Generation of User-defined Landscapes for Multi-actor Plan-making

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Kymo SLAGER
PhD candidate
Design systems group
Faculty of Architecture, Building and Planning
P.O.Box 513
5600 MB Eindhoven
The Netherlands
Tel: (+31) 40 247 2388
Fax: (+31) 40 245 0328
E-mail: c.t.j.slager@tue.nl

Bauke DE VRIES
Professor
Design systems group
Faculty of Architecture, Building and Planning
P.O.Box 513
5600 MB Eindhoven
The Netherlands
Tel: (+31) 40 247 2388
Fax: (+31) 40 245 0328
E-mail: b.d.vries@tue.nl

Joran JESSURUN
Software engineer
Design systems group
Faculty of Architecture, Building and Planning
P.O.Box 513
5600 MB Eindhoven
The Netherlands
Tel: (+31) 40 247 2388
Fax: (+31) 40 245 0328
E-mail: a.j.jessurun@tue.nl

Abstract: In this paper the functioning of the landscape generator is presented. The landscape generator is developed as part of the planning support system called Simlandscape. Using real-world spatial data and a user-defined intended landscape typology, the landscape generator progresses for satisfying an overall fitness function. This fitness function is compiled of a set of criterion functions describing configurational characteristics of a landscape typology. When the overall fitness function is satisfied a landscape configuration is generated. Discerning technical characteristics with respect to other optimisation techniques, are the use of straightforward design input rules (criterion functions) and its ability to produce acceptable results in considerable time.

Keywords: landscape generator, collaborative spatial-planmaking, landscape typology, PSS, spatial optimisation

1. INTRODUCTION

Contemporary regional spatial planning processes are complex. A multitude of public and private stakeholders rely on each other to develop high quality spatial plans (Hajer et al. 2000). The challenge is to reconcile all conflicting interests into a realistic development vision (Spaans 2006).

An important phase in each spatial planning process is the collaborative design of different plan alternatives for identified problems at hand. We call this the plan-making process. Aiming for broad social support and successful realization of planned developments, this process is ideally organized with all (public and private) stakeholders involved from the early beginning of the process. However, in reality governmental organizations often only consult relevant private stakeholders (citizens, project developers, interest groups etc.) about plans which are designed in advance.

Independent of the level of participation strived for, we suggest to facilitate an interactive platform at which professionals with or without private stakeholders collaboratively design on development plans and explore future developments.

Digital support tools developed for spatial planning pratice are also known as Planning Support Systems (PSS). Since GIS technology forms the backbone, tens of planning support systems (PSS) have been developed with a strong focus on analysis (e.g. impact assessment), evaluation (e.g. multi-criteria analysis), visualization (e.g. virtual reality) or simulation (agent-based systems) (Arentze et al. 2006). The support for collaborative plan-making, with dedicated feasible interactive design tools received relatively litlle attention. Some incentives have mainly focused on sketch planning tools to support early phases of scenario building with as final graphical result 'sketchy' (GIS-based) maps (Geertman et al. 2003, Hopkins 2004, Harris 2001, Al-Kodmany 2002), others addressed the use of virtual reality and CAD-environments to support bottom-up development proposal visualisation and management (Hatna et al. 2007, Kwartler et al. 2001).

An important part of our PSS is the development of the landscape generator. On basis of landscape typologies, it produces possible future landscapes at a very comprehensible level of detail: landscape components. With the landscape generator, plan alternatives are generated and subsequently suggested developments can be assessed in comprehensive detail. Resulting images should not be considered to be a definite design, but more as plausible future landscape elaboration. In this paper, we focus on the functioning of this landscape generator. It combines techniques of traditional spatial modelling approaches, such as cellular automata, shape grammars and evolutionary algorithms. In section 2 we give a short overview of the broader PSS in which the landscape generator has its function and which requirements are posed. In section 3 we present the process flow of the landscape generator. Section 4 illustrates a specific case. Finally, in section 5, conclusions are drawn and interesting further developments are posted.

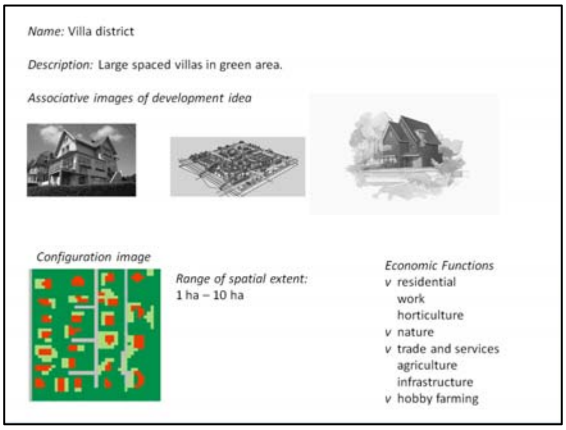
2. SHORT OVERVIEW OF PROPOSED PSS

In this section, we shortly discuss the main features of the developed Planning Support System in the research project Simlandscape. The PSS includes a set of interrelated hardware and software tools to support the collaborative design process of spatial plan-making. The software tools are not necessarily restricted to one type of hardware, but the design tools are mainly designed for tangible user interfaces, such as touchtables and maptables. These tables are suitable to support plan-making in a collaborative manner, in analogy with contemporary plan-making processes.

