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3D urban data to assess local urban regulation influence

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ABSTRACT

Systematically assessing the influence of new urban plans is an important challenge for designing them efficiently. In this paper, we propose a method to assess the influence of local 'Right to Build' regulations on constructibility. Our method is based on an optimization algorithm that generates building configurations. This method requires a geographic model that supports the formalization of the Right to Build regulation in order to check if a building respects it. The proposed approach relies on the trans-dimensional simulated annealing optimization method, which produces building configurations composed of a set of parametric objects (boxes in our implementation). Our proposition is released as the SimPLU3D Open-Source project (http://ignf.github.io/simplu3D/). In this paper, we present some tests and results based on this implementation and a use related to the assistance to 'Right to Build' designers.

1. Introduction

Cities are concerned with many economical, social or environmental issues. In order to regulate their evolutions, Master Plans are designed by municipalities or administrations with the support of public discussions. These plans may be defined at different scales according to their aims and the concerned phenomenon (traffic, air pollution, constructibility, *etc.*). They are applied to specific territories and their content combines spatial data (organized in maps) and legal information (compiled in texts). One issue concerning these plans is to assess their effectiveness and notably to evaluate their forseen influence.

This paper focuses more specifically on local urban constructibility regulations. This type of regulation, very frequent in industrialized countries, aims to define rules that regulate how buildings can be built on a parcel. Respecting these rules is mandatory to receive a building permit from the local administration. These rules can cover the 3D morphology of buildings, their aspect and their functions. They are generally expressed through free-formed texts. Thus, two issues about the exploitation of this type of regulation can be highlighted. (1) **Non expert citizens** may have difficulties to understand these rules expressed in legal terms. Most citizens do not have the necessary skills to assess how a district may change by implementing a new plan or what it can be possible to build if they buy a parcel. (2) **For local administrations**, even if they have the necessary skills to assess the influence of a plan on one parcel in terms of constructibility, it is extremely time consuming to assess the influence of the plan on an entire city or to evaluate different plan scenarios.

In this context, we propose an approach to make the information conveyed by these plans more tangible, by simulating 3D buildings consistent with constructibility regulations.

Providing a 3D modeling helps evaluating the potential impact of urban regulations for different topics such as floor area ratio assessment or solar energy development (Kämpf, Montavon, Bunyesc, Bolliger, & Robinson, 2010). It also improves public participation by using 3D geovisualisation application to illustrate the plans (Brasebin, Christophe, Jacquinod, Vinesse, & Mahon, 2016).

Our work is focused on the French regulation expressed through LUPS (Local Urban Planning Schemas). These plans are local and their contents are not harmonized on the whole French territory. Thus, in our approach, we consider a generic formalization of local urban regulations that offers the possibility to manage local particularities. Nevertheless, our proposition can be extended to be adapted to regulations of other countries.

2. Related work

Different works intend to ease the comprehension of urban regulation in 3D through several types of approaches:

- linking regulation to related geographic features in a 3D viewer (Métral, Falquet, & Cutting-Decelle, 2009);
- producing buildable hulls from geometric constraints (El Makchouni, 1987; Murata, 2004; Brasebin, Perret, & Haëck, 2011);
- offering the possibility to explore a predefined set of parametric

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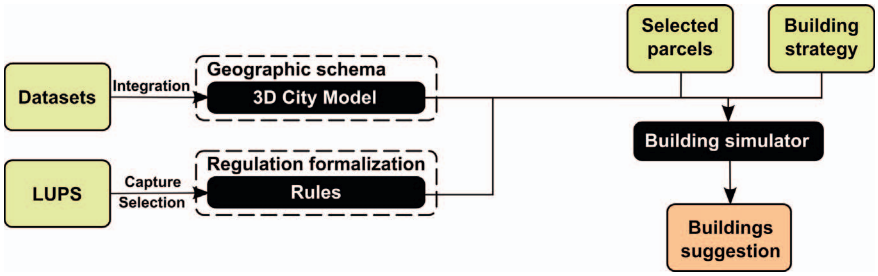

Fig. 1. Global proposition of the paper.

buildings respecting rules (Coors, Hünlich, & On, 2009);

- generating buildings (Turkienicz, Gonçalves, & Grazziotin, 2008; Parish & Müller, 2001; Brasebin, 2014) or
- proposing extensions to existing buildings (Laurini & Vico, 1999).

Among these works, building generation offers, in our opinion, the most promising results as it directly provides objects that may be built.

