MASTER

Shape grammars as a method of design

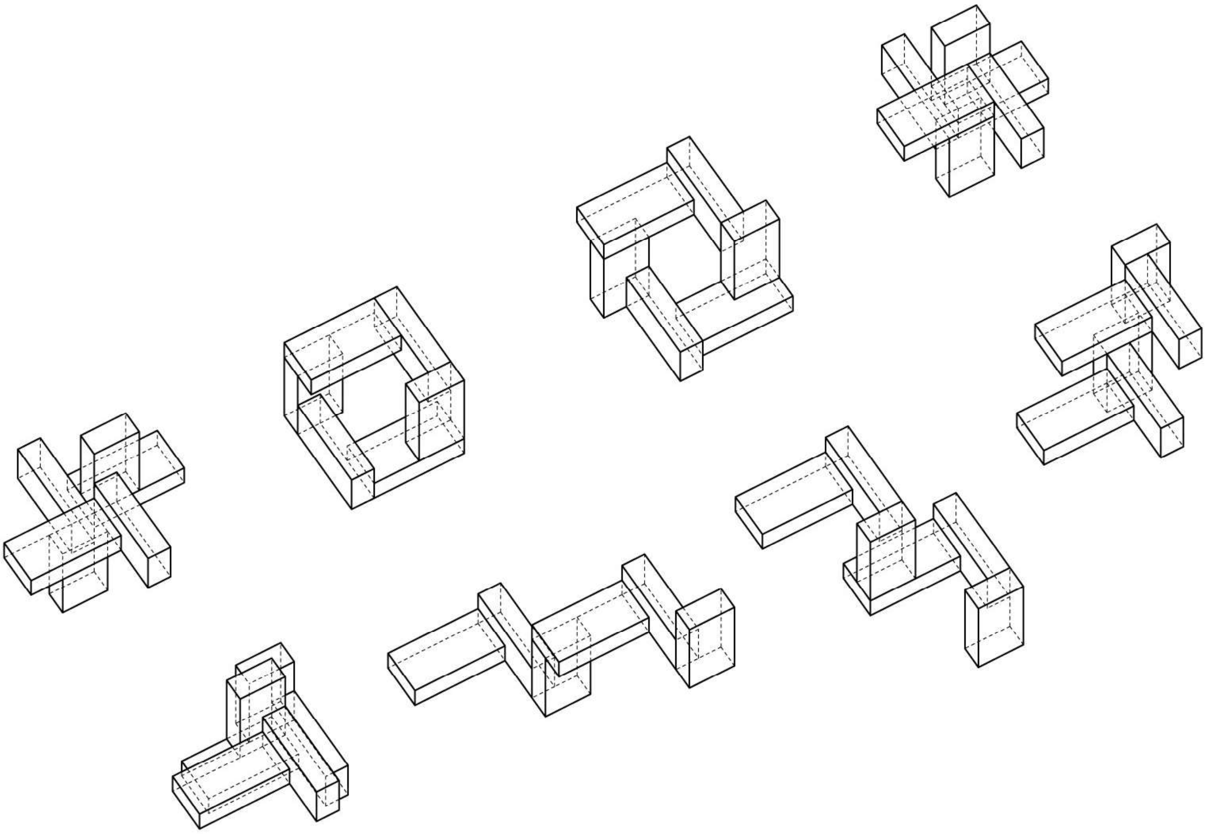
a study on the translation of the architectural design process into the design of a shape grammar

Gooren, E.M.A.J.

Award date:
2017

Shape grammars as a method of design

A study on the translation of the architectural design process into the design of a shape grammar



Ellen Maria Adriaan Josephina Gooren
0675173 | s086278
e.m.a.j.gooren@student.tue.nl

Architectural Engineering and Design and Desicion Support Systems (DDSS)
Faculty of Architecture, Building and Planning
Technical University of Eindhoven
August 2016

Graduation committee:
Prof. dr. ir. B. (Bauke) de Vries - Chair of the graduation committee
Ir. M.H.P.M. (Maarten) Willems - Tutor for the department of Architecture
Ir. ing. A. (Aant) van der Zee - Tutor for the department of DDSS

Shape grammars as a method of design

A study on the translation of the architectural design process into the design of a shape grammar

Ellen Gooren

Summary

This research investigates the use of shape grammars in the architectural design process. Where a linguistic grammar describes and declares the structure of a language, a shape grammar is argued to describe a language of design. Only, the rules are applied to shapes and spatial configurations instead of words and sentences. George Stiny and James Gips introduced shape grammars in 1972 and argued that they were usable in two ways: the analysis of contemporary or historic styles of designs and the synthesis or creation of completely new and original styles of designs. (Knight, 1991). However, the application of the analytical shape grammars has been studied to a greater extent than the so-called original grammars. This research focuses on this design process. In order to gain an understanding of shape grammars, three existing grammars are analysed. By formulating a design brief for a mass-housing project, an attempt to create a shape grammar through design is made and studied in order to gain insight in its design process and development. This shape grammar is thereafter translated to a program, or tool, that generates the results of the grammar. The process is then evaluated and issues that have surfaced during the design of the grammar are discussed. This research finally aims to answer the research question "How does the architectural design process translate into the course of developing a shape grammar?" through numerous recommendations and remarks essential for the design of a shape grammar.

Content

"It is inconceivable today to imagine designing buildings without the use of computers. They are used at every step of the architectural process, from conceptual design to construction. Three-dimensional modeling and visualization, generative form finding and scripted modulation systems are just some of the practices employed by architects and building consultants."

– Iwamoto, L. 2009

Preface

This book is the result of a year of research from a graduation studio that combines design systems and architecture. The chair of design & decision support systems focuses on the use of 3D modelling, generative design and virtual reality, to name but a few, and architecture is concerned with the art and science of designing the built environment. Ensuring a complementary collaboration between these two departments has been essential in this studio and project. The use of a tool with generative properties should remain only a tool, supporting the design process of the architect. According to Lars Hesselgren (2009) "Generative design is not about designing a building, it's about designing the system that designs a building." As regards the design process, intentions and goals, it is important to remain critical when exploiting the strengths and benefits of using such a design system. Generally, the course of writing a program in general requires you to define a logical structure in a project, to distinguish and identify every contributing factor. How does each part support the total system, what role does it fulfil? This knowledge needs to be represented and recreated in the script of your tool.
In this project I attempt to create a shape grammar, which is essentially a set of rules regarding shapes and their transformations, describing one or multiple designs. In order to understand the fundamentals of designing with shape grammars, the first chapters introduce you to the subject, after which the actual design of the shape grammar will be explained.

Introduction

Introduction

Where a linguistic grammar describes and declares the structure of a language, a shape grammar is argued to describe a language of design. Only, the rules are applied to shapes and spatial configurations instead of words and sentences. When George Stiny and James Gips introduced shape grammars in 1972, they argued that they were usable in two ways: the analysis of contemporary or historic styles of designs and the synthesis or creation of completely new and original styles of designs. (Knight, 1991). However, the application of the analytical shape grammars has been studied to a greater extent than the so-called original grammars. Apparently, the creation of shape grammars through a design process is more challenging. This research focuses on this design process. By formulating a design brief for a mass-housing project, an attempt to create a shape grammar through design is made and studied in order to gain insight in its design process and development.

This shape grammar is thereafter translated to a program, or tool, that generates the results of the grammar. This program provides results fast and in abundance, easing the evaluation of the grammar. In addition, a program (the automated shape grammar) has no preferences and therefore each solution is equally 'good', provided that it satisfies the rules of the grammar. Architects, or human beings for that matter, always have a preference. This preference, consciously or unconsciously, derives from years of experience, or perhaps just personal taste. This preference causes us to reject some possibilities immediately. This is mainly a good thing, since we often recognize a good or bad result straightaway. However, it is possible that results that don't seem quite viable at first could lead to a good design in a way we can't quite expect. Through using a shape grammar, these results will never be falsely discarded. The program could generate results that you possibly would never design yourself. Therefore, examining this use of shape grammars and thus exploring an alternate method of design could be valuable and result in designs not likely to be imagined or conceived using a conventional design method.

This book is divided into four different chapters. In the first chapter, the fundamentals of shape grammars are explained and illustrated by discussing three examples. The second chapter contains the shape grammar I designed in the use-case of a mass housing project. This grammar has been converted to a program I wrote using the programming language called 'Python', which will be discussed in the third chapter. The fourth and last chapter contains a critical review on the design process of this grammar. The obtained learnings on the design process of a shape grammar in general are described, in order to answer the following question:

"How does the architectural design process translate into the course of developing a shape grammar?"

Shape Grammars

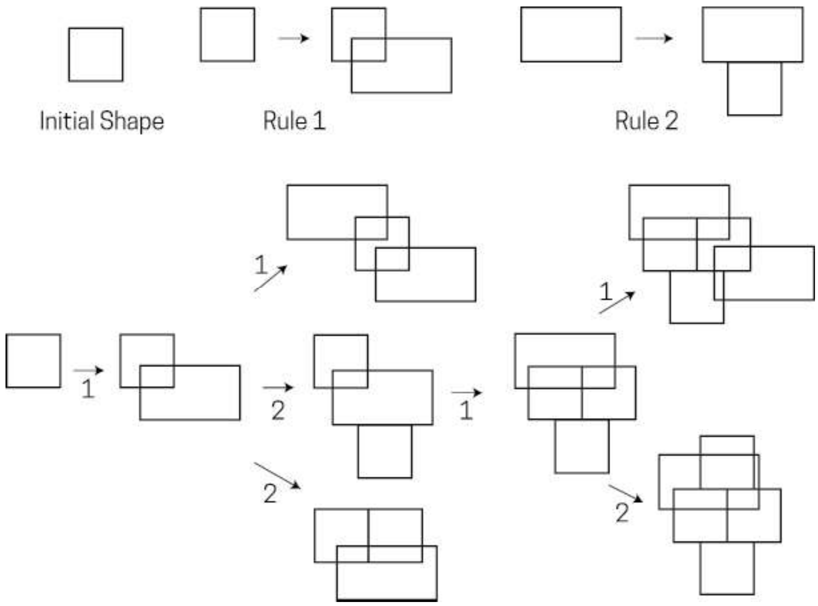


Fig 2. An example of the derivation of a shape grammar with two rules

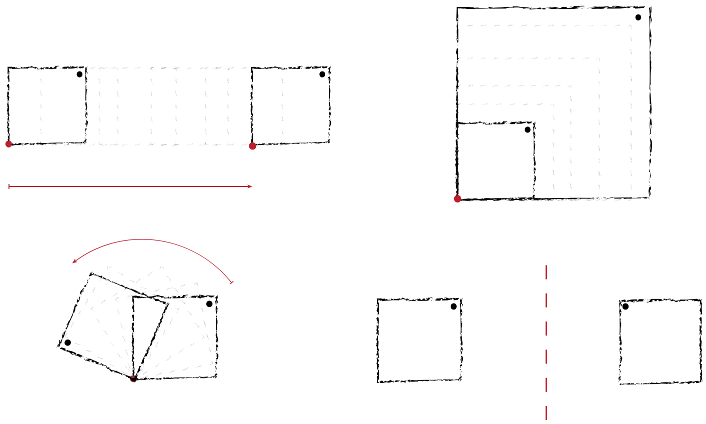
Introduction

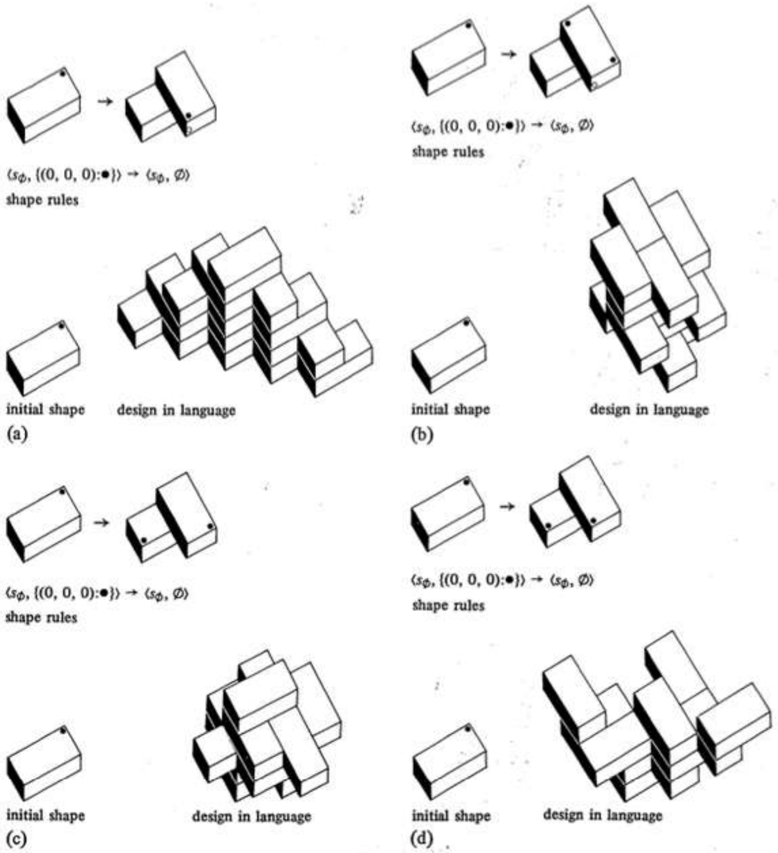
What are shape grammars?

This graduation project investigates shape grammars. In this first chapter, the fundamentals of shape grammar theory and application will be discussed. Several aspects involving shape grammars will be evaluated to help understand how they work.

As a grammar for a language of speech describes and defines the structure or system of that language, a shape grammar describes a language of design. It contains a set of transformational rules that apply to shapes. There is always an initial shape on which a transformation described in the rules is applied. The transformed shape will then again be transformed according to the rules, and so on.

Shape grammars were first introduced in 1971, in a paper written by George Stiny and as a part of the IFIP Congress. In 1976 a second article was published on the two practices of shape grammars: one where shape grammars could be used to form a new design, and one where it is used as an analytic tool to study a certain design language. Although Stiny introduced an approach for the creation of a design grammar, this application of shape grammars remained untouched for many years. This unlike the analytical approach, which has been developed and explored repeatedly over the past decades. The first research into the analytical approach of shape grammars was conducted by Stiny in 1977, when he created a grammar based on Chinese Lattice designs. A year after that, Stiny and Mitchell made a grammar of architectural nature. They analysed a series of villas of Andrea Palladio and made a Shape Grammar capable of describing several of Palladio's villas, as well as generating designs for new but similar designs. This shape grammar will be discussed more extensively further on in this chapter, as it has been the fundament of many analytical grammars.





Top: fig 3. The Euclidian transformations of a shape

Bottom: fig 4. The different use of a marker in a shape grammar

Transformation of shapes

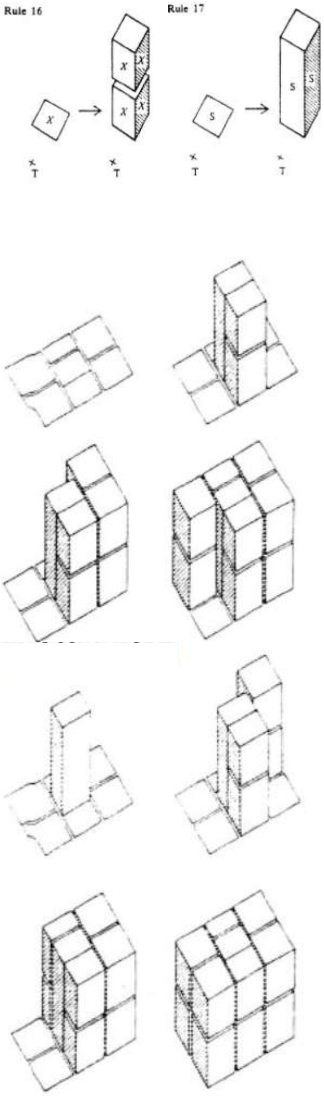
A fundamental characteristic of shape grammars is that it produces multiple solutions on a single set of rules. These rules are the foundation of the design language represented by the shape grammar. These rules can add, replace, change or remove shapes and transform the spatial composition of the solution. Every transformation is based on the Euclidian transformations, which allow a shape to change:

- location	(translation)
- size	(scale)
- orientation	(rotation)

Or a shape can be reflected across a line (Stiny, 1980a).

Markers and labels

In addition to shapes, markers or labels can be added to supply additional information about shapes and to guide them (Knight, 1983). A marker can provide information for rules such as orientation, or specify how a rule is to be applied. In the image on the left you can see how placing a marker differently can lead to different results. Labels often add information to a shape which ensures that a specific set of rules will be applied to that shape. Labels can for instance be added to shapes that represent spaces with a certain function, or a specific type of wall. For example, with the addition of a label, the shape that represents a wall can now either be transformed into a wall with a window, or into a wall with an entrance. Labels provide control over the use of rules, and can have different appearances, such as letters, numbers, dots, crosses, etc.

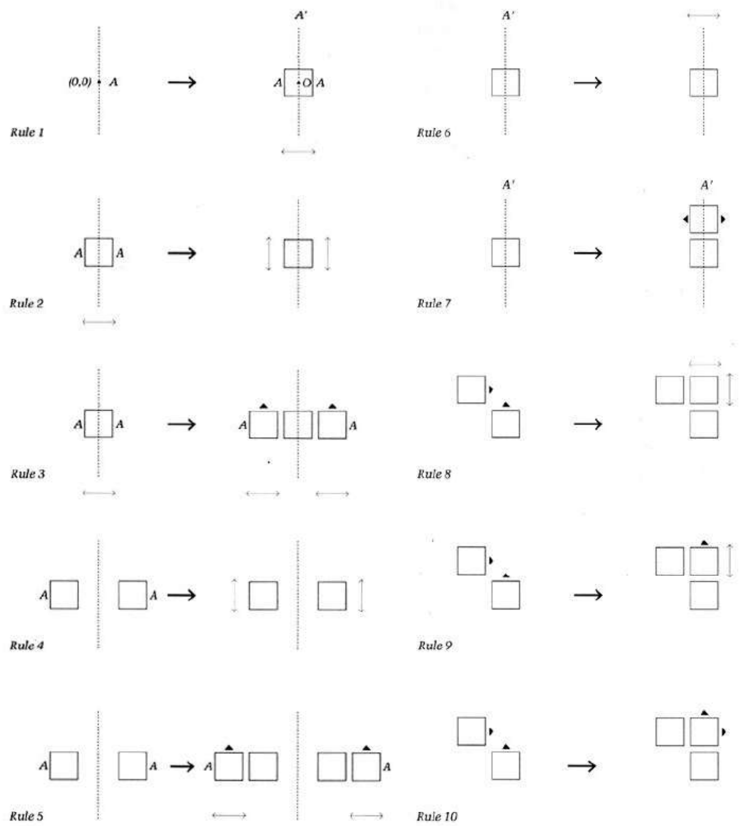


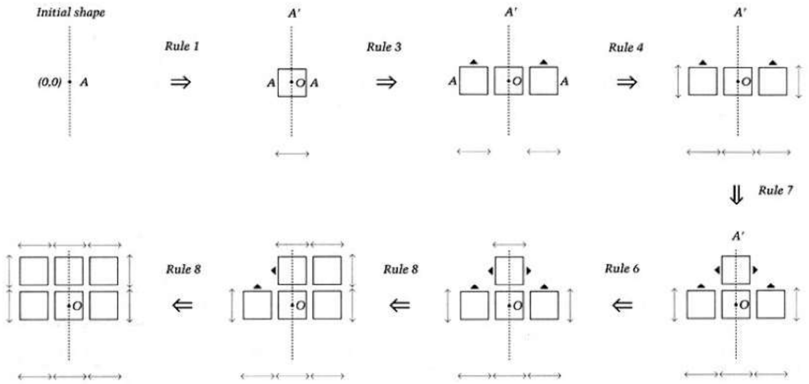
Left: fig 5-7. Houses from the Queen Anne House Grammar

Right: fig 8. A part of the derivation of the Queen Anne House Grammar

The use of shape grammars in architecture

Where, according to Stiny (1976) shape grammars were suitable for both analysis and design, the implementation of shape grammars in architecture has been mostly analytical of nature. These studies aim to describe design languages in terms of spatial rules. They are capable of recreating the analysed buildings and creating new buildings within the determined boundaries and criteria of the analysed design language. A few examples of these studies are The Palladian Grammar by Stiny and Mitchell (1978), a shape grammar based on a series of villas designed by Andrea Palladio; The Prairie House Grammar by Koning and Eizenberg (1981) based on Frank Lloyd Wright's prairie houses; The Queen Anne house grammar by Flemming (1987); a Traditional Chinese architectural grammar by Li (1998); a Housing grammar on Alvaro Siza's Malagueira houses by Duarte (2001) and the Hayat house grammar by Colakoglu (2005). All these grammars have different goals and approaches. Three of these grammars will be further elaborated: The Palladian Grammar, the Malagueira House Grammar and the Prairie House Grammar. From the three examples, the Palladian grammar, the Malagueira house grammar use a top-down approach, increasing the level of detail as the grammar progresses, whereas the prairie grammar uses a bottom-up approach, starting with a single element and extend further from that focal point. The Palladian grammar is a grid-type grammar, where the shapes are created from a grid of squares. Rules can provide different combinations of joining squares to create new shapes. The Malagueira House grammar is a subdivision grammar, starting with a single shape (the provided plot) and subdividing this shape according to the proportions specified in the rules. The Prairie House grammar is an additive grammar, where new shapes are added around a focal point. In the case of Frank Lloyd Wrights' prairie houses, this focal point is the fireplace. The rules specify how shapes may be added around this central point in the design.