In order to support multi-actor communication effectively digital design tools are developed that operate on different levels of detail. These design tools are developed in a GIS environment to make instantly use of spatial analyses possible. The look and feel of the software is non-GIS like. The system provides design tools for both public and private actors. Actors with a more top-down interest on the development area, like governmental professionals (planners, architects, ecologists, hydrologists, cultural historian etc.) are supported with design tools, that are developed to design from initial sketching, through generic zoning down to specific allocation of functions and corresponding landscape layout. Actors with a more bottom-up interest, like citizens, project developers and other interest groups are supported with design tools for design at the cadastral lot level up to a project level.

The use of landscape typologies is central in the system. They provide a interdisciplinary format for stakeholders to structure development ideas. These are allocated to features drawn on sketch layers. By offering the typologies in a user-friendly library, users efficiently design, alter or combine plan scenarios. Moreover, the landscape typologies are related to models used for performance calculation or visualisation.

Three types of landscape typologies are distinguished: zone typology, project typology and a lot typology. A *zone typology* describes an intended development or a set of developments, by an indicative name, a description, a set of associative images and a set of intended economic functions. A zone typology consists of one or more project typologies or lot typologies. A *project typology* has the same attributes as a zone typology, but has an investor for realization. A project typology consists of one or more lot typologies. A *lot typology* has the same attributes as the zone typology, but is specific in spatial extent (can only be allocated to one cadastral lot at a time), has normally an investor (owner) for realization, and its physical layout is visualized by a configuration image with landscape components such as buildings, trees and other landcover. (see figure 1 for an example lot typology).



Name: Villa district

Description: Large spaced villas in green area.

Associative images of development idea

Configuration image

Range of spatial extent:
1 ha – 10 ha

Economic Functions
v residential
work
horticulture
v nature
v trade and services
agriculture
infrastructure
v hobby farming

Figure 1: an example of a lot typology: villa district

The most specific design level supported are the landscape components. In an ideal PSS all described design tools can be used on demand.

The landscape generator produces, based on the information stored in a lot typology a possible future landscape. These possible future landscapes are generated at the comprehensable level of landscape components and supports discussion among the stakeholders. The landscape generator generates configurations to a full range of different lot geometries and site-specific surroundings. The output claims to resemble the configuration image. In the next section we describe the process flow of the landscape generator.

3. PROCESS FLOW OF LANDSCAPE GENERATOR

The landscape generator generates a landscape configuration for one or more pre-selected cadastral lots. In this section, we first explain the (pre-)processing steps to produce suitable input files, then we discuss the main procedure and finally we describe the (post-)processing steps to save the results for latter use and visualisation. Each process step is discussed in detail below. Although more than one cadastral lot can be processed by the model, the following description assumes processing of one cadastral lot.

3.1 Pre-processing steps: prepare the input

Three input files are necessary to generate a landscape configuration, namely cadastral lot geometry, topographic map and a configuration image. The lot geometry defines the boundaries of the *site* (area to be transformed into the new landscape configuration). The topographic map defines the existing situation of the landscape at the *site*. The landscape typology defines the characteristics of the intended future landscape.

First, the conversion of source files into an intermediate table is discussed (see figure 2: 1) conversion). Then, the derivation of characteristics from the configuration image is described. (see figure 2: 2) derivation) Finally, the compilation of the fitness function is explained. (see figure 2: 3) compilation)

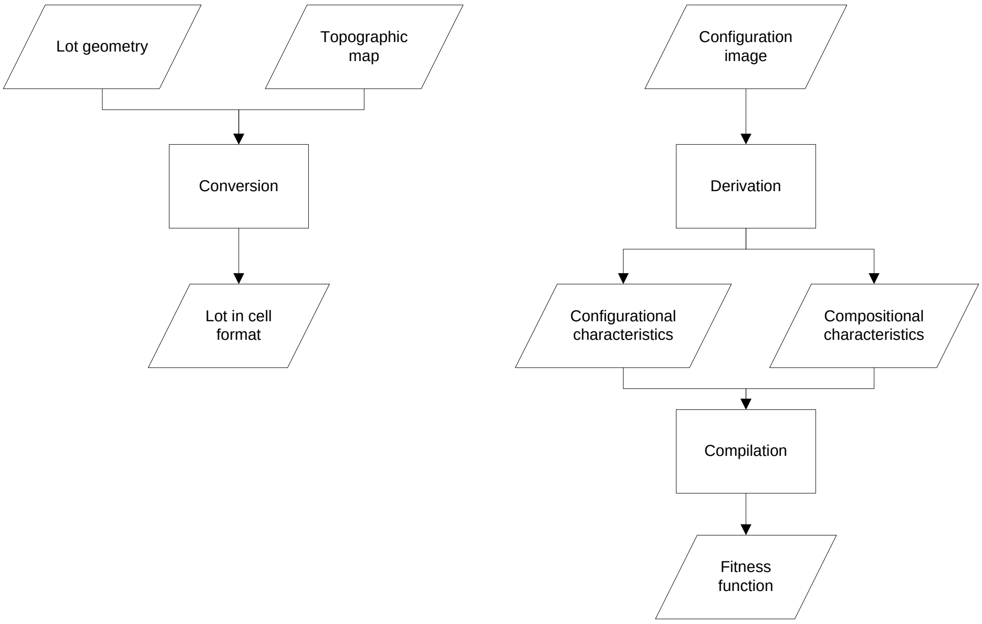


Figure 2: 1) conversion of lot geometry and topographic map into a lot in cell format; 2) derivation of characteristics from the landscape typology visualisation; 3) compilation of a fitness function

