Towards the use of Cr-rules and Semantic Contents in ASP for planning in GIS

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Abstract. The paper proposes the integration of CR-prolog and semantic contents in ASP to add planning capabilities to a Geographical Information System. Nowadays, cr-rules are used to restore the consistency of a program giving the diagnosis of possible causes of failure in a plan. However, in this paper we propose to use cr-rules to obtain an alternative plan in case of the ideal plan fails, i.e., we give an additional use for cr-rules. In particular, we show the use of cr-rules in a situation related to the risk zone of volcano Popocatepetl. We show an example about how we can obtain alternative evacuation routes, using cr-rules.
Keywords: Answer sets, GIS, Planning.

1 Introduction

Government is responsible for the long-term health, safety, and welfare of citizens. It knows that people could be at risk from different types of disaster such as terrorist attacks, extreme weather events such as hurricanes, earthquakes and volcano eruptions. Having a plan seems to be the best response to the threat of such events. Hence, government should have emergency management applications in order to give support in definition of these emergency plans [J00].

Our work is related to planning for emergency evacuation. Nowadays, Mexican government has defined evacuation routes to put in safe people living next to the risk zone of volcano Popocatepetl in case of an eruption occurs. Hence, it seems to be very useful to have planning operation as part of a Geographical Information System (GIS) in order to give decision support. Besides, our work will be part of a current project about natural hazards in the Popocatepetl volcano zone [SR01].

Today, GIS technology has limits to solve specific problems. Normally planning in GIS is made with geometric operations and is supposed that data describing the environment are completely know and static [BCCW96]. We think that an Answer Set approach should be explored in order to add planning capabilities to a GIS. One advantage of using an Answer Set approach is that it offers a declarative approach for planning and it allows to obtain a GIS analysis in case of have incomplete knowledge.

In this paper, we present a situation related to the risk zone of volcano Popocatepetl. We use an answer set approach to model how an agent can get an evacuation route. In [BG03] cr-rules are introduced and they are used to give a diagnostic in case of inconsistency. We propose to use cr-rules to obtain alternative plans to achieve the agent goal. Now, we propose to give an additional use to cr-rules.

The paper is structured as follows. We show the importance of adding planning operation as an extension of a GIS and of using an answer set approach. Next, we introduce a GIS example related to the risk zone of volcano Popocatepetl. In this example, we show how to obtain an alternative evacuation route, using cr-rules. Finally, we present future work related to Cr-rules and Semantic Contents in Answer Set Programming and our conclusions.

2 Planning for GIS problems: An Answer Sets approach

Nowadays, the Mexican government has defined evacuation routes to put in safe people living next to the risk zone of volcano Popocatepetl in case of an eruption occurs [SR01]. However, to define effective evacuation routes it is necessary to consider the traffic flow capacity of roads and critical danger points (e.g. bridges likely to be destroyed by an earthquake at moment of volcano eruption). Additionally, is required that the applications used by government allow the analysis of potential effects of emergencies on evacuation routes and traffic flow. Moreover, in this kind of applications results important modeling the effect of placing emergency facilities and response capacities in particular locations. Then it seems to be very useful to have planning operation as part of a GIS system in order to give decision support.

We have adopted an Answer Set approach focused on the planning that an agent in dynamic domains does presented in [Bar03]. One important characteristic of these domains is that they allow considering a main agent and other agents doing actions, referred to as exogenous actions. Exogenous actions are beyond the control of the main agent and may modify its environment. The architecture of agents in dynamic worlds consists of repeated execution of the following steps:

1. Observe the world and add the observations (about agent's actions and exogenous actions) to the agent's set of observations(O).
2. Construct a plan (sequence of actions) from the current moment of time to achieve the goal.
3. Execute the first action of the plan and add this execution as an observation to the set (O).

Now we present a situation related to the risk zone of volcano Popocatepetl. In Figure 1 we show a map of volcano Popocatepetl rounded by towns in risk and roads. We have the information about evacuation routes and towns in risk in the data base referred in [SR01].