However, a first limit of these approaches is to be based on a small set of rules that does not represent the diversity of existing urban regulations. In this paper, we propose a generation process based on a generic extensible model of rules. Another limitation is that most existing generation processes proposed are based on heuristics, for example grammar based generation, which requires prior knowledge about the generative steps of the building configurations. Thus, using such approaches requires to define the right generation process that fits with every configuration and to adapt it with the different possible regulations.

Building generation methods are explored in various fields such as architecture (Frazer, 1995), urban planning (Rittel & Webber, 1973), geosimulation (Ruas et al., 2011), building reconstruction (Musialski et al., 2013) or computer graphics (Wonka, Wimmer, Sillion, & Ribarsky, 2003). The goal of the generation differs according to the domain. Vanegas (2013) distinguishes geometric from behavior based approaches, even if they are not always discordant. Behavior based approaches aim to produce buildings by integrating human processes and decisions whereas geometric approaches are designed to create fast and visually believable objects. As the objective of this paper is to simulate urban regulations, it is necessary to integrate preferences of different agents that design buildings in order to assess the impact of the rules for different actors (for example, households or promoters). Generally, these preferences are translated into utility functions that agents try to maximize.

To maximize such functions, optimization methods are used such as Multi-Agent Systems (Ruas et al., 2011) or meta-heuristics like evolutionary algorithms (Frazer, 1995) or simulated annealing (Bao, Yan, Mitra, & Wonka, 2013) combined to geometric generative methods like primitive instancing (Perret, Curie, Gaffuri, & Ruas, 2010; Kämpf et al., 2010) or shape grammars (Talton et al., 2011). In order to integrate constraints, a large set of methods and their comparison are described in (Coello Coello, 2010) including rejection, penalization of the optimization function or fixing solutions that do not respect constraints automatically.

3. Global proposition

The global proposition of this paper is synthesized in Fig. 1. In order to exploit knowledge about local urban regulations, we propose a model that allows both a generic formalization of rules and a generic formalization of geographic features mentioned in these rules. These aspects are briefly introduced in Section 4. In order to simulate buildings, we propose an approach based on a trans-dimensional simulated annealing algorithm (TDSA) (Singh, Isaacs, Ray, & Smith, 2008), which uses our proposed model, and which generates building configurations according to a strategy on a set of parcels (Section 5). An implementation and some experiments are then presented (Section 6).

4. Urban regulation model

In this section, we briefly introduce the content of French LUPS (Section 4.1) and the scope of the model (Section 4.2. Then, we provide a short description of the 3D geographic schema (Section 4.3) and a presentation of elementary geometric constraints (Section 4.4). Finally, the proposed rule formalization is introduced (Section 4.4.1) and the ability of the model to be applied on real documents is discussed (Section 4.4.2). In this paper, we only give a brief presentation of the urban regulation model based on an already published complete model (Brasebin, Perret, Mustiére, & Weber, 2016).

4.1. Short introduction to LUPS

3D building morphology of French cities is regulated at a local scale through the Local Urban Planning Scheme (LUPS)[1]. Each LUPS specifies a zoning plan where each zone is assigned a type[2]. For each type or subtype of a zone, 14 or 16[3] articles have to be defined (Table 1). These articles have normalized titles imposed by the French National Urban Code ([4]). For instance, it induces that, for all French LUPS, article number 10 always limits the height of buildings. Nevertheless, the contents of each article are free; each municipality can express its own set of regulations. A great diversity appears in the expression of rules from the same article in different LUPS. Thus, it is impossible to list all possible rules.

4.2. Scope of the model

In LUPS, the different rules mention geographic features and associated information. For instance, let us consider the following rule (geographic features are in bold, relationships and attributes are underlined): If the width of a **road** is smaller than 7 m then distance between the **borders of this road** and adjacent **buildings** must be higher than 3 m in order to properly implement this rule in a GIS, roads, borders of roads and buildings have to be modeled, as well as adjacency and distance relationships between roads and buildings, but also information about road width and building height.

We synthesized the required information by looking up LUPS from several municipalities and a best practices summary (Gridauh, 2013). By analyzing these texts, we extracted the relevant geographic features, relationships and information used to define rules. We synthesized the most common forms of rules in accordance with the scope of our work. Rules that do not concern buildings or parcels are ignored. This filter suppresses from our scope articles that consider parking or vegetation for example. Furthermore, we do not integrate rules referring to architectural elements of buildings too detailed to be available on whole

[1] LUPS for PLU: Plan Local d'Urbanisme.
[2] The typology of such zones includes urban zones type *U*), zones to be built (type *UA*), agricultural zones (type *A*) and natural or forested zones (type *N*).
[3] According to LUPS version.
[4] Code de l'Urbanisme.