Participatory Planning Process for Controlling Urbanization: an Inverse Model Approach

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ABSTRACT
This study proposes the use of a novel mathematical modeling approach denoted as *inverse model for urban planning* to support local government decision-making process. As opposed to traditional methods, the point of departure is a desired future defined by stakeholders followed by the question "what shall we need to do today to get there". We test the power of the proposed method using a land-use change model in a region in the south Chile to control future conflicts around land-ownerships between the population and the dominant indigenous ethnic group. Results of the model are expected to help local government with the actions to be made today to avoid conflicts in the future. Additionally we expect this study to be the starting point of a smart governance framework project in which the definition of desire future scenarios can be assisted by electronic means such as 3D visualization software.

CCS Concepts
• Applied computing~E-government

Keywords
Inverse-model; Urban Planning; Land-Use Change Model; Smart Governance

1. INTRODUCTION
It is generally accepted among experts that the urbanization rate worldwide is growing at very high rate. According to the United Nations (2014), today 54 per cent of the world´s population lives in urban areas, while by 2050 nearly 67 per cent is projected to be urban. This put pressure on land use as urbanization occurs at expenses of rural and agricultural areas. Thus, there is an urgent need to address *today* a set of key questions so as to secure urban sustainability in the *future*. For instance: Are cities prepared to cope with this rapid and massive rural-urban migration in the upcoming years? Are governments and stakeholders aware of the negative effects of uncontrolled urbanization on people´s welfare? Are governments' actions pointing to the right direction accordingly? As stressed by United Nation (2014), all depend very much on decisions made *now* in preparation for this rapid urban growth.

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To answer these questions, urban planners very often rely on the outcomes of land-use change models. This type of modeling is intended to relate the agricultural-urban land use change over a certain period of time to a set of socio-economic, geographical, and environmental determinants. The majority of the land-use change models in the literature are intended to predict or forecast future land-use scenarios based on current trends. However, Dreborg (1996) argues that the fruitfulness of these forecasting approaches in long-term of complex problems may be doubted. Dreborg (1996) claims that based as it is on dominant trends, it is unlikely to generate solutions that would presuppose the breaking of trends by following traditional forecasting methods. In order to deal with this inconvenient, Gret-Regamey and Crespo (2011) introduced a novel approach denoted as *Planning from a future vision: an inverse model in spatial planning*. Unlike traditional methods, the point of departure of the inverse model is a desired future defined by stakeholders. The solution of the inverse model provides planners with a set of values for key land-use drivers to reach a desired future level of urbanization. In other words, the output of the inverse model becomes the recommended actions to be taken *today* in order to avoid uncontrolled urbanization in the future.

The main purpose of this paper is to support urban planning decision-making processes by providing local governments with a set of decision rules of actions to be made *today* in order to secure urban sustainability in the *future*.

2. THE INVERSE APPROACH
The inverse model is an innovative mathematical approach frequently employed in geophysical science to derive a set of key parameters characterizing a physical system from observed data. Due to its power in dealing with complex systems, the approach has also found applications in other areas such as medical imaging (Courdurier et alt, 2009), atmospheric and oceanic modeling (Bennet, 2005), and more recently in spatial planning (Crespo and Gret-Regamey, 2012). Briefly, the inverse model can be seen as the "reverse version" of the traditional forward model approach. In the latter case, the starting point is a given set of model´s parameters from which new data is to be generated. Conversely, in the inverse model approach the analysis starts with a set of given data from which those parameters characterizing the system under study are derived. Both approaches are depicted in Figure 1, where G is a

linear or nonlinear mathematical operator linking the model´s parameters (m) with a vector of data (d)

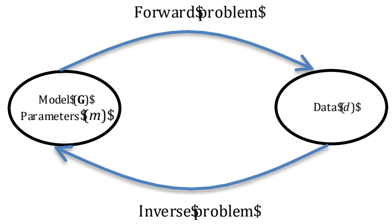

Figure 1. Representation of the forward and the inverse model

3. CASE STUDY – PLANNING FOR A FUTURE LEVEL OF URBANIZATION IN THE ARAUCANIA REGION IN CHILE

As a case study we choose the Chilean Araucania Region located about 670 kilometers south the capital Santiago. The population of the region amounts approximately at 890.000 inhabitants of which 25% are Mapuches, the most dominant indigenous ethnic group in Chile. The population of the region has been experiencing a rapid growth over the last decades. For instance, since 1970 the people living in Temuco, the capital of the region, has tripled. This has increased demand for lands and worsened the long-lasting conflict around land-ownerships between Mapuches and the rest of the population. Accordingly, it becomes urgent for local governments to steer urbanization in to a desired future level given by all stakeholders of the region.

4. METHODOLOGY

4.1 Econometric Model

For the purpose of performing the inverse analysis, it is first necessary to define our forward model. To this end, we choose as our forward model a binary logistic regression as formulated by Xie et al. (2005). We use data collected in two time periods 1997 and 2007 to regress the probability of rural-urban land-use change in the Araucanía region on a set of land-use change determinants including distance to the nearest city, distance to roads, terrain slope, terrain elevation, areas classified suitable for forestry or agriculture, and land use owned by Mapuches indigenous among others.

4.2 Calibration of the Model: A Local Regression Approach

In order to calibrate the logistic regression, we propose the use of a local regression method in preference to the traditional regression methods. By using a local analysis, the relationships (model's parameters) between land-use changes and their determinants can be examined at each location (or cell) of the study area, as opposed to traditional regressions methods by which only global parameters can be obtained. Geographically weighted regression (GWR), introduced by Fotheringham et al. (1996), is a simple but powerful local regression technique by which a set of estimated parameters is obtained at each location.

4.3 Inverting the Model

Once the land-use model has been calibrated, and local parameters estimated, the next step is to invert the model. As opposed to the *forward* model, in which land-use changes can be predicted based on both model's parameter estimates and the value of land-use determinants, in the *inverse model*, the analysis focuses on finding the optimal combination of values of land-use determinants so as to guarantee the achievement of the desired future, which in our case, will be given by a preferred location-specific land-use in the region.

5. EXPECTED RESULTS

One of the advantages of the inverse model is that its solution is not unique. In our case study, this means that there is more than one possible combination of land use determinants to achieve the desired urbanization level. This is referred to as *trade-off* analysis and is by far the most valuable contribution of this approach. Thus, results of this study are to provide local governments with not just a single but also a set of possible alternatives to solve land-use conflict in the region. In addition, it is expected that results of this study can be integrated into a smart governance system in which the definition of the desired future can be visually assisted by electronic devices or 3D visualization software.

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