3.1.1. conversion of lot geometry and topographic map into a lot file in cell format

The *site* in the landscape generator is represented by a regular raster of grid cells. The dimensions of the cells are 6 x 6m, since one of the most important landscape components, buildings (footprints), can realistically be represented in these dimensions (e.g. 12 x 6m, 12 x 12m etc.). Besides, with this cell size, the system is still able to produce results in moderate time (within hours).

In the ArcGIS software a python script is constructed to automate the conversion from a selected lot in the cadastre file (polygon) into an intermediate lot file with cell information. This file is in the landscape generator used to initialize the *site*. (see section 3.2). The file also includes information about the extent (amount of rows and columns), x and y coordinates of corners, and cell size information.

Due to realistic irregular boundaries (polygon) of lots, cells are part of the site when more than half of them fall within the boundaries. In addition, a buffer along the border of the site, consisting of one cell, is included to represent the surroundings. It is included to introduce surroundings-specific influences. It is the only site-specific influence we consider in this part of the system. Soil or geo-morphologic characteristics at that location are not included, but assumed not to conflict with the generated landscape design (see section 2).

The landscape components represented in each cell in the existing situation (in the site and just outside) are known and classified as shown in table 1. Information of the existing situation is extracted from the topographic map at scale 1:10000. The present categories of the topographic map are generalized into the components (table 1). The classification of landscape components is based on a standard set of typologies. It represents multiple land cover classes which are quite similar to topographic map elements. Of course, this list can be extended.

Table 1: Values representing landscape components in intermediate table

Landscape component	Value
Maize	1
Grass	2
Building – type 1 (other)	3
Building – type 2 (residential)	4
Hard space	5
Water	6
Forest	7

A landscape component is described by one cell or a cluster of cells. Sometimes in the process of conversion from the topographic map, a cell covers more than one landscape component. In this situation, the landscape component with largest proportional area is allocated to the cell.

Only yard space (hard space) is represented in the landscape generator. Current infrastructural networks are used, but no new infrastructural networks are generated.

The distinction in the intermediate lot file between cells belonging to the site and cells belonging to the surroundings is made by adding a value of 100 up to the landscape component value. The cells with values higher than 100 will be considered *fixed*, i.e.

unable to be converted to some other landscape component.It sometimes occurs that the landscape typology consists of components, that for successful representation, require to be aligned perpendicular to the main orientation of the site. (e.g. tree lines, buildings) In this case the source files are rotated in advance of conversion. The extent of rotation is determined by looking for an orientation of the coordinate system that aligns best with the most lines inside the lot geometry.

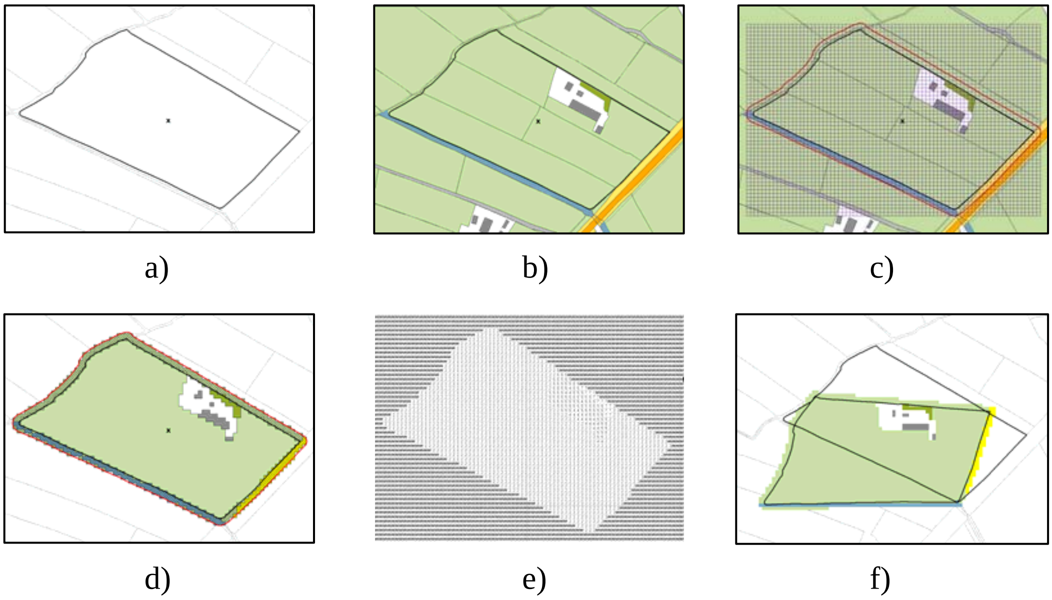
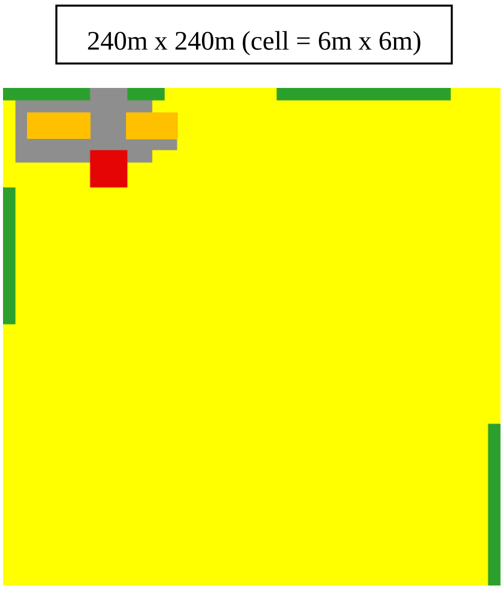


