Energy consumption as design principle

Aant van der Zee.
Department of Architecture, Building and Planning
Eindhoven University of Technology
e-mail: a.v.d.zee@tue.nl

Bauke de Vries.
Department of Architecture, Building and Planning
Eindhoven University of Technology.

Abstract

In this paper we will outline the development of a design tool, for the early design phase, based on an integral design strategy, with respect to energy-performance and spatial layout. The proposed tool will help the designer to generate a draft that fulfills both criteria and analyze their mutual effect.

Energy consumption reduction is implemented by the government in the Netherlands and many other countries by gradually reducing the energy performance coefficient over the past years. Designers and engineers have adjusted their design and materials such that could meet the new standard. However, up to now this has not lead to dramatic changes in the architectural layout of buildings. We anticipate that at some point substantial changes in design and material use are needed. Our aim is to find this point through the generation of design alternatives for housing as a function of decreasing energy consumption

1. Introduction

After WO-II in the Netherland the "Leitmotiv" in Dutch building industry was mass housing production. There were after the war far too few houses for the Dutch population, so the building industry sought ways to build houses in less time mass production of dwellings. This resulted in the development of the so-called

"doorzonwoning" (see figure 1). It was an easy and fast to build dwellings type, till to today this is still the most build housing type. To reduce the heat loss the cavity layer was partial filled with an insulation material.
Because of the changing climate, energy consumption reduction has now become a hot topic in building industry. Early in the 1994 the Dutch government made a new building code to reduce the energy transmission for buildings and dwellings. The total energy performance of a building is expressed in the energy-performance-coefficient. This coefficient has to be less then 1.0 (for dwellings), the lower the better the energy performance will be. During the following years this index is decreased till 0.75 nowadays. It is our expectation that in the following years the Dutch government will decreased this index further. The building industry will first increase the insulation (more insulation or newly development insulation materials) in the building envelope as an easy way to fulfill the energy reduction constraint. There will come a point at which further increasing of the insulation layer will gain less reduction against substantial extra costs. It is our belief that increasing the reduction energy reduction of buildings cannot continue without changing the layout of the building.

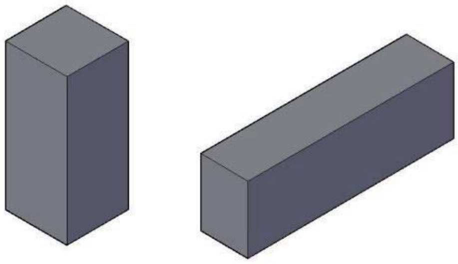

Figure 1.1 Extreme solutions

In this paper we explore the possibilities to use a genetic algorithm in search of new dwelling types which are better suited for low energy housing. This will be done for building blocks, which has as two extreme solutions namely: "row houses" and "high-rise apartments building" (see figure 1.1).

Our approach to Generative Design takes the Dutch building codes and regulations as a starting point. In the following section we will apply our GD system and imply current codes with respect to lighting, energy consumption and minimal requirements for furnishing [4].

2. First experiment

In order to validate the application we use a simple test design project, consisting of 8 rooms, each with a minimum and maximum area. This simple client's brief is a typical requirement for a Dutch one-family house. The relations and areas of the rooms are presented Table 2.1.

Rooms			Relationship between rooms									
Name	Min.	Max.		V1	V2	V3	V4	V5	V6	V7	V8	B
Circ.room space	2	10	V1									
Entree	2	10	V2									
Living	15	40	V3									
Kitchen	10	15	V4									
Bedroom 1	20	25	V5									
Bedroom 2	12	15	V6									
Bedroom 3	12	15	V7									
Bathroom	5	10	V8									
Environment	-	-	B									
Total area	78	140										

Table 2.1 Client's brief

The goal of this experiment was to see if it is possible to generate existing housing types [3]. In this experiment we used the above mentioned client's brief as starting point. We used some typical constrains:

1) Relationship between the rooms (see table 1.1);
2) Maximum and minimum area of the rooms (see table 1.1);
3) Maximum number of floor levels (max 3 floor levels);
4) Energy performance (EPC < 1.0)
5) Construction (there have to be sufficient load bearing walls).