Top: fig 9. Rules for grid creation from the Palladian Grammar

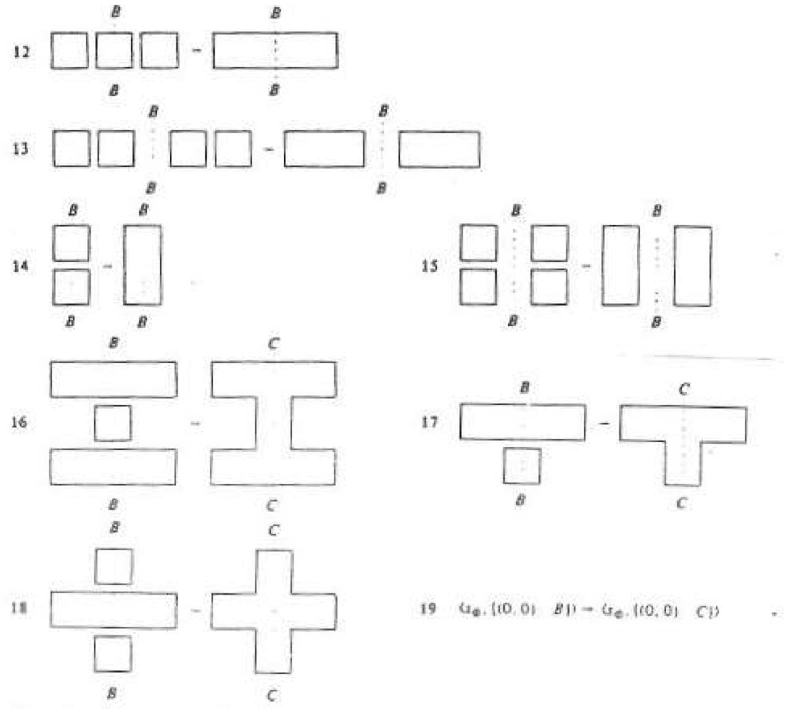
Bottom: fig 10. A derivation of the rules to create the grid

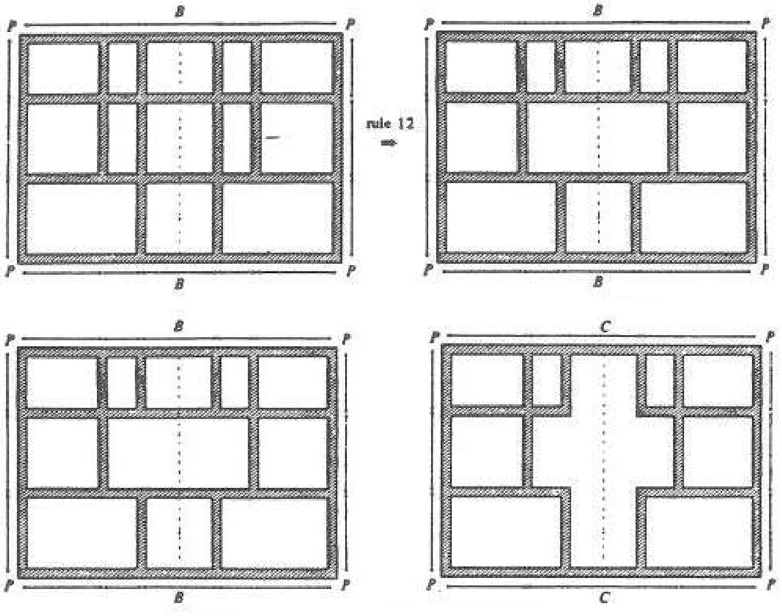
The Palladian Grammar

One of the first Shape Grammars created in an architectural context is the Palladian Grammar. George Stiny and William Mitchell attempted to reconstruct the Palladian villas from Palladio's four books of architecture ('I quattro libri dell'architettura') and succeeded to form a grammar that describes all but two. The Palladian grammar consists of sixty-nine rules that are applied in eight different stages in the following sequence:

1. Grid definition;
2. Exterior-wall definition;
3. Room layout;
4. Interior-wall realignment;
5. Principal entrances – porticos and exterior-wall inflections;
6. Exterior ornamentation – columns;
7. Windows and doors;
8. Termination.

In the first stage, the main grid is defined using ten rules in an additive process. The created bi-laterally symmetrical grid will function as an underlying fixed structure of the villa plans. The first rule defines the starting shape and symmetry axis. Rules 2 to 5 ensure the entire width of the grid and terminate labels so that further expansion in with is prevented. Rules 6 and 7 accomplish this for the height of the grid. Rules 8 to 10 fill in the corners to complete the grid. The grammar will now continue to the second stage, where the outer walls are defined by applying a single rule which creates a boundary around the entire grid. The inner room-layout is created using 7 rules in the third stage. These rules allow a transformation of the grid where the grid cells are combined to create the inner spaces. In stage four, wall-realignment rules provide the opportunity to create less rigid configurations, but it is optional and not used very frequently. Basically, these rules account for deviation from the symmetry or other minor anomalies from the rules. The rules in stage five





Top: fig 11. Rules for room layout

Bottom: fig 12. Creation of room layout in derivation process establish specific details in the floor plans. The entrances are constructed by employing 23 rules which are subdivided in different entrance-types: a portico, a loggia or an ornamented column entrance.

Exterior ornamentation is added using 7 different rules in stage six. Columns are added to every different type of entrance. Stiny and Mitchell (1978) described this stage as follows: "Each of these rules may be considered a column schema which applies under certain 'lexical' conditions. The use of different arrangement of columns is similar to the use of different words in a fixed syntactic context."

Wall openings to facilitate the placement of windows and doors are made in stage seven. The windows can be placed on each facade, but no windows can be placed on the symmetry axis. Due to the bi-laterally symmetry in the plans, there will always be an odd number of windows in the east-west elevation. In the final stage, the design process is terminated. Throughout the process, labels are used to guide the generation process of the floor plans. The last rules will erase the labels, if the rules of the previous seven stages are correctly applied. Only the plans with a completely unlabelled state at the end are included in the language of the grammar.

This grammar will only create a two-dimensional plan for the villas. It is not a complete grammar of Andrea Palladio's style; it is only partial. The design of the façades for instance, or Palladio's system of proportion are scarcely or not included in this grammar.

Fig 13. Villa Rotonda by Andrea Palladio

Fig 14. Villa Saraceno by Andrea Palladio

Top: fig 15. Malagueira Houses by Alvaro Siza

Bottom: fig 16. Different floor plans in the Malagueira Grammar

The Malagueira House Grammar

The 'Malagueira house grammar' describes Alvaro Siza's patio houses in Malagueira. This is a mass-housing project, with 35 different houses designed between 1977 and 1996. This grammar has a different approach than the Palladian Grammar. Where the Palladian Grammar was based on a grid-structure, the Malagueira grammar uses a top-down approach and is a subdivision grammar. The first step, however, is an additive step. In this step the initial shape of the plot is defined and the edges are labelled to state whether they border a street or a house. In the second stage the plot is subdivided and the location of the house within the plot and the outdoor yard is determined: the interior and the exterior space. Throughout the next stages, each floor is further subdivided by the following 7 stages:

1. Start
2. Locate functional zones
3. Define circulation scheme
4. Divided zones into rooms
5. Introduce details
6. Introduce openings
7. Terminate

These stages are first applied to the first floor. The first step initiates the subdivision process and encloses the floor. In the next step, the functional zones are located. The outside zone will be either at the front or at the back of the lot, establishing to which of the two house-type the house will belong. The floor will be further subdivided into several zones: living, sleeping, service and patio. The rules are extremely detailed, even regarding structural restrictions for a maximum span between walls, which walls are load-bearing and their location, which will influence the derivation of the second floor. Once the functional zones are assigned within the plot, circulation is covered in stage three. The main entrance from the yard is placed, and the staircase will be arranged in such a manner that it ensures a satisfactory circulation scheme for the dwelling.

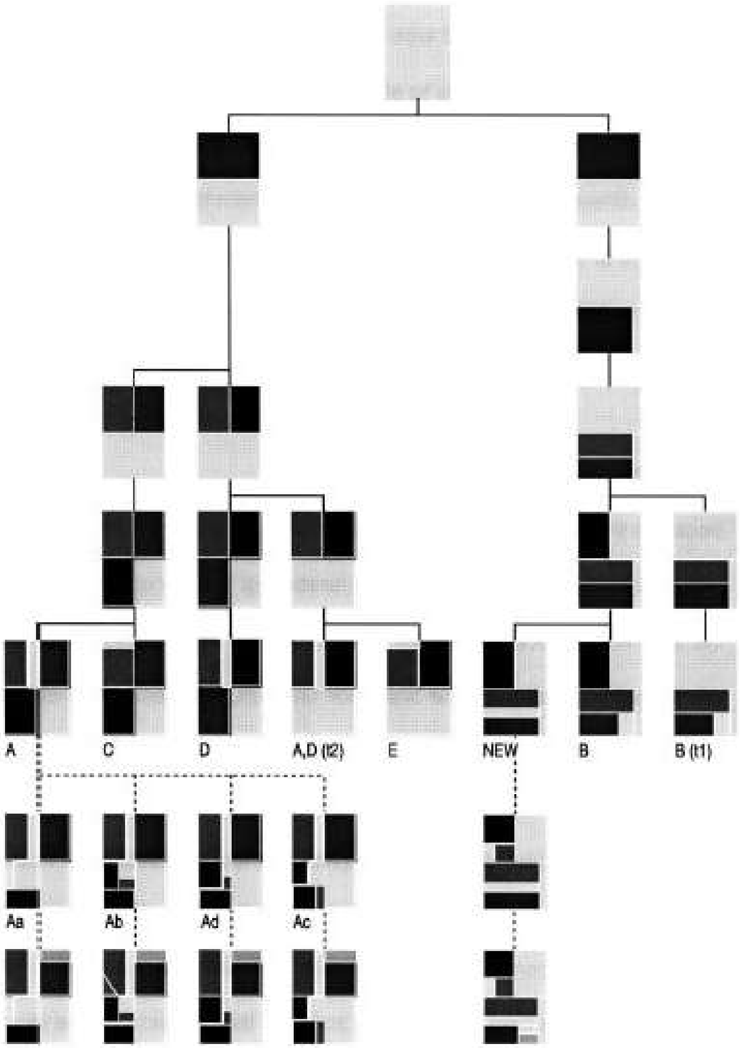
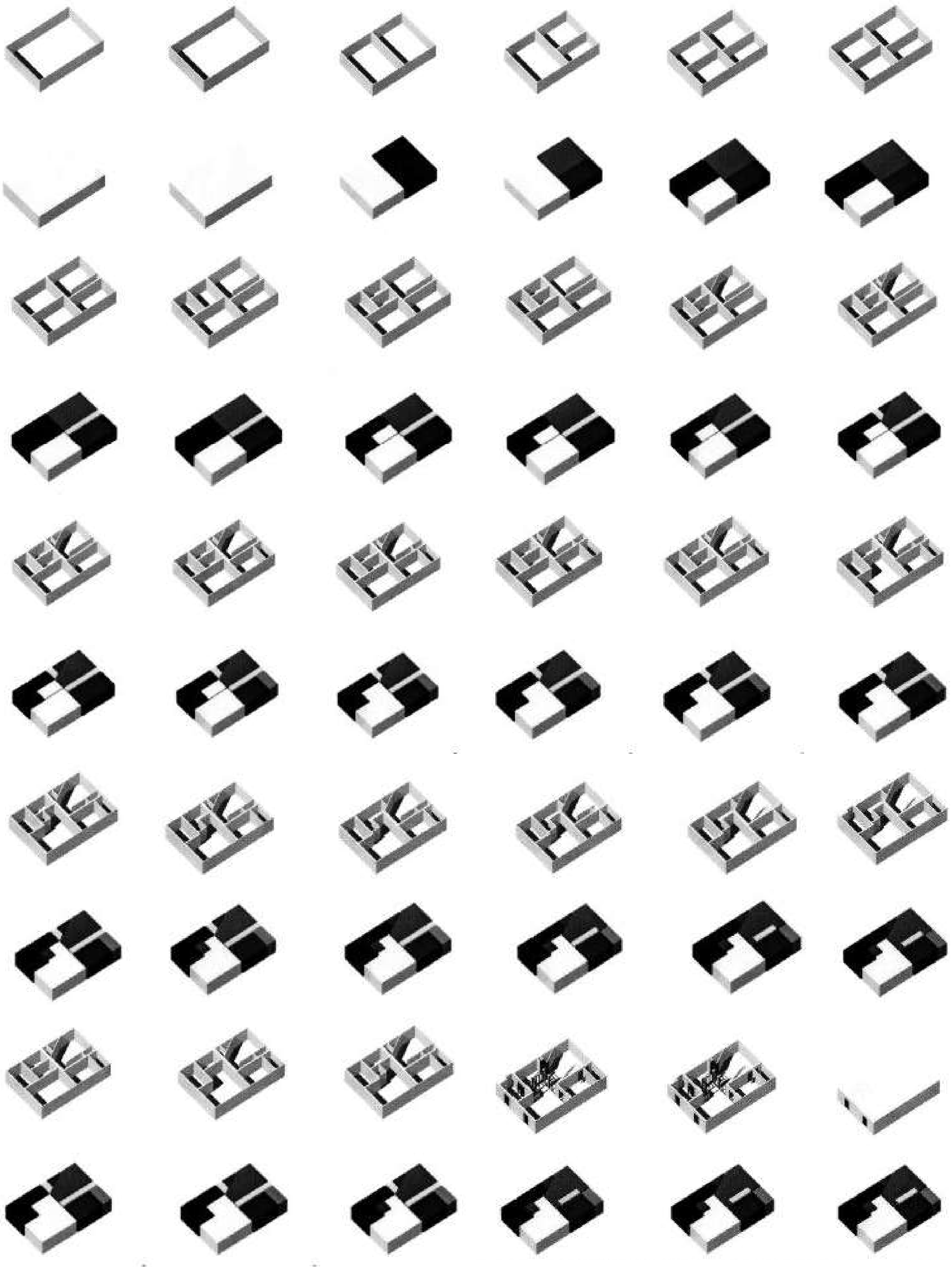


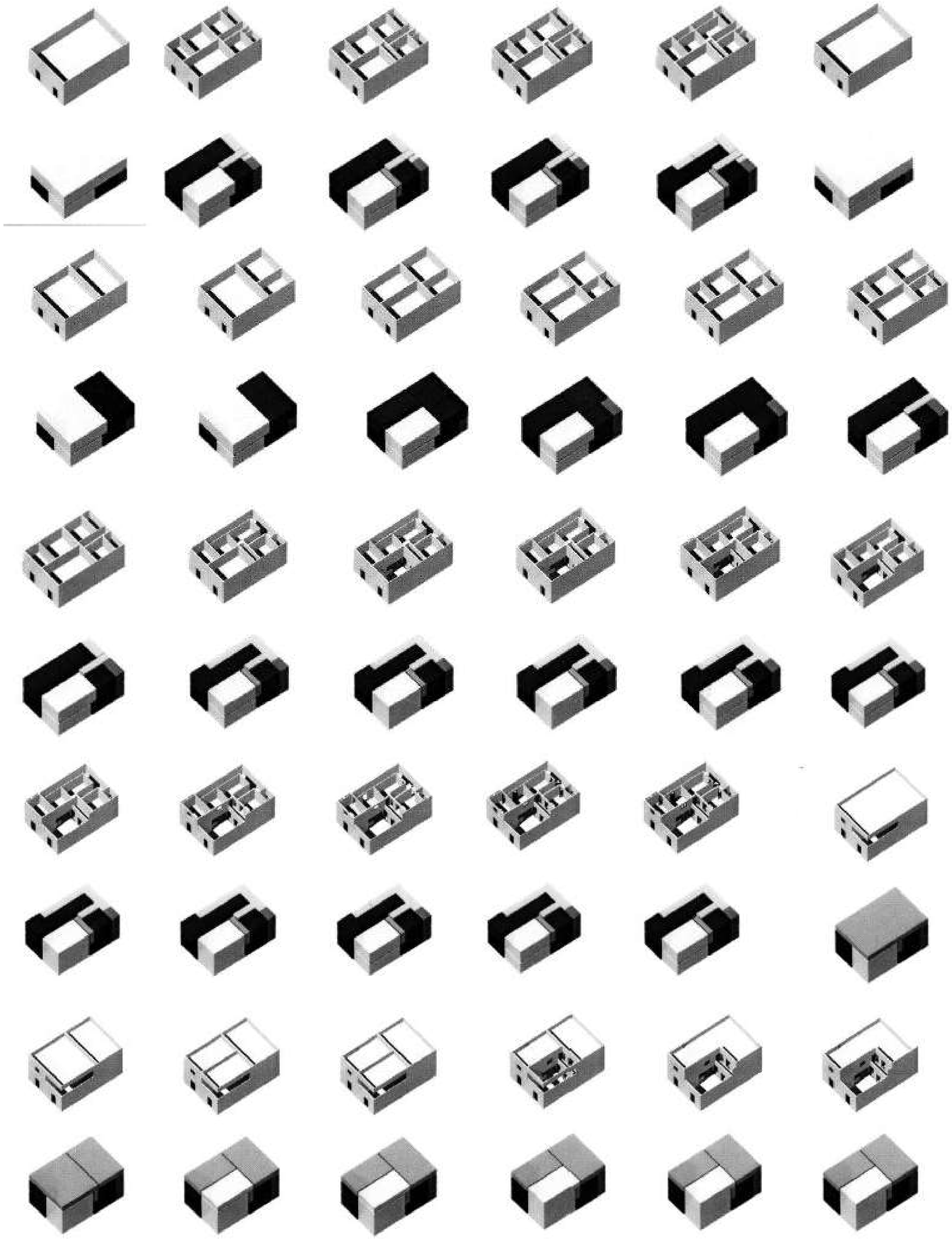
Fig 17. Derivation of the Malagueira Grammar

Again, these rules are quite detailed. The rules cover the design of the stairs up to the thread-depth and take the location and direction of ceiling's pre-stressed concrete beams into account, so that the stairs will run parallel to the beams. In the fourth stage, the separate functional zones are being subdivided into rooms. There are several obligatory rooms and a set of optional rooms. Obviously, the obligatory rooms are placed in every house, where the collection of optional rooms will be determined depending on the desired program. There are five types of rules that apply in this stage: dividing, extending, assigning, connecting and permuting rules. The dividing rules, as the name implies, divide a functional zone in rooms. Extending rules divide a zone which will be an extension of the adjacent zone. The assigning rules assign the last remaining room. The connecting rules can connect two rooms with the same function under specific circumstances, and the permuting rule can change the function of rooms, so that in special cases a second floor can be avoided. Hereafter, the constructed floor plan is further detailed in step five. Wall thickness is changed depending on their location: exterior (thickness is increased) or interior (thickness is decreased), the stairs are finalized or details such as chimneys are added. In stage six openings are created in different rooms, in relation to openings on different floors to maintain symmetry in the façades. This symmetry is not achieved in the placement of windows in front yard houses, due to a corridor accessing the yard.

In the last stage, the design process proceeds from the first to the second floor and the entire process starts again. When this phase is reached in the second floor sequence, the process is terminated and redundant labels are removed.

After the second floor is created, which has less steps in its derivation since many labels were already created during the derivation of the first floor, the terrace is defined, which also has fewer steps in its derivation. This stage holds rules that enclose the terrace or extend chimneys.





Top: fig 18. Malagueira Houses by Alvaro Siza

Bottom: fig 19. Malagueira Houses by Alvaro Siza

Fig 20. Malagueira Houses by Alvaro Siza

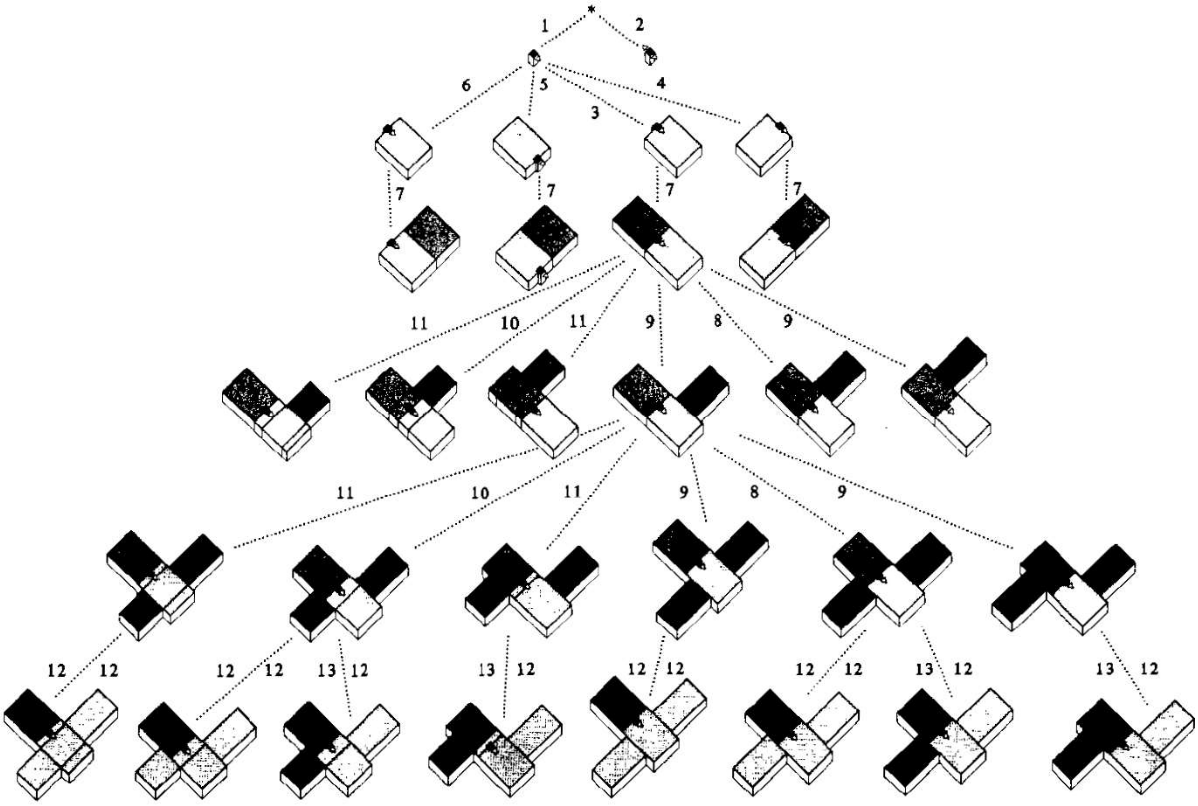


Fig 21. Possible derivation in the Prairie House Grammar

The Prairie House Grammar

The Prairie house grammar is an additive grammar, where 3-dimensional spaces are inserted around the main focal point in the houses: the fireplace. The designs have a consistent underlying spatial compositional structure. This grammar is based on the designs of eleven of the Prairie houses and was created by H. Koning and J. Eizenberg in 1981. The grammar shows a step-by-step generation of the eleven analysed designs, as well as the design of three new designs in the prairie-style. The houses selected for the grammar have purposely different features.

