Urban Land Use Planning using Answer Set Programming
- Preliminary Report -

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Abstract. The urban planning is required to direct the cities development based on the sustainable use of its territory. On the other hand, Answer Set Programming (ASP) is a logic programming paradigm with the ability of non-monotonic reasoning, which has contributed to solving complex problems in a short period of time, providing a considerable number of possible outcomes to the same problem. The treatment of sustainable urban planning by using ASP has not been proposed so far. This article aims to demonstrate by using a declarative approach, a modelling exercise using basic knowledge about a mix of urban land usage. Also, showing alternatives for a better functional integration of green and habitational areas, as well as a discussion of further research using this approach.

Keywords: Urban Planning, Urban Land Usage, Answer Set Programming, Knowledge Representation and Reasoning

1 Introduction

The need to think about an ordered cities growth, the relationships between living things and their environment and planning the cities development, are not new topics. The proposal on strategic measurements to improve the conditions of urban cities, is one of the topics considered in the Agenda 21, to promote the construction of an international sustainable model for the twenty-first century [13].

Derived from the above, with support from the United Nations Environment Programme (UNEP), different countries worldwide have joined forces in order to adapt environmental policies into their development processes with a sustainable approach. Also, the Institute of Hygiene, Epidemiology and Microbiology of the Ministry of Public Health of Cuba in coordination with the World Health Organization (WHO) and UNEP through the Latin American and the Caribbean Regional Office, have proposed a classification of six universal principles for planning a sustainable urban ecosystem [19]:

1. Ensure proper water supply.
2. Keep protected vegetation.
3. Preserve soil quality.
4. Ensuring sustainable conditions for wildlife.
5. Keeping potential of regional food production.
6. Create a human scale urban environment.

Taking into consideration the principles 2,3 and 6, this article proposes forming a basic knowledge that serves an intelligent system in resolving a complex combinatorial problem. An example of this is the ecological order for a given territory at the scale of a functional integration of green and residential use areas.

Initially this article mentions works that link the use of technology as a support to progress in the field of organization of urban territories, then the land use term is defined as part of sustainable urban planning and an introduction to ASP is provided. Consecutively both issues are linked to generate a proposal where ASP contributes to the definition of urban land use. This paper concludes with a discussion of the preliminary results and future work.

2 Backgrounds

Land use and urban planning in general have been areas of interest to the scientific community. Reason why, they have developed works that employ technology as a way to propose alternatives for cities improvement. For purposes of this paper, the works mentioned below have used some method of Knowledge Representation (KR).

One of the first works is the URBYS system, defined as an expert system for urban areas analysis through knowledge representation for decision-making [16]. There are studies that address the selection of industrial zones [17] under a system called MATISSE which, by decision tables represents knowledge as a set of rules and their respective actions. Likewise decision tables have also been used to introduce functional classification theory to land use planning [18].

Changing the subject, ontologies is another used and proven approach in works like OSMoSys [12] which seeks to harness the potential of Web applications as interactive tool gathering information from urban areas as well as information generated by humans through smart devices and social platforms.

It should be noted that these examples where different approaches within urban planning, especially in land use alternatives have used AI to resolve or attack a problematic. Nevertheless, so far none has taken advantage of the benefits of ASP to solve these problems and that is why the strategy proposed in this article is unique in its class.

3 Land Use within Sustainable Urban Planning

A standard definition of land use is the employment that humans make the earth's surface, covering the management and modification of the natural environment to make it a built environment[3]. Examples are human settlements that involve industrial parks, shopping centers, roads, green and residential areas, among others.

Within the universal principles for sustainable urban ecosystem planning previously mentioned, three of them are directly linked to land use planning purposes considering the functional integration [8] between green and residential use areas. The first of them reference the maintenance of the protected vegetation, mentions that preserving natural environmental areas including trees, people, plants and animals can benefit from the environmental services provided. The second mentions the preservation of soil quality, which, can be achieved by using high quality soil on green areas. Poor quality soils should be used for construction of buildings and other infrastructure. The third refers to the adaptation of patterns of land use to meet the needs of residents. These three principles handle certain rules, restrictions, conventions or preferences that allow forming a knowledge base for modeling desirable behavior in order to adapt to conventional urban spaces.