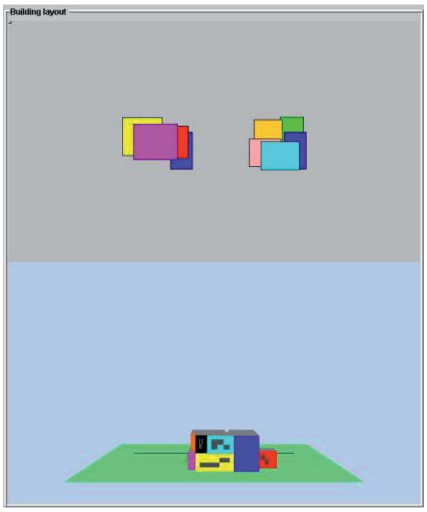

Figure 2.2 A typical solution

Overall the results of the system were not as neatly and smoothly as the examples from practice (figure 2.2). But the Dutch dwellings experiment demonstrates that dwellings can be reproduced from implying building codes.

3. New experiment

Energy consumption reduction is implemented by the government in the Netherlands and many other countries by gradually reducing the energy performance coefficient over the past years. Designers and engineers have adjusted their design and materials such that could meet the new standard. However, up to now this has not lead to dramatic changes in the architectural layout of buildings. Our aim in this experiment is to find this point through the generation of design alternatives for housing as a function of decreasing energy consumption. We start with a normal heat resistance (= 2.5 W/k) for the envelope and let the GA generate shapes that meet the energy performance coefficient given the spatial conditions. Subsequently, the energy performance coefficient will be reduced to study the changes in spatial layout.

In order to generate alternatives, which can be tested against the energy performance constraint and spatial conformances, the design is parameterized. Each dwelling is considered as a volume with a constant volume but different measurements. The overall shape of the building is a summation of volumes (= dwelling). We depict housing, as parameterized apartments, corridors and envelopes. Each of the parameters represents physical, geometrical and topological properties. By systematically changing these variables, the GA [1, 2] is able to generate alternative spatial configurations and envelope sections [5].

In our next experiment we use the same application with a few minor adaptations to the new problem. First of all we will have to adjust the genotype and will use less constrains. For this experiment we will use only a few basic parameters concerning:

1) Shape of the building;
2) Heat resistance of the walls;
3) Number of floor levels;
4) Area of windows in walls;
5) Energy performance of the building (EPC).

In the next paragraph we will briefly discuss the parameters.

3.1 Building shape

The overall shape for the building will be parameterized, into 3 variables namely the width, length, and number of floors. These properties will affect all other constrains.

3.2 Walls

In our model we use calculated mean heat resistance. This needs a translating from out-come to realistic construction.

In the Dutch building regulation the minimum heat resistance for outside walls is 2.5 K/W. If the wall consists of 40 cm fiber wool with a lambda of 0.025 W/(m.K) the heat resistance would be 16 W/k, so if we choose a maximum value 20 instead of ∞ we get a bandwidth for the solution will be is $2.5 < R_c <= 20$.

3.3 Floor levels

Because of the nature of the phenotype it is possible that some floor/floor-spaces do not exists, say, we have spaces on the ground floor, second, third, sixth and eight layer (see figure 3.1 a). In the data model we reorganize the data that need re-ordering to get a consistent model. In that case layers on which the spaces are located are renumbered to become consecutive (see figure 3.1 b).

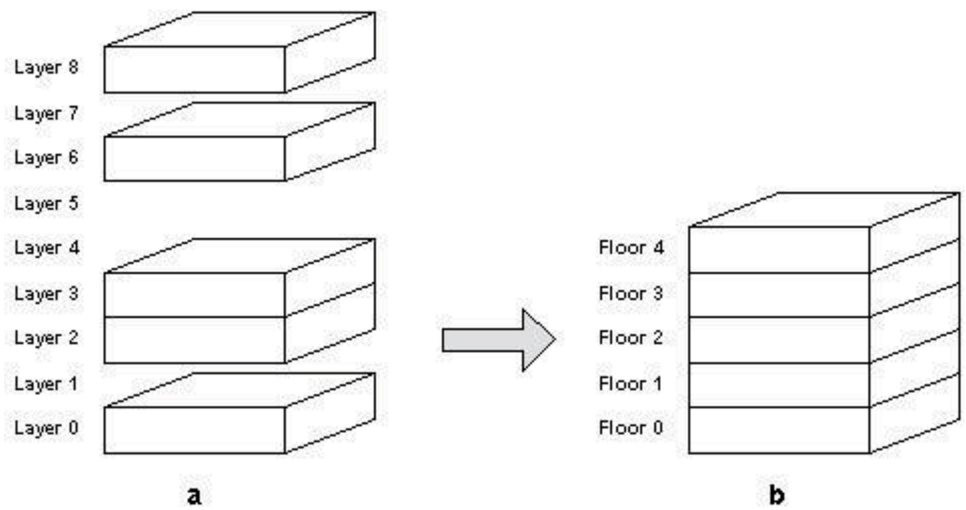

Figure 3.1 Floor layers

In our new experiment we will constrain the number of floor levels to 5.
The solution bandwidth will be 1 <= Fl <= 5.