Figure 3: a) cadastral lot; b) topographic map overlayed with cadastral lot; c) cadastral lot, topographic map and surroundings border (red) overlayed with raster; d) graphical result of conversion to raster; e) result of conversion to raster; f) special case: before conversion lot is rotated

3.1.2. derivation of configurational characteristics from a landscape typology

As mentioned in section 2 a landscape typology is a central concept in the landscape generator, since it describes the intended landscape configuration at a selected site. One of the core elements of the landscape typology for the landscape generator is the configuration image. This configuration image is reproduced into the lot geometry.


240m x 240m (cell = 6m x 6m)

Maize (1 - yellow):
- instances: 1
- prop.area: 92.6
- perimeter: 198
- fractal dimension index: 1.0689

Building – type 1(3 - orange):
- instances: 2
- area: 10 cells (1), 8 cells (2)
- perimeter: 12 (1), 12 (2)
- fractal dimension index: 1.0566 (1), 1.0881 (2)

Building – type 2 (4 – red square):
- instances: 1
- area: 9 cells (18x18m)
- perimeter: 12
- fractal dimension index: 1

Hard space (5 - grey):
- instances: 1
- prop. area: 2.7
- perimeter: 58
- fractal dimension index: 1.422

Forest (7 – dark green)
- instances: 5
- prop. area: 3.0 (total): 14.6 (1), 6.3 (2), 29.2 (3), 22.9 (4), 27.1 (5)
- perimeter: 106 (total): 16 (1), 8 (2), 30 (3), 24 (4), 28 (5)
- fractal dimension index: 1.4248 (1), 1.2619 (2), 1.527 (3), 1.4944 (4), 1.5173 (5)

Figure 4: example landscape typology with relevant spatial metrics from FRAGSTATS

To objectively derive characteristics of this image we make use of FRAGSTATS software, which calculates spatial metrics out of landscape patterns. The derived information is used to define a fitness function that generates landscape configurations at the site, with resembling characteristics as the typology (see 3.1.3).

FRAGSTATS makes a distinction between compositional and configurational characteristics of a landscape. This is adopted from the field of landscape ecology, which tries to quantify landscape patterns with spatial metrics, which is considered a prerequisite to the study of pattern-process relationships. (McGarigal et al. 1995) They distinguished two general categories in spatial metrics: those that quantify the *composition* of the map without reference to spatial attributes, and those that quantify the *spatial configuration* of the map, requiring spatial information for their calculation.*Composition* refers to features associated with the variety and abundance of landscape components, but without considering the spatial character. *Spatial configuration* refers to the spatial character and arrangement, position, or orientation of instances of components within the landscape.

3.1.3. compilation of a fitness function

Only a subset of spatial metrics available in FRAGSTATS are relevant to be used as base for the definition of the overall fitness function. (see alse figure 4) The landscape generator uses this overall fitness function, which consists of one or more individual criterion functions. The landscape generator now provides ten different criterion functions, as presented in table 2. The criterion functions are categorized in compositional vs. configurational criteria and in criteria related to the landscape component vs. criteria related to an instance of a landscape component.

Table 2: criteria functions available in the landscape generator

Criteria	**Related level**
Compositional (COMP)	
COMP1. total proportional area	landscape component (LC)
COMP2. total exact area	landscape component (LC)
COMP3. amount of instances	landscape component (LC)
Configurational (CONF)	
CONF1. exact area	instance of landscape component
CONF2. proportional area	instance of landscape component
CONF3. maximum exact perimeter	instance of landscape component
CONF4. maximum exact perimeter	landscape component
CONF5. exact minimum / maximum aspect-ratio of boundingbox	instance of landscape component
CONF6. proportional minimum/maximum level filling of the boundingbox	instance of landscape component
CONF7. proportional minimum/maximum edge of an instance connected to a landscape component	instance of landscape component

Here we shortly describe the definitions of the criterion functions available.