"Consistency in grammar is therefore the property -- solely -- of a well-developed artist-architect. Without that property of the artist-architect not much can be done about your abode as a work of Art. Grammar is no property for the usual owner of the occupant of the house. But the man who designs the house must, inevitably, speak a consistent thought-language in his design. It properly may be and should be a language of his own if appropriate. If he has no language, so no grammar, of his own, he must adopt one; he will speak some language or other whether he so chooses or not". (Wright, 1954)

There are two types of fireplaces: a single-hearth fireplace and a double-heart fireplace. They can be placed anywhere on the site. When the fireplace is located, there are four rules describing how the living zone may be added. Then, a single rule follows to add a service zone, (kitchen and pantry) which completes the core-unit of the prairie house. The design can now continue and expand in four different directions. This core-unit can later on be extended upwards to form a second level, housing bedrooms. Four rules describe how the obligatory additions to the core-unit may be applied, after which 6 rules assign functions to the undefined spaces. Using these rules, a total of eighty-nine compositions can be generated in the prairie house style. In the next stage of the grammar, a set of rules describing ornamentation can be applied to complete the prairie houses. Some of these ornamentation rules are obligatory in the designs, they add basic architectural elements such as roofs or basements.

Fig 22-24. Prairie Houses by Frank Lloyd Wright

Other rules can be applied optionally. They add porches, terraces, extra corners etc. These rules significantly increase the number of possible variations. The rules describe to a very detailed level how the roof is to be constructed, and that, in some cases, balconies are created "not only for decorative purposes or where functionally desirable, but also to complete designs where the inclusion of a small, isolated piece of sloping roof would appear clumsy". (Koning and Eizenberg, 1981, 315) After this stage, a few rules follow to match the level of detail in Wright's designs. These rules are subtractive, as opposed to the previous additive rules.

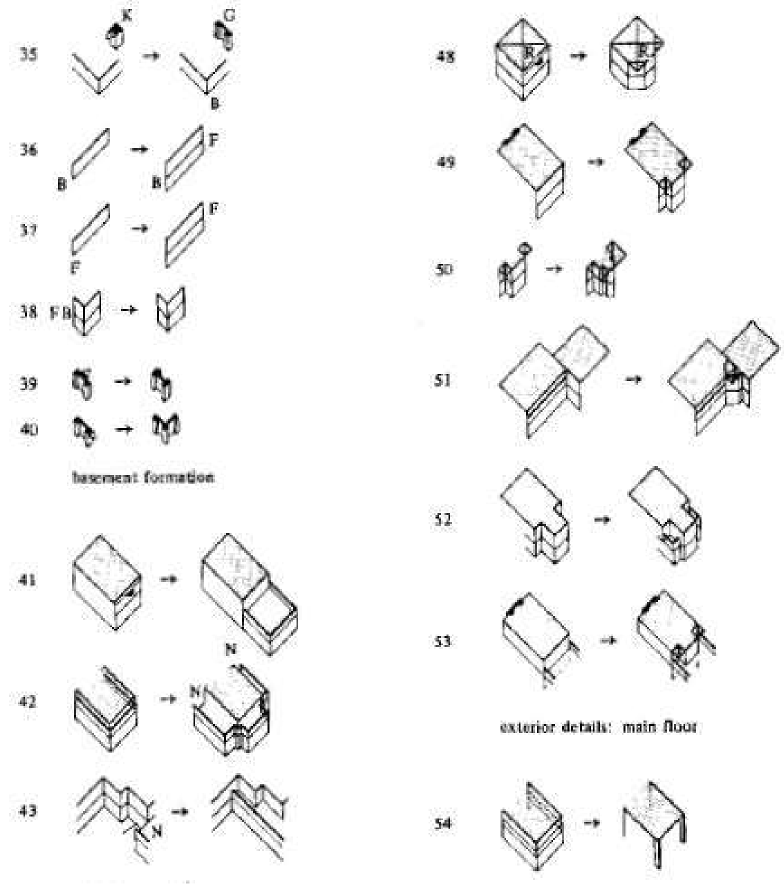
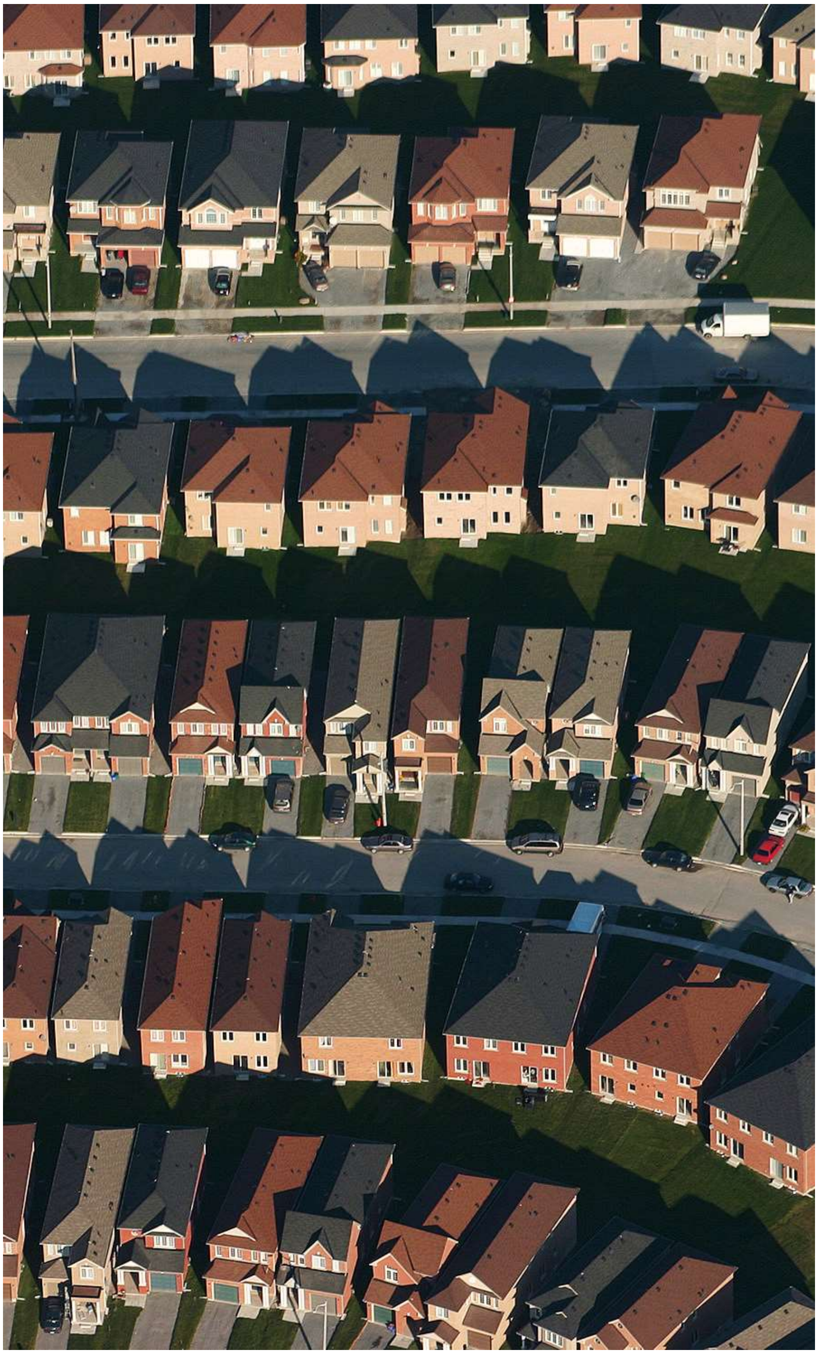


Fig 25. Rules from the Prairie House Grammar

The Grammar



Introduction

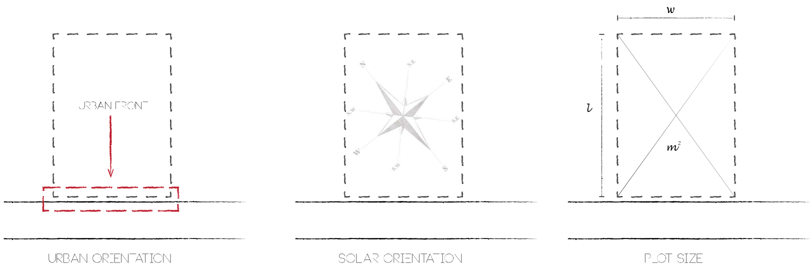
A Mass-Housing grammar

In this part I will explain the grammar I designed. First, the project brief used to guide the design process will be described, after which the grammar and its rules will be explained. In addition, several essential aspects regarding the design capabilities of this grammar are discussed to provide insight in the generative properties of the grammar, and the originality of its results. The intended approach for the design of this grammar, focuses entirely on the experimentation with rules. To prevent a prejudiced set of rules based on analysis of sketches and design concepts established in a conventional way, a clear architectural vision was deliberately not developed. The assignment is formulated to help evaluate the results and provide a framework for developing new rules, but new rules are to be formulated purely from evaluating the generated results.

The Assignment

Motivation for the chosen assignment and grammar-type

In order to start with the creation of the grammar, a grammar-type had to be selected. After studying the three examples of shape grammars, the addition-grammar used in the prairie house grammar was eliminated. These grammars evolve around a specific focal point in the designs on which the addition rules are based. With no specific design strategy or framed architectural concept and the intention to , focus on the other two grammar types: grid-grammar and subdivision-grammar. Where one the objectives is to experiment with the creation process of a grammar as a design strategy, thus to let the (hopefully) unexpected results provide for new design idea's, the grid grammar was more appealing. In a subdivision grammar, you start with a shape, and this shape gets subdivided conforming the predefined rules. And while within this shape, the results may vary and very well be interesting, the result will always remain within the boundaries of the first shape thus limit the originality of the possible results. The results made by a grid-grammar create more unexpected results, as it has a more generative nature. In addition, one can differ in grid-size which increases the originality of different solutions.
The choice of a mass-housing project for the design brief is derived from the value of a design language in such an assignment. For large-scale housing development, a design language described by a shape grammar can be of great significance through providing a high degree of architectural variety in results, while they remain in harmony.



Top: fig 27. Input from location

Middle: fig 28. Design for the expansion, filled with results from the grammar

Bottom: fig 29. Input from context

Assignment

Input from location

The location can provide a lot of input for the grammar. Building heights for instance, or the distance from the front door to the street, orientation or urban context. These are all incentives for rules or design boundaries without impairing the generative properties of the grammar. The site for this mass-housing project is located in the south of Eindhoven. A location on the edge of existing urban tissue ensures a certain level of freedom, but a partial connection with the existing tissue provides support for the design of the expansion. When examining the area, it becomes apparent that there are three different building typologies. The building typology for this grammar will be free-standing houses, in order to maintain as much freedom in building shape as possible. The chosen location (shown in red) is therefore suitable, where it continues in the surrounding ring of detached houses, creating a continuous flow in the existing tissue. In creating the urban tissue of this expansion, following this ring-structure and aiming for an ideal orientation of front/back axis - East/West axis shaped the plan to its current structure. There are several aspects concerning the urban design that influence the results of the grammar. The building heights and roof type in combination with the distance from the plot border to the front of the house need to have a proportion suitable with the dimensions and type of the street. Dimension-wise, the roads can be subdivided into two types: a primary road and a secondary road, with a second type of primary road that borders the area. The dimensions for the roads are derived from the dimensions of the surrounding roads to create a similar street type and ensure a connection with the surrounding tissue. When a specific plot has been chosen, information is provided from its context. The urban orientation: which side(s) of the plot borders the street; The solar orientation and the size of the plot. These three contextual influences provide possible grounds for further rules.

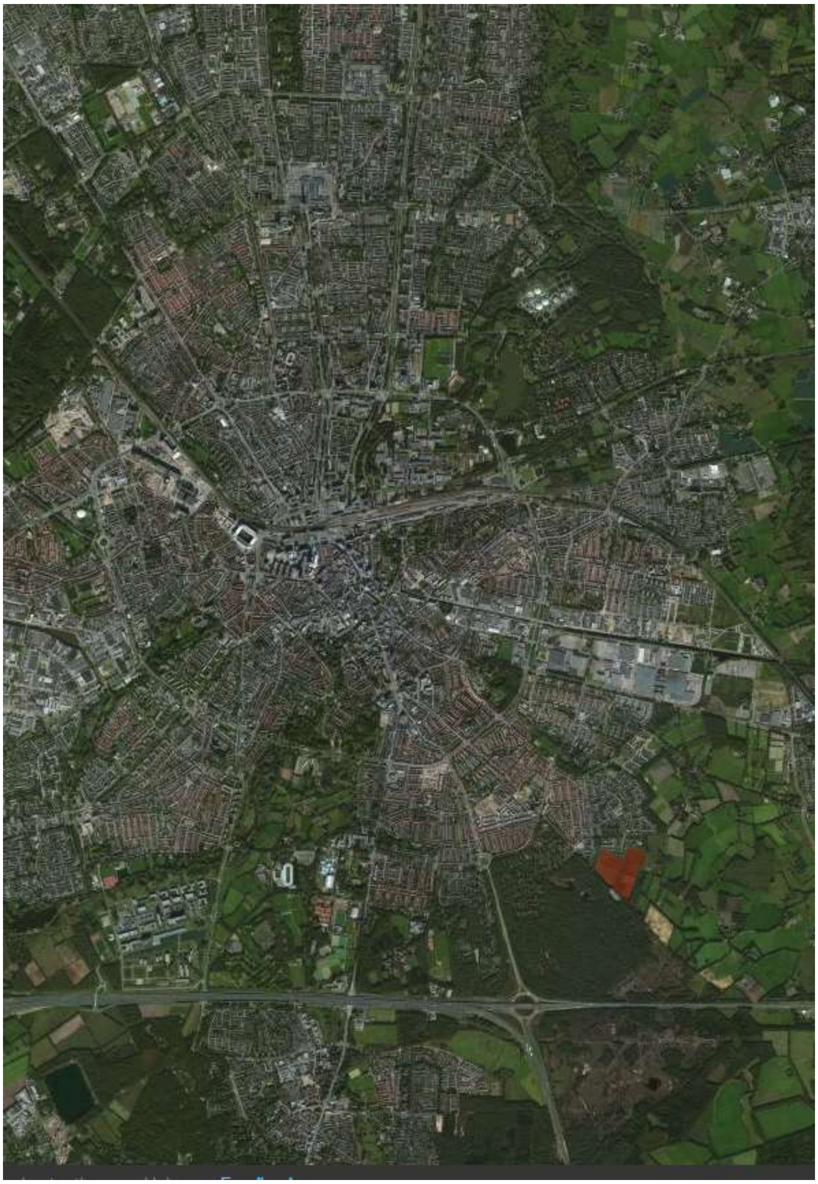


Fig 30. Eindhoven from the sky, with the site location in red.

Assignment

Input from user

In order for the grammar to create a house on the assigned plot, it first needs information of that specific plot, considering each plot is different and not all designs have to house the same type of user. This user input is divided into two different sections. In the first section, information is derived from the context and the inhabitants. Each plot has a different size, a different solar orientation and a different urban context (which side borders a street). The information regarding building typology is the number of users, the number of bedrooms and a quality level. To increase the level of variety in possible outcome, each house is assigned a quality level. For instance, a family of two can have a house of the same square meters as a family of four. The family of two get larger spaces and thus a higher quality level, than the house of the family of four which have smaller spaces and thus a lower quality level. This however has nothing to do with the actual quality of the house, it's more of a ratio of the number of users and total square meters. Finally, the number of floors, balconies and roof type are all boundaries that are inherited from the urban design. The second part of the user input this information is combined with the functional and architectural requirements. The first contains the relations between different functions. The aesthetics contain the actual shape grammar and creates the spaces. At last the dimensional and spatial requirements per function, which can differ due to a different quality level.

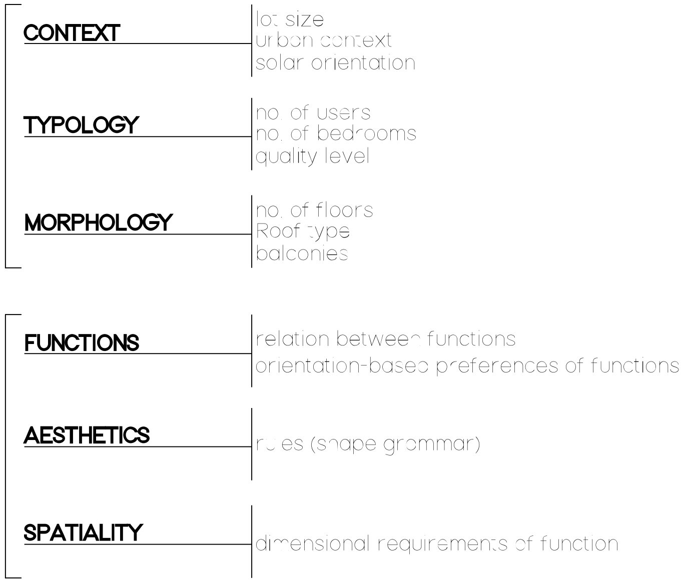


Fig 31. User input

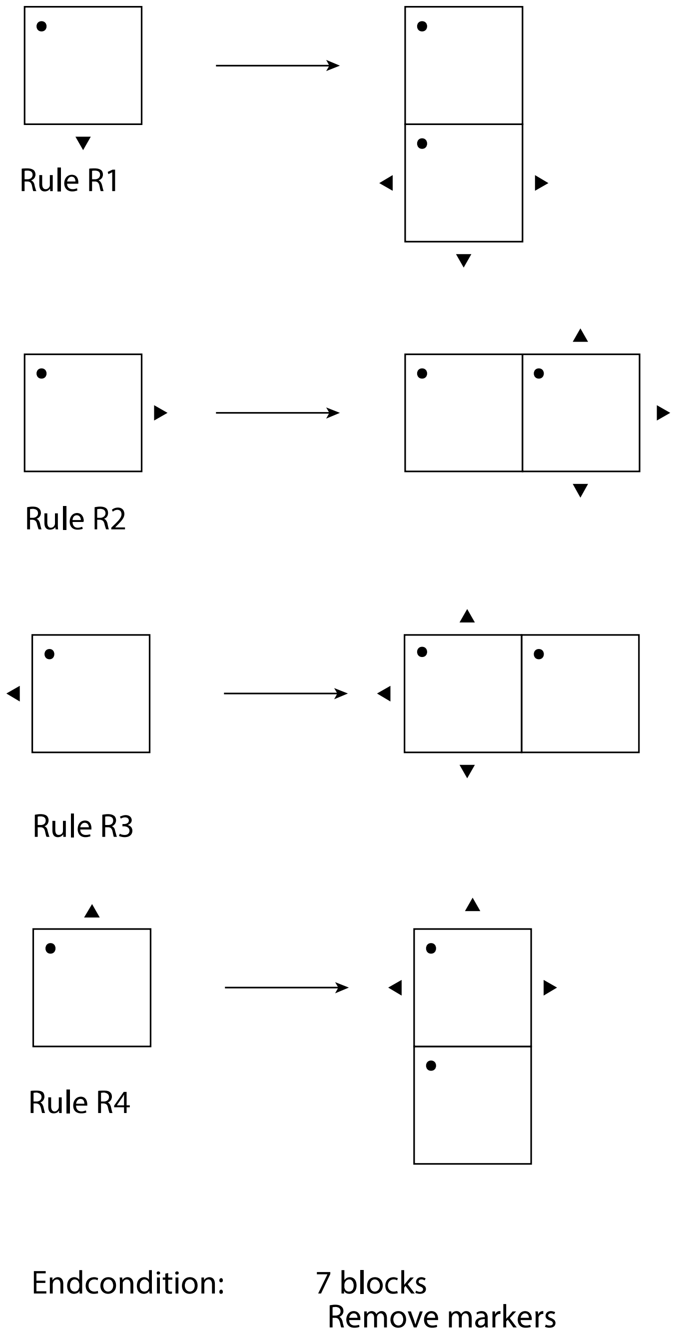


Fig 32. Four rules for the grammar

Creating a house

The rules

The formulation of rules is a challenging part in the process of designing a shape grammar. It is difficult to comprehend the consequences of formulating a rule. Especially since the rules combined describe the structure of the design language, a single rule is but a fragment of that. The first rules for this grammar are therefore very basic: one cell of the grid can expand towards one of the four sides: left, right, up and down. In order for the grammar to start, a base grid needs to be generated. This process is similar to that of the Palladian grammar, but with the use of the rules from Yingzao Fashi, who enhanced and refined the rules for the creation of the grid from the Palladian grammar. The grid is created according to the size of the chosen plot. A starting grid cell is determined by regulations in context: the distance from the front door to the sidewalk.

In the process of the grammar, a few key elements can be discerned: the sequence of spaces/functions and their order, the spatial demands of each space/function and the size of the grid. Below, these elements will be shortly explained. Further on, these elements will be illustrated in an example of the derivation of a result from this grammar.

The shapes are generated with these four rules, but there are different set of rules to ensure the expansion to a new space, the addition of doors or the drawing of the spaces. Besides these rules, there are also rules in the form of constraints. The aforementioned asset of shape grammars being that it provides many results, can also be a disadvantage, since all these results need to be evaluated in order to formulate new rules. Terry Knight introduced 'expert grammars': "Different approaches to connecting grammars and goals have been suggested. One approach is direct. It involves writing rules with the foreknowledge that the generated designs will meet, or start to meet, given goals. In order to do this, the behaviours and outcomes of rules must be predictable in some way". Grammars with so-called expert rules gives a certain promise that an outcome will be acceptable and feasible. However, the full extent or purpose of the

opportunities that using shape grammars to design are not fully exploited. The problem with weaker grammars, grammars whose rules are less strict leading to a wider range of outcomes and solutions, is that many of these solutions are not useful or feasible. To narrow the solution-set down to acceptable outcomes without drastically changing the rules, the use of constraints and goals could offer a solution. Through establishing constraints and goals, more influence can be applied in the process of rule selection and transformation. These constraints and goals become a separate part of the grammar. The constraints in this grammar apply to the proportion of the generated spaces, which will be explained further on. Two things will happen when using these constraints and goals: in each step of the process, meaning when a rule is selected to transform your shape, the beforehand set constraints must be met. If this is not the case, the rule is proved invalid and another rule will be tried. This process repeats until a suitable match is found that meets the constraints. If a match is made and your constraints are satisfied, the goals are checked. If a goal is reached, the execution stops. If not, the process backtracks and another alternative is found until the goal is achieved. Using these constraints and goals in a grammar could provide a solution for the many results a grammar would otherwise produce. The constraints and goals are basically a layer of restrictions on top of your set of rules to ensure that inapplicable results are filtered out, leaving only the feasible results for you to consider.