4 Answer Set Programming

Several researchers have proposed the use of ASP as a solution to the paradigm of knowledge representation and reasoning [2] [7] [9] [10], also since its inception, ASP has been considered as the most suitable and effective computational processing mode for non-monotonic reasoning and Knowledge Representation (KR) [2] [3] [11]. This perspective has promoted the creation of high performance and efficiency Answer Set Solvers.

ASP has been tested successfully in areas, which involve problems of combinatorial search using a considerable amount of information to process [7]. It is noteworthy that at the University of Potsdam has developed software as Clasp, Gringo [5], Clingo [6], among others[4], which have been recognized worldwide for its capacity and performance applied in ASP [1] [4].

Additionally, ASP is based on a simple yet expressive rule language that allows users to easily model problems in a compact form. The solutions to such problem are known as answer sets or stable models [15].

4.1 Problem Representation in Logic Form

To properly represent a problem it is necessary to segment it into three logical components: Facts and Constraints, Preferences and Real Scenarios or Input:

- Facts and Constraints: are those foundations that we can get from a specific problem whether they are not going to change or are prohibited. In other words are the guidelines and parameters involving sustainable urban planning.

[3] https://en.wikipedia.org/wiki/Land_use

[4] More information about the Potsdam Answer Set Solving Collection software: http://potassco.sourceforge.net

- Preferences: Establish rules and restrictions about situations preferable over others [14].

Modeling rules, constraints and preferences give us the parameters of what is desirable, undesirable and preferably having and not having to solve a problem based on the input. This information will be extracted from literature and real sustainable cases (RSC) to become KB (Fig1).

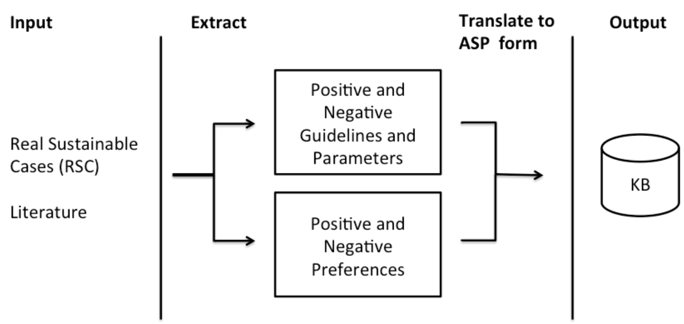

Fig. 1. Information extraction to create KB

- The Real Scenario or Inputs: refers to the current situation once modeled the problem. This needs to include a well-detailed description or specific characteristics of a determined urban center. This set will call R (Fig2).

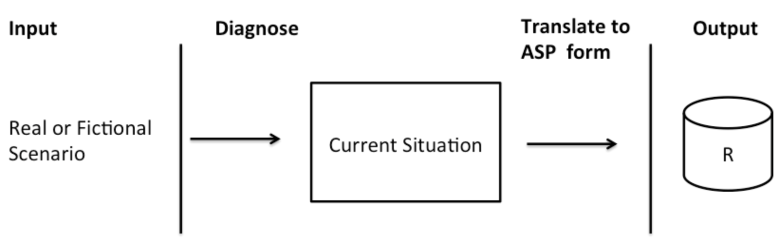

Fig. 2. Real or fiction case extraction to create R

If R changes, the result will be different even if KB does not change. The benefits of ASP allow us depending on the complexity of the problem, is possible to have a wide range of perspectives for decision-making from the same R.

5 Land Use Representation in ASP

Once represented a complex problem as specified in the preceding paragraphs, it is necessary to translate this information into logical language for ASP. Taking as example urban land usage, there may be more than 3 or 4 ways to grow a city or use lands in a proper way.

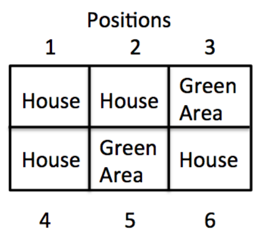

Fig. 3. Example of houses and green areas distribution by KB definition

The Figure above (Fig3) shows an example of an area which it has been demonstrated to be appropriate to build residential houses and green areas, but the field should contain one-third of green areas at all times. In other words if we have an area that can store 6 buildings, 2 of these must be green areas, the other 4 must be houses.

To represent KB we can define two rules such as: 1. In each position is possible to build whether a house or a green area. 2. Desirable number of green areas is equal to the total space divided by 3.