Three compositional criteria are implemented: 1) total *proportional* area occupied by a landscape component; 2) total *exact* area occupied by a landscape component; 3) amount of instances of a landscape component.

1. total proportional area occupied by a landscape component

This criterion is satisfied if the total *proportional* area occupied by all instances of a landscape component at the site equals a user-defined proportion.

2. total exact area occupied by a landscape component

This criterion is satisfied if the total *exact* area occupied by all instances of a landscape component at the site equals a user-defined amount of cells.

3. amount of instances of a landscape component

This criterion is satisfied if the amount of instances of a landscape component at the site equals a user-defined amount.

The number of instances is retrieved by making use of the floodfill algorithm. This algorithm determines the area connected to a given cell in a multi-dimensional array. We implemented it with the 4 directions variant, which means that only directly connected cells (North, West, South, East) with identical Landscape Component are considered an instance. In our case, it should be noted that the floodfill algorithm starts at the upper left corner of the site, processes cells row-by-row and ends at the bottom right corner of the site. This implies that instances are indexed likewise.

Seven configurational criteria are implemented: 1) exact area occupied by an instance; 2) proportional area occupied by an instance; 3) exact maximum perimeter of an instance; 4) total exact maximum perimeter of a landscape component; 5) exact minimum aspect-ratio of the bounding box of an instance; 6) proportional minimum level filling of the bounding box of an instance; 7) proportional minimum edge of an instance connected to an other landscape component.

1. exact area occupied by an instance

This criterion is satisfied if the *exact* area occupied by an instance of a landscape component at the site equals a user-defined amount of cells.

2. proportional area occupied by an instance

This criterion is satisfied if the *proportional* area occupied by an instance of a landscape component at the site equals a user-defined proportion.

3. exact maximum perimeter of an instance

This criterion is satisfied if the exact maximum perimeter of an instance of a landscape component at the site equals or is lower than a user-defined maximum.

The exact maximum perimeter of an instance of a landscape component is determined by a two-way procedure. Firstly, loop over the site row-by-row and count the cells of the same instance of the landscape component. Secondly, loop over the site column-by-column and add up the cells of the same instance of the landscape component. The sum of this procedure gives the exact maximum perimeter.

4. exact maximum perimeter of a landscape component

This criterion is satisfied if the exact maximum perimeter of all instances of a landscape component at the site equals or is lower than a user-defined maximum.

5. exact minimum/maximum aspect-ratio of the bounding box of an instance

This criterion is satisfied if the exact aspect-ratio of the bounding box of an instance of a landscape component at the site equals or is higher than a user-defined minimum and equals or is lower than a user-defined maximum.

The exact minimum aspect-ratio of the bounding box is determined by the following procedure. Firstly, the boundingbox is simultaneously constructed as the floodfill algorithm advances, by initializing the bounding box when a new instance is encountered, and subsequently by adding 1 in one or both of the two dimensions (i,j) when the concerned instance is expanded. Then, the aspect ratio of this bounding box is retrieved by dividing the longest side by the shortest side of the bounding box. The orientation of the bounding box (and thus of the instance of a landscape component) cannot be configured.

6. proportional minimum/maximum level filling of the bounding box of an instance

This criterion is satisfied if the proportional minimum level filling of the bounding box of an instance of a landscape component at the site equals or is higher than a user-defined minimum and equals or is lower than a user-defined maximum.

7. proportional minimum/maximum edge of an instance connected to a landscape component

This criterion is satisfied if the proportional minimum edge of an instance of a landscape component to an other landscape component at the site equals a user-defined minimum and equals or is lower than a user-defined maximum.

The proportional edge is simultaneously stored as the perimeter of an instance of a landscape component is constructed. Besides the counting of the cells for perimeter determination in the procedure, the landscape component of the neighbouring cell, sharing the same border segment, is preserved.

The landscape generator should satisfy the overall fitness function in order to generate a landscape configuration. Let the overall fitness function be composed by *n* criterion functions, the landscape generator tries to satisfy for all of them, by sequentially optimising individual functions:

$$\sum f(\text{criterion}_n) \qquad (1)$$

The order of the functions in the overall fitness function is important, because of the sequential optimisation procedure by the landscape generator. Since the solution space of results decreases with each criterion fulfilled, a balance should be found in avoiding to set the criterion function too strict to produce a result, and in relaxxing the criterion function too much to produce a plausible result (Slager et al. in prep.).

The actual definition of the fitness function is done by the modeler in advance. The following general guidelines are used as decision rules.