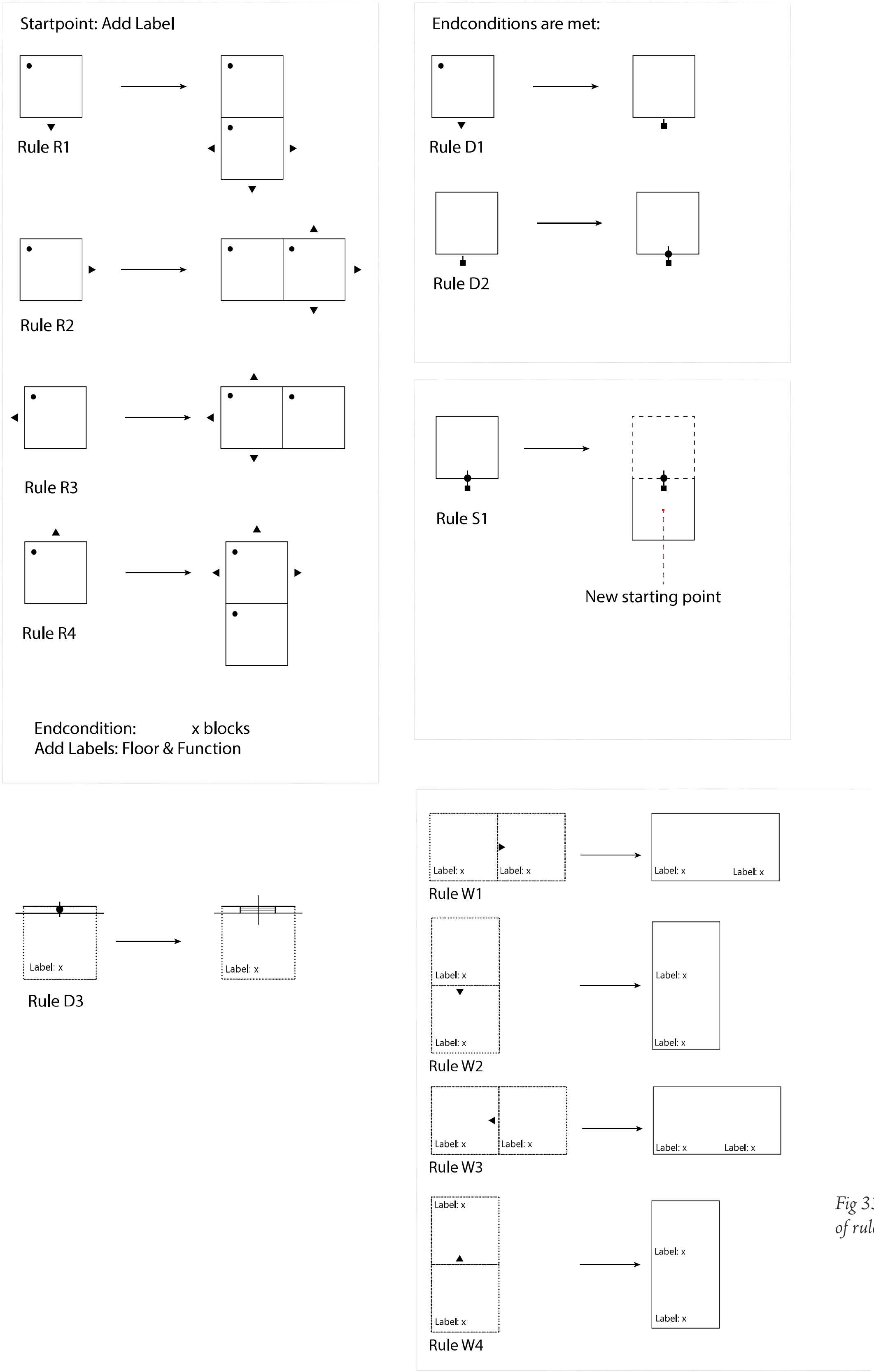
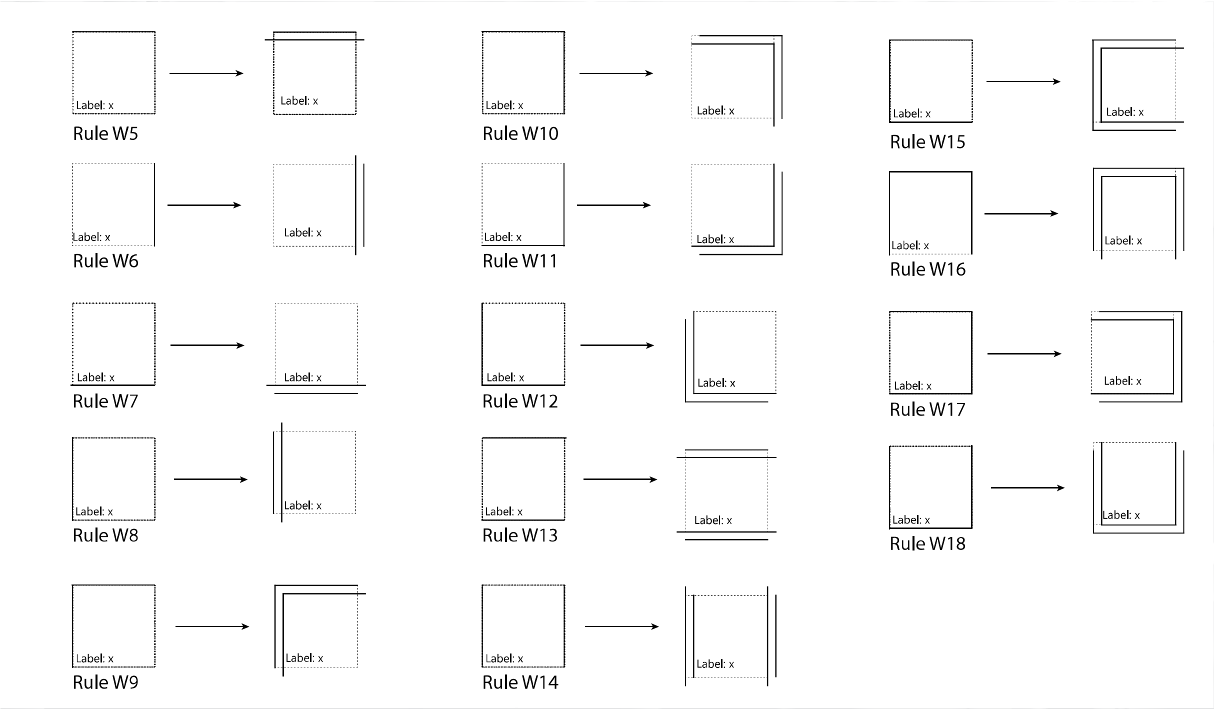


Fig 33. Collection of rules



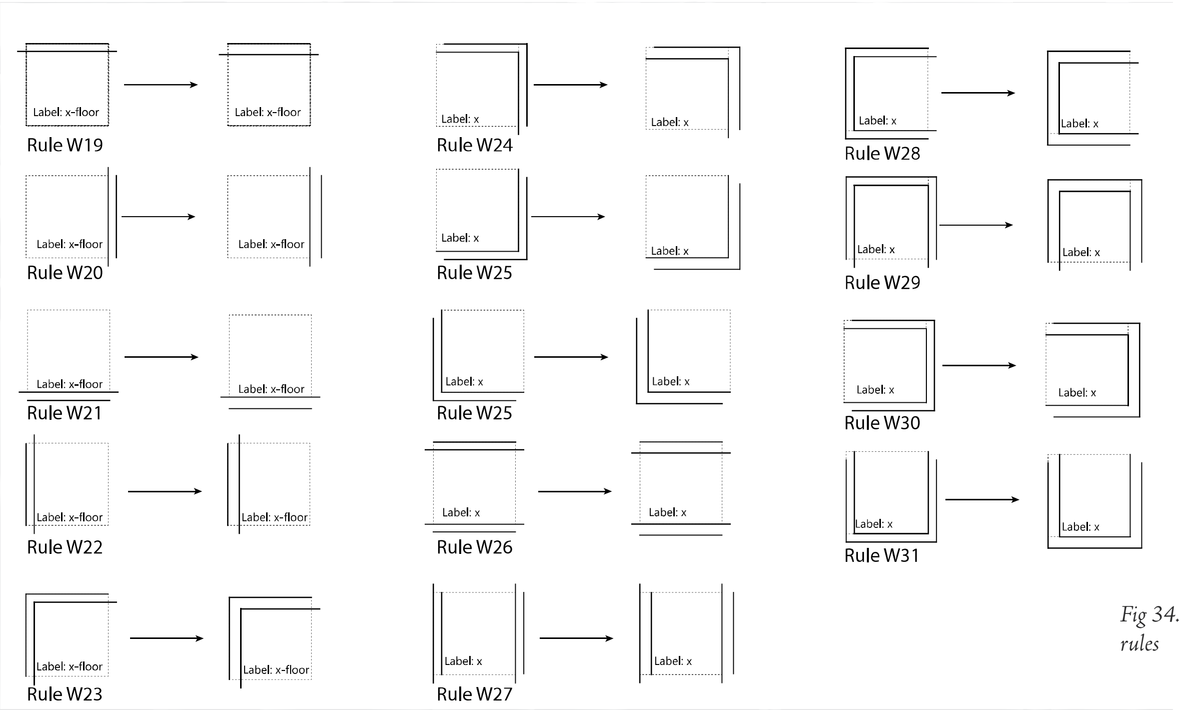
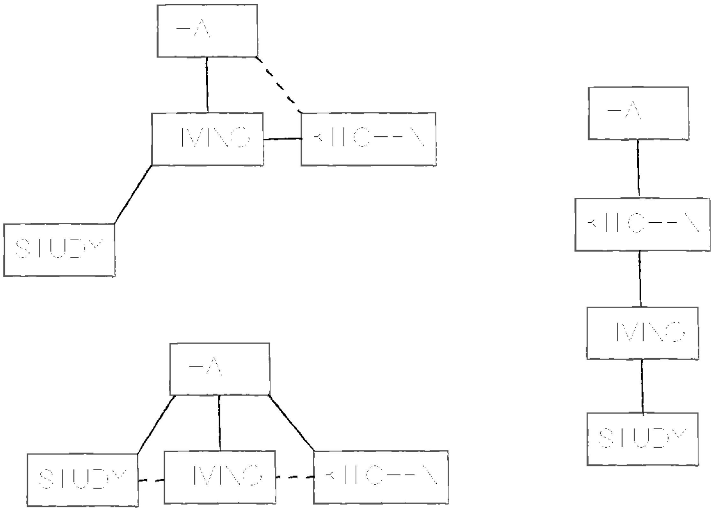
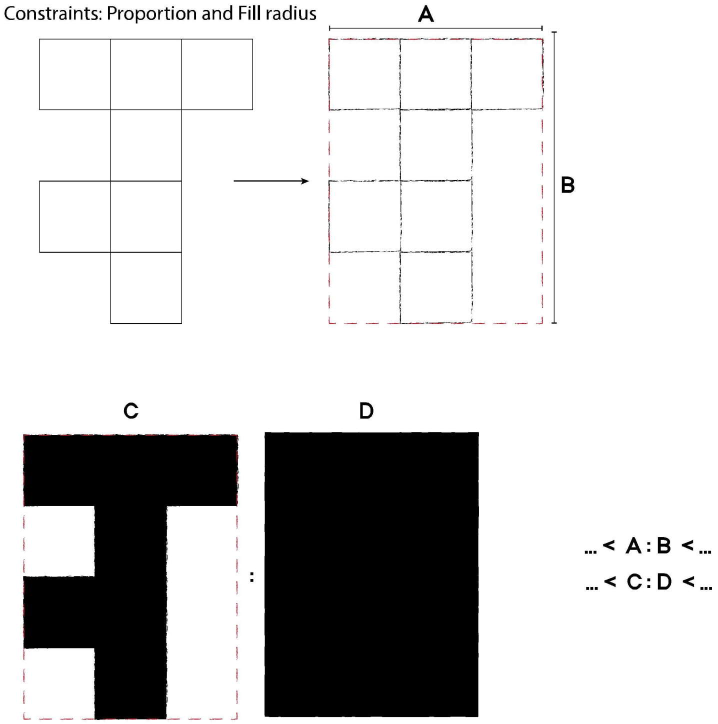


Fig 34. Drawing rules





Top: fig 35. Relations between spaces

Bottom: fig 36 Rules for proportion and fill ratio

Sequence of Spaces

Using a shape grammar for creating architecture is about more than creating shapes and spatial compositions. When created for architectural purposes, a shape, or enclosed space, has a function. Two adjoining spaces have a relation. This provides a frame for the grammar. The relation between the spaces can be predetermined, as can be the order in which each space will be created. In this grammar, the hall is always first the first space that is created: this is the only fixed point in the grammar, since it is derived from the urban context. Once the hall is created, the living room will be generated next. The spaces adjacent to the living room are the study and the kitchen. These are the only predetermined relations between the spaces. However, there is always a possibility that the plan is generated thus that the study borders both the living room and the kitchen, but they will not be connected through a door. The predetermined order in which the spaces are created is: Hall – Living room – Kitchen – Study --- (new level) – Hall – Bedroom – Bedroom – Bathroom – Room. On the second level, there is no relation between spaces, except for the hall, which has a connection with every other space.

Spatial demands

As previously stated, there are only four rules. However, the generated spaces harbour different functions and these functions often have different spatial requirements. A hall for instance, has different demands than a living room or a kitchen. A hall often needs to be connected to more spaces and is in need of less floor space, therefore it is expedient to be narrow and long. This way, more spaces can be attached without the hall taking up more valuable space than is necessary. In addition, to ensure that spaces become inhabitable, false results have to be filtered out. For instance, the grammar could generate a result for a space that is 7 meters wide and 1 meter deep, which would be highly unsuitable. A person

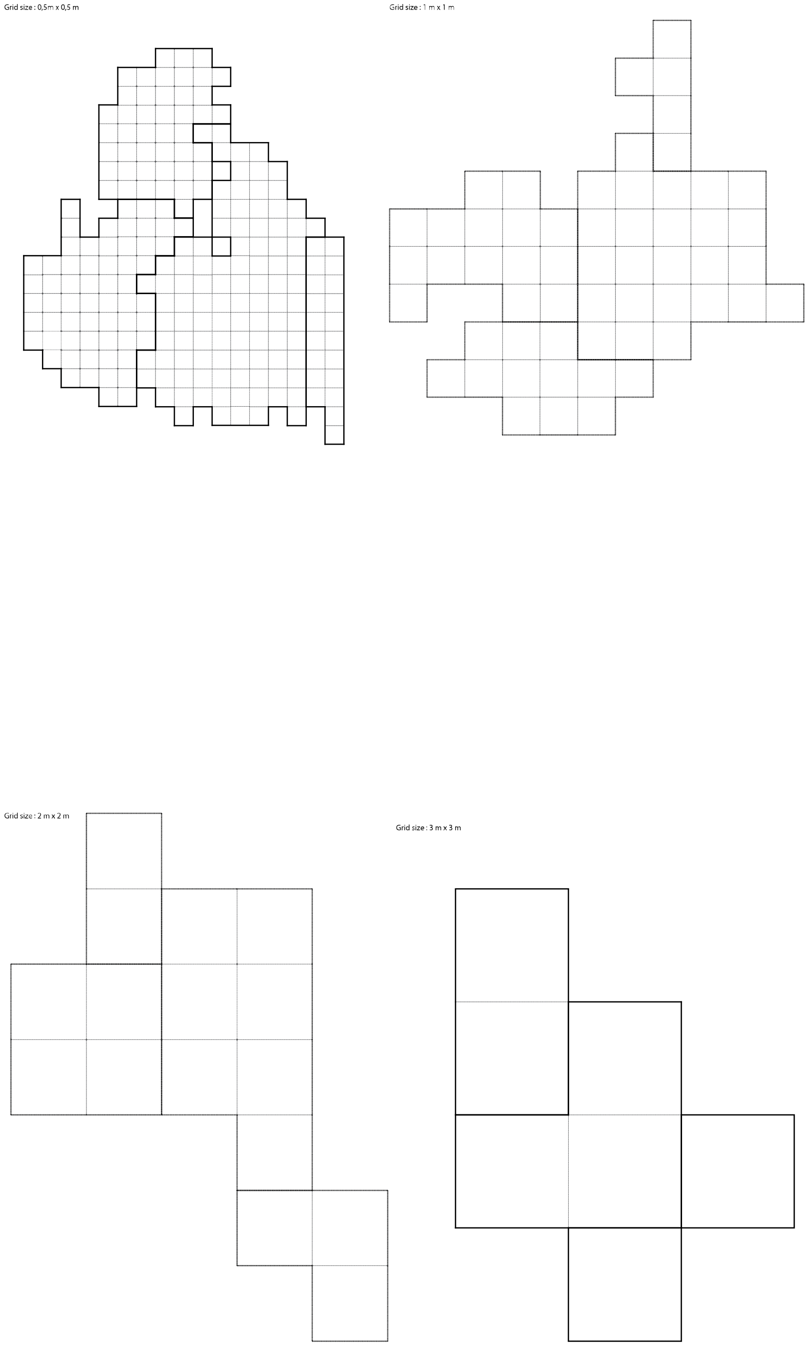


Fig 37. The influence of the grid size on the generated result

would never design a space like this, however regarding the rules this is as much a valid outcome as a space of 3 x 3 meters. Therefore, all spaces have to meet certain proportional demands. These demands can be formulated in rules, specified to the corresponding function. Besides these proportional demands, a space also needs to have a certain amount of square meters. These sizes are derived from the user input and determine when the derivation of a space ends.

Grid Size

This grammar is a grid grammar. The size of one grid-cell can be anything. From 0,1 x 0,1 In a grid-grammar, the size of one grid-cell can be anything from 0,1 x 0,1 m to 5x5m. The size of the grid greatly influences the results. When a space has a desired area of 20 m2, the number of derivations is exceedingly higher with a smaller grid-size. The smaller the grid-size, the more diverse the results will become. However, this also requires more attention in follow-up rules, since a protrusion of 0,5m x 0,5m is quite impractical. When choosing a larger grid-size, solutions become less divers but a protrusion of a single cell can be less inconvenient. For this grammar, a grid-size of 2,5 x 2,5 m is chosen, where this grid-size provided the most balance between the originality and inconvenience of the generated results. m to 5x5m. The smaller the grid-size, the more diverse the results will become. However, this also requires more attention in follow-up rules, since a protrusion of 0,5m x 0,5m is quite impractical. When choosing a larger grid-size, solutions become less divers but one cell can be less inconvenient.

Connecting spaces: adding doors

When a space is created, the cells on the edge of the space can provide a starting point for a new space. Once a connecting cell is randomly selected, a marker is added which will be transformed to a door in a later stage of the grammar. It is possible that a space needs to be connected with more than one space. This is the case for the living room, which has a connection to both the kitchen and the study. Once the living room is generated, a starting cell for the kitchen is selected and the generation for the kitchen begins. Once the kitchen is generated, the starting cell for the study is selected from the remaining available edge-cells in the living room. It is possible, that in generating the house so far, the living room is completely enclosed by the kitchen and the hall. In this case, a valid starting cell for the study cannot be determined, and the last generated space will be erased and generated again.

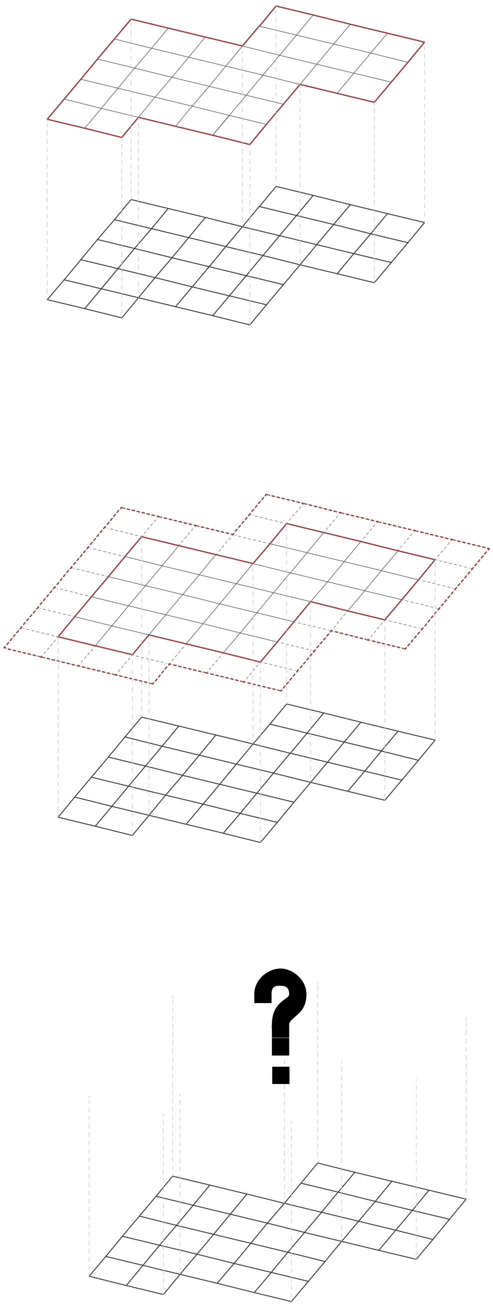


Fig 38. Principles for generating the second level

Second level

To add a second level to the building, there are a three alternative possibilities. One: the outline of the first level will be extended to the second level and will therefore act as the outline of the second level as well; Two: the outline of the first level will function as a foundation for the second level, where the second level can add rows of cells to extend the outline; Three: create a whole new level with no regard to the underlying structure.

In the case of possibility one, you needn't worry about additional structural solutions, since there won't be any cantilevers. However, this approach of creating a second level does limit the generative freedom for the upstairs spaces considerably since they are bound by the outline of the lower level.

In the case of possibility two, additional structural solutions are required depending on the chosen size of grid cells and the number of cells allowed to expand the ground level with. The generative freedom for the upstairs spaces is increased, however still bound by a predetermined outline.

In the case of possibility three, additional structural solutions are most likely required, no matter the chosen grid-size. The second level possesses ultimate generative freedom which greatly increases the chance to a successful solution, however there is a possibility that the second level deviates from the ground level entirely, which can be an undesired result since it is very inefficient use of plot-space.

