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A DIRECT GENERATIVE CAD TOOL FOR THE SITE LAYOUT OF COMMUNITIES WITH SOLAR ACCESS TO EACH BUILDING

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"Solar Rights", solar radiation, solar communities, Computer-Aided Architectural Design, design tools.

ABSTRACT

A method for the design of communities with solar access to each building is presented. The method allows the determination of the minimum possible distance between the buildings that enables insolation, the maximum height allowed for a given building without violating the "Solar Rights" of its neighbors, and how low the window or the passive solar collector can be placed on the wall and still be insolated in winter. The fundamental idea is to use a computer and CRT to generate the entire envelope of the families of design solutions. These solutions provide the required open space between buildings to sustain the "Solar Rights" of the building under consideration. This envelope of solutions serves as a nomogram on the basis of which the location of each building in the solar communities is determined. The method creates an unlimited space of solutions, leaving the final design to the architect's imagination.

INTRODUCTION

The availability of direct solar radiation in winter in residential houses has presented an important problem in urban design, in particular in solar communities. One aspect of the problem is the minimum distance allowed between buildings, taking into account their orientation and heights, so as to provide direct solar radiation to all residents while keeping high urban density.

One way to design a solar community with solar rights to each resident is to apply an evaluation CAD technique. In this way the solution is approached by trial and error, i.e., by examining the effect of modification in all design parameters like height, distance, etc., and later changing each one so as to obtain an optimal solution. Our discussion will focus on another technique, a direct generating CAD method.

In direct generating CAD technique, the computer programs produce design solutions which satisfy predetermined requirements, in contrast with evaluative programs that are used to analyze and compare different design solutions generated manually by the designer. Although a generative program can generate an unlimited number of design solutions in a single run, it does not require a very detailed data set to describe the building and its surroundings like evaluative programs do. Therefore direct generative CAD tools can be easily used in the first design stage where most of the important design decisions are made, while evaluative CAD tools are to be used in the late design stages.

The principles of the method are similar to those applied in a former model developed by Shaviv for designing shading devices (1-5) and are as follows:

1. Determine the period and time of day during which insolation is desired.

2. Derive a nomogram of the envelope of all possible locations of buildings with their allowed heights to enable the insolation of a given passive solar collector.

3. Use the nomogram in the first design stage to determine the location and height of each building min the solar community, or the best location for the passive solar collector on the wall of a given building.

A microcomputer is used to generate the nomogram and present it on a monitor. This nomogram include the complete family of solutions for a given orientation and exposure demands.

THE SOLAR RIGHTS MODEL

consider a passive solar collector of length A. Let C x D be the plan in front of the passive collector and let L be a pole located at some point in this plane. Our goal is to find how tall the pole can be so that it does not cast a shadow on the lowest points of the solar collector located along the line A (see Figure 1). We divide the plane C x D into a fine grid. The size of the grid is determined by the designer. A pole of length L is imagined to be located at each grid point. The length L is calculated so that the shade of the pole reaches exactly the section A and does not extend beyond it. In this case the length L of the pole is stored, otherwise a flag is assigned to this grid point. A flag means that there is no limitation on the height of the pole located at this particular grid point. Obviously, the length L varies with the parameters of the problem (the azimuth of the solar collector, period of insolation, etc.)

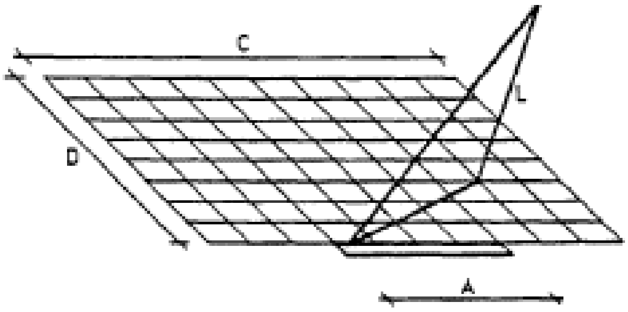

Fig. 1. The division of the place C x D to a fine grid. A is the location of the passive collector and L is the length of the pole.