Each landscape component derived from the configuration image should be represented as accurate as possible in the site. An assumption here is that the configuration image and the site have identical areas. All landscape components (except grass) are represented accurate in size, in form and at internal position. For example with internal position we mean that buildings should be connected to yards. Relaxation is only allowed respective in internal position, in form and size of non-buildings. (see section 4 for an example)

In many cases the site area is different in size than the configuration image. As mentioned in section 2, a surface parameter is attribute of the landscape typology. This surface parameter defines the minimum and maximum area for which the landscape typology (and its configuration image) applies. In general, we assume that characteristics of buildings are of most importance. Independent of site size, buildings keep their dimensions. In figure 5, the procedure is presented to account for this assumption. If there is only one building to be allocated, the loss or gain of cells, is distributed in proportion to the other landscape components, keeping their relative compactness in mind. If there are more buildings to be allocated, the gain of cells (in case of larger size of site) is distributed over additional instances of buildings. If the size of the site is smaller than the configuration image, but within limits, the loss of cells is beard in proportion by other landscape components, keeping again their compactness in mind. In case of individual trees, the amount is increased or decreased, but never their dimensions.

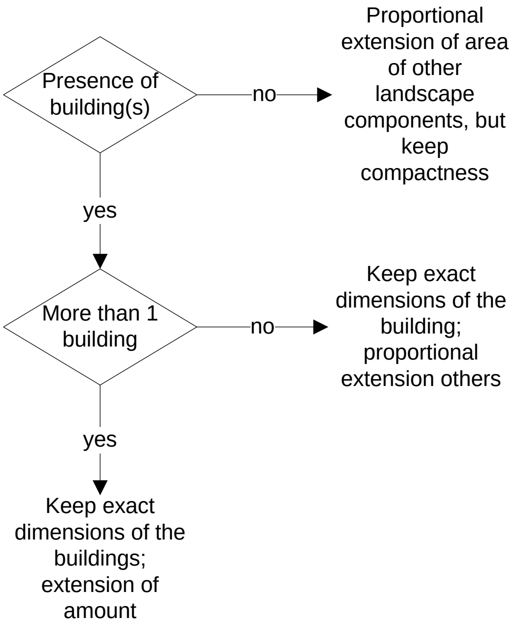


Figure 5: procedure to be used in case of difference in size between configuration image and site

3.2 Generating landscape configurations

The landscape generator initializes the site representation, calculates the overall fitness function of a “start” situation, selects and swaps a pair of cells, calculates the overall fitness function of the “adapted” situation, checks for improvement of the overall fitness function and stops and creates a result when the overall fitness function is satisfied. (see figure 6)

3.2.1 Initialization of the site in the landscape generator

Firstly, the site is initialized by loading the file information produced in step 3.1.1. Secondly, the initialized site is completely cleared. Thirdly, the cells with landscape components are completely random (independent of locational characteristics) allocated according to the sizes imposed by the first compositional criterion, defined as the *total proportional area occupied by a landscape component*. (see 3.1.3.)This assures that in all stages of the satisfaction process, the amount of area allocated to a landscape component remain equal. As mentioned before, the surroundings are set *fixed*.

