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Satisfaction of the Solar Bounding Box constraints

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ABSTRACT: This paper presents an approach for the production of the solar bounding box (SBB). This is the optimum volume conditioned by both the urban rules of form and solar envelope rules. The urban rules are defined by the urban zoning regulations of a city. The solar envelope defines the largest volume that doesn't cast its shadows on neighboring buildings during critical periods of sunshine. The object here is the digitally assisted construction of the volume that satisfies these two constraints on a given urban area. The purpose is to design buildings respecting the solar rights.

KEYWORDS: Solar access, solar envelope, multi-agents system, solar bounding box

INTRODUCTION

The purpose of this paper is to present an approach for the production of *solar bounding volume (SBB)*. This is the spatial delimitation of the volume respecting both the urban rules of form and solar envelope rules.

The urban rules are defined by the urban regulation of a city. They result in an *Authorized Bounding Box (ABB)* [1]. However, we noticed from studies of insolation in urban areas that these rules are generic and insufficient to define the best conditions of solar access [2, 3, 4].

The solar envelope rules define the maximal limits of a volume that doesn't cast its shadows on neighboring buildings during critical periods of sunshine. This concept protects solar rights in urban areas and at the same time is a useful instrument for urban planning [3]. In fact, it allows achieving high ranges of density while preserving solar rights. This has a direct impact on energy consumption of buildings, thermal comfort and quality of life as well.

Computational modeling of solar envelope has been a center of interest of several studies [5, 6, 7, 8, 9, 10, 11, 12]. The proposed approaches have shown difficulties to manage the forms complexity. Graziotin presents an approach for the modeling of the solar envelope and the urban reglementary volume [13]. However, it does not directly produce the constraints volume (urban and solar envelope constraints). The user should proceed by trial and error experiments to find the urban reglementary volume and include it in the solar envelope volume.

This paper proposes an interactive way to manage both urban and solar envelope constraints. It presents a multi-agents approach transforming all these constraints into one or several *Solar Bounding(s) Box(es) (SBB)*. We notice here, that the constraints are an application and an actualization of the rules in a given urban area. The

object, here, is the formalization of the problem of morphing (action of shaping) [14] of the *SBB*. This formalization would allow the modeling then the development of a design tool for architects or a decision support tool for urban planners.

THE SOLAR BOUNDING BOX

The solar bounding box (*SBB*) is a spatial delineation of the optimum volume conditioned by both the urban rules of form and the solar envelope rules. It is an *Authorized Bounding box (ABB)* integrating the constraints of solar access of neighboring buildings.

The urban rules

In the model of the *ABB*, the urban rules are classified into three main categories: (i) rules linked to the public domain which identify the boundaries and set the relations between public and private space, (ii) rules linked to the neighborhood domain (inter-parcel rules), they define the relations between constructions belonging to neighboring parcels, (iii) rules linked to the private domain (intra-parcels rules). They define relations between constructions on the same parcel. These rules can be classified in a hierarchy based on urban history and their preponderance in urban codes (case of Algeria, France and Tunisia) (Tab.1a). Each constraint is defined by its priority (public, neighborhood or private), its rank (corresponding to the importance of the rule in a given category) and its target value (maximal value to reach).

The solar envelope rules

The solar envelope rules, as defined by Knowles [15], are the *cut-off time* and the *shadow fences*. The cut-off time is the period of time T of assured solar access. Each

time limit, defined by the hour, the day and month, determines a precise position of the sun. The position x of the sun is determined by its altitude angle H and its azimuth Az . Therefore, we have:

$$T = [T_{xi}(A_{zi}, H_i), T_{xf}(A_{zf}, H_f)] \text{ and } T=[t_1 \cap t_2 \cap t_3]$$

Where i = initial time limit, f = final time limit

t_1 is the useful time of sunshine depending on climate specifications of each region. t_2 is the useful time of sunshine based on the balance of the different requirements of sunshine throughout the year. This idea was first developed by Pereira [10] and it is based on the user satisfaction or dissatisfaction with the solar radiation. This is represented by a ponderation system of the solar radiation as a function of the difference in magnitude between *the external air temperature* and *neutral temperature*. The method determines the beneficial hours of sunshine in winter and undesirable radiation in summer. Finally, t_3 is the useful time of sunshine according to the building function.

