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OPTIMIZATION OF THE ANNUAL SOLAR IRRADIATION AVAILABILITY IN URBAN ENVIRONMENT

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ABSTRACT

A mathematical model is proposed to optimize the annual solar irradiation availability where the placement of the buildings in urban environment improves the use of solar energy resource. Improvements on the solar energy potential of the urban grid are reached by maximizing the exposure of incident solar irradiation on roofs and facades of buildings. The proposed model considers predominant, the amount of direct solar radiation, omitting the components of the solar irradiation diffused and reflected. The dynamic interaction of buildings on exposure to sunlight is simulated aiming to evaluate the shadowing zones. The search for optimal topological solutions for urban grid is based on a Genetic Algorithm. The objective is to generate optimal scenarios for the placement of buildings into the urban grid in the pre-design phase, which enhances the use of solar irradiation.

Keywords: optimization, solar irradiation, urban topology, shadowing, genetic algorithm.

INTRODUCTION

With the oil crisis in the seventies and increasing comfort conditions of houses, particularly in cities, there arose the need to rethink urban planning, making it more sustainable. Solving this problem can have several approaches, notably: (i) Reduction of energy consumption, (ii) Bioclimatic architecture (iii) Replacement of primary energy sources by renewable hydroelectric energy from endogenous resources. If on the first item, it may be the result of policy implementation of voluntary or forced sustainability rules, the latter depends on how the man thinks the implementation and construction of housing. The third item relates statement paradigm replacing the current energy matrix, based mainly on use of fossil fuels by renewable energy sources, especially solar energy available throughout the earth's crust. With the goal of contributing to the optimization of this resource, some authors have proposed models aiming to improve the use of solar energy. Caldas and Norford (2002) and Caldas et al. (2003), used a Genetic Algorithm (GA) to optimize the construction budgets by minimizing costs with HVAC, lighting and building itself. Hensen (2004) developed an application in Java environment using a GA as a mechanism for evaluating the performance of project design coupled with creative functionality. Panão Oliveira et al. (2008) presented thermal performance indicators for urban construction related to the placement of buildings on the north-south alignments. Robinson and Baker (2000) considers a GA to manage energy consumption for application to urban environment.

The problem of optimal placement of buildings on urban grid environment using GAs or other evolutionary techniques has been investigated by some authors as Xiyu et al. (2005), Znouda et al. (2007) and Kämpf and Robinson (2009). In this paper a mathematical model based on the optimal placement of buildings that favors the use of solar energy, also allowing its electrical or thermal conversion is proposed. By maximizing the area of exposure to incident solar irradiation on roofs and facades of buildings, improvements on the energy performance of the urban matrix are reached. Thus, it contributes decisively to reduce dependence on other forms of energy less environmentally friendly.

MODEL OF SOLAR IRRADIATION EVALUATION

The proposed model for the determination of solar irradiation is described in this section (Duffie and Beckman, 2006). At each instant the incident solar irradiation on a tilted surface can be given by the following expression:

$$I(\beta) = I_{Bh} \cos\theta_I + I_D + I_{Th} \tag{1}$$

where $I(\beta)$ is the global incident irradiance on a surface with slope β, I_{Bh} is the direct irradiance incident on a horizontal surface, θ_I is the angle of solar incidence, I_D is the diffuse component of the irradiance and I_{Th} is the reflected component of the irradiance. Integrating in order to time the equation (1), between the rising and the setting of the sun, the radiation that reaches a plane with a slope β located at the earth's surface is obtained for each day of the year as follows:

$$H(\beta) = \int_{sunrise}^{sunset} I(\beta)\, dt \tag{2}$$

The proposed model considers the overriding value of direct sunlight, so it falls to 2nd order, the components of diffuse and reflected solar radiation.

The determination of the amount of solar radiation incident on a surface involves the estimation of some variables. These variables are, in addition to the geographical coordinates of the place, the sunlight angle δ, which can be calculated by Cooper's equation (Duffie and Beckman, 2006):

$$\delta = 23.45 \cdot \text{sen}\left[\left(\frac{360}{365}\right) \cdot (n + 284)\right] \tag{3}$$

being n the number of the day of the year (Julian day, from 1 January = 1 to December 31 = 365). The solar altitude α is the angle between the celestial horizon of the observer and the position of the sun given by equation (3) and is defined by,

$$\alpha = arcsen(\cos\phi\ \cos\delta\ \cos\omega + sen\,\phi\ sen\delta) \tag{4}$$

that depends on the latitude of the place ϕ, the solar height angle δ and the angle ω establishing the position of the sun at every moment. The angle of sunrise is defined by the equation

$$\omega_{SR} = -arccos(-tg\,\phi\ tg\delta) \tag{5}$$

and the angle of sunset is given by

$$\omega_{SS} = arccos(-tg\,\phi\ tg\delta) \tag{6}$$

The limits of integration in equation (2) are obtained from equations (5) and (6) for each day of the year at the local latitude ϕ. Figure 1 depicts the relationships between the angles and geographical coordinates. The solar azimuth is the angle γ shown in Fig. 1, and defined by

$$\gamma = \arccos\left(\frac{\text{sen}\,\alpha \cdot \text{sen}\,\phi - \text{sen}\,\delta}{\cos\alpha \cdot \cos\phi}\right) \quad (7)$$