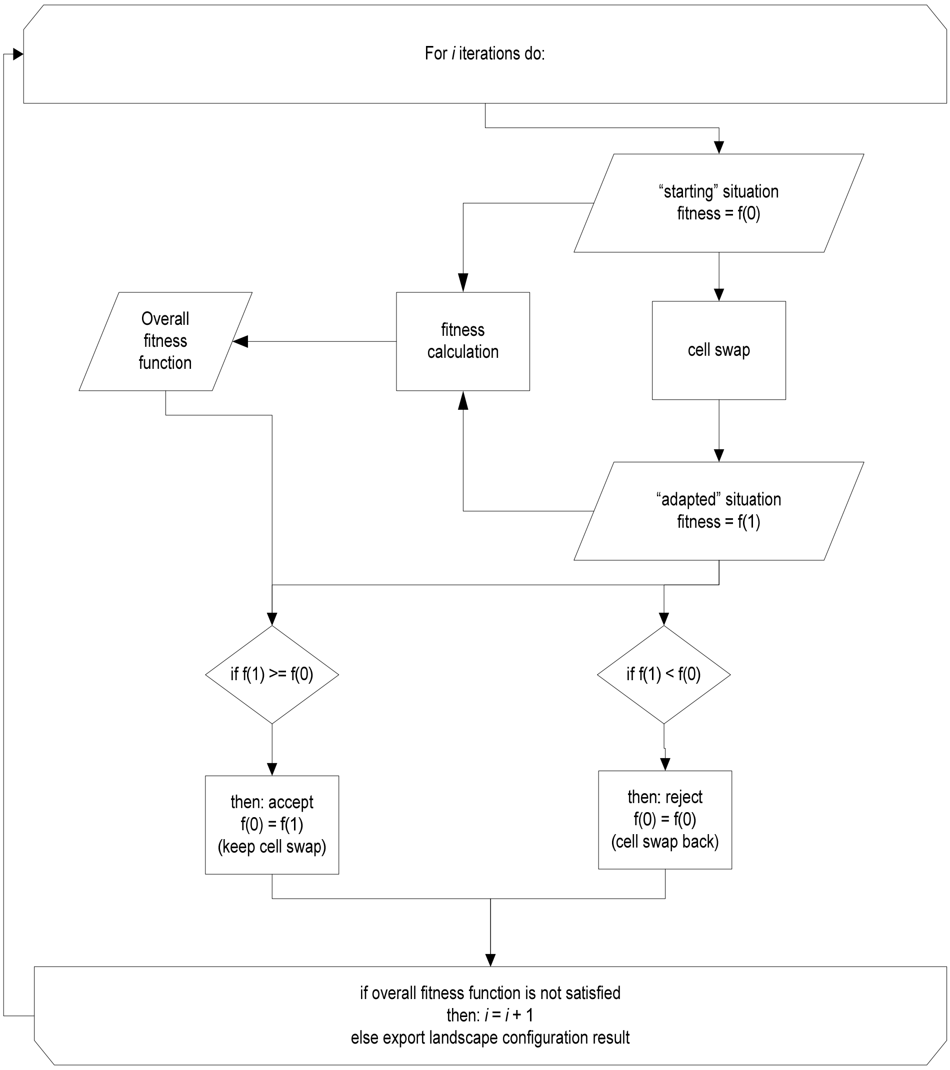


Figure 6: loop of landscape generator

3.2.2 calculation of overall fitness function of "starting" situation

The fitness of the "starting" situation is calculated. Fitness calculation is dependent on the order of criterion functions to be assessed.

3.2.3 swapping a pair of cells

Two cells are selected in a partial random fashion; some important constraints on this selection process apply. The two cells are forced never to be identical landscape components, and should neither be *fixed.* The values of this pair of cells are swapped.

3.2.4 calculation of overall fitness function of "adapted" situation

The fitness of the "adapted" situation is calculated.

3.2.5 decision of acceptance or rejection of cell swap

If the fitness equals or increases in the "adapted" situation with respect to the "starting" situation, the cell swap is accepted; if the fitness decreases the cell swap is rejected and swapped back.

3.2.6 producing a landscape configuration

As long as the overall fitness function is not satisfied the procedure is repeated with a different cell swap. If it is satisfied the landscape generator exports the results into a new intermediate lot file with cell format with common characteristics as the one introduced in 3.1.1.

3.3 Post-processing steps: prepare the output for visualisation

Here we describe the post-processing steps in order to be able to use it in the planning support system.

Conversion of output files to visualisation

The lot in cell format produced by the model is automatically loaded as raster file in ArcGIS, re-projected (and rotated back) to the right location and converted into a vector representation. Then, the cadastral lot polygon is used to clip the generated landscape components to the correct lot boundaries and finally the generated landscape configuration substitute the current landscape configuration.

4. ILLUSTRATION

In this section, we illustrate how the landscape generator produces a real landscape configuration out of input data. A real-world case is chosen in order to show detailed behavior of the landscape generator. As starting point we take the prepared files discussed in section 3.1.1. The goal of the case is to produce a landscape configuration which resembles the example landscape typology presented in figure 4: the farmland with wooded banks.

First, we define the overall fitness function, composed of different criterion functions. Secondly, we initialize the site and the "starting" situation. Thirdly, we present some intermediate results and finally we demonstrate how the final landscape configuration, fits in its surroundings.

4.1 Definition of the fitness function

The fitness function is defined using the spatial metrics values in figure 4. The fitness function has the following set of criterion functions:

1. total proportional area of hardspace (5): 2.7 %
2. total proportional area of forest (7): 3.0 %
3. total exact area of buildings – type 1 (3): 18 cells
4. total exact area of buildings – type 2 (4): 9 cells
5. total proportional area of maize (1): 92.6 %
6. amount of instances of hardspace (5): 1
7. maximum exact perimeter of hardspace (5): 60
8. amount of instances of buildings – type 1 (3): 2
8. amount of instances of buildings – type 2 (4): 1
9. proportional minimum edge of instance (1) of buildings – type 1 (3) to hardspace (5): 95 %
10. proportional minimum edge of instance (2) of buildings – type 1 (3) to hardspace (5): 57 %
11. proportional minimum edge of instance (1) of buildings – type 2 (4) to hardspace (5): 62 %
12. exact area of instance (1) of buildings – type 1 (3): 8 cells
13. maximum exact perimeter of instance (1) of buildings – type 1 (3): 12
14. maximum exact perimeter of instance (2) of buildings – type 1 (3): 14
15. maximum exact perimeter of instance (1) of buildings – type 2 (4): 12
16. proportional maximum edge of instance (1) of forest (7) to maize (1): 70 %

17. proportional minimum edge of instance (3) of forest (7) to hardspace (5): 30 %
18. proportional minimum edge of instance (4) of forest (7) to hardspace (5): 30 %
19. amount of instances of forest (7): 5
20. proportional area of instance (1) of forest (7): 22.4%
21. proportional area of instance (2) of forest (7): 28.6%
22. proportional area of instance (3) of forest (7): 14.3%
23. proportional area of instance (4) of forest (7): 6.1%
24. proportional area of instance (5) of forest (7): 28.6%
25. maximum exact perimeter of instance (1) of forest (7): 25
26. maximum exact perimeter of instance (2) of forest (7): 30
27. maximum exact perimeter of instance (3) of forest (7): 17
28. maximum exact perimeter of instance (4) of forest (7): 9
29. maximum exact perimeter of instance (5) of forest (7): 31
30. exact minimum aspect-ratio of the bounding box of instance (2) of forest (7): 14:1
31. exact minimum aspect-ratio of the bounding box of instance (5) of forest (7): 14:1

The values resemble the spatial metrics values in figure 4. However, the perimeter values of non-buildings are slightly corrected for the fact that the site area is 1660 cells (= 6 ha) and the configuration image is 1600 cells. The perimeter is derived from the fractal dimension index, proposed by FRAGSTATS. This index reflects shape complexity across a range of spatial scales. The perimeter of the instance equals 4 times *e* raised to the power of the fractal dimension index times the instance area, divided by 2.