In this grammar, the base grid for the second floor is created according to possibility two: one row of cells is added to every cell in every outward direction.

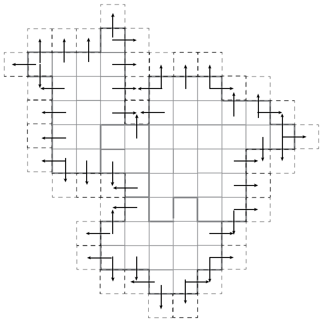


Fig 39. Principles for generating the second level

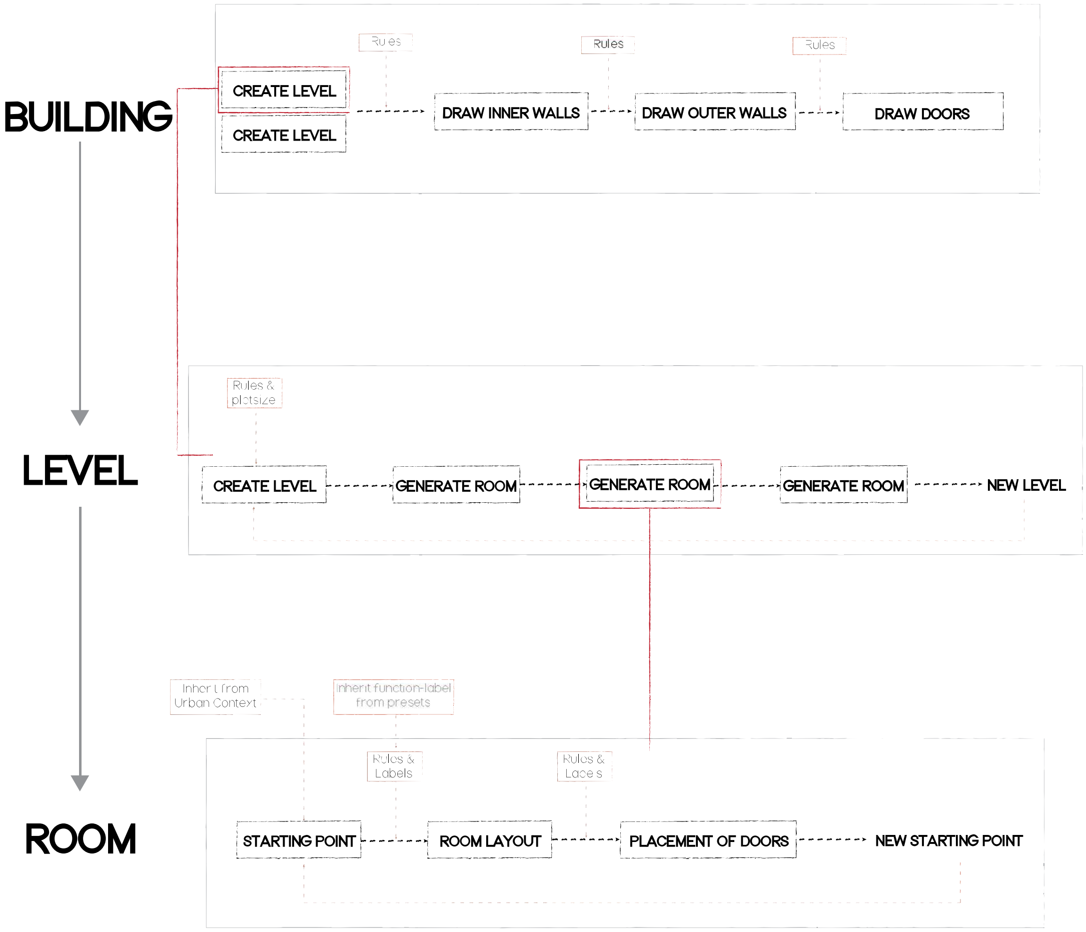


Fig 40. Structure of the grammar

Grammar structure

Building

When starting the grammar, the context provides us with the size of the chosen plot, and therefore the size of the grid, a starting point for the hall and a number of floors to be created. First, each level will be created according to the rules. After every level has been made, a different set of rules providing the drawing of (inner and outer) walls and doors creates the graphical output.

Level

In addition to a starting point, the size of the grid and a number of floors, the relation between different functions and the order in which they are to be made is also predetermined. The ground level is always created first. Then, according to the proper predetermined order, each room will be formed following the corresponding set of rules. After every room intended for its level is created, the grammar will continue to a new level.

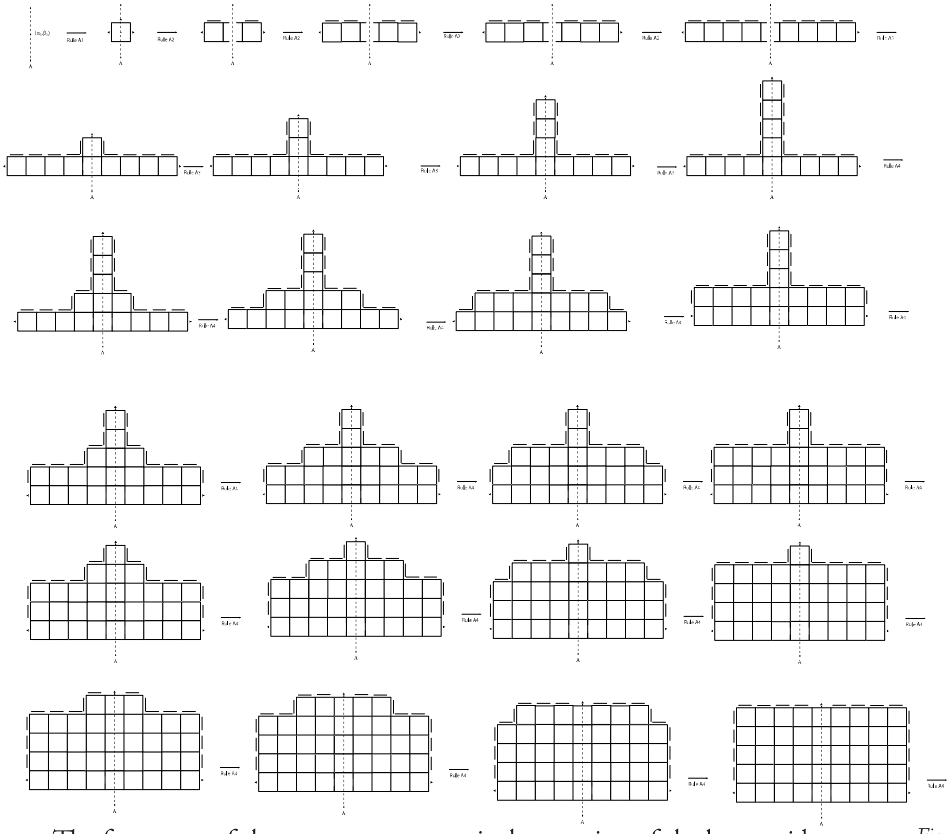
Room

When creating a room, one is always provided with a starting point. From this starting point, the room will be generated using the four basic rules described in the beginning of this chapter. A space will be created and when the end condition (a specific number of created grid-cells, in accordance with the predetermined area requirements of the corresponding function) is met, the space will be checked to see if the spatial requirement(proportion) have been met. If these requirements have not been met, the space will be erased and the process will begin again from the starting point.

Grammar example

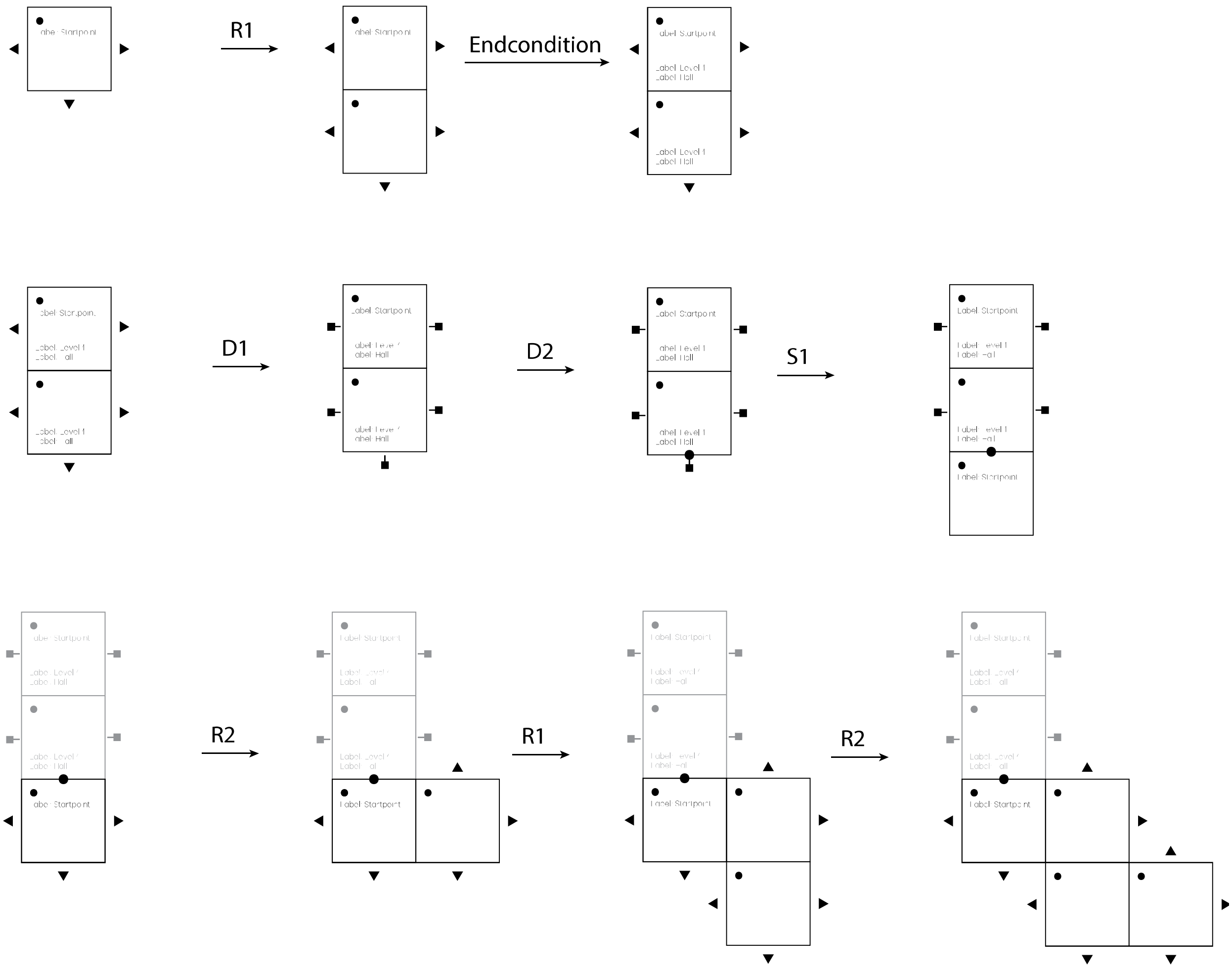
Building

On the following pages, the generation of one result will be demonstrated and elaborated. You will be guided through the entire process of the generation of a design using this grammar.



The first stage of the grammar process is the creation of the base-grid. This grid is generated using the Yingzao Fashi rules, which follows the rules for the grid-creation of the Palladian grammar, but with improvements. These rules use the requested number of left-right and top additions to create a grid of the dimensions you desire. In this project, the size of the grid is in accordance with the size of the assigned plot.

Fig 41. Derivation of the grammar



The starting location within the created grid is determined by restrictions from the urban situation. There is a specified distance from the street to the front of the house, on which this starting point is located. This cell will be the starting point for the hall. The end-condition is related to the desired area, or number of cells in a space. In the case of the hall, this number is two, corresponding with 5 m by 2,5 m. Once this number is reached and the created space satisfies the required proportional demands, the markers on the cells change and the cells receive labels concerning the function of the created space and the floor on which the space is located. The new markers allow for a connecting space to be chosen, and a new cell with the label 'starting point' is added. The order in which the rooms are to be generated is predetermined, and the next space to be created is the living room. The same process starts again