In Fig. 1, the angles shown have the following meanings: ϕ - Latitude, angular position relative to the equator and positive in the northern hemisphere with $\phi \in [-90^o; 90^o]$; δ - Declination, is the angle between the line connecting the centers of the sun and the earth with the equatorial plan; β - Inclination, angle between the plane of the surface and the horizontal plane, γ - Azimuth angle of the surface, is the angular distance between the local meridian, and the projection of the normal to surface in the horizontal plane; ω - Hour angle, is the angle measured in the celestial pole, between the observer's meridian and the meridian of the sun (takes the value of 0° at noon in solar time); θ_S - Angle of incidence, is the angle between the direct irradiation on the surface and the normal direction to the surface; θ_Z - Zenith angle, is the angle of incidence of direct irradiation on the surface relatively to the normal direction at local position; α - Solar elevation angle, is the angle between the horizontal line and the direction of the incident solar beam, is the complement of the zenith angle; γ_S - Solar azimuth angle, is the angle between the projection of direct irradiation on the horizontal plan and the line indicates the South pole. Shifts to Eastern of North-South axis are negative and to West of that axis are positive.

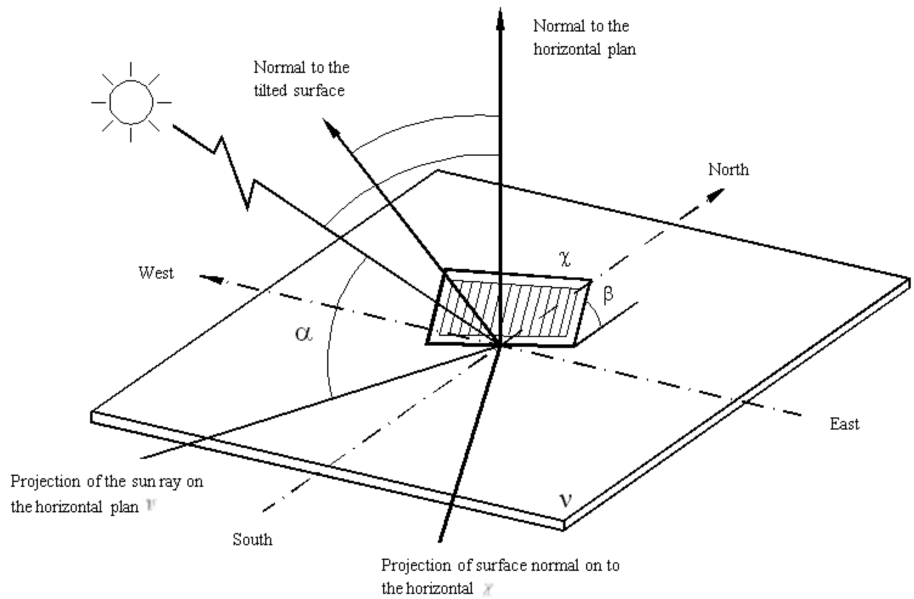

Fig. 1 Angles definitions and geographical coordinates

The solar incidence angle θ_Z is obtained from

$$\begin{aligned}\cos\theta_Z = {} & sen\,\delta\, sen\,\phi \cos\beta - sen\,\delta \cos\phi\, sen\,\beta \cos\gamma + \\ & + \cos\delta \cos\phi \cos\beta \cos\omega + \cos\delta\, sen\,\phi\, sen\beta \cos\gamma \cos\omega + \\ & + \cos\delta\, sen\,\beta\, sen\,\gamma\, sen\,\omega\end{aligned} \quad (8)$$

The incident direct solar irradiation on a facade with any orientation and any slope over a time interval corresponding to one degree of the apparent angular motion of the sun and equivalent to 4 minutes in the time scale, is given by

$$RAD_{int}(\omega,n) = \frac{1}{15}\, I_{SC}\left[1 + 0.033\cos\left(\frac{360\,n}{365}\right)\right]\cos\theta_z \tag{9}$$

being $I_{SC} = 1367\ W/m^2$ a solar constant (Duffie and Beckman, 2006). The daily amount of irradiation $RAD^{day}(n)$ is given by

$$RAD^{day}(n) = \sum_{\omega=\omega_{SR}}^{\omega_{SS}} RAD_{int}(\omega,n) \tag{10}$$

The annual value of irradiation RAD^{year} is given by the sum of the values obtained in (10) with $n \in [1, 365]$:

$$RAD^{year} = \sum_{n=1}^{365} RAD^{day}(n) \tag{11}$$

Equation (11) allows calculating the incident irradiation on four building facades neglecting the effect of other buildings located on the urban grid.