3.4 Windows

In order to translate a grid from the genotype we translate the genotype-number back into '1' and '0'. A '0' corresponds to a closed wall and a '1' correspond to a window. This array is a 1 dimensional representation of a 2 dimension grid, see figure 3.4. In this way there is flexibility in window size, shape and location. Some restrictions are made by

1) A minimum offset from the wall perimeter, so there can't be a window place at the edge of a wall;
2) A window must be built up from a minimum number of grid cells, this is necessary so there will be no windows with the area of 1 grid cell.

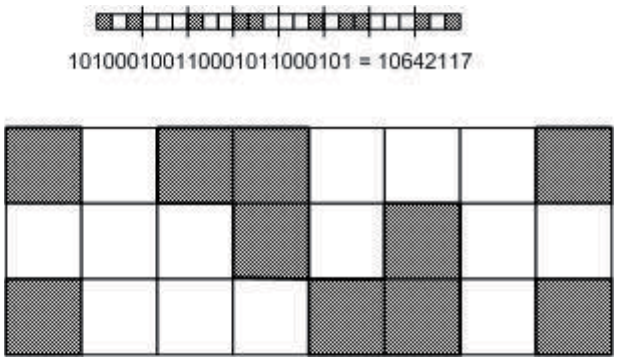

Figure 3.2 Window grid

The number of possible windows solutions is controlled by the grid dimensions. For a draft design a grid of 3 x 8 is adequate. Each grid size has it own maximum number, 2(i+j) + 1, where I en j are the grid dimensions. The maximum number corresponds with a wall made entirely out of glass.

According Dutch regulation every room need to have at least 0.5 m^2 window, and the window area can't be larger then the containing wall. Because of the way we designed the window this is impossible.
The bandwidth of the solution will be: $0.5 <= A_{win} <= A_{wall}$

3.5 Energy performance objective

In the Netherlands the energy performance of a building is calculated according to a national norm [3]. This norm provides the terminology and calculation methods of the energy performance of dwellings. The energy performance (Q_{pres_tot}) is a function of the total outside area of the enclosures, the heat resistance of the used material, window orientation and area, used heating installation etc. The total energy performance of a building is expressed in the energy-performance-coefficient. The objective is that this coefficient (EPC) is less then 1.0, the smaller the better the energy performance will be. It is our understanding that this objective will (indirectly) decrease the total area of the outside enclosure.

$$EPC = Q_{pres\_tot} / (330.0 * A_{g\_verw} + 65.0 * A_{verlies}) \qquad \text{eq. 1}$$

Where:

Q_{pres_tot}	Characteristic energy consumption of a building	A_{g_verw}	Total 'living' area
EPC	Energy performance coefficient	$A_{verlies}$	Total heat loss area of a building

The solution bandwidth will be $0 < EPC <= 1.0$

3.6

The experiment will consist of several runs of the application. For each run the EPC value will be decreased by 0.25. The application has to find values for the other parameters, as there are: building shape, heat resistance of the walls, number of floor levels, windows area in the walls, to fulfil the EPC constrain, each of this set values can be decode into a building shape. In this way we can see what typical solutions are for a specific EPC value

4. What can expect

We hope to establish prove that by decreasing the EPC-constrain there will a turning point in the layout development of low energy housing.
We hope to see that the shape will slowly grow into a cube. However it won't be a perfect cube because of the fact that the ground floor has a better heat resistance then walls. To gain as much as possible positive influence of the sunlight, the windows will be located mainly in the south façade.

But what ever the result will be the GA has proven to be a valuable tool in building research.

5. Further experiments

After this experiment we will investigate what the influence will be of the spatial layout of the city on the energy reduction of dwellings.

Therefore the genotype must be extended to "hold" more buildings then the one in our former experiments. And there has to implemented a new constrain which deals with the influence of the shadows casting on dwellings by nearby buildings.

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