PROLOGUSED TO REPRESENT AND REASON QUALITATIVELYOVER A SPACE DOMAIN

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ABSTRACT

Spatial reasoning is a relevant topic in artificial intelligence with applications in geographical Information System, robotics, content-based image retrieval, traffic engineering. Additionally formal representation of knowledge allows the processing in a computer. Prolog is a programming language used in artificial intelligence that is useful to represent knowledge and perform a search, by asking questions in the knowledge base. Prolog can be used to develop a variety of applications like check the consistency or to perform any kind of reasoning. This article proposes the use of Prolog as a representation model and a reasoning engine to describe the topological relations between several objects in a geographic space, using the RCC model. The application of this simplifies the constructionprogram, allows us to focus on the spatial problem.

KEYWORDS

Knowledge based systems, Prolog, RCC model, topology, AI languages, Programming languages, spatial reasoning, spatial representation.

1. INTRODUCTION

Prolog is an Artificial Intelligence (AI) language that can be used for applications of symbolic computation like relational databases, mathematic logic [26], abstract problem solving, understanding natural language, design automation, symbolic equation solving, biochemical structure analysis and other areas of artificial intelligence [1, 23]. Today it is difficult to find applications for Prolog. The language is often used just for teaching AI topics, Discrete Mathematics or related subjects. Today there are efforts to develop platforms to execute Prolog in a multithreaded environment, in order to enhance its performance [25].

In [2] we can find that the elements of a Knowledge Based System. We can find an Inference engine, a user interface and a knowledge base as we can see in. Additionally, in [3,4]. We can see that the difference between an expert system and a Shell is only the knowledge base, where the shell has no knowledge. Prolog has some characteristics that can be used to build acknowledge based system and serve as an interface between the search engine and the user interface.

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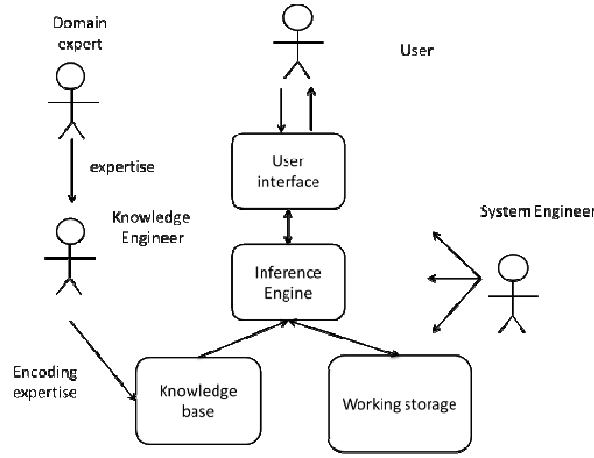

Fig. 1 Component of a Knowledge base system [3].

Prolog have a wide application as an Automated Theorem-proving [20]. For example as we can see in [21], it can be used to perform a Case Based Reasoning to construct a representation to define the properties of a waste treatment in order to know the similarities between the cases. In [24] it is used to solve a traditional AI problem that is the SAT solvers [20,24] and in [27] shows an application performing queries on ontologies with the OWL[1]standard. Finally we can see the importance of Prologwether we saw the different variantsof this language like Golog [20], the extension Bousi-Prolog [28] and some implementations in Java and frameworks [29,30].

In this article, we show how Prolog can be used to define rules over a space and determine the consistency in a knowledge base. Section 2, contains some theorical considerations about topologic spatial relations and information about the RCC model. Section 3 Describes a spatial domain, where element in spaces can be categorized and recognized. Section 4, shows how Prolog and the RCC model are related. Finally Section 4 contains a conclusion about this work.

2. THEORICAL CONSIDERATIONS

2.1 QUALITATIVE REASONING AND REPRESENTATION

Qualitative spatial reasoning and representation, are widely used in several areas of artificial intelligence, for example in Geographic Information Systems, planning, robotic navigation, natural language process, visual languages, content image retrieval, traffic engineering, computer networks, 3d modelling, virtual reality [6-10].In Artificial Intelligence, we can see that one of the task of an intelligent agent is to perform a spatial reasoning with the intention of solve a problem [11]. One of the main goals of the spatial reasoning is: provide a symbolic language closer to the common sense of human beings [12]and reasoning with incomplete information, we can see and example of fuzzy logic in the spatial domainin [22]. On the other hand knowledge representation allows to have mechanisms to identify important elements of the space such as topology, orientation, shape, size and distance [13], which are the essential properties to describe the relations between objects in the space [14].