APPROACH TO SOLAR IRRADIATION AVAILABILITY

After calculating the incident irradiation on the facades over the year, the interference in a building set is studied. So, the projected shadows of the buildings during the day and the year are determined. The values obtained will be deducted from the amount of irradiation received by simulating the losses due to shading of a building in the context of its integration into the urban grid.

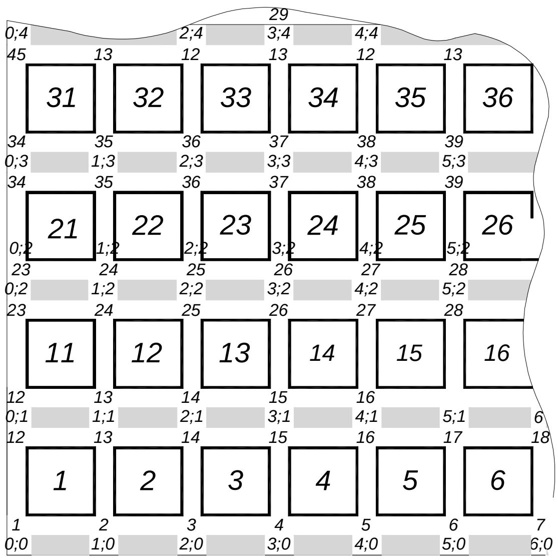

Fig. 2 Placement possibility's for buildings in urban grid environment

To study and maximize the potential of solar irradiation exposure it is necessary to define the topology of the placement zone of the urban grid. To identify the positioning of buildings a mesh of rectangular elements with four nodes each is considered, as shown in Fig. 2. The numbering of the mesh nodes and their geometric coordinates enable the identification of any building in urban grid through their respective nodes. Indeed, the nodes of the element where the building is located establish its connectivity into the grid and define its positioning relative to other buildings.

To build a model that represents the dynamics of shading is firstly necessary to verify the condition of shading. This condition relates the length of the shadow projected by a building to be lit by sunlight with the distance between buildings. Secondly, assuming the existence of shading it is necessary to consider, in the definition of the problem, the hypothetical shaded areas by mutual interaction of a couple of buildings in urban environment. Accordingly, it proceeds to the evaluation of so-called start and end angles of shadow and the projected shadow length defined on the plan of urban grid. The proposed model for calculation of incident solar irradiation is based on the analysis of mutual effect between two buildings and subsequent analysis of the overall design solution proposed for buildings disposition in the urban grid environment. Thus, considering the relative position of a pair of buildings into the grid, it is defined four possible alignments according to their position on the landscape: i) alignment oblique left (code K = 1, the second and fourth quadrants), ii) alignment oblique right (code K = 2, the first and third quadrants), iii) horizontal alignment (code K = 3), iv) vertical alignment (code K = 4). The code refers to the designation used in the implementation of the numerical code for dynamic shading model.