Listing 1.1. Basic Land Use Example in ASP

```
1  1{houseInPosition(P),greenAreaInPosition(P)}1:-position(P).
2  1 {houseType(C,P) : house(C)} 1 :- houseInPosition(P).
3
4  housesNumber(N)        :- N = #count {houseInPosition(C)}.
5  greenAreasNumber(N)    :- N = #count {greenAreaInPosition(C)}.
6
7  desiredNumberOfGreenAreas(A/3) :- area(A).
8  :-greenAreasNumber(N),desiredNumberOfGreenAreas(NAV),N!=NAV.
9
10 built(house,TC,P)     :- houseType(TC,P).
11 built(greenArea,P)    :- greenAreaInPosition(P).
```

The Basic Land Use Example code above shows the set of rules and restrictions that arises for KB where lines 1 and 2 talk about the rule 1. Lines 4 and 5 carry the counting houses and green areas. Line 7 calculates the total of green areas to have by dividing the total space by 3 and line 8 restricts that the number of green areas were different than the calculated. Finally, lines 10 and 11 indicate where the houses and green areas will be built. On the other hand it is necessary to define the current scenario or R1 defining a first example indicating that the area is of size 6 and there is only one kind of house to be built.

Listing 1.2. Basic Land Use Example for R1

```
area(6).                     %% Area with 6 slots for construction
position(1..A) :- area(A).   %% Therefore there are 6 positions
house(1..1).                 %% Exist 1 type of house

%% Constraint that in the 5th position a house must be built
%% This can be a bad quality land
:- built(greenArea,5).
```

If only using the first three lines, we can see that there is a total of 15 solutions combining in the 6 spaces, the number of houses and green areas respecting the corresponding number of green areas. Adding the constraint that the area number 5 is not suitable for a green area construction, so a house must be built. This may satisfy certain qualities of the land mentioned in the previous section. Running this example will deliver a total of 10 solutions. This amount of results could simplify decision-making, but it is possible that in another scenario R2, there are three different models of houses to be built. The complexity of this issue has been raised for a total of 1,215 viable results. It is worth to mention that if we add the same constraint listed above, the number of results will decrease to 810.

Listing 1.3. Basic Land Use Example for R2

```
area(6).                     %% Area with 6 slots for construction
position(1..A) :- area(A).   %% Therefore there are 6 positions
house(1..3).                 %% Exists 3 types of houses
```

Finally, if later we found a real scenario like R3 expressing a land where fits 9 buildings instead of 6, and applying the same KB, the total results exponentially increase to 61,236. Again, by adding the mentioned constraint we can limit the result to 40,824.

Listing 1.4. Basic Land Use Example for R2

```
area(9).                     %% Area with 9 slots for construction
position(1..A) :- area(A).   %% Therefore there are 9 positions
house(1..3).                 %% Exists 3 types of houses
```

In summary, KB has not changed over time but R has exemplified three different cases and the results show an exponential growth leading to an extensive analysis before a decision can be made. The more complex the problem, the more results we can get. It is worth noting that the greater the details modeled in R including constraints, more specific results we can get, limiting an exponential growth and making easier the analysis of the results and decision-making.

6 Discussion

In this paper is presented a simple yet effective approach for proposing alternatives to land use with ASP solving. A new and innovative approach to begin to contribute to the understanding of the urban structure and planning with the help of ASP. Also it is demonstrated that the declarative programming approach fits properly in the urban problems modeling.

It is worth mentioning that the set of characteristics of an urban society is manifested in its territorial structure, therefore, each city will have a different soil use structure [8]. This article does not include a detailed description of the spatial structure of an urban center in particular; reason why it is planned for future research, enrich the knowledge base (KB) so it is enough to be adapted to different contexts (R). In order to find the best plan for land use structuring or restructuring, considering the needs of functional integration for a specific urban ecosystem, and also, respecting the methodology and problem-solving strategy presented in this article. Hence is considered possible to explore and venture later in the 6 universal principles for sustainable urban planning.

Finally, once advanced the following works where both KB and R are in a higher level of maturity, we will seek to test four hypotheses, which are:

- Review a real scenario R to determine whether or not this particular zone makes a proper use of lands.
- Recommendations or modifications for R with the purpose of finding alternatives to fulfill a proper land use.
- Projections of how R can be developed in short, medium and long term.
- Forecasts that show how R could grow if certain changes or adjustments on prior knowledge are not made.

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