Fig 42. Derivation of the grammar

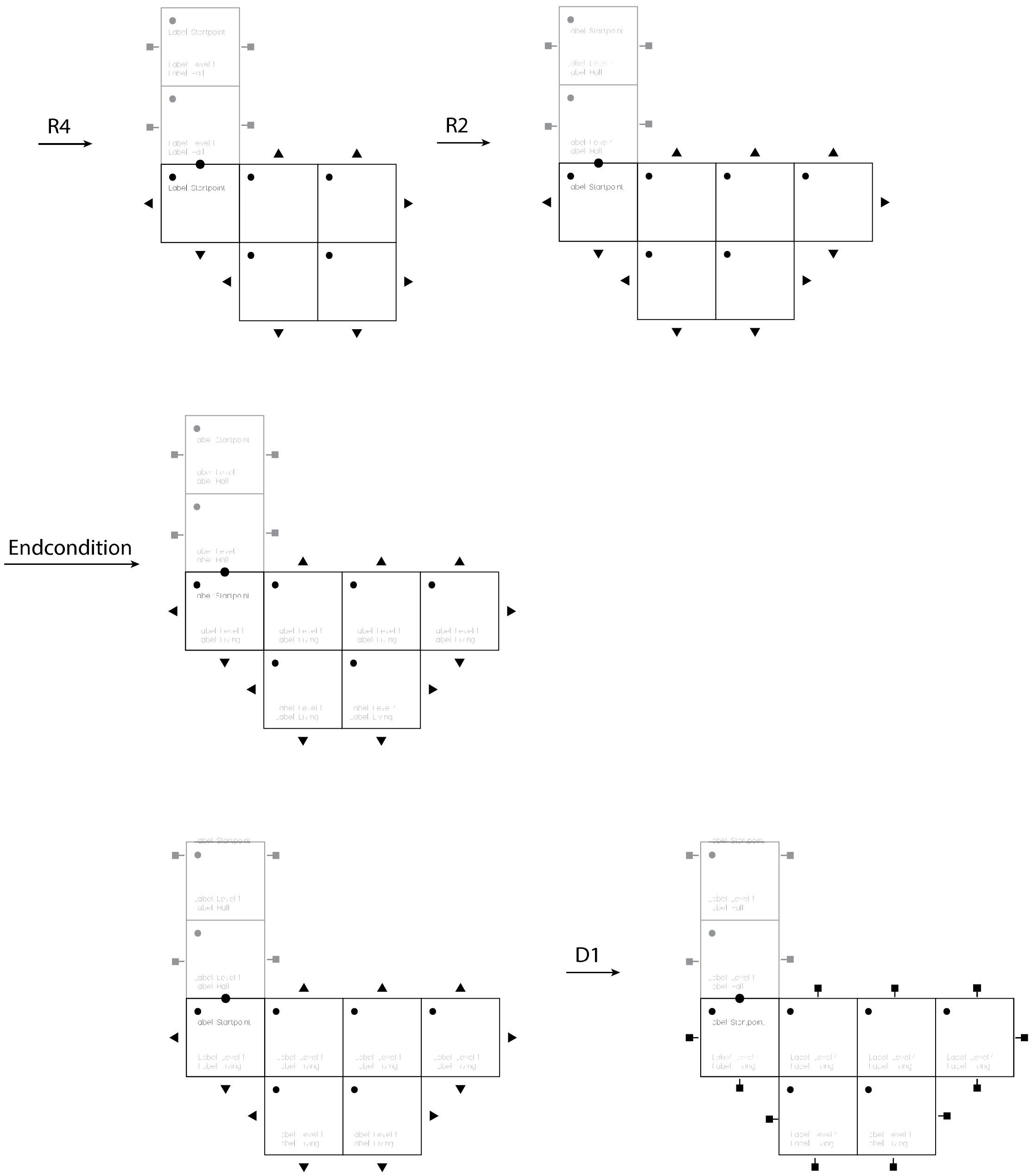


Fig 43. Derivation of the grammar

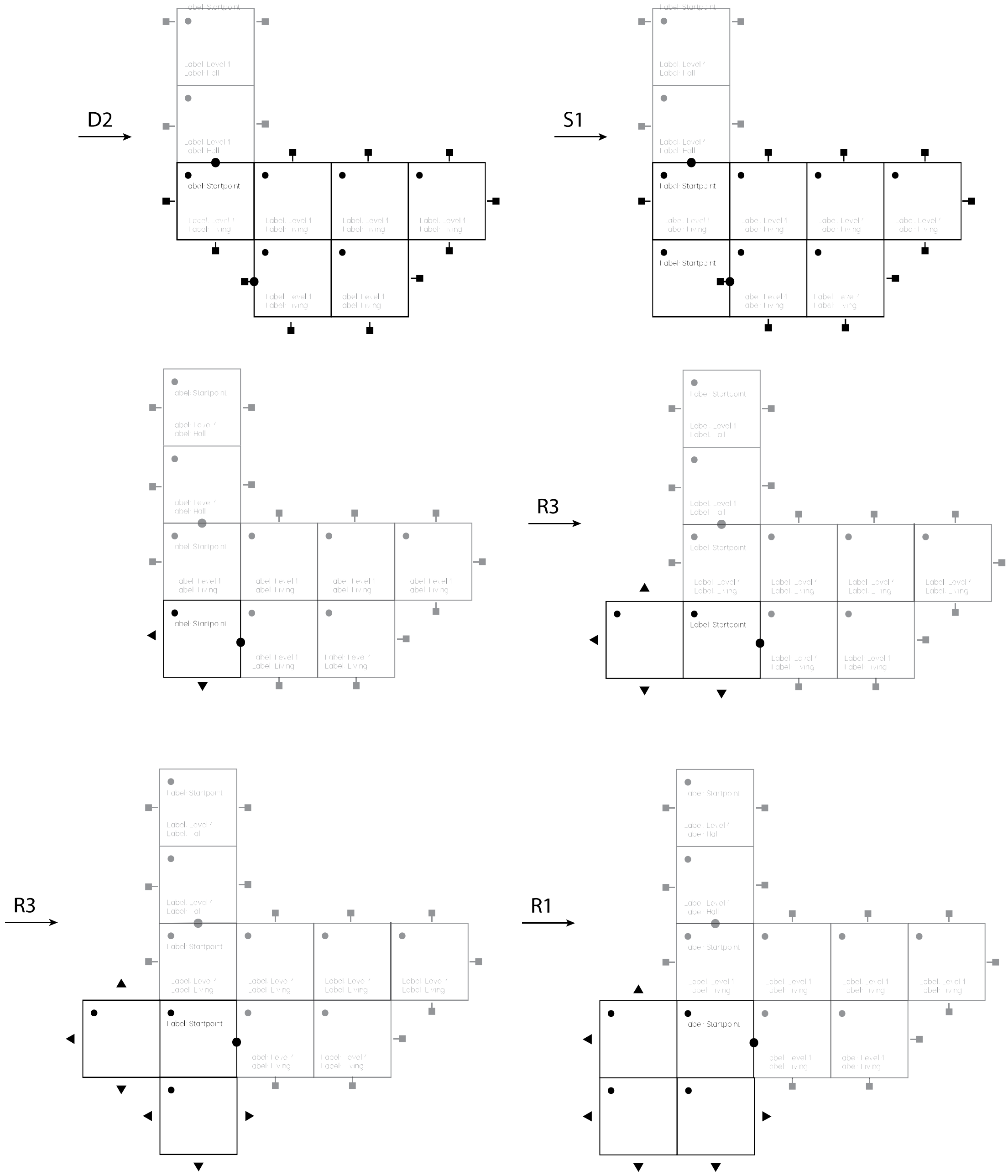


Fig 44. Derivation of the grammar

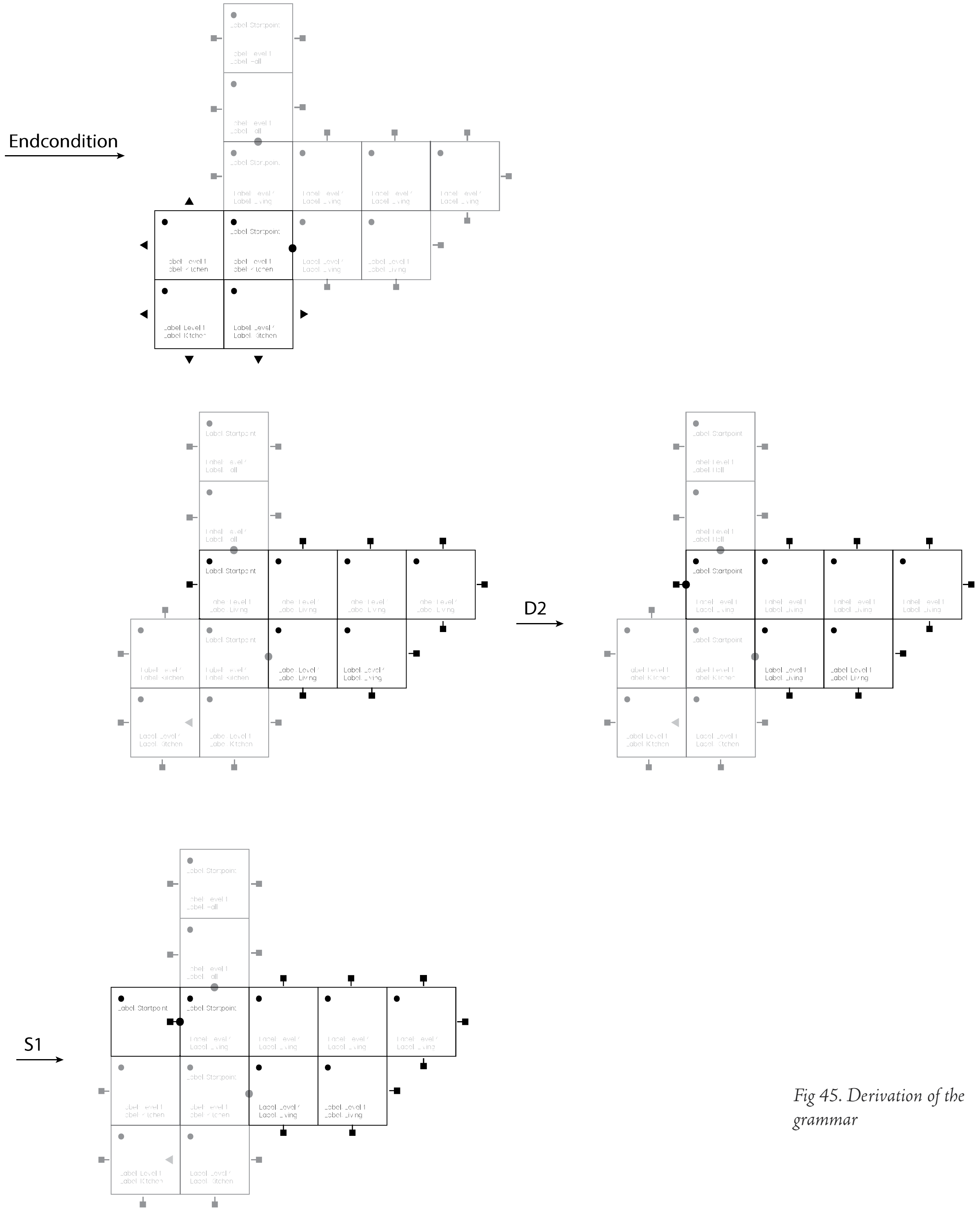


Fig 45. Derivation of the grammar

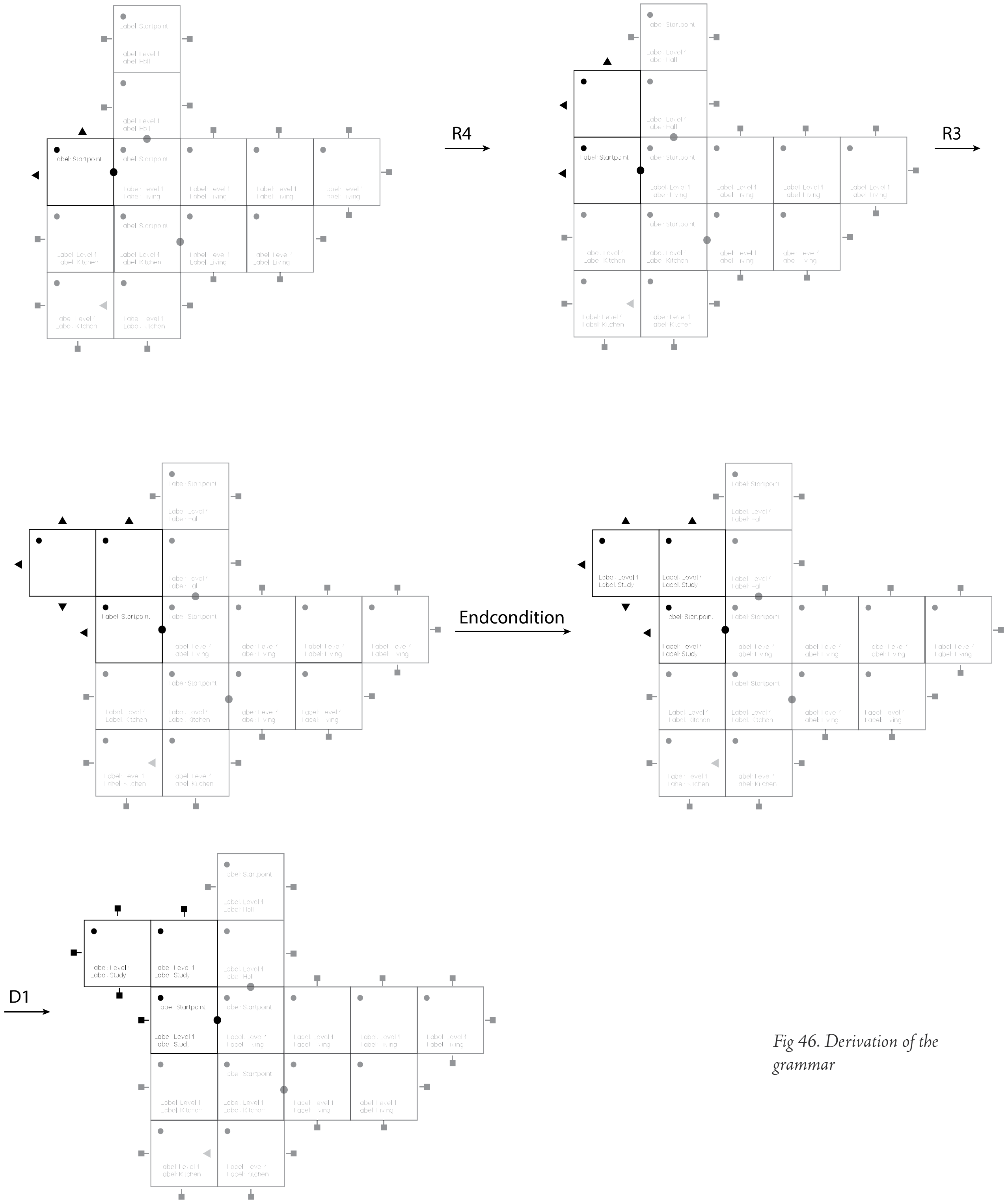
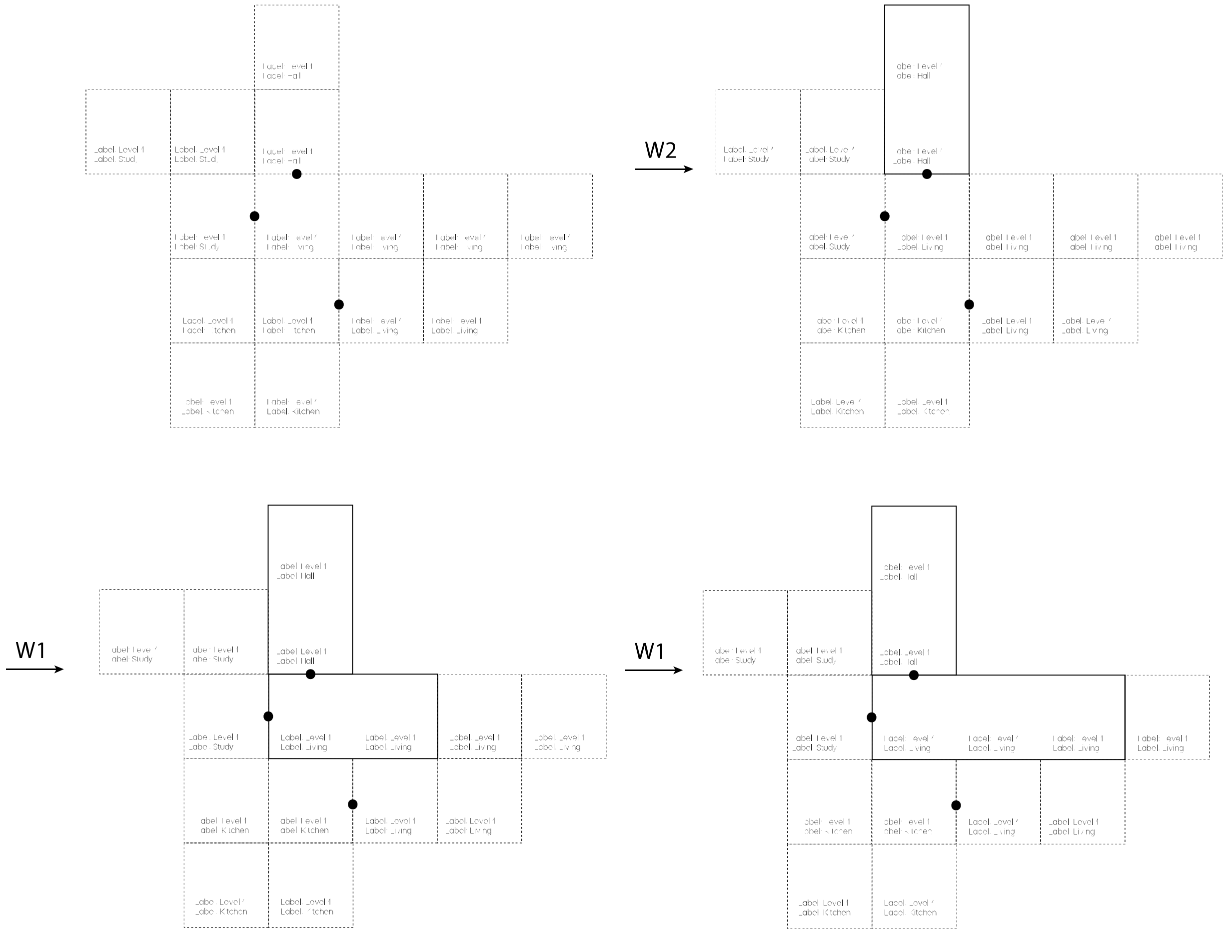
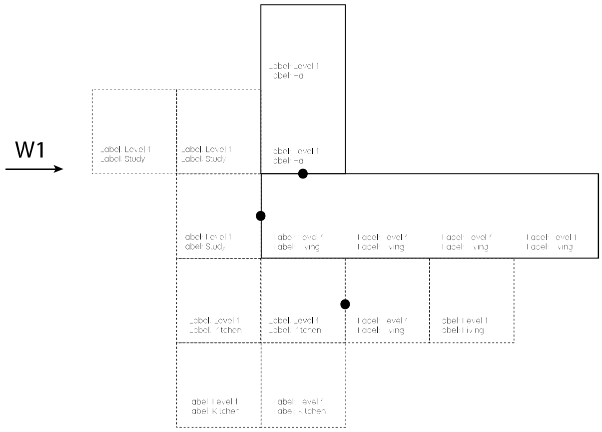


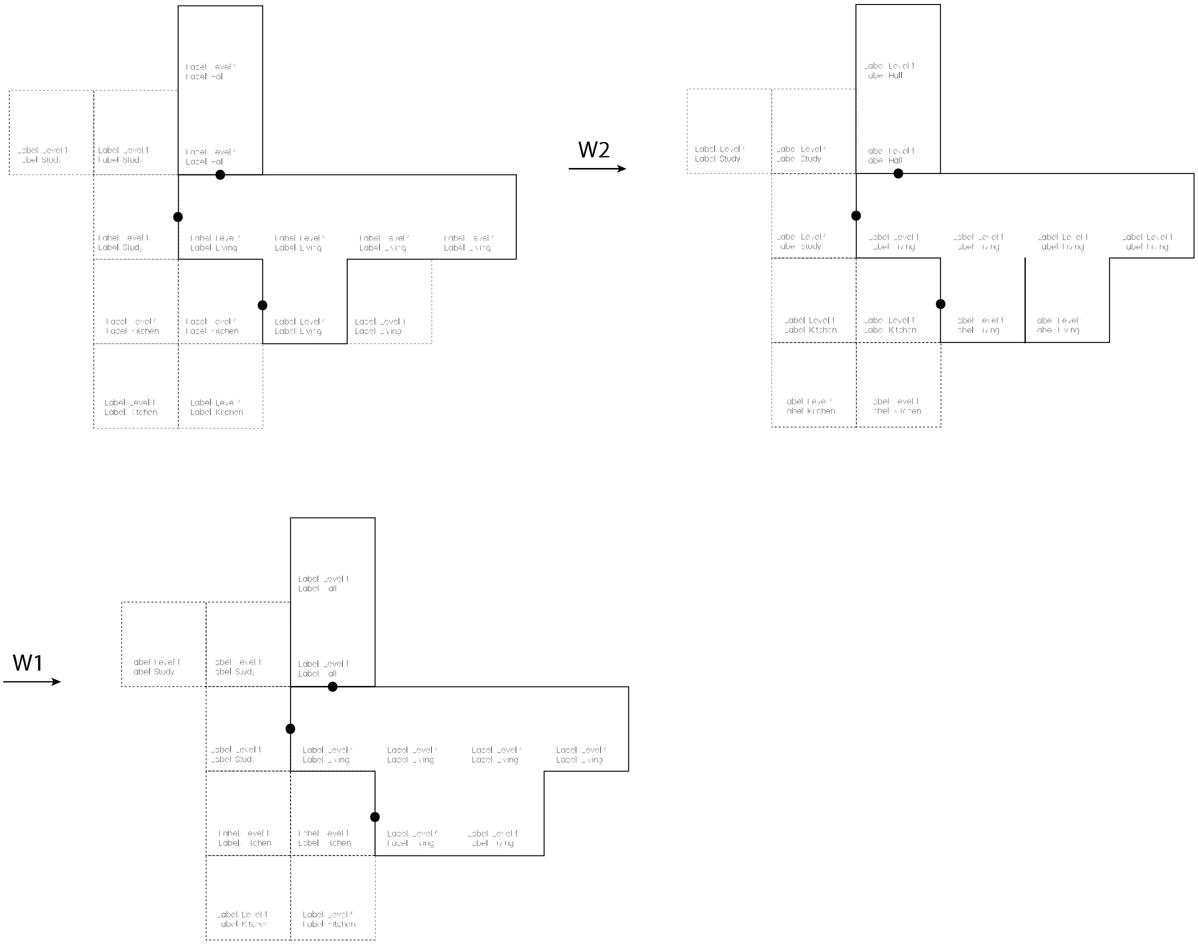
Fig 46. Derivation of the grammar





Once every demanded space on a floor-level is created, the same process is repeated on the second floor. A new grid is created, and the same starting point is assigned for the upstairs hallway. This cell will also house the stairs and form the connection between the two floors. After the second level is generated, the spaces can be drawn. First, a single outline around a generated space is drawn.

Fig 47. Derivation of the grammar



Once every space has a drawn outline, this outline will be converted to a double outline, a wall. There is a separate set of rules, transforming each cell in a space to the corresponding wall-element. When each space is surrounded by walls, the outer walls increase in thickness. This happens in the same way, only now the entire floor will be treated like a single space.

Fig 48. Derivation of the grammar

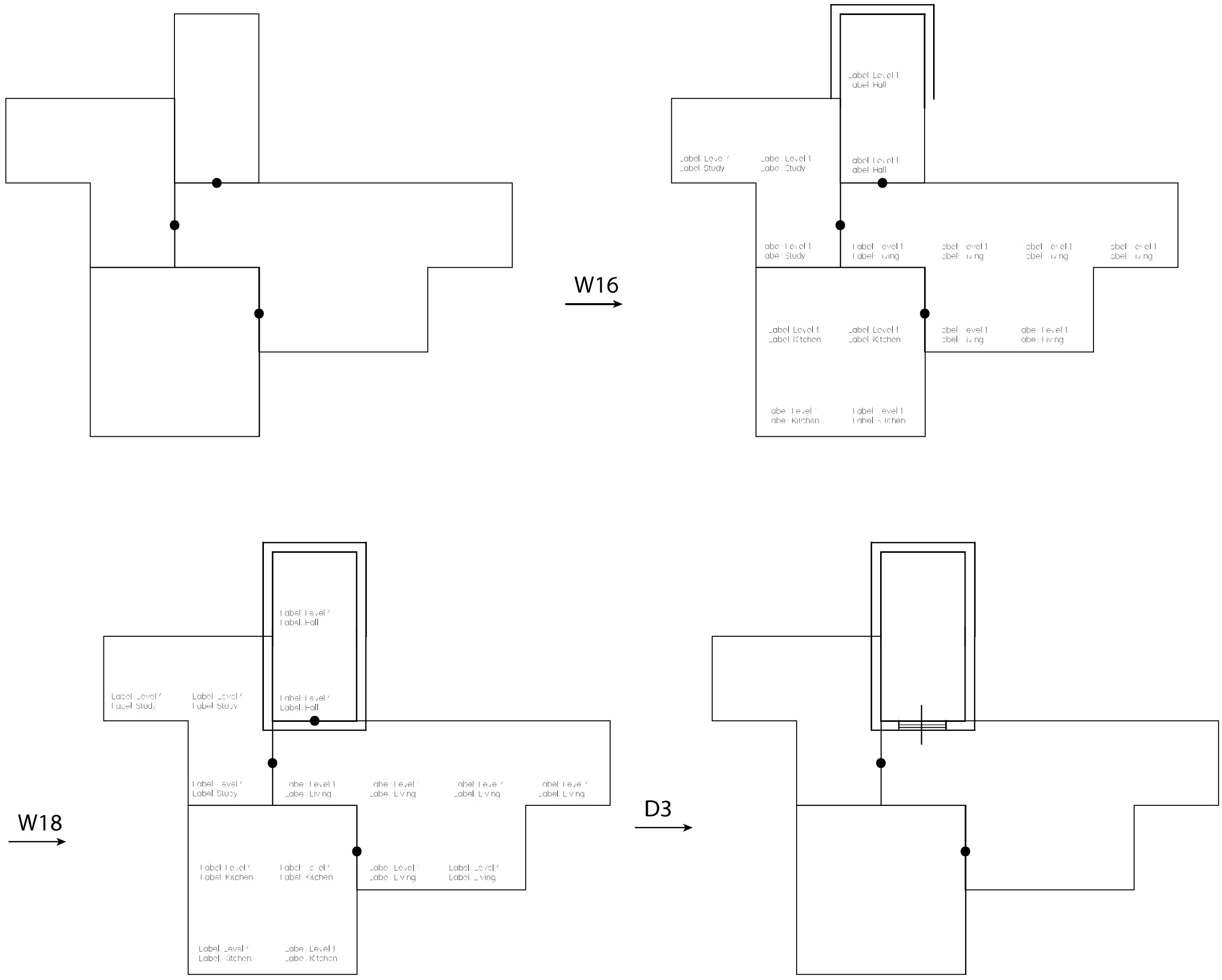


Fig 49. Derivation of the grammar

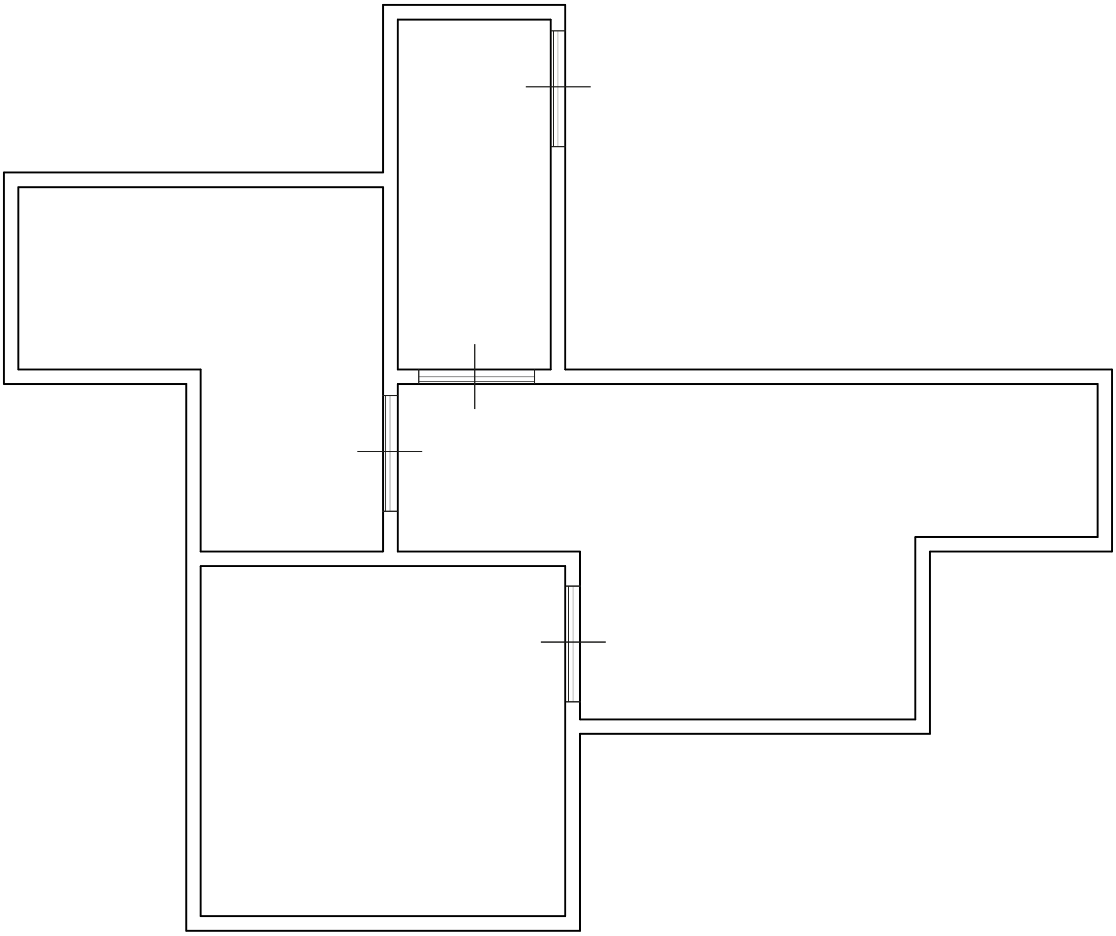
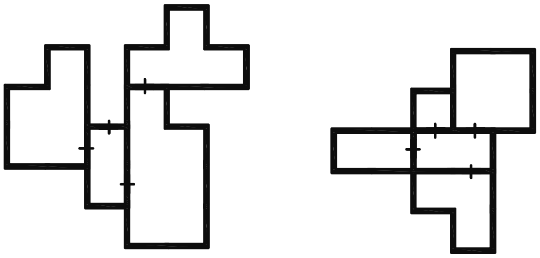
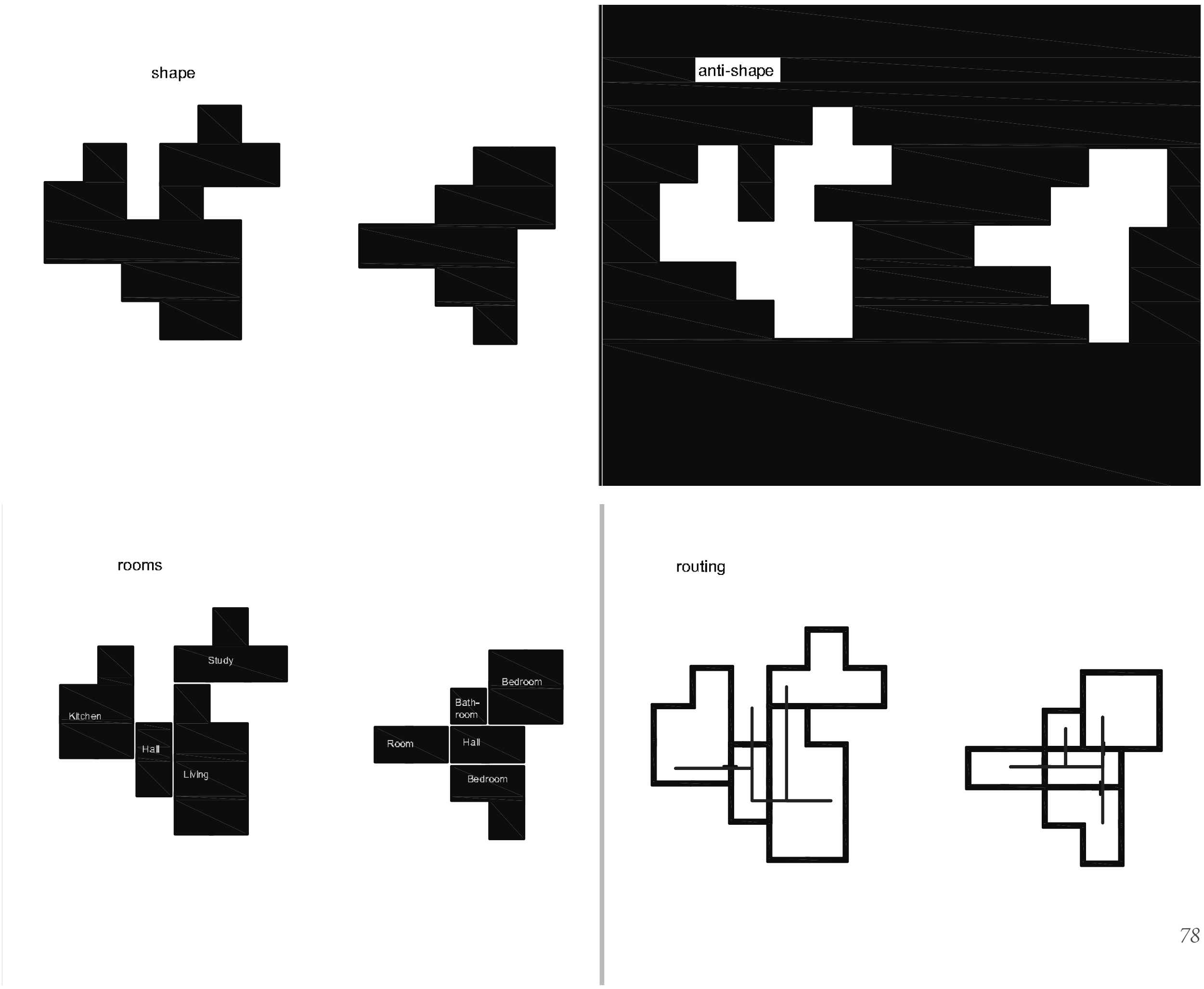


