Agent-based Modelling for Green Space Allocation in Urban Areas
Factors Influencing Agent Behaviour

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Abstract: The task of green space allocation in urban areas consists of identifying a suitable site for allocating green areas. In this proposition paper we discuss about a number of factors like crowdedness, design, distribution and size that could discourage inhabitants to visit a certain green urban area. We plan to cluster our urban residents into several population segments using an Agent-Based Model and study the system in different predefined scenarios. The overall objective of this work is to provide spatial guidance to planners, policy-makers and other stakeholders, and shed light on potential policy conflicts among standard policy criteria and user preferences. We will evaluate this potential within a targeted stakeholder workshop.

1 INTRODUCTION

Pressure on green spaces close or within the city boundaries is significant and likely to grow (Glickman, 1999). These areas have been increasingly recognised that are important components of urban ecosystems, providing various kind of important environmental and social services (Haviland-Jones et al., 2005; Takayama et al., 2014). Hence, it is vital for planners and decision-makers that the provision of these areas is performed maximising the impact, the benefits and the attractiveness of each of the selected parcels (Uy and Nakagoshi, 2008) in compliance with a sustainable urban development.

However, to fully understand the interactions of the involved complex phenomena and be capable of dealing with a large number of environmental and socio-economical constraints, scientists need a better and larger set of ecologically meaningful methods that can be applied to spatial multi-criteria evaluation and conservation decision making. In this regard it can be mentioned the use of models and interactive computer-based systems (Church, 2002). These models could both, explore and extrapolate the dynamics of the system to infer future trends or also understand the nature of the processes within it.

In the concrete case of green space allocation, the existent literature covers specific range of issues like the protection and restoration of valuable and degraded areas (Zucca et al., 2008), the preservation of carbon stocks (Marinoni et al., 2009) or the definition of ecological corridors (Ferretti and Pomarico, 2013) among others. In these studies, data are normally gathered by on-site surveys, a series of spatial observations and by experts' knowledge.

In the present proposition paper we are specially interested in the analysis of the factors which negatively influence the frequency of visit of a certain park. In this regard, the utility of this work will be twofold.

Firstly, as problems related to location-allocation of resources are in nature multiobjective (Watts et al., 2009; Nelson et al., 2009), we propose the implementation of a multiobjective planning extension of our current urban model (Vallejo et al., 2013), focused on these discouraging factors. The analysis of these elements in a diversified population allows us to capture and understand the most relevant synergies and conflicts created by the interactions with other dynamics included in the model like demographic growth, urban extension and environmental degradation.

Secondly, we also intend to make a more active use of population demographics and background information for grouping parks visitors according to different interests and personal characteristics using an Agent-Based System approach (ABS). ABS is a technique particularly suitable for studying socio-economic and environmental trends based on heterogeneous individual interactions and it complements other equation-based techniques by means of the ex-

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ploration of individual-level behaviours (Brown et al., 2006).

In this matter, ABS has been extensively used to study urban growth phenomena (Huang et al., 2013; Matthews et al., 2007) where it supports the representation of different rich individual profiles, normally parametrised from quantitative surveys (Robinson et al., 2012).

In Section 2 the description of the problem is presented. Section 3 depicts the negative factors that could decrease the number of visits of a certain park. Then, in Section 4, the model to be extended is briefly explained and the future methodology and modifications are illustrated. Finally, Section 5 is concluded with a short discussion.

2 DESCRIPTION OF THE PROBLEM

Open space planning from a demand perspective (Maruani and Amit-Cohen, 2007), uses attributes from the specific target population to find the most efficient green allocation strategy as a response to social requirements over gardens and parks.

Distance from the park to the dwelling is commonly considered the major factor that influences the visit frequency and activities undertaken in parks (Björk et al., 2008; Woolley, 2003). The selection of this concrete feature in planning is based on the observation that only a small percentage of users takes any means of transport to access them (Wong, 2009). Consequently, parks at a short distance are visited more often than large remote parks (Roovers et al., 2002).

With the use of the spatial distribution of the green areas and the population density among other features, a zoning analysis can be used to create a ranking of location alternatives on the basis of their overall attractiveness for the future new park. The process includes the conduction of a multicriteria land suitability analysis and the posterior selection of optimal sites through an optimisation process according to a measurable criterion.

However even if from this quantitative perspective the provision of green areas has been carried out following an efficient process, this fact does not necessarily imply that final users have enough incentive to visit them. In this matter, there is a scarce number of studies which are focused on the factors that could limit the use of these green areas (Bixler and Floyd, 1997; Hitchings, 2013).