The shadow fences are the restrictive limit of casting shadows. A construction should not project shadows above this limit. The definition of shadow fences depends on surrounding environment (road, residential parcel, warehouse...). This affects significantly the solar envelope size. A warehouse, a parking or a taxiway does not need as much hours of solar access as a residential construction.

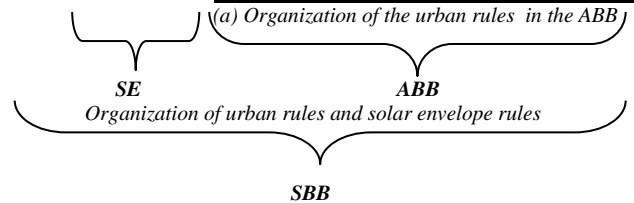
Organization of urban rules and solar envelope rules

We propose, here, to introduce a new layer of rules (rules of the solar envelope) in the organizational model of the *ABB* (Table 1a). The solar envelope rules intervene in the public domain, the neighborhood domain, and the private domain as well. Elements of the public domain (reads, squares, parks...) define the *cut-off time* and delineate the *shadow fences*, therefore, they determine the solar envelope. The last constitutes a restriction of some rules linked to the public domain (maximum height...). Similarly, the solar envelope rules intervene in the neighborhood domain and private domain. The solar envelope is also a restriction volume for some rules linked to the neighborhood domain (Prospect in relation to the common limit ...) and the rules linked to the private domain (Floor area ratio...)

To avoid redundancy between urban rules and solar envelope rules we propose a new classification of these rules by the following table:

Table 1: Organization of urban rules and solar envelope rules

Class	-A- Solar envelope rules	-B- Urban rules		
		B ₁ Rules linked to the public domain	B ₂ Rules linked to the neighborhood domain	B ₃ Rules linked to the private domain
Rank				
1	Cut-off time	Alignment	Prospect in relation to the common limit	Context of construction
2	Shadow fences	Prospect of alignment		Plot ratio
3		Maximal height		Floor area Ratio
4		Slop of roofs	view servitude	Distance between the buildings on the same parcel
5			Servitude of clear of the day	Patio size



By applying the rules linked to the public domain (B₁ class) and the solar envelope rules, we obtain a *SBB* of order number 1. The *SBB* of order 2 corresponds to a volume that integrates the rules of the B₁ class, the rules linked to the neighborhood domain (B₂ class) and the solar envelope rules. The *SBB* of order 3 incorporates the rules of the B₁ class, the B₂ class, the rules linked to the private domain (B₃ class) and solar envelope rules. The *SBB* of order 3 is the most restrictive volume. It takes into account both the urban rules and the solar envelope rules (Fig.1). Each volume of order (n) includes all the constraints of volumes of order (n-1). However, the passage from one order to another does not occur in a linear and deterministic way.

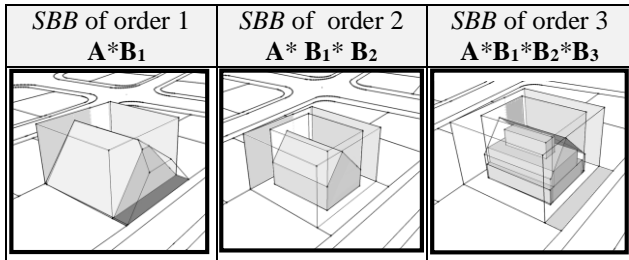


Figure 1: Production of the SBB according to the notion of order

PRODUCTION OF THE SBB

Here we will proceed to the illustration of the model with a real case located in the North Lake of Tunis. This illustration will help us to visualize different situations of production of the SBB.