The calculation of L(i,j), namely L at grid point i,j, is carried out on the 21st of every month and for every hour during which insolation of the given solar element is required. The minimum of L(i,j), L(i,j)min, during the entire exposure period, is stored. This L(i,j)min is the maximum allowed height of the building located at point i,j without depriving the direct sun from the passive solar collector under consideration. The distribution of L(i,j)min in the plane C x D is the nomogram for the design of the layout of the solar community. Figure 2 shows the table and an axonometric presentation of the results presented in the table. Three numbers appear in the table for each grid point. The upper one is the maximum allowed height L(i,j)min. When L(i,j)min = FLAG + 99.99 it means that no limitation exists for this particular point. Nothing is drawn above the projected mesh point if no limitation exists. The location of the passive solar collector is defined by assigning 00.00 to these grid points. The next two numbers below the upper one are the month and the hour when L(i,j) = L(i,j)min. One can see that L(i,j)min is obtained at different months and hours for different i,j.

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TABLE OF YEARLY MAXIMUM SOLAR ENVELOPE
AZIMUTH OF SOLAR ELEMENT= -15.0
WIDTH OF SOLAR ELEMENT=   6.0   MAXIMUM DISTANCE=   8.0
 99.99 99.99 99.99   .00   .00   .00   .00   .00 99.99 99.99 99.99
  0  0  0  0  0  0  2 15  2 15  2 15  2 15  2 15  0  0  0  0  0  0
 99.99 99.99   .83   .81   .50   .50   .50   .50 99.99 99.99 99.99
  0  0  0  0  1 15  1 12  1  9  1  9  1  9  1  9  0  0  0  0  0  0
  2.96  1.66  1.66  1.62  1.00  1.00  1.00  1.00 99.99 99.99 99.99
  2 15  1 15  1 15  1 12  1  9  1  9  1  9  1  9  0  0  0  0  0  0
  2.49  2.49  2.49  2.44  1.90  1.50  1.50  1.50  1.50 99.99 99.99
  1 15  1 15  1 15  1 12  1 10  1  9  1  9  1  9  1  9  0  0  0  0
  3.32  3.32  3.45  3.25  2.53  2.00  2.00  2.00  2.00 99.99 99.99
  1 15  1 15  1 13  1 12  1 10  1  9  1  9  1  9  1  9  0  0  0  0
  4.16  4.31  4.06  4.06  3.17  2.50  2.50  2.50  2.50  3.60 99.99
  1 15  1 13  1 12  1 12  1 10  1  9  1  9  1  9  1  9  2  9  0  0
  5.26  5.17  4.87  4.87  4.42  3.80  3.00  3.00  3.00  3.00 99.99
  1 14  1 13  1 12  1 12  1 11  1 10  1  9  1  9  1  9  1  9  0  0
  6.03  6.03  5.68  5.68  5.15  4.43  3.50  3.50  3.50  3.50  5.04
  1 13  1 13  1 12  1 12  1 11  1 10  1  9  1  9  1  9  1  9  2  9
  6.89  6.89  6.50  6.50  5.89  5.07  4.00  4.00  4.00  4.00  5.76
  1 13  1 13  1 12  1 12  1 11  1 10  1  9  1  9  1  9  1  9  2  9
Pause.
Please press <return> to continue.
 another run?
 0-stop
 1-change design parameters
 2-change period of insolation
 3-change type of output
 4-change output device
 5-change scale of drawing
 enter 0-5
0
Stop - Program terminated.
```

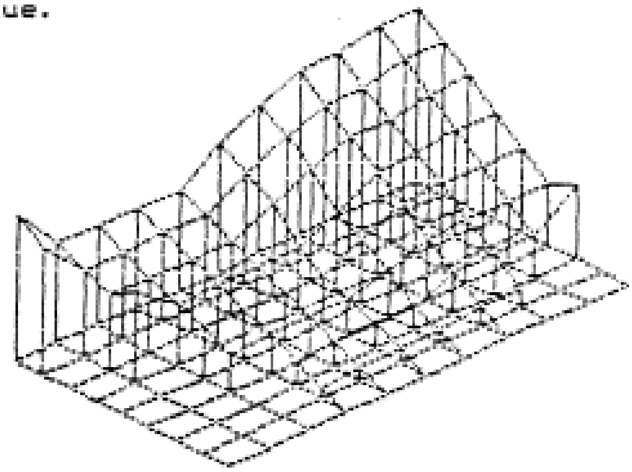

Fig. 2. A table and a nomogram for the design of solar community for a passive solar collector facing 15° east to south.

The insolation period required for the passive solar collector depends on the time of the day during which the building is occupied, the orientation of the collector, and the local climatic conditions. The last two factors determine the amount of radiation incident on a particular passive collector and can easily be calculated for each hour and day in the year.

The data required for the creation of such a nomogram is easy to prepare and includes: the longitude and latitude of the location of the neighborhood; the azimuth of the passive solar connector and its length A; the place C x D; the size of the grid and the required insolation period (see Figure 3).

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sunexng
 A MODEL FOR CALCULATING SOLAR RIGHTS
 BASED ON A METHOD DEVELOPED BY PROF. EDNA SHAVIV
 WRITEN BY PROF. EDNA SHAVIV
 **************************************************
 enter latitude
32.
 enter longitude
 positive-if east to greenwich
 negative-if west to greenwich
35.
 enter time difference
 +; if later   then greenwich (generally:east lat.)
 -; if earlier then greenwich (generally:west lat.)
2
 enter azimuth of solar collector
 0;due south, -;eastward, +;westward
-15
 enter width of solar collector
6
 enter no. of devisions
 to left(m1), front(m2), & right(m3) of collector
 m1+m2+m3<13
3,4,3
 enter distance from solar collector
8
 enter no. of devisions from element to collector(n)
 n<13
8
 **************************************************

 enter months; month1, month2
1,2
 enter hours; ihour1,ihour2
9,15
 **************************************************
 enter type of output
 0-print only sun position
 1-sum over period+graph
 2-sum over period+months. Graph for period
 3-sum over period+months. Graph for period+months
 4-sum over period+months+hours. Graph for period
 5-sum over period+months+hours. Graph : period+mont
 enter 0-5
1
 **************************************************
 enter text output device
 1-screen
 2-printer
 3-file sunex.dat
 enter 1-3
1
 **************************************************
```