Fig 50. Derivation of the grammar



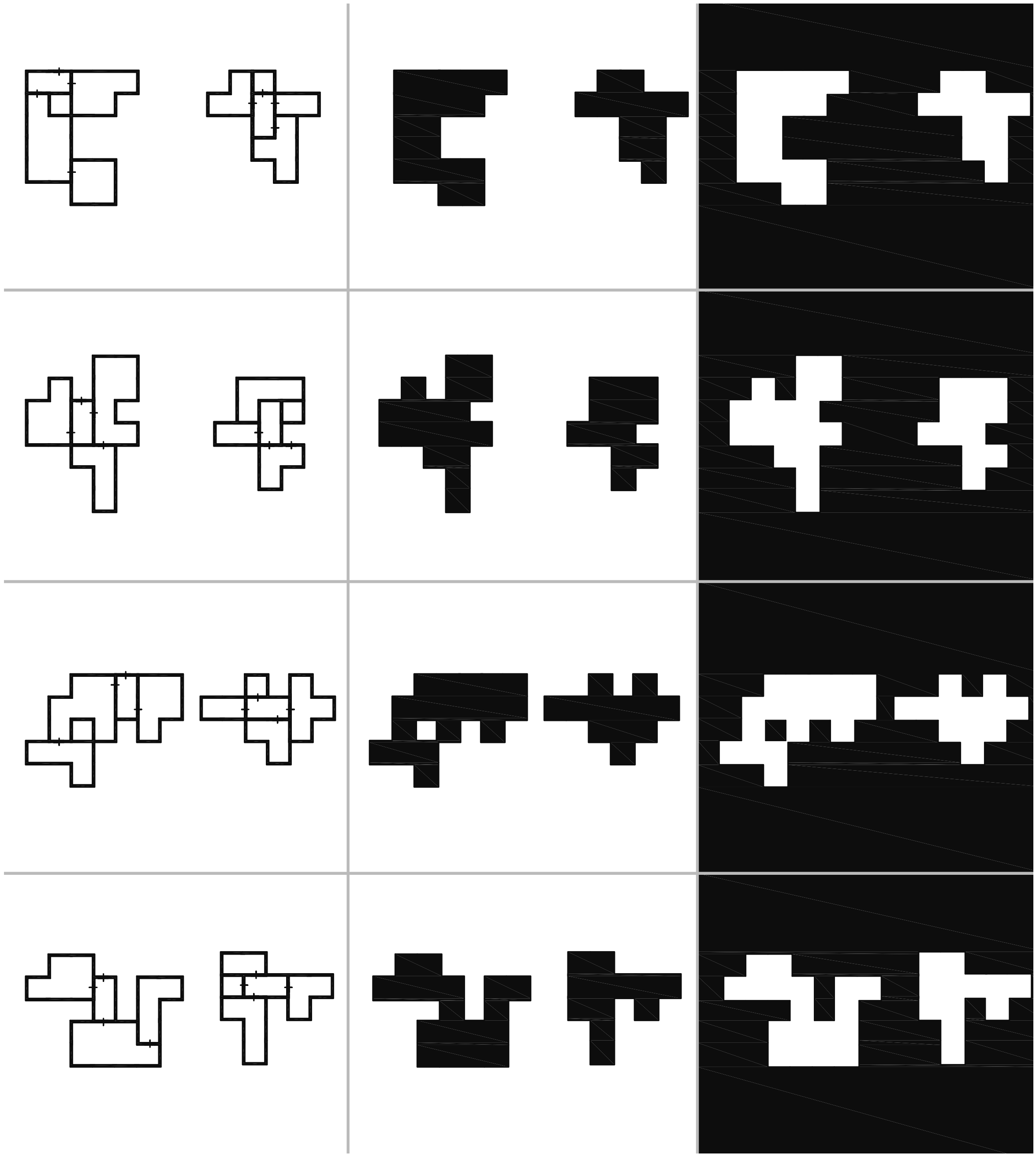

shape
anti-shape
rooms
Study
Kitchen
Hall
Living
Bedroom
Bath-
room
Room
Hall
Bedroom
routing

Grammar results

Analyzing the generated results

Once the first rules are made, you can start generating results. With the use of an interpreter, as was the case in this project, these results can be generated quickly. This is beneficial, because every time you examine and evaluate the results, you get a chance to question your intentions, preferences or dislikes. In order to derive new rules based on the generated results, intentions and objectives need to explicated.

Even though there are still very few rules, the results have multiple aspects that can be evaluated. These aspects are highlighted in the drawings on the left: on the top you see the regular floor plans from both floors; in the middle on the left you can see the positive space created by the entire floor, on the middle right you see the negative space; on the bottom left the different functions can be seen and the routing between these functions on the bottom right. Each of these methods of analysis bring different aspects to light. For instance, looking at the positive/negative space drawings, there were several promising plans. These results contained shapes that created a half-open garden, where the other half is embraced and enclosed by the shape of the building. Other shapes were too rugged or angular. However, it could very possibly be so that the plan that looks promising in one analytical drawing, is the opposite when regarding other aspects. Using these different ways to look at a result, amplifies the importance of certain aspects which helps explicating your design intentions for the further development of rules.



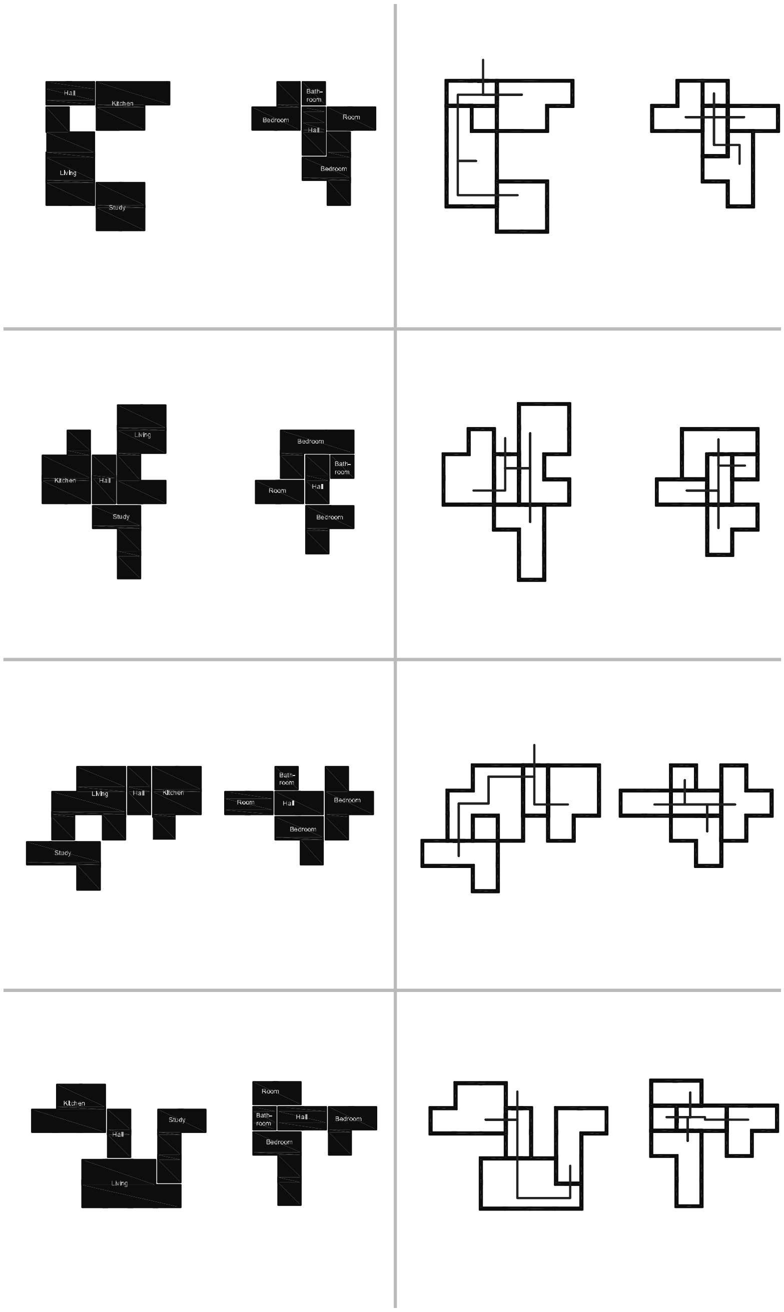
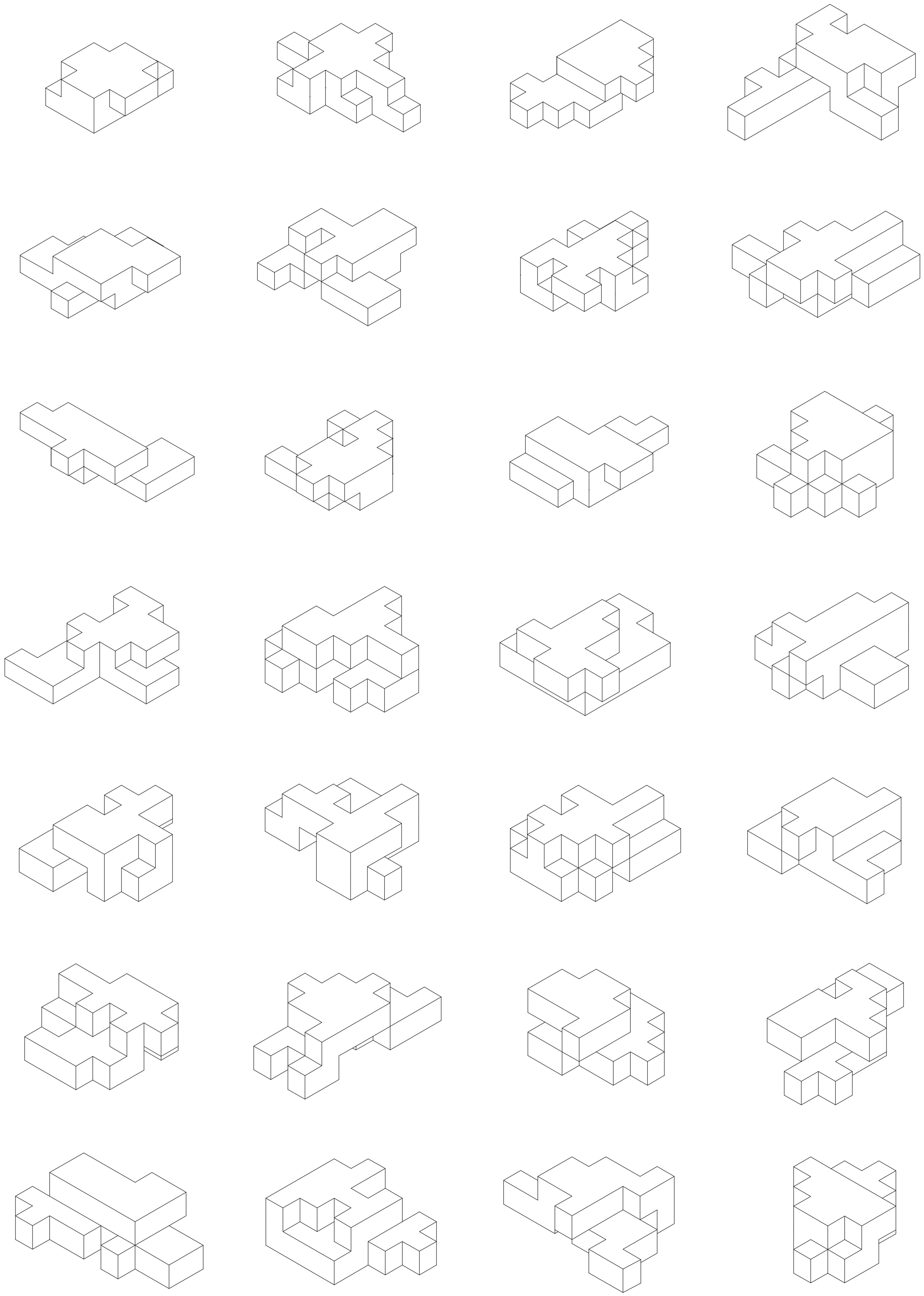
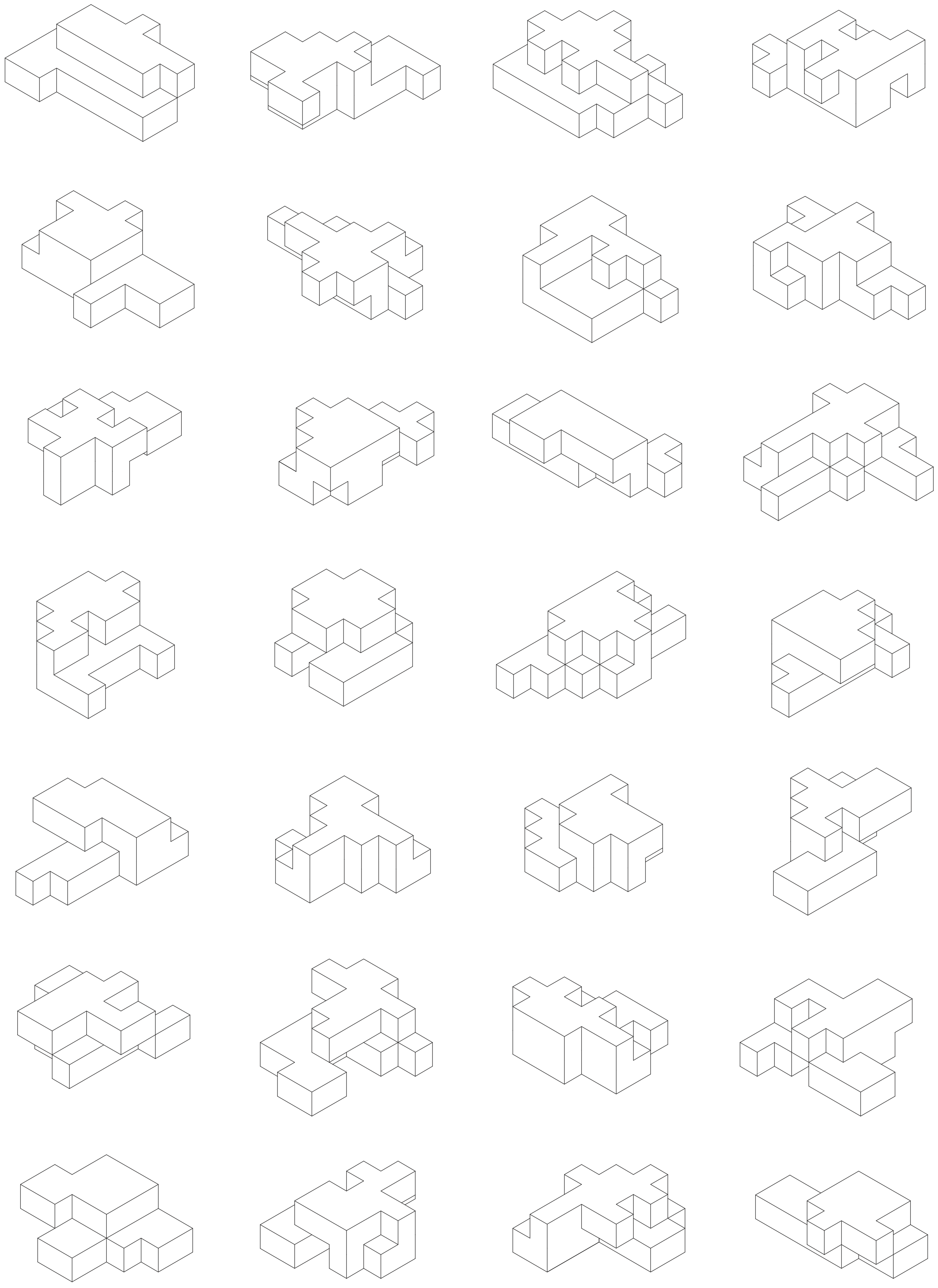


Fig 51. Analysis of the results





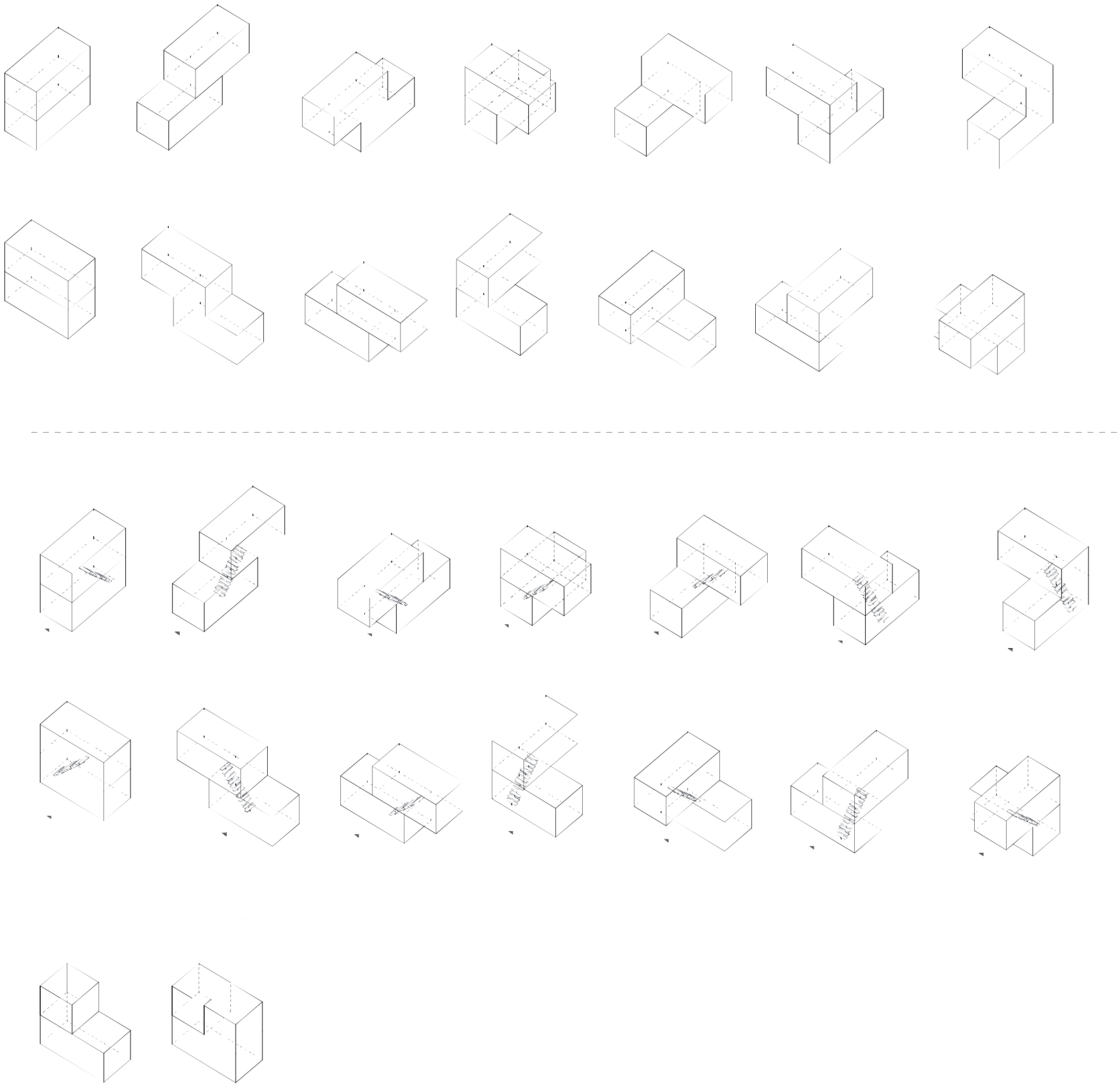


Fig 52. New rules

New rules

New rules can be derived from analysing the results. For instance, when looking at the results it becomes evident that in some cases the cells located above the living room are not occupied, offering possibilities for a void; Another possibility for an unused cell on the second floor is a roof terrace, accessible from one of the bedrooms; Lastly, there are only a few possible configurations for the downstairs and upstairs hallway: since the starting point for the house, which is the starting point for the hall, is also the starting point for the hall on the second level, this provides an opportunity for a connection between floors. From the way the downstairs and upstairs hallway are positioned above one another, rules for placing the stairs can be made. To ensure that every possibility for the placement of doors are not blocked by the stairs, they are always placed in the middle.