For the modeling of the SBB, we apply on the ABB the solar envelope constraints. The last is the maximum volume that the ABB should not exceed. Applying this rule we obtain from (1) to (n) solar bonding boxes (Fig.2). We can then distinguish two major cases of production of the SBB: (a) The ABB exceeds the limits of the solar envelope (case N°1 and N°2). The solution of the SBB will be the intersection volume between the ABB and the solar envelope ($SBB = ABB \cap SE$). The application of the Boolean method involves the reduction of the constructible volume, (b) the ABB is included in the solar envelope volume ($ABB \subset SE$) (case N°3). The solution of SBB is confounded with the ABB ($SBB \equiv ABB$). However, the maximum values of the solar envelope are not reached and a part of it remains empty. Thus, we notice that by applying the Boolean method, the SBB solutions are not optimized.

RESULTS AND DISCUSSIONS

The main goal of this work is the modeling of the volume of urban and solar envelope constraints. The application of the Boolean approach allows to verify the inclusion or not of the ABB in the solar envelope volume (Fig 2.). It implies, however, the reduction of the constructible volume. This is counter-productive considering the actual urban densification politics. On the contrary, a multi-agent approach allows achieving at best the target values of urban and solar envelope constraints. This is here a problem of satisfaction of constraints distributed across multiple intelligent agents.

The multi-agents approaches are actually a center of interest in many fields including town and country planning [16] urbanism [17, 18] and architecture [19, 1, 20]. These approaches have shown relevance in solving

complex problems. The autonomy of the agents allows, in fact, to manage and to interact with the various aspects of the problem. Their distributed character resolves well the complexity of modeling of a given form.

Solutions of the ABB		Solutions of the ABB and solar envelope	Solutions of the SBB
N°	<u>Urban rules</u> Alignment :2m maximal height: 28m Plot ratio:0.6 FAR :3	<u>Solar envelope rules</u> Cut-of time:10h-14h December 21 Shadow fences : ABCD	<u>Urban rules and solar envelope rules</u>
1			$ABB > SE$ $SBB = ABB \cap SE$
2			$ABB > SE$ $SBB = ABB \cap SE$
3 . . .			$ABB \subset SE$ $SBB = ABB$
n			$ABB > SE$ $SBB = ABB \cap SE$

Figure 2: Production of the SBB solutions

From our Knowledge, there is no approach based on a multi-agents system which manages both the urban and solar envelope constraints. The goal here is to guide the system to search the target values by defining a *pertinence degree* of the constraints. The notion of pertinence is developed by Boudon [21]. It is defined as “the point of view from which is considered a measure”. It is also “the relationship between the measure and the reference space”. We talk here about the solar pertinence and we attribute a biggest order of importance to the solar envelope constraints. The solar envelope constitutes a *reference space* that allows achieving the *measure* (target values) of the urban reglementary constraints. Thus, the system proposes n solutions of the SBB then makes the selection of the best ones. This selection is done in a way that permits achieving the target values and according to a pondered factor given to solar envelope constraints.

In this perspective, a MAS approach for the production of the *SBB* would first resolve the modeling complexity of the considered form and secondly, it would optimize the system to the choice of optimal *SBB* solutions.

CONCLUSION

In this paper we presented an approach for the production of the *Solar Bonding Box (SBB)*. We used the multi-agents system and more specifically an existing approach of the modeling of the *Authorized Bonding Box (ABB)*. We then integrated into the proposed model a new layer of constraints, namely, the solar envelope constraints.

This work is a contribution to the multi-agents system researches in architecture. This is a promising way to resolve the complexity that characterizes the architectural design process. A multi-agents approach allows the optimization of the production of the *SBB*, it orientates the system to the choice of the best solutions of the *SBB*. This promotes the urban densification and meets at the same time the requirements of the sustainable development, two major challenges of nowadays urban policy.

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