4.2 Initialization of the site

After clearance of the current configuration at the site, it is initialized by optimising the first five criterion functions in the overall fitness function (see section 4.1). This is done by randomly allocating the amount of cells to be occupied by landscape components. (figure 7) The initialized site is used as "starting" situation for the loop.

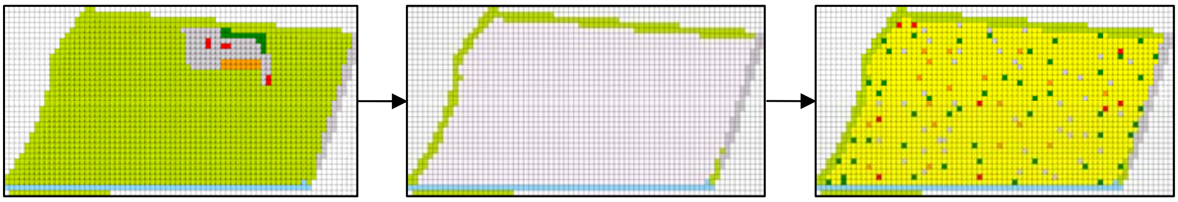


Figure 7: results of initialization site; from left to right; 1) current situation; 2) cleared situation; 3) "starting" situation; legend: light green = grass, dark green = trees, grey = hard space, light blue = water, orange = building type 1, red = building type 2

4.3 Satisfying the overall fitness function

The first five criterion functions are satisfied, and remain satisfied until all other criterion functions are optimised. The sixth criterion function is not yet optimised, since the amount of instances of hard space (in white) in the "starting" situation (figure 7.3), equals 44. This is much more than the value 1 stated in the specific criterion function. A pair of cells is swapped, and if in the "adapted" situation the amount of instances is closer to the criterion, the swap is accepted.

In figure 8, three more illustrations of intermediate results can be found. The most left image is the result of the optimized sixth criterion function with 1 instance of hard space. Note that the instance is not yet optimized in shape (as defined in criterion seven). The middle image is an intermediate result of the site, where the fitness function is satisfied for the first 19 of its criterion functions. The most right image shows the landscape configuration when the overall fitness function is satisfied.

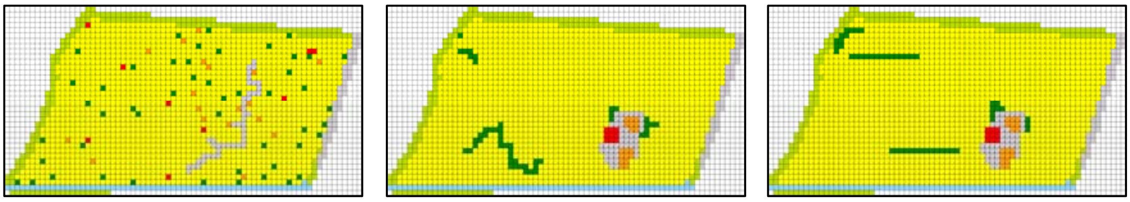


Figure 8: intermediate results of the landscape generator

4.4 Post-processing of the landscape configuration

In figure 9 a set of three generated landscape configurations are presented. They differ significantly, but they all satisfy the overall fitness function compiled in 4.1. The final legend is adjusted to the topographic map legend.

Figure 11: possible results of landscape generator

5. CONCLUSIONS AND DISCUSSION

In this paper we presented the functioning of the landscape generator. The landscape generator is part of a larger system with efficient design tools to be used in collaborative spatial plan-making processes.

The landscape generator is able to produce landscape configurations which resemble a configuration image. This configuration image is part of a landscape typology. A landscape typology describes and visualizes a future intended spatial development. The landscape generator combines major parts of traditional methods of spatial modelling techniques, such as shape grammars, cellular automata, linear programming and evolutionary algorithms. However, one of the most important discerning features of the landscape generator is that it enables the user to (re-)produce expected landscapes within configurational and compositional requirements. Traditional methods have often different goals, like micro behavior modelling in cellular automata. Evolutionary algorithms and shape grammars have often difficulties in defining design rules for different contexts and may have substantial performance problems.

In the current version, the landscape generator sometimes becomes trapped in local (sub-)optima. Partly, this is solved by relaxing the criterion functions or running the process simultaneously on more than one processor. In a future version, we intend to integrate the simulated annealing method into the process.

A good example of applied simulated annealing is given by Aerts et al. (2002). We expect this will prevent the trapping problem and probably will also speed up the process.

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