Chapter 10

Conclusions

In this thesis we have proposed to investigate and evaluate the capabilities of Answer Set Programming to represent disaster situations in order to give support in defining evacuation plans.

We have come to the conclusion that using Answer Sets is possible to represent disaster situations and overall to take advantage of the capabilities of Answer Sets and of the different Answer Set approaches that currently exist to obtain the alternative evacuation plans. In this work we studied some of these approaches in order to define the evacuation plans. Additionally, we shown how and why the Answer Set approaches studied were useful to define evacuation plans. Finally, we presented some lacks of these Answer Set approaches that we addressed in this work.

Since most of the information needed to model an evacuation plan problem corresponds to geographic information, we analyzed how geographic information about the disaster zone can be translated into a format that Answer Sets is capable to understand. In particular, we proposed a procedure to construct the hazard zone background knowledge from geographic information. This procedure was a direct result of our own experience dealing with this kind of data. We also presented the information which would be ideal to have in order to model an evacuation plan problem and in particular a volcano evacuation plan problem. It is worth to mention that in this work we tested all of our results with a short part of the real geographic data about Volcano Popocatépetl hazard zone, and with part of the information that would be ideal to have to model an evacuation plan, since the total real data of this zone were obtained almost at the end of this work.

The scenario that we considered in this work models a hazard zone where towns, in risk, roads and shelters are defined. Moreover, some of the roads are part of a set of pre-defined evacuation routes. Our scenario, also considers that in a real case is possible that part of the pre-defined evacuation routes become blocked, and then generation of alternative evacuation plans is necessary.

In our first attempt to model the alternative evacuation plan problem we used *Answer Set Planning* [16] since it provides a natural and elegant way to model planning problems where it is possible to represent states, initial states, actions, executability conditions and effects of actions, and goals in order to obtain the feasible plans. However, we realized that using only Answer Set Planning to specify these kind of planning problems does not result in a natural way. Hence, we studied and applied different Answer Set approaches that were useful to obtain the evacuation plans, such as, *CR-rules, Minimal Generalized Answer Sets, Ordered Disjunction programs* and *Language* $\mathcal{PP}$ for planning preferences.

We proposed to extend our model of evacuation plans adding CR-rules. Then, taking advantage of the definition of a CR-rule we use it only if there is no way to obtain an evacuation plan when part of the pre-defined evacuation route is blocked. Additionally, since the semantics of a CR-program is defined in terms of the minimal generalized answer sets, we proposed a characterization of them in terms of ordered disjunction programs.

However, the alternative evacuation plans obtained adding CR-rules to the Answer

Set Planning problem specification do not consider any other characteristic of the path that they follow. Then, we realized that we needed to apply the concept of preference to obtain an appropriate evacuation plan. Currently, in Answer Sets there are a lot of approaches dealing with preferences. In particular, we studied and analyzed language $\mathcal{PP}$ since, it allows to express preferences at different levels over the alternative plans and because it allows us to express preferences over plans where the satisfaction of these preferences depends on time and on their temporal relationships.

While we used $\mathcal{PP}$ to express preferences we realized that there are some preferences that cannot be expressed in a simple and natural way since they result very large. Then, in order to have a natural representation of these kind of preferences we defined $\mathcal{PP}^{par}$ language. $\mathcal{PP}^{par}$ is an extension of $\mathcal{PP}$ language where propositional connectives and temporal connectives allow us to represent compactly preferences having a particular property. Since we consider that language $\mathcal{PP}$ could take advantage of the working framework of propositional Linear Temporal Logic LTL to express preferences, we also presented a brief overview about the relationship between language $\mathcal{PP}$ and LTL.

We also studied ordered disjunction programs since they allows us to represent alternative, ranked options for problem solutions. We proposed an extension of them to a wider class of logic programs that we called *extended ordered disjunction programs*. Moreover, we shown that in particular extended ordered rules with negated negative literals could be useful to allow a simpler and easier encoding to obtain the preferred plans with respect to a preference expressed in language $\mathcal{PP}$. We also considered them to obtain the maximal answer sets of a program characterizing an Argumentation Framework such that these maximal answer sets correspond to the preferred extensions of it.

Finally in this work, we introduced the notion of *Semantic Contents of a program* as an alternative point of view to obtain different answer set semantics of a program.

In particular, we show how to obtain the *standard answer sets*, the *generalized answer sets*, the *minimal generalized answer sets* and a new answer set semantic introduced in this section called *partial answer sets*. In particular we presented an example in a planning domain where partial answer sets could be useful.

An interesting topic to future research is the application of some Answer Sets approaches aimed to make the generation of answer sets more effective in the generation of Evacuation plans. For instance with respect to their memory requirements such as in [5].

Another research direction is about modeling dynamic domains using Answer Sets to generate evacuation plans where all characteristics of relevant exogenous events (for instance an explosion or lava flows) occurring in a hazard zone and the complete information about a hazard zone can be considered. The Answer Set approaches used in [3] for model dynamic systems and in [10] to model lava flows could help us in this research direction.

Finally, it would be interesting to extend our use of Semantic Contents to find some other answer set variants, such as preferred answer sets for Ordered Disjunction Logic Programs and then, analyze their use to obtain the evacuation plans. For instance in [48] some short examples using partial answer sets from Semantic Contents are illustrated.