Population segments divided by gender, age, household composition and socio-economic status differ in how they use and perceive green areas (Burke et al., 2009; Eisler et al., 2003). This fact makes very challenging to find a unified policy which achieves a complete fulfilment of these diversified demands. For instance, it can be mentioned that elderly people show lower frequency of use due to personal mobility, health and security fears (Payne et al., 2002; Burgess et al., 1988), meanwhile children have higher needs of open areas for playing and social interaction when they live in high populated dwellings (Loukaitou-Sideris and Stieglitz, 2002; Crane et al., 2006).

Based on that premise, our main interest is the study of some of these factors (crowdedness, size, distribution and design) in an urban growth model using an Agent-Based System framework in order to improve the understanding of the individual perceptions that directly influence the frequency of use to these open spaces. This knowledge can firmly contribute to the design of more comprehensive green policies which enhance the satisfaction of a larger number of residents.

3 FACTORS TO STUDY

In the following section factors that could discourage people to visit parks and their interconnections are introduced.

3.1 Crowdedness

High population density in green areas is associated with various factors including population and urban growth, a higher demand of these spaces created by the rise of the average standard of living and an increasingly environmental awareness on the society (Cheshire and Sheppard, 1998; Kline, 2006; McPherson, 2006).

Crowding perception is a subjective concept which can be perceived when the area is highly congested with heavy pedestrian and vehicular use. Depending on the specific user profile the perception of crowdedness may be different. For instance, fairly experienced users feel more intensively the saturation when they compare their current visit with past experiences (Ditton and Sutton, 2004; Vaske et al., 1980) and when they use the area more frequently (Arnberger and Brandenburg, 2007). These local visitors can feel the saturation as a factor which decreases their quality of life (Lankford and Howard, 1994; Brunt and Courtney, 1999; Williams and Lawson, 2001).

The congestion can provoke different compensatory measures like time and intraspatial displacement if any suitable alternative exists (Hall et al., 2000; Shelby et al., 1988; Manning et al., 2001) and may decrease the importance of the distance to the park for its use (Kaczynski et al., 2008). This inter-spatial displacement implies also extra costs in terms of time and transportation which can be a problem for low socioeconomic individuals who cannot afford to move to other green areas outside the city (Heritage, 2008).

3.2 Size & Distribution

Size is an important factor to take into account when patterns of use of green areas are analysed (McCormack et al., 2010) considering that larger parks are capable of supporting a wider range of activities. Consequently this factor increases their attractiveness (Broomhall, 1996). It is a common practise to group parks into two different types: urban local green areas selected for daily outdoor activities and beyond build-up areas used for excursions or weekend sports (Arnberger, 2006). Morancho (Morancho, 2003) concludes that it is better to have numerous small green areas than a few large parks.

There are studies that connect the concept of distance with size. Pouta (Pouta and Heikkilä, 1998) creates a classification relating type of green area, size and distance. He defines the minimum size for local parks to be between 1.5 and 3 hectare reachable in 300 meters and outdoor recreational parks in 20-25 hectare at 1 kilometre. The European Commission has recommended that residential proximity to green spaces should be limited to 300 meters with an area of at least 5000 m^2 (Tarzia, 2003).

Another important aspect to consider is the topological distribution of these areas within the city. It is rather common to find cases where parks are non-homogeneously distributed. Instead, they are generally concentrated over some districts which provoke the existence of extensive areas with a lack of proper provision.

A non-homogeneous set of green areas contributes to the appearance of inequalities where some people have easier access to nature areas in their local neighbourhoods than others (Pickett et al., 2001). In general underprovision and an overall lower level of vegetation cover are more common to find in low income areas (Iverson and Cook, 2000; Pham et al., 2012). This factor is an important environmental equity issue for city planners.

3.3 Design & Green Services

Design is another important element which influences the frequency of use of green areas (Schroeder and Daniel, 1982) and contribute to the improvement of health and wellbeing (Floyd et al., 2008). Users travel further distances to visit a certain green area if it has extended characteristics and enhanced aesthetical factors (McCormack et al., 2006; Epstein et al., 2000). Commonly size and design are also concepts linked together due to the fact that larger parks permit the allocation of a wider offer of services (Giles-Corti et al., 2005).

However, as a negative factor, the level of greenery and physical barriers like inadequate facilities to interact with the park (walking trails), lack of transport choice, poor accessibility or unaffordable recreational activities may discourage some people to use these parks.