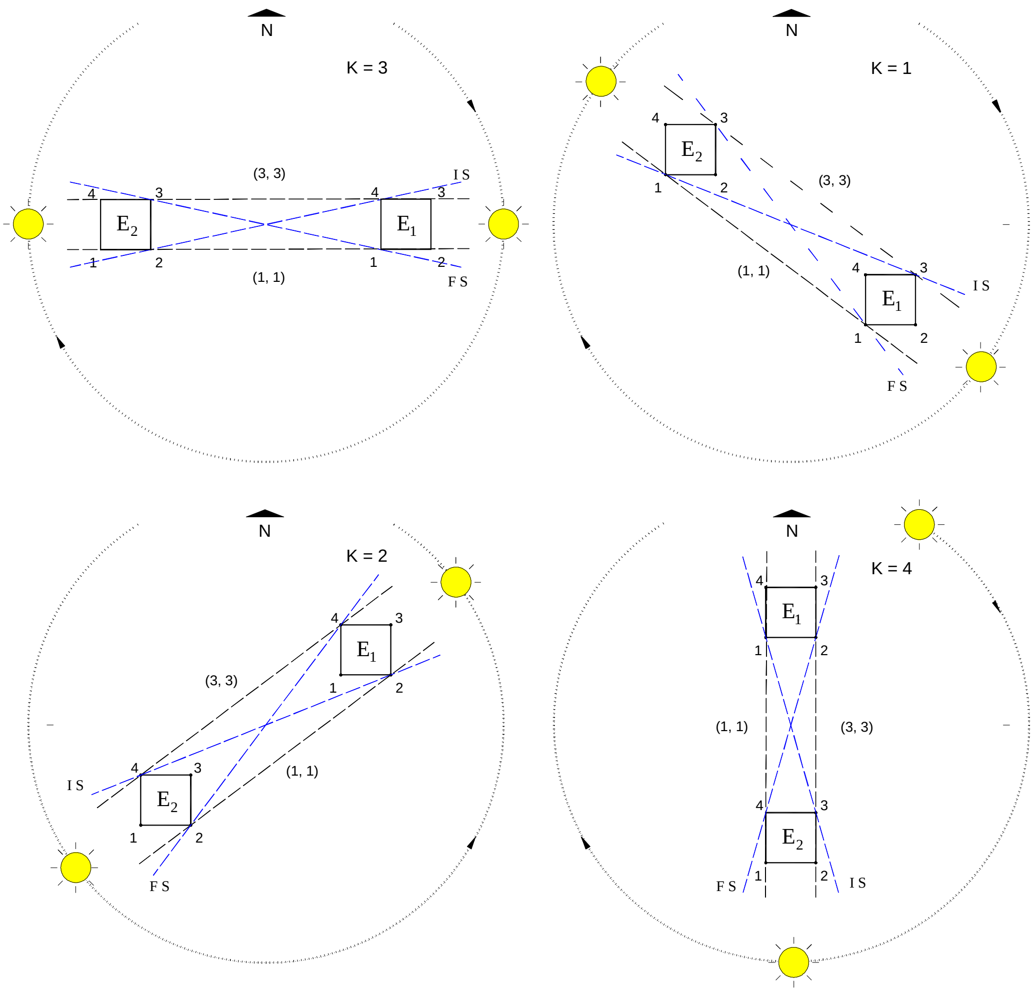

Fig. 3 Relative positioning of two buildings on the plan of the urban grid

Figure 3 shows in detail the different scenarios considered in the relative positioning of two buildings in the urban grid plan. In the comprehensive analysis all possible combinations of pairs of buildings are considered, which makes redundant and unnecessary analysis of alignments of three or more buildings. The shadows projected by the interposition of buildings in the path of the sun's rays do not allow a full or partial exposure. The factors associated with the relative positioning of buildings in urban grid, the sunlight angle, etc., change of the shadows at each instant during the day, and on every day throughout the year. Considering this fact, it is necessary to analyze the dynamic shading quantifying their influence on solar irradiation received by roofs and facades of the buildings. The shading areas are considered in the calculation model of the potential of solar exposure.

Set up a pair of buildings E_1 and E_2, whose relative position corresponds to a given alignment. By convention and respecting clockwise, E_1 is the first building to be lit by the sun at each day and thus its shadow is projected on another one during sometime. Given the great distance from the sun to the earth when compared with the dimensions of buildings, it is considered that the solar rays are transmitted parallel to each other. Let’s consider the numbers 1, 2, 3 and 4 identifying the vertices of the rectangle where a building is located, arranged in a counterclockwise direction with the first one beginning at the lower left corner.

There are geometric elements that play a key role in defining the different shading scenarios, they are: i) the straight line of early shading IS; ii) the straight line of end shading FS; iii) the line of the end of the illuminated area; iv) the line of the resumption of the lighted area. These lines are still being defined from the nodal coordinates associated with the two buildings as shown in Fig.3. Common to all scenarios there are the lines AS and AI, related to the advancement of shadow and light, respectively. The AI and AS lines run around a fixed point of reference, describing a rotation angle which is directly proportional to the apparent relative motion of the sun (assuming the Earth as an absolute referential).

The shade range is limited by two angles, denoted by early shading angle ω_{IS}, and end shading angle ω_{FS}, corresponding to the position of the sun in its apparent motion, throughout the day between sunrise and sundown. While the angular position of the sun is within the range defined by the two angles, more precisely $\omega_i \in [\omega_{IS}, \omega_{FS}]$, there is the possibility of a building to project its shadow on another one. The angles ω_{IS} and ω_{FS} are defined by the relative position of the pair of buildings in the urban grid and depend on the considered alignment.

The approximation model used to calculate the area of the projected shadow is based on the four previously described scenarios considered for the interaction of a pair of buildings. As an example it is considered a detailed analysis for the morning period (AM). The transition between the three zones of partial or total shading previously identified is performed continuously. Whereas the apparent movement of the sun it appears that the zone 1 is characterized by the reduction of area of the illuminated facade with the advance of the shading front. During the course of the sun path is described a portion of arc corresponding to the center angle $\Delta\omega^{(i)}$ defined from ω_{IS}. The width of the portion of shaded facade of building E_2 is directly proportional to the center angle $\Delta\omega^{(i)}$:

$$L_1 = \frac{L_t}{\Delta\omega^{(1)}} \Delta\omega^{(i)} \qquad (12)$$

where L_t represents the maximum width of the projected shadow according with shading scenario into analysis and $\Delta\omega^{(1)}$ is the center angle described by the sun path inside zone 1.

Inside zone 2 the area is accounted considering entire width L_t of facades as shaded. This situation occurs when $\omega_i \in \left[\omega_{IS} + \Delta\omega^{(1)}, \omega_{FS} - \Delta\omega^{(2)}\right]$. The width L_t is equal to the sum of both sides of rectangle corresponding to the basis of shaded building for the scenarios of left (K=1) or right (K=2) oblique alignments. For the others two scenarios of horizontal and vertical alignment of buildings (K=3 and K=4 respectively), L_t is equal to the length of shaded side of the rectangle corresponding to the basis of building.

