplifications both over a normal search and rescue scenario, and the scenario set out by Strens and Gardner.

The most significant simplification from both is the absence of buildings complicating the line of sight from the helicopter to survivors. The decision to remove this was the complication of calculating whether there is line of sight as it would introduce a third dimension in the model, with resultant complications in geometry and helicopter strategy. With further time this would be the highest priority new feature to model.

The physics of the helicopters in the model are not a particularly accurate representation of helicopters in real life. Aside from trivial aspects such as no bounding to their top speed and unlimited acceleration, the helicopters fly unrealistically as they have a zero turning circle. In reality (and in the Strens and Gardner scenario) the helicopters should only be allowed to turn by a certain number of degrees per tick. This could be fairly easily introduced into the model, however it was chosen not to as it would not manifest itself in any changes to the helicopter's strategies – they would simply take longer to carry out the same flight path. A second unrealistic aspect of the helicopters that could be rectified in the model is the linear fuel consumption. In reality, higher speeds should use more fuel per distance travelled. This would be an interesting aspect to model, as travelling at higher speeds would identify the survivors quicker, but require more refuelling, so may or may not take longer to identify all survivors. With this feature in the model, an optimum speed for different scenarios could be found.

Finally, the scout interface for this model is poor. Much of the interesting human intervention in this model has to be performed by manual redefinitions in the tkeden input window. Improvements to the interface could include features such as drag and drop for moving survivors and helicopter bases on-the-fly, and double clicking on survivors to make them 'priority targets'.

3.1 Limitations of EDEN

The model is not very extensible – it is difficult to add more survivors or an additional helicopter because of limitations of the EDEN language. This is because there is no concept of an object or a prototype – a template of something that behaves in a certain way with dependencies with its environment, from which more instances can be created. For example, in order to a third helicopter, approximately 150 lines of code would need to be copied and modified (e.g. "heliTwo" to "heliThree"), with a further 50 new lines added as extensions to logic branches (i.e. if heliOne == something || heliTwo == something || **heliThree == something**).

A potential solution to this problem is the CADENCE notation developed by Nick Pope. This was not considered in this model as the notation has yet to reach maturity, and documentation on it is not easily available, however it is a notation to consider in the future for models requiring the prototype concept.

4 Suitability of model

This model suffices to show the three properties set out in the introduction, to demonstrate the strengths of Empirical Modelling concepts in this scenario.

1. **Modelling changing observables** – this is fairly trivial, but can be seen by the helicopter moving each tick, which is represented in the Donald window.
2. **Changing behaviour based upon changes to the observables** – the greedy strategy used by the helicopters allows for the moving of the nearest survivor to a helicopter to immediately affect the helicopters path. Likewise, if that nearest survivor becomes identified by another helicopter, the course changes. The transition of a survivor from unknown to known by close proximity to a helicopter typically affects that helicopters both, as the newly known survivor will likely be closer than the target survivor
3. **Easily incorporated human interaction –** The lack of a scout interface for most human interaction perhaps suggests that this interaction is not easily incorporated, however through redefinitions in the tkeden input window, a human can affect the working of the model significantly. The priority target feature outlined in section 2.2 is the best example of this, however other changes can also have a significant effect. For example, the moving of a helicopter base from the bottom to the top of the grid has a large affect on the range of the helicopters, as they can work from South to North identifying survivors, and stay in the North longer as there is now a refuelling point there. Though the concept of 'moving' a helicopter base is unrealistic, it could be seen as modelling the possibility of setting up a third helicopter base in the north and the effect it has on the search and rescue effort.

The simplifications and omissions from the model have already been discussed in section 3. In addition to these there were some aspects of the model that made it an unsuitable model of search and rescue. The strategies for determining the flight paths of the helicopters were weak. The greedy strategy resulted in a lack of coordination between the two helicopters; frequently both helicopters would be going for the same cluster of survivors, or in the case of both helicopters trying to go for the same target, frequently the wrong one went for the target (rather than the closer one) because target selection was on a 'first come first served' basis – if one helicopter already targeted a survivor the other helicopter couldn't.

5 Conclusion

In conclusion, this model is a fairly limited model of a search and rescue scenario. Simplification and omissions from the model due to time constraints on the project have resulted in a model that provides a conceptual look at search and rescue rather than a faithful model. However, this conceptual look does serve to demonstrate some strengths of the Empirical Modelling approach.

In terms of Empirical Modelling being able to provide a strong solution to the scenario set out by Strens and Gardner, the concepts of an EM approach lend themselves well to the approach, however the current implementation of these concepts, EDEN, lacks the object oriented features to be able to solve the problem with reasonable development effort.

References

M.Strens, A.Gardner Sensor Planning Research Challenge Specification v1.3 QinetiQ 2006