Fig. 3. The data required for the creation of the solar right table and nomogram.

USING THE MODEL FOR THE DETERMINATION OF SOLAR RIGHT'S

a. The Determination of the Height of Buildings in Solar Communities

The table and the isometric drawing provide the allowed height of each grid point in the place C x D (see Figure 2). In this particular case study, a passive solar collector of length 6 m oriented 150 east to south is assumed. The plane C x D was chosen to be 15 x 8 m and the grid 1.5 m in C direction and 1 m in D direction. This means that the last row in this table gives the allowed heights at a distance of 8 m from the given passive collector and the row above it - the allowed heights in a distance of 7 m. Figure 4 gives the allowed contour of the northern elevation of a building 15 m long located 8 m away from the passive solar collector. We find that the allowed heights for the building change from 3.18 m to 6.89 m, which means that two stories building can be designed only on the west side of this building without depriving the solar rights of the given building with it's given passive solar collector.

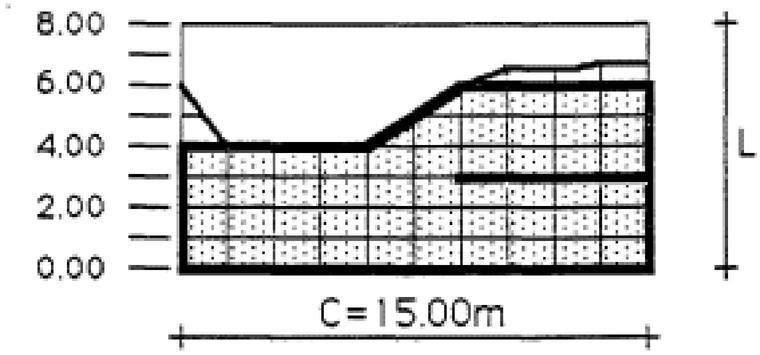

Fig. 4. The northern elevation of the highest allowed building at a distance of 8 m south to the collector.

b. - The Determination of the Minimum Distance Allowed Between a Passive Solar Collector and a Building with a Given Height

Suppose a building 3 m high and 15 m long should be located in the space C x D without shading the passive solar collector A. We can use the table given in Figure 2 to determine the minimum allowed distance for placing this building. Figure 5 presents the exclusion zone, namely the zone where a 3 m high building is not allowed to be located. This zone is shown in Figure 5 with doted grey. Such analysis can help us to learn about the population density that can be achieved for different orientations and heights of given designed buildings.