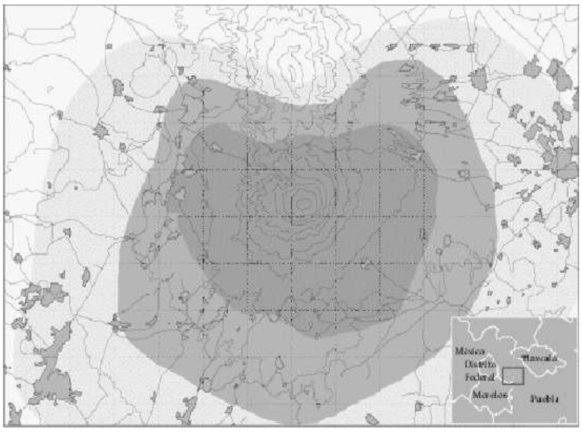

Fig. 1. Volcano Popocatepetl rounded by towns in risk and roads

The roadway network is represented by a directed graph. The evacuation route is a path in this graph. We consider that towns are connected with other towns by roads, each road is made up by segments, and each segment is represented by $road(P, Q)$ where P and Q are nodes. Some segments can belong to an evacuation route. There is an exogenous action $block(Q)$, which causes node Q become blocked. If one segment of road is unblocked and belongs to the evacuation route, it is possible to travel by this segment when the zone is in risk. We consider an agent capable of performing the action, $travel(P, Q)$. We assume that actions take one unit of time. The *action* is defined by the rule:

$$action(travel(P, Q)) \leftarrow road(P, Q), route(P, X), route(Q, X).$$

This rule says that it is possible to travel from P to Q if there is a segment of road from P to Q and if the edge between P and Q belongs to the evacuation route. Exactly as Plan Operativo Popocatpetl office in Mexico indicates. The *effects of this action* are expressed by the following rules:

$$caused(position(Q), travel(P, Q)) \leftarrow edge(P), edge(Q).$$
$$caused(neg(position(P)), travel(P, Q)) \leftarrow edge(P), edge(Q).$$

The first rule says that if the agent travels from P to Q then the new position is Q, and the second rule says that if the agent travels from P to Q then the agent is not in position P. Normally, the action travel is executed. However, there are two exceptions to this action expressed as follows:

$$noaction\_if(travel(P, Q), neg(position(P))) \leftarrow edge(P), edge(Q).$$
$$noaction\_if(travel(P, Q), blocked(Q)) \leftarrow edge(P), edge(Q).$$

The first rule states that it is impossible to travel from P to Q when the agent is not at position P. The second rule states that it is impossible to travel from P to Q if edge Q is blocked. Here $position(P)$ and $blocked(Q)$ are *fluents* which define the possible domain states [Bar03].

In order to show how this program works, we give some specific values for the background knowledge. We take only some segments of roads from two towns in Huejotzingo from our GIS database referred in [SR01]. Huejotzingo is part of the Popocatepetl risk zone.

Figure 2 shows the segments of road used in our example. The segments of road are the following:

$road(507, 508)$. $road(508, 1096)$.
$road(1096, 1102)$. $road(1102, 1113)$. $road(1113, 1116)$.
$road(1096, 1105)$. $road(1105, 1131)$. $road(1131, 1109)$. $road(1109, 1113)$.

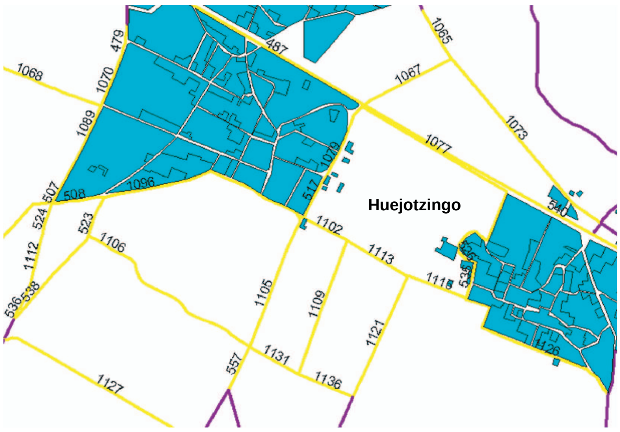

Fig. 2. A zoom in between two towns from Huejotzingo

We also have the following two rules to represent that we need an evacuation route from node 507 to node 1116.

$$initially(position(507)). \quad finally(position(1116)).$$

Also, we assume that only nodes 507, 508, 1096, 1102, 1113 and 1116 belong to the evacuation route. The result is the following plan:

$travel((507, 508), 1)$. $travel((508, 1096), 2)$. $travel((1096, 1102), 3)$.
$travel((1102, 1113), 4)$. $travel((1113, 1116), 5)$.