These rules are derived only from analysing the results. It is possible that these rules offer a suitable solution in some cases, but it could very well be that in other situations, following these rules is not the best option. To test these rules in practice, they needed to be applied in a more elaborated design. Additionally, the elaboration of results could offer new insights in the spatial qualities or weaknesses of the generated results. When given these results as a starting point, how would they be designed further?

House A **House B** **House C** **House D**

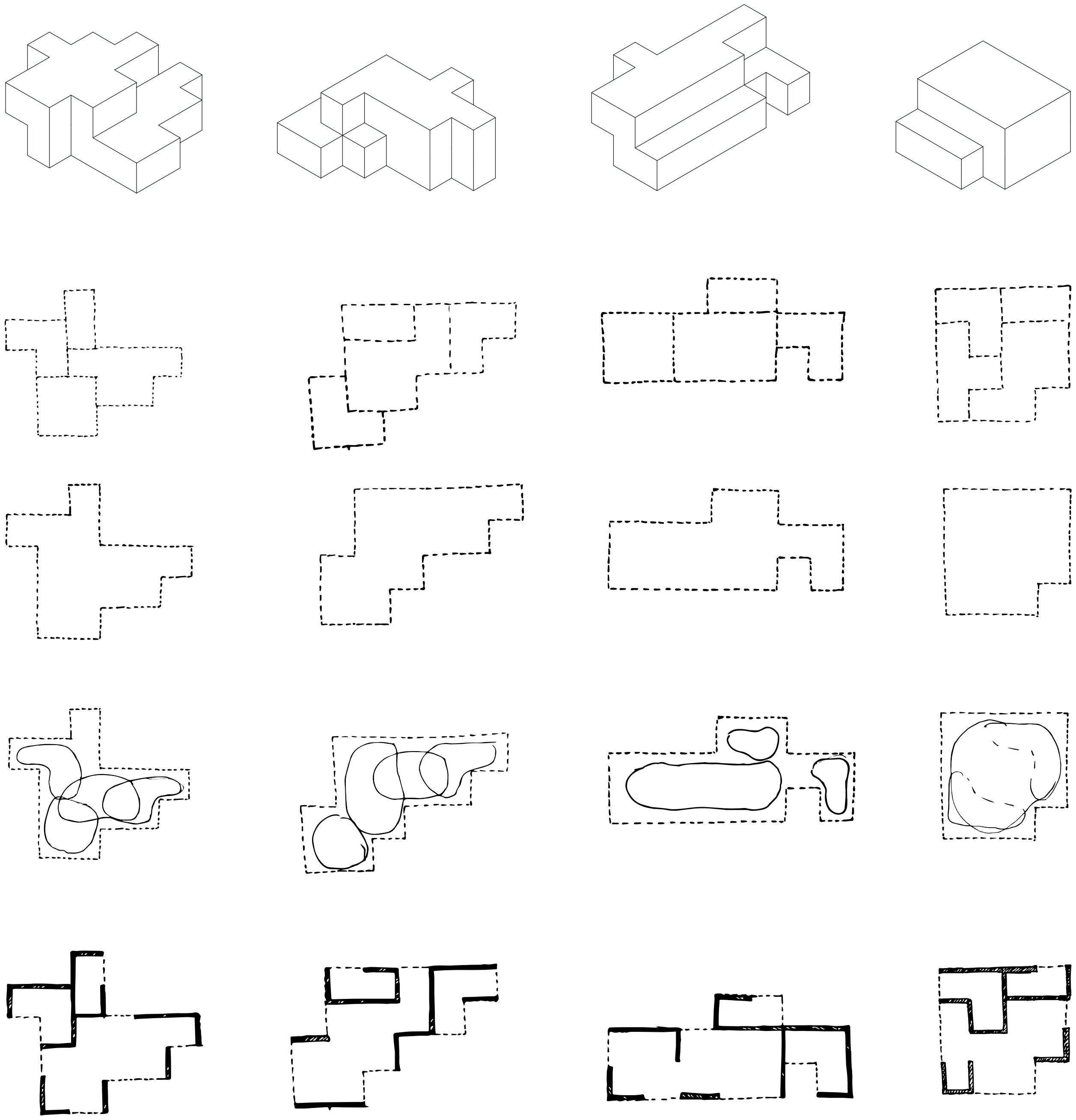


Fig 53. Design principle

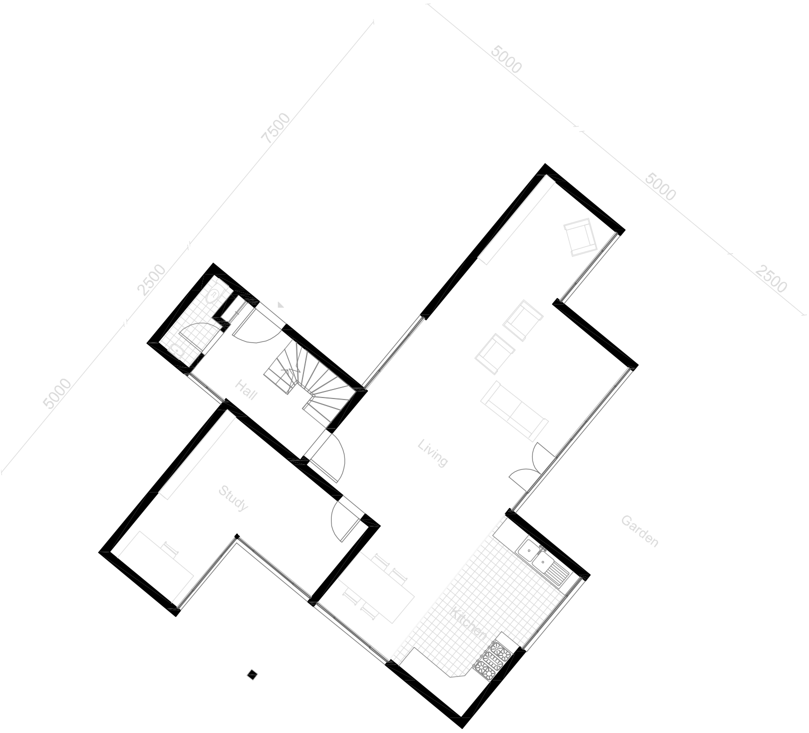
Elaboration to sketch designs

Four results are chosen to be elaborated further. In choosing these results, differences between the results and the possibilities for the new rules to be applied are considered. The results differ in overall shape; the way in which the second floor is positioned on top of the first floor/ Is it an efficient vertical extension, or do the two levels have very little common cells; different shapes of the generated spaces or the same shapes but in a different configuration. When designing a house without a grammar, these floor plans would probably never be designed in such a way.
The angular and jagged lines are characteristic for this grammar, but whether they contribute to a spatial quality in these homes is yet to be determined. Nonetheless, the diagonally positioned corners from House B for instance, help define the outer space and provide opportunities for a connection between inside and outside. Also, the linearity from House C would probably not be designed this way if not for this grammar. Now this rectangular shape in combination with the shifted rectangular second level rouses my interest.

These plans form the basis for sketch designs. When the results are generated, each space is enclosed by walls. Starting with the sketch design of these results, the walls are removed and the configuration of spaces is perceived as a configuration of functional zones. Due to the distinctive shape created by the grammar, all kinds of corners emerge. Through removing the inner walls, several spatial focus points can be distinguished. Walls are placed to enhance and strengthen these spatial focus points, creating distinctive spaces. From these new basis plans, the four designs are elaborated to sketch designs.

House A

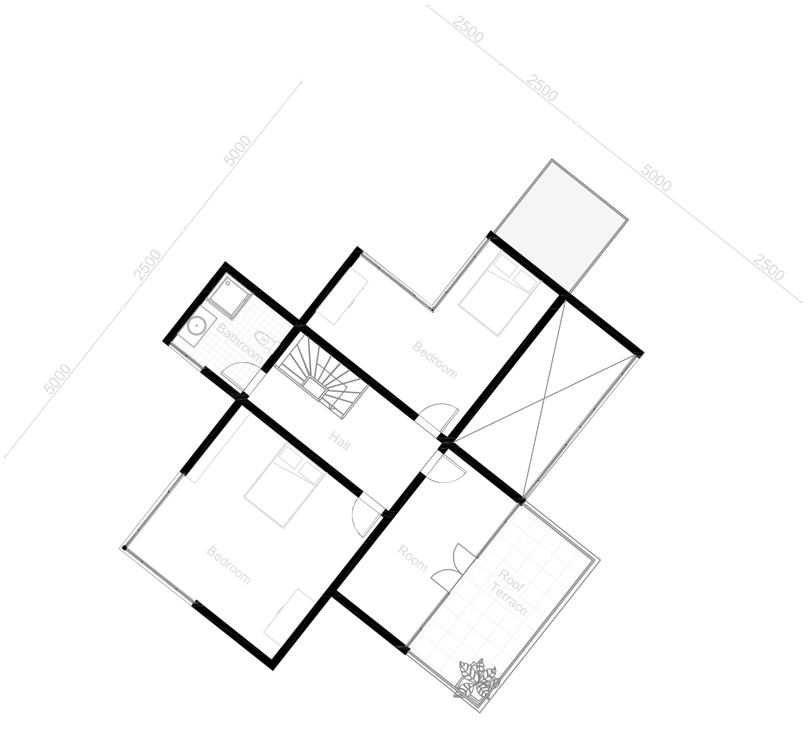
Floor plan: level 0



The predetermined rules for the positioning of the stairs has been discarded. The strategically placed walls and windows ensure a connection to the garden as well as enclosed corners to retreat or just sit and read a book.

House A

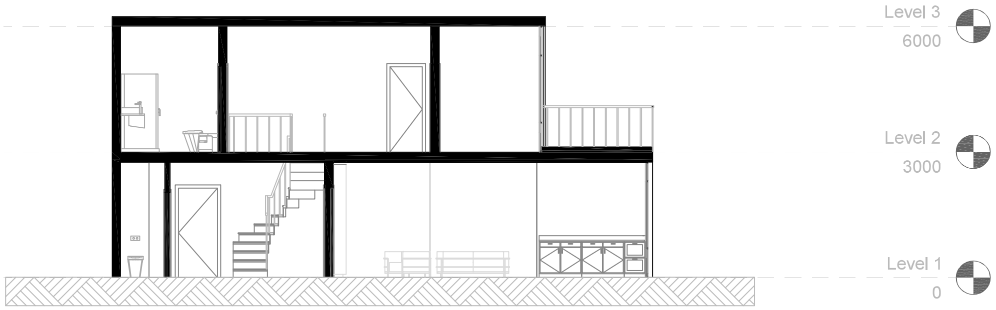
Floor plan: level 1

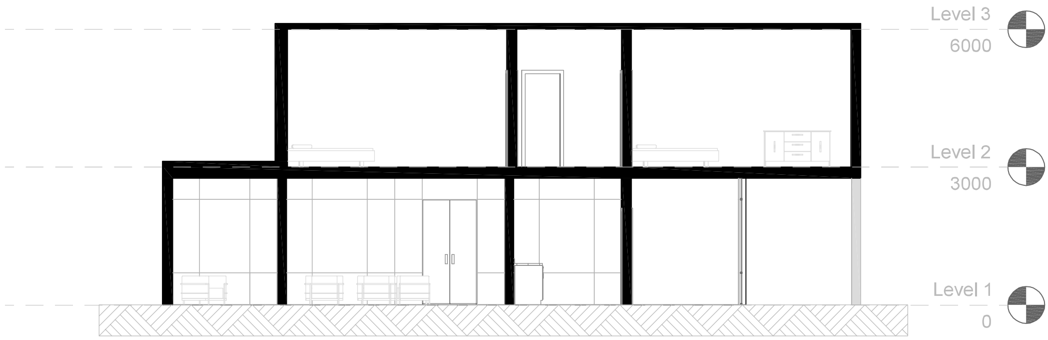


The rules for the void of the living room and the roof terrace have been taken into account. Whether or not a void can be made depends on the availability of the cells directly above and on the possibilities for the adjacent rooms to receive daylight. The bedroom bordering the void has another side whence it can acquire daylight, which makes this void possible. The location of the roof terrace has been decisive in allowing this rule. A connection to the garden is desirable, which is why the rule for creating a roof terrace is used in this design.

House A

Section AA’





House A

Elevations

North

East

South

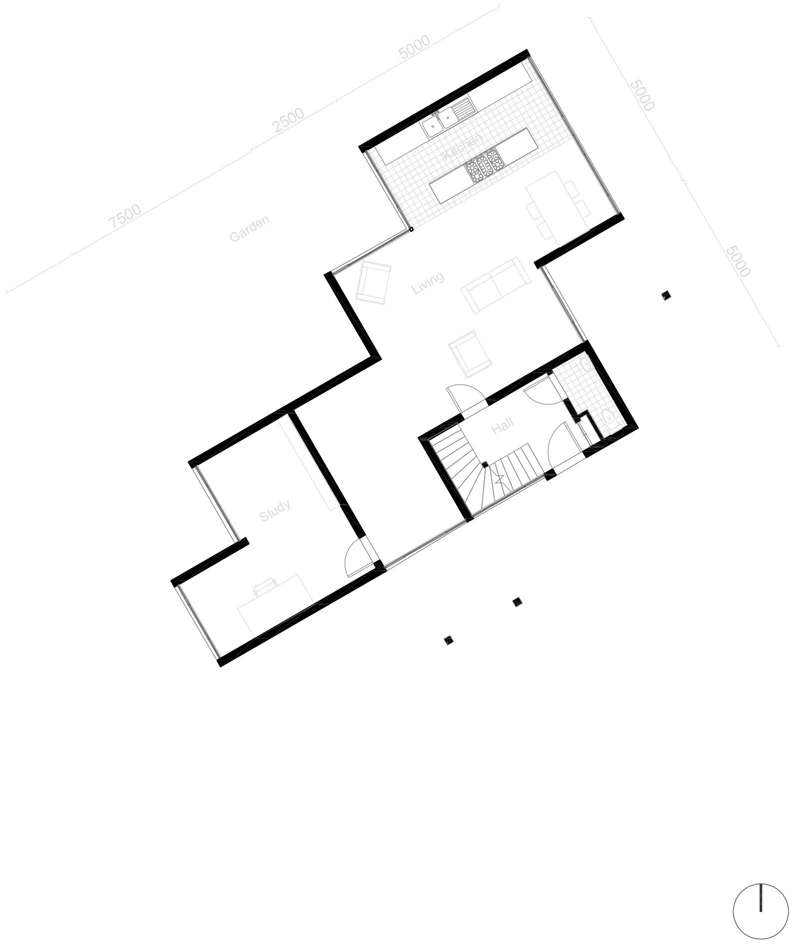
West

House A

Impressions

House B

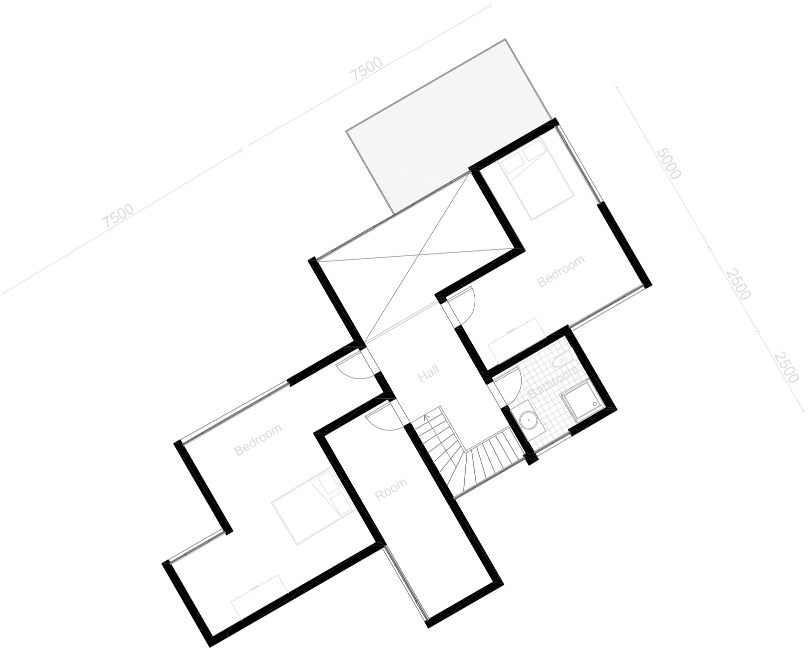
Floor plan: level 0



The predetermined rules for the positioning of the stairs have again been discarded. The configuration and placement of walls connect the living room with the kitchen, placing the focus point of the space on the border of these two functions. The study, located on the other side of the house, is very secluded, making it suitable to retreat and work or study. However, as a result, the space between the study and the hall is now undefined.

House B

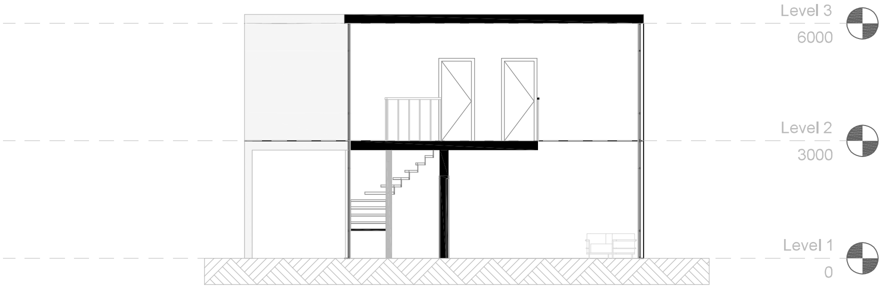
Floor plan: level 1

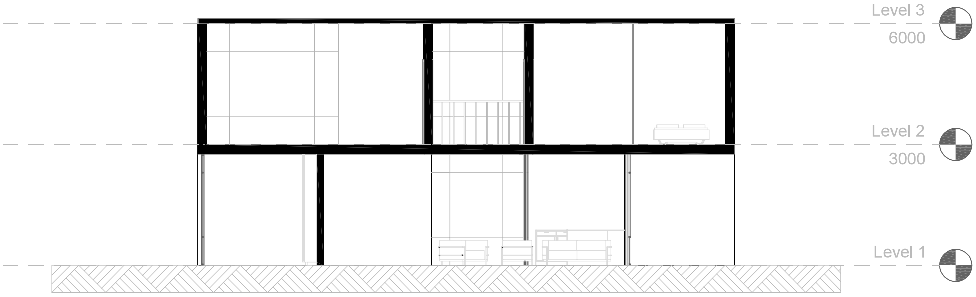


Again the rules for the void have been applied, and in this case there is a connection between the upstairs hallway and the living room. Despite the suitable location for a roof terrace connected to the garden, these rules have not been used due to the connection of the roof with the glass facade of the void, and the shape of the bedroom.

House B

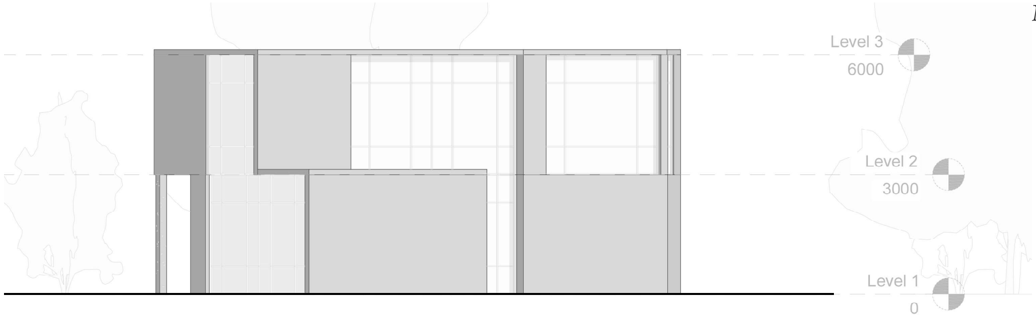
Section AA' & Section BB'



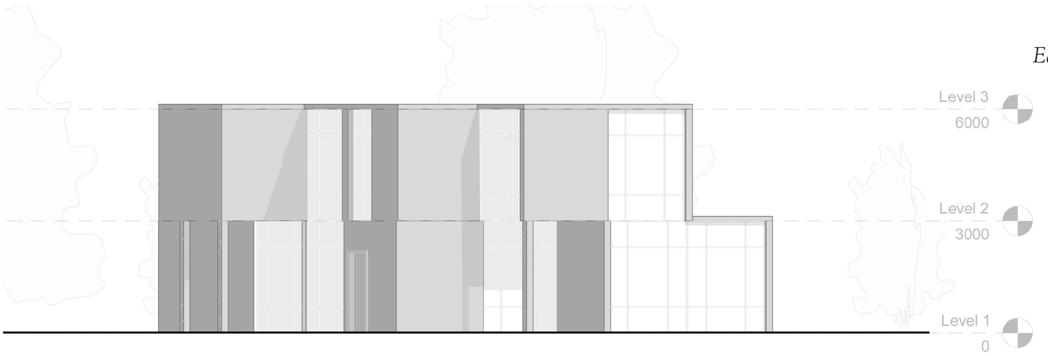


House B

Elevations

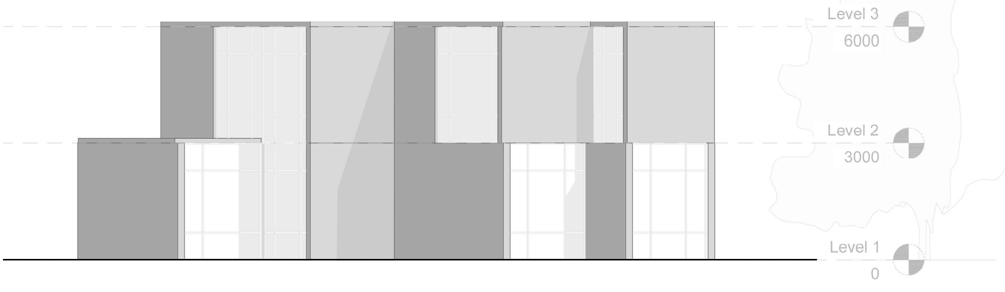


North



East