4 MODEL

The approach presented in this paper will be based on an extension of a green location-allocation planning model defined to work under high levels of uncertainty (Vallejo et al., 2014). The model was successfully applied as an exploratory tool to analyse the potential use of Genetic Algorithm techniques in the allocation of a certain number of green parcels in a predefined time horizon. The theoretical model follows the classical microeconomic equilibrium model of Alonso (Alonso, 1964) within a canonical monocentric/policentric framework in which externalities, in form of green areas, have been introduced.

In our framework, the landscape is represented as a lattice of homogeneous cells (Fig. 1), each associated with a single land-cover class. The set of land uses is divided into residential that comprises the subclasses available, new and old, recreational and underdeveloped. Currently recreational cells are homogeneous in size and configuration.

The model is capable of generating a city with multiple Central Business Districts where cells tend to be more densely populated as the number of inhabitants grows. These centres represent the places where commercial and business activities are primarily concentrated.

In the model, urban population is represented by agents whose interactions and endogenous economical choices are the basis for the urban infrastructure. Agents search the maximisation of an utility function in the pursue of an economic competitive equilibrium for space between housing and community costs which causes the emergence of urban patterns. Each agent can be characterised by their age, working status and family structure. As an additional externality

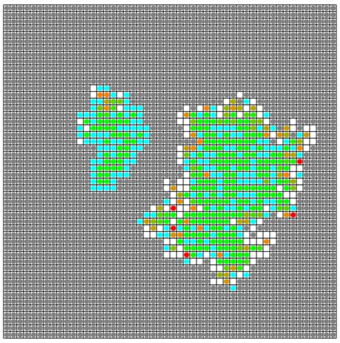

Figure 1: Evolution of a city with 2 Central Business Districts.

the model includes a positive tendency to live close to green areas. To include that feature in the model, agents are able to pay more for this kind of dwellings. This increases their demand and, as a consequence, classical patterns of growth are partially perturbed.

A Genetic Algorithm approach (GA) (Holland, 1975) is a heuristic used to find a distribution of cells that will be transformed into parks. The selection of green spaces is performed sequentially and it is limited by the current configuration of the system in terms of budget and land availability. Every possible subset of selected cells has associated a fitness value that quantifies the inhabitants' satisfaction. This satisfaction is calculated only by the amount of green areas located closer to them, measured in terms of distance.

4.1 Model Extension

The proposed extensions of our model can be outlined in the following points:

- Defining different agent's profiles according to their familiar structure, gender and ageing factors. To each profile it will be assigned predefined motivations to visit green areas and different patterns of use. The varied typologies will be based on data collected from quantitative studies published in the associated literature.
- Enriching the characterisation of green parcels to include the aforementioned factors and their interdependences. This will permit the existence of parks larger than a single cell in size with different designs, levels of greenery and activities to be undertaken.
- Defining the rules that allow us to decide for each agent which parks would visit and with which frequency. Taken into consideration are their location in the grid and their patterns of use according to their personal profile. Using the resulted population density and the size of each park, included will be the concept of crowdedness which will decrease the level of satisfaction of the affected population.
- Creating some scenarios in which the final spread of parks are not homogeneously distributed, in order to study how the population could cope with crowded green areas or a lack of provision. The use of scenarios is proved to be useful in the study of the impact of multiple socio-economic dynamics in an urban context (Murray-Rust et al., 2013). In each scenario, the model will be optimised using a GA technique for a multi-objective set of characteristics encompassing the minimisation of economical costs and the maximisation of both the population satisfaction and the protection of the highest ecological valued areas.

5 CONCLUSIONS

Conflicting on land use could provoke a lack of provision of green services necessary for the inhabitants of a city. The contribution of this proposition paper aims to analyse factors which may prevent local people to visit parks located in their vicinity. In order to do that an extension of our current resource allocation model will be carried out to analyse possible facilitators and constraints that influence the frequency of use of a set of defined parks in a series of predefined scenarios within a multi-objective framework.

According to a varied set of typologies, the population that is represented by an Agent-Based System, will be enhanced to depict different population profiles according to ageing, genre, marital structure and socio-economic factors. Each of these groups should interact with the set of green areas in different ways.

The results and conclusions gathered will support experts, planners and decision makers to further understand the numerous situations where people may decrease the visit frequency of parks in liaison with a drop in the level of service that the parks offer to the local population. We will evaluate the level of suitability of our approach in a targeted stakeholder workshop.

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