The plan reads as follows: the agent should travel from 507 to 508 at *time* 1, from 508 to 1096 at *time* 2, from 1096 to 1102 at *time* 3, etc. All the edges in this plan belong to the evacuation route. Now, if an exogenous action occurs. For instance, a mudflow blocks part of the road, we add to the background knowledge the following rule:

$$initially(blocked(1102)).$$

This rule says that the node 1102, which belongs to the evacuation route, is blocked. The result is that the program is inconsistent and the agent is not able to find an evacuation route because of the fact that action travel only works if all the edges belong to the same route. Hence, now the problem is to find an alternative evacuation route. In the following section, we propose the use of *cr-rules* [BG03] to solve this problem.

3 Cr-rules and planning in GIS

In [BG03] each rule of a CR-Prolog program is referred as a regular rule. However, if an agent has no way to obtain a consistent set of beliefs using regular rules it is possible to restore consistency using cr-rules and some exogenous actions that may have occurred in the past. Then, using cr-rules makes it possible to obtain a diagnosis of the reason for the inconsistency. The example presented in [BG03] illustrates the use of cr-rules. Let P be the following program:

$a \leftarrow \text{not } b.$
$\neg a.$
$r_1 : b \stackrel{+}{\leftarrow} .$ % r_1 is the name of the cr-rule

The first two rules are regular rules and the third rule is a cr-rule. Cr-rule r_1 says that the agent is allowed to believe in b if the agent has no way to obtain a consistent set of beliefs using regular rules only. We can see that the program P is inconsistent without the use of r_1. Consistency can be restored using r_1, leading to the answer set $\{\neg a, b\}$.

It may be worth noting that in [BG03] a set of examples about the use of cr-rules are given. Among these examples there are two that show how cr-rules can be used to generate plans of minimal length. In this paper, we propose to give an additional use to cr-rules.

We propose to use cr-rules to restore consistency and to obtain alternative plans to achieve the main agent goal. Let us suppose as an example, that it is not possible to obtain an evacuation route from node 507 to node 1116 and the initial occurrence of an exogenous action has occurred. The program has regular rules only and the exogenous action says that the node 1102, which belongs to the evacuation route, is blocked. Then, in order to restore consistency and obtain an alternative plan we propose to add to the program the following cr-rule:

$$r_2 : action(travel(P, Q)) \stackrel{+}{\leftarrow} road(P, Q).$$

This rule says that it is possible to travel from P to Q if there is a segment of road from P to Q. This cr-rule does not check if the edge between P and Q belongs to an evacuation route or not, as the regular action *travel* defined previously. As we described before, this cr-rule should be used only if the agent has no way to obtain a plan when an exogenous action occurred.

The result of adding this cr-rule when the exogenous action $blocked(r1102)$ occurs is the following plan:

$travel((507, 508), 1)$. $travel((508, 1096), 2)$. $travel((1096, 1105), 3)$.
$travel((1105, 1131), 4)$. $travel((1131, 1109), 5)$. $travel((1109, 1113), 5)$.
$travel((1113, 1116), 6)$.

We can see that the plan indicates the agent should travel from 1096 to 1105 at *time* 3 in spite of node 1105 not belonging to the evacuation route. The same occurs for nodes 1105, 1131 and 1109, hence the agent has found an alternative evacuation route. The implementation of this example was inspired by an example from [Bar03] and we have used Smodels [Sim95].

4 Conclusions and future work

Currently, we have started to explore the use of Semantic Contents [OZ03] of a program to obtain the semantics needed in planning and cr-rules. Cr-rules programs are closely related to abductive logic programs [KM90,Gel91]. The semantics of cr-rules programs is given by the notion of *minimal generalized answer set* [BG03]. We propose to use the Semantic Contents [OZ03] of a program since it represents a mathematical structure from which we can obtain, in a uniform way, different answer set semantics. Among these semantics are those needed to perform planning and diagnosis such the standard definition of answer sets and minimal generalized answer sets. The *Semantic Contents* of a program is a set of pairs obtained from the union of the program and a set of formulas, all of them satisfying certain properties [OZ03]. It is important to emphasize that we can obtain the Semantic Contents of a program for every logic that satisfies few basic properties.

As we mentioned, cr-rules use minimal generalized answer sets in order to select the sets of cr-rules needed to restore consistency of a program. Additionally, to apply cr-rules to restore the consistency of a program is necessary to know the possible causes of inconsistency. However, it is not always possible to know which are all the possible causes of inconsistency. We think that it is possible to obtain the *partial answer sets* from the semantic contents of the program [OZ03] to infer from it the biggest amount of knowledge in order to give support to define a new possible cause of inconsistency. Hence, this new possible cause of inconsistency can be added as a cr-rule to the program in order to restore consistency. Actually, we are working on this.

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