The zone 3 is characterized by reduction of the width of the shading area which results from advancing of light front defined by the width L_2 of the illuminated area on the building E_2. This width L_2 is proportional to the center angle $\Delta\omega^{(i)}$ described by apparent motion of sun and defined from $\omega_{FS} - \Delta\omega^{(2)}$:

$$L_2 = \frac{L_t}{\Delta\omega^{(2)}} \Delta\omega^{(i)} \tag{13}$$

where $\Delta\omega^{(2)}$ is the total center angle described by the sun inside zone 3.

The width $W(\omega_i)$ of the shadow projected on the building E_2 during the morning (AM) is then defined as

$$W(\omega_i) = \begin{cases} L_1 & if \quad \omega_{IS} \le \omega_i \le \omega_{IS} + \Delta\omega^{(1)} \\ L_t & if \quad \omega_{IS} + \Delta\omega^{(1)} \le \omega_i \le \omega_{FS} - \Delta\omega^{(2)} \\ L_1 - L_2 & if \quad \omega_{FS} - \Delta\omega^{(2)} \le \omega_i \le \omega_{FS} \end{cases} \tag{14}$$

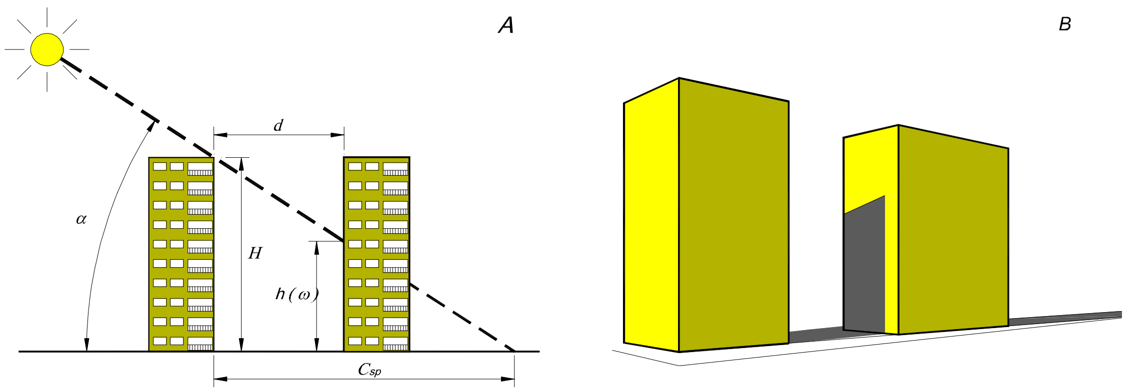

Fig. 4 Identification of the projected shadow: α - Solar height angle;
C_{sp} - Length of the projected shadow; H - Height of the building;
$h(\omega)$ - Height of the projected shadow; d - Distance between buildings

The area of shaded region is defined as

$$A(\omega_i) = W(\omega_i)\, h(\omega_i) \tag{15}$$

where $h(\omega_i)$ is the height of the projected shadow. The same kind of reasoning is made to obtain similar expressions for the afternoon (PM) where there is a shadow projection on the building E_1. To calculate the height of the projected shadow $h(\omega_i)$ let's consider Fig. 4 from where it is observed that if the shading exists it depends on the height of the building projecting shadow, the solar height angle and the distance between buildings. There it will place the shade on the facade of a building where the distance between a pair of buildings is less than or equal to the length of projected shadow as shown in Fig. 4. Thus the height of the projected shadow is given by:

$$h(\omega_i) = \begin{cases} H - d\ tg\left[\alpha(\omega_i)\right] & if \quad d \leq \dfrac{H}{tg\left[\alpha(\omega_i)\right]} \\ 0 & if \quad d > \dfrac{H}{tg\left[\alpha(\omega_i)\right]} \end{cases} \tag{16}$$

where H is the height of the building which makes shadow, d is the distance between buildings E_1 and E_2, and α is the solar height angle defined by

$$\alpha(\omega_i) = \frac{\pi}{2} - \theta_z(\omega_i) \tag{17}$$

being θ_z calculated from equation (8). The calculation of the distance between two buildings follows a methodology based on the use of nodal coordinates locating the rectangular basis of the building disposed on the urban grid as referred in section 3.1.

The calculation of equation (16) is carried out only when the solar azimuth angle belongs to the range of angles limited by the start and end of shadow identified in the analysis, i.e. $\omega_i \in [\omega_{IS}, \omega_{FS}]$.