We can identify different formalisms to relate geographic objects, one of these are the topologic relations, like the 9-intersection model of Egenhofer [15], the RCC model of Cohn [16], and their

[1] Ontology Web Language. https://www.w3.org/OWL/

variations such as RCC5, RCC23 [17]. RCC model and 9-intersection, has become one of the most popular models to describe binary topological qualitative binary relations [18].

2.2 The RCC8 Model

The RCC model describe Euclidian regions or topological between two objects. In the next figure we can see the relations of the model [19]

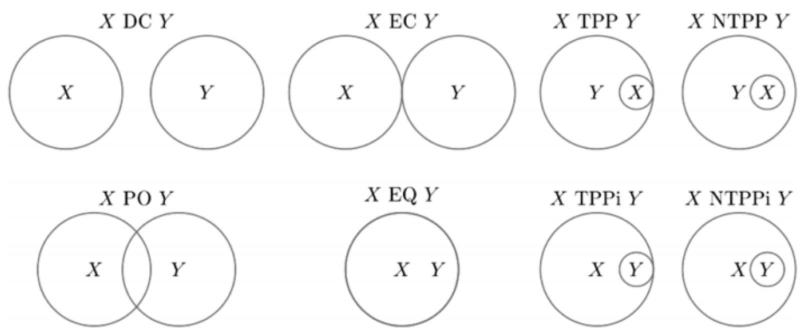

Figure2. RCC8 model

The relations of the model are.

- Disconnected (DC)
- Externally Connected (EC)
- Tangential Proper Part (TPP)
- Non-Tangential Proper Part (NTPP)
- Partially Overlapping (PO)
- Equally Connected (EC)
- Tangential Proper Part Inverse (TPPi)
- Non-Tangential Proper Part Inverse (NTPPi)

3. Describing A Domain

I order to use Prologto reason over a space domain, closely as a way the human thinks.In the space domain, we need to define some spatial relations like directional relations and topological relations, for example as we can see in the following image.

Fig. 3 Lake of Bourget

If we can detect the objects A and B,by using any kind of segmentation image. For these purposes we will identify A as a body of water and B as a green area. Having defined the two objects we need to define the spatial relation between them and the spatial relation in this case is a topological one. In the next propositions we can express this knowledge.

We can have the following sets of facts.

A is blue
B is green
So we can have three rules
If A is blue, then is a body of water.
If B is green, then is forest.
If B surrounds A, then A is a lake

We can see the previous facts and rules in Prologin the following in figure

```
blue(blue).
green(green).
surround(green,blue).
geographic_relation(A,B):-write('there is a  '),green_area(A),write(' and there is '),body_of_water(B),
write(' then '),surround(A,B),write('it is a lake').
body_of_water(A):-blue(A),write('body of water').
green_area(A):-green(A),write('forest').
```

Figure 4. Identified elements.

If we ask for the relation of them

```
1 ?- geographic_relation(green,blue).
there is a  forest and there is body of water then it is a lake
true .
```

Also we may have another implementation in the space like the image below.

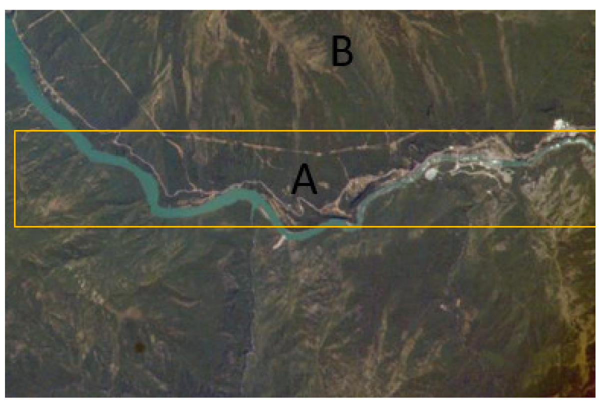

Figure5. Identified elements.

We just need to extend our Knowledge base with the following rules and change the facts. Of course, the granularity we apply to our domain, the more punctual answers we obtain.

Blue is a body of water
Green is a forrest
B is external/surronds A then A is a lake and B and A conforms a forest
B cross A then A is a river.
River is a body of water.

In Prolog can be seen like this (Figure 6).

```
blue(blue).
green(green).
traverse(blue,green).
```

Fig 6. Facts of the elements.

And we can construct the rules of inference, with the intention to define, the spatial relation of A and B.

```
geographic_relation(A,B):-write('there is a  '),green_area(A),write(' and there is '),body_of_water(B),
write(' then '),surround(A,B),write('it is a lake').
geographic_relation(A,B):-write('there is a  '),green_area(A),write(' and there is '),body_of_water(B),
write(' then '),traverse(A,B),write('it is a river').
body_of_water(A):-blue(A),write('body of water').
green_area(A):-green(A),write('forest').
```

Fig. 7 Rules of Inference.