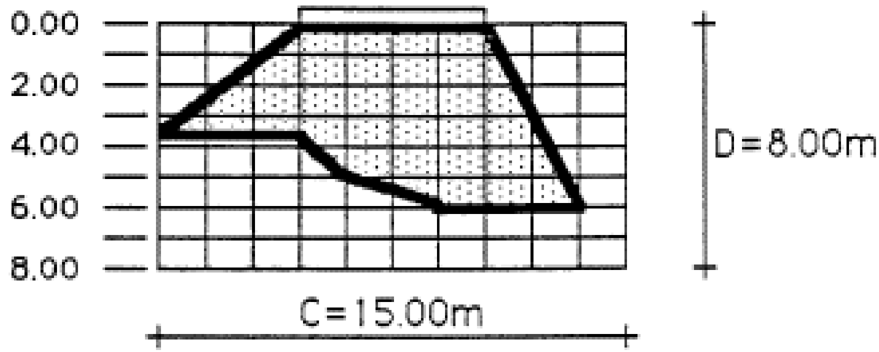

Fig. 5. The minimum allowed distance for locating 3 m high building.

c. Determination of the Form of the Passive Solar Collector.

When the location of the nearest building south to the passive solar collector and its height is predetermined, one can use the model to determine the correct form of the passive solar collector. Let us take for example, a 6 m long and 6 m high building located at a distance of 8 m from the passive solar collector. Assume also that the building is parallel to the passive solar collector and exactly in front of it. We can use the nomogram to design the form of the passive solar collector that will not be shaded by this building. To find out the form of the solar collector, we return to the problem of finding the allowed height L(i,j)min throughout the insolation period but only during the critical hours that appear in the table of Figure 2.

Table 1 summarizes the maximum heights that were obtained at a distance of 8 m from the passive collector facing 15° east to the south and at each critical hour included in the table of Figure 2. This table provides the required data for solar collector design.

MONTH	HOUR	-	-	-	+	+	+	+	+	-	-	-
JAN	09.00							3.98	3.98	3.98	3.98	
JAN	10.00						5.06	5.06	5.06	5.06		
JAN	11.00					5.88	5.88	5.88	5.88			
JAN	12.00			6.50	6.50	6.50	6.50					
JAN	13.00	6.89	6.89	6.89	6.89							
FEB.	09.00								5.77	5.77	5.77	5.77
LIMITING HEIGHTS					3.98	3.98	5.06	5.88				

Table 1. The maximum allowed heights of building at a distance of 8 m, at different critical hours (Azimuth = 15° east to south.)

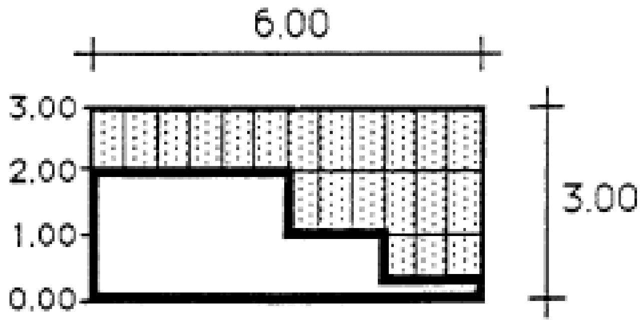

Fig. 6. The lowest possible line for the passive solar collector.

Figure 6 shows the lower line obtained for the passive solar collector facing 15° east to the south. This lower line was obtained by subtracting the limiting numbers which appear in Table 1 from the height of the building (6 m). There is no limitation on the upper line of the passive collector, and a height of 3 m was chosen arbitrarily. One can see that in this particular case, of passive collector oriented 15° east to the south, the collector cannot reach the ground and should have a staggered shape. However, if the 6 m building would be shifted to the west by 4.5 m (or the passive collector is shifted by 4.5 m to the east), the lower line of the passive collector could reach the ground, as can be seen in the table of Figure 2.

CONCLUSIONS

The model presented in this paper is a CAD tool that can be implemented in the schematic design phase. The input data required are not very detailed, a virtue that ease the use of the model in the early design phases, where no geometrical information on the form of the building nor the general layout are fixed.

This model demonstrates the use of computers to generate solutions rather than evaluate manually created design solutions. in our approach the space of all possible design solutions is created first. The final design solutions is chosen out of this space on the basis of criteria not included in the model (aesthetics, for example). Such an approach makes possible the design of many variations of efficient and beautiful nonstandard design solutions.

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