The previously presented dynamic shading model should be considered together with the shading condition which defines the moment when the shade of a building interposed between the sunlight and other building reaches this last one as shown in Figure 4. There will place the shade on the facade of a building where the distance between a pair of buildings is less than or equal to the length of projected shadow as follows,

$$d \leq C_{sp} \tag{18}$$

where the length of projected shadow is calculated as

$$C_{sp} = \frac{H}{tg\left[\alpha(\omega_i)\right]} \tag{19}$$

and so the shading condition is defined as

$$d \leq \frac{H}{tg\left[\alpha(\omega_i)\right]} \tag{20}$$

being d a fixed value for each pair of buildings disposed on urban grid.

Using the proposed simulation model for the dynamics of shading it is possible to evaluate the effect of projected shadows interaction of a set of buildings on urban grid environment and to calculate corresponding incident solar irradiation.

Considering the model presented for solar irradiation calculation and the dynamic shading model previously proposed, the amount of daily solar irradiation received on a facade of the illuminated building will be given by

$$RAD_u^{day}(n) = \sum_{\omega=\omega_{SR}}^{\omega_{SS}} RAD_{int}(\omega,n)\left[1-\frac{h(\omega)\,W(\omega)}{A_T}\right] \qquad (21)$$

where A_T is the total area of the facades of each building exposed to solar irradiation, ω_{NS} is the sunrise angle, ω_{PS} is the sunset angle, and RAD_{int} is the direct solar irradiation calculated from equation (9). The product $h(\omega)W(\omega)$ in equation (21) defines the area of the shaded region resulting from the dynamic analysis performed for shading motion. The amount of the annual useful incident irradiation is given by the sum of the values obtained from equation (21) with $n \in [1, 365]$ as follows

$$RAD_u^{year} = \sum_{n=1}^{365} RAD_u^{day}(n) \qquad (22)$$

The value defined in equation (22) is calculated for each building considering four facades. To calculate the annual incident solar irradiation associated with a design solution must consider its topology on the urban grid environment defined previously and to make a global analysis. The main parameters to consider in the global analysis model are:

- The latitude of the place;
- The slope of the facades;
- The number of buildings on the design solution;
- The disposition of buildings on urban grid with the definition of nodes, elements and their connectivity.

The vector of design variables **x** has a dimension equal to the number of buildings considered in the analysis. The vector **x** defines the topological distribution of buildings on urban grid. The disposition of each building in urban grid environment is indicated by element number that holds the building as previously described.1. It is thus possible to define the geometry of the problem needed to simulate the dynamic process of shading.

The overall analysis is based on the following steps:

1st Step. Definition of all combinations of pairs of buildings associated with the design solution through a combinatorial analysis;

2nd Step. Dynamic simulation of shading for each pair of buildings;

3rd Step. Calculation of annual incident solar irradiation with analysis of the mutual influence on each pair of buildings;

4t Step. Repeat the procedure for all pairs of buildings defined in step 1;

5th Step. Determination of the total annual incident solar irradiation associated to the set of buildings on urban grid environment.

The total annual incident solar irradiation of the set of buildings on urban grid environment is defined as

$$RADT(\mathbf{x}) = \sum_{k=1}^{N_{comb}} \left(RAD_u^{year}\right)_k \tag{23}$$

being N_{comb} the number of combinations associated to design solution.

OPTIMIZATION MODEL

An optimization model is presented aiming to obtain the optimal positioning (disposition) of the buildings on urban grid environment. The optimal solution is found by minimization of the effect of projected shadows of the set of buildings and maximizing by this way the incoming solar irradiation on facades of all buildings. With this model, the concept that lets it explore the space in the urban design phase of housing clusters is introduced, where the parameters are defined by the optimization of urban design variables. The model simulates the interaction of buildings on exposure to sunlight. The research of topological optimal solutions for the urban grid is performed using a Genetic Algorithm. The ultimate goal is to generate scenarios, using an optimization algorithm for positioning the buildings on urban grid environment, which enhances the solar exposure potential.

The topology optimization problem aiming to obtain the optimal solar irradiation incoming is then defined as follows:

$$\underset{\mathbf{x}\in\Omega}{Maximize}\ RADT(\mathbf{x}) \tag{24}$$

subject to

$$g_k(\mathbf{x}) = \frac{d_k(\mathbf{x})}{\bar{d}} - 1 \leq 0 \quad , \quad k = 1,\ldots,N_{comb} \tag{25}$$

where Ω is the domain defined by the urban grid array associated to possible positioning of buildings, d_k is the distance between two buildings belonging to k-th combination of a pair of buildings determined by the design solution, and $\bar{d}$ is the minimum allowable distance. The vector of design variables **x** has a dimension equal to the number of buildings considered in the design solution that is previously defined.

The method of searching for the optimal positioning of the set of buildings aiming the maximization of the incoming solar irradiation on the facades is based on a GA. The flow diagram of the proposed GA is shown in Fig. 5. The model for calculating the incident irradiation presented in Section 2 and the model dynamic shading Section 3 are considered.