4. Applying PROLOG To The Space Domain Using The RCC Model

4.1 Identifying The Relation Objects Using The RCC Model

Suppose we have the following set of objects from A to F, as described in the figure 1. We want to obtain the relations between them.

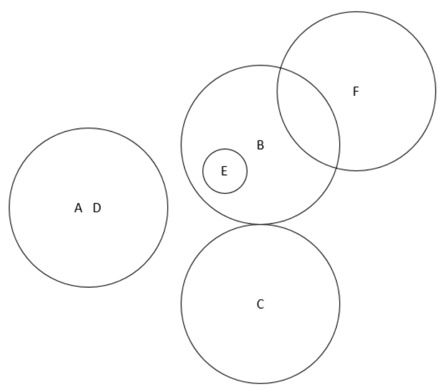

Fig 8. A set of five objects

We need to have an appropriate representation of the objects. For example we can represent them in Prolog as predicates (As show in figure 2).

```
dc(a,b).
ec(b,c).
eqq(a,d).
po(f,b).
pp(b,e).
```

Fig 9. Set of five facts that represent a space domain.

Where the description is the following: dc denotes a is disconnected from b, ec denotes b is externally connected with c, eqq denotes a is equally connected with d, po f partially overlaps b and pp b tangential proper part e.Then, if we can obtain the relations between several objectsProlog can be used to describe the relation, we can just search the relations between all the elements in our knowledge base. Then to generalize, for every object that we can read, we can define the rules we see in figure 10.

```
relation(X,Y):-eqq(X,Y),write('For: '),write(X),write(' with '),write(Y),write('are EQ'),nl.
relation(X,Y):-dc(X,Y),write(' For: '),write(X),write(' with '),write(Y),write('are DC'),nl.
relation(X,Y):-ec(X,Y),write(' For: '),write(X),write(' with '),write(Y),write('are EC'),nl.
relation(X,Y):-po(X,Y),write(' For: '),write(X),write(' with '),write(Y),write('are PO'),nl.
relation(X,Y):-pp(X,Y),write(' For: '),write(X),write(' with '),write(Y),write('are PP'),nl.
```

Figure 10. Definition of the relations.

Having load the knowledge base, and the rules. We can ask Prolog about the relations in the knowledge base by writing the following questions.

?-relation(X,Y).

The results of the search we obtain is the relations between all the elements in the knowledge base. As we can see in the in the figure 11.

```
1 ?- relation(X,Y).
For: a with d are EQ
X = a,
Y = d ;
 For: a with b are DC
X = a,
Y = b ;
 For: b with c are EC
X = b,
Y = c ;
 For: a with b are EC
X = a,
Y = b ;
 For: f with b are PO
X = f,
Y = b ;
 For: b with e are PP
X = b,
Y = e.
```

Figure 11. Results of the question.

4.2. Checking The Consistency

To verify the consistency between all elements in the knowledge base we add a predicate we can see these changes in line two and three. As we see it is not possible for the objects *a* and*b* to be disconnected and externally connected. The conclusion is that it must be an error in the knowledge base.

```
2    dc(a,b).
3    ec(a,b).
4    ec(b,c).
5    eqq(a,d).
6    po(f,b).
7    pp(b,e).
```

Figure 12. Knowledge base with inconsistency errors.

To check the consistency we can use a conjunction to find if there is an error in the knowledge base.

```
consistency(X,Y):-dc(X,Y),ec(X,Y),
write('These objects can not be Externally connected and Disconnected at the same time').
consistency(X,Y):-dc(X,Y),eqq(X,Y),
write('These objects can not be Disconnected and Equally connected').
consistency(X,Y):-dc(X,Y),po(X,Y),
write('These objects  can not be  Disconnected and Partially conected').
```

Figure 13. Rules for consistency.

For example, we can define that a relations between two objects like A and A since are the same, we can omitted. As we can see in the code, no other object in the relations have the same consistency error as we define so we obtain false.

```
2 ?- consistency(X,Y).
These objects can not be Externally connected and Disconnected at the same time
X = a,
Y = b ;
false.
```

5. CONCLUSIONS

In Prolog define relations between a pair of objects does not requires much complexity, it is just requires the facts and the rules of the space domain. Also the representation of knowledge it is closer as the human common sense. To perform reasoning we simply need to ask about the objects related in the knowledge base and Prolog performs the reasoning.Additionally Prolog allows to check the consistency so we can evaluate if there is an error identifying objects. The knowledge base accepts add more knowledge and can be processed all the information again.So in sum Prolog can describe all the objects in the space.Prolog can be integrated to a variety of applications as a shell of and knowledge base, whether there are defined the objects and their relations.

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