The genetic algorithm performs the search of the optimal solution based on four operators: selection, crossover, mutation and deletion. The proposed GA is based on previous developments used in industrial applications (Conceição António, 2002; Castro, 2004; Conceição António and Afonso, 2011). The stopping criterion used in the evolutionary process is based on the relative variation of the mean fitness of a best reference group belonging to the population, for a fixed number of generations, and the feasibility of the best fitted solution.

The fitness function is defined in Equation (24). A control algorithm suitable for verifying the admissibility of the constraints defined in equation (25). Integer code format is adopted for the entire chromosome of each design solution, being this encoding genotype equal to the numbering of the elements on the urban grid previously defined.

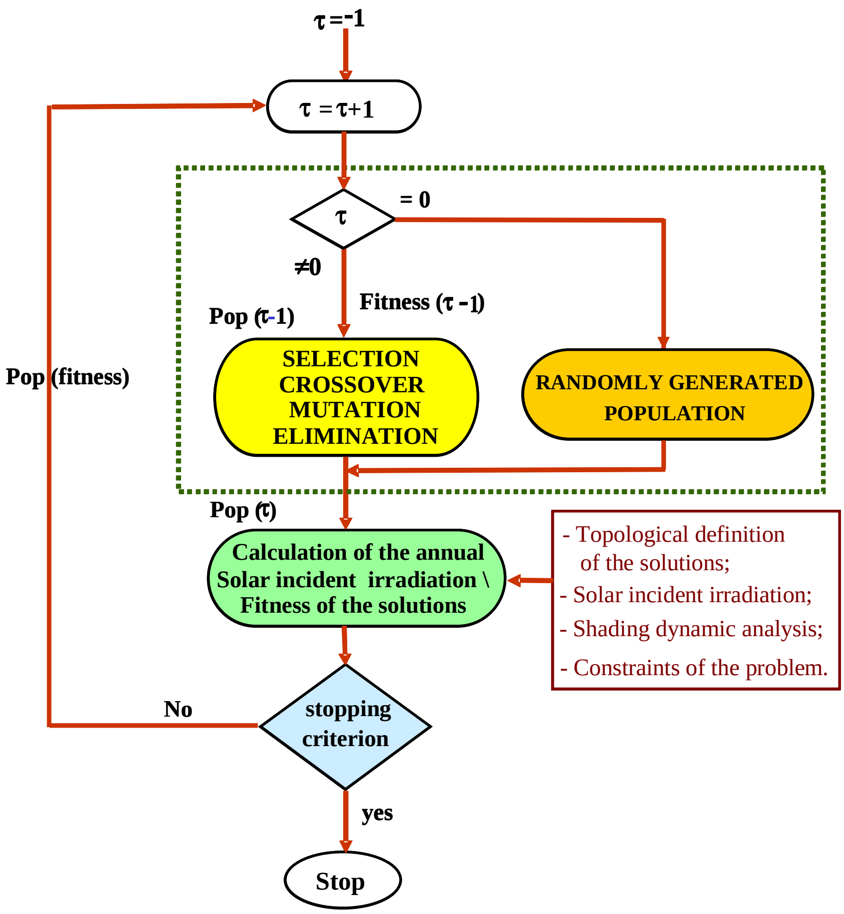

Fig. 5 Flowchart of the Genetic Algorithm

RESULTS

The studied design considers 10 buildings with 10 floors, with four vertical facades and height of 30 m. The latitude of the place is 40 degrees north. Figure 6 shows six classical topological solutions (A, B, C, D, E, F) considered in the analysis. These solutions are compared with the topological optimal design solution (G) presented in Fig. 7 and obtained using the proposed optimization model. The code of each topological solution referred to positioning of the buildings into the urban grid environment is according to Figure 2 and is presented in Table 1.

Figure 7 shows the topological distribution corresponding to the optimal solution. The optimal solution has a dispersion of buildings by the urban grid space separating them from each other reducing the adjacency indices and increasing the occupancy rate of urban grid environment.

The energy gain allocated to the annual solar potential obtained with the optimal solution is computed and compared with each conventional classical topological solution. The percentage values are described in Table 1. By examining the table the optimal solution (G) has a potential exposure to sunlight higher than any other solutions and superior to 10 % for one of the cases. Despite the increase in the occupancy rate of the urban grid this should not be an inconvenience but an opportunity for careful landscape management between buildings. It should be noted that the total area of implementation is not changed in any of the solutions thus remaining constant.

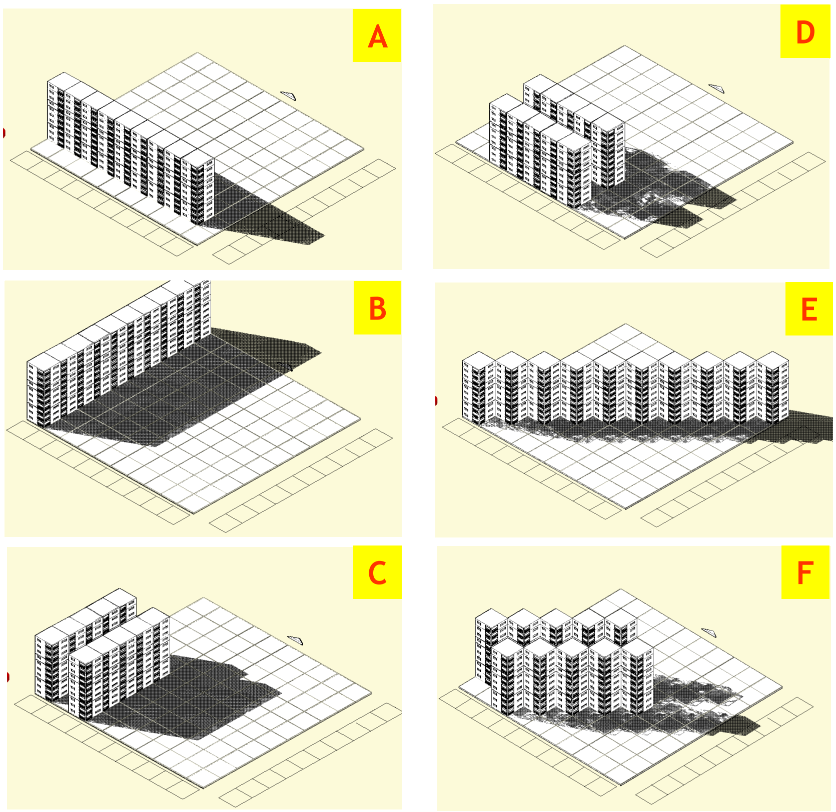

Fig. 6 Topology of classical solutions with 10 buildings

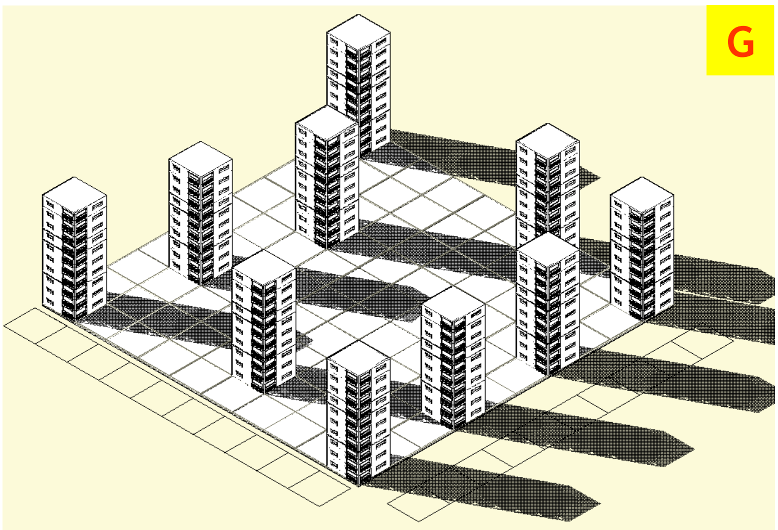

Fig. 7 Topology of the optimal solution (G) for 10 buildings

Table 1 Comparison of classical solutions (A-F) with optimal design (G)

	Positioning solutions						
building	A	B	C	D	E	F	G
1	1	1	1	3	1	3	1
2	2	11	11	4	12	14	10
3	3	21	21	5	23	25	70
4	4	31	31	6	34	36	63
5	5	41	41	7	45	47	91
6	6	51	3	33	56	11	32
7	7	61	13	34	67	22	16
8	8	71	23	35	78	33	40
9	9	81	33	36	89	44	100
10	10	91	43	37	100	55	97
Energy (*)	10.145,0	10.453,3	10.222,0	10.342,3	10.863,7	10.703,7	11.198,0
OPT (**)	10,38%	7,12%	9,55%	8,27%	3,08%	4,62%	0,00%

(*) Energy annually received on facades of the buildings, kWh

(**) Enhancement degree of the optimal solution compared to each classical solution

Optimal Solution

CONCLUSIONS

A framework of the models used for simulation and generation of various geometries for different organizations of the urban grid is presented. The development of a numerical simulation model that supports a set of buildings inserted into the urban grid is formulated and presented. Taking into account the effect of shadowing between buildings the annual amount of energy received from the direct solar radiation is calculated using the developed model. The apparent motion of the sun is simulated and the areas of shading due to the interaction of buildings in the urban context are identified. Some cases of geometries associated with various possible placements for groups of buildings are presented and the corresponding solutions are ranked as to their best value.

Given the need to obtain urban grid designs enhancing sun exposure and due to the inability to simulate those exhaustively, the study, definition, formulation, development and validation of an optimization model of the solar potential is carried out. The design variables are identified, the objective function is defined and the mathematical formulation of the optimization problem of the solar potential is presented. A genetic algorithm to search the optimal design solutions is proposed and developed. The main details of the research method in particular the operators of the genetic algorithm are described. Examples of application of optimal design are presented. The obtained solutions are compared with the conventional classic configurations for urban grid based on solar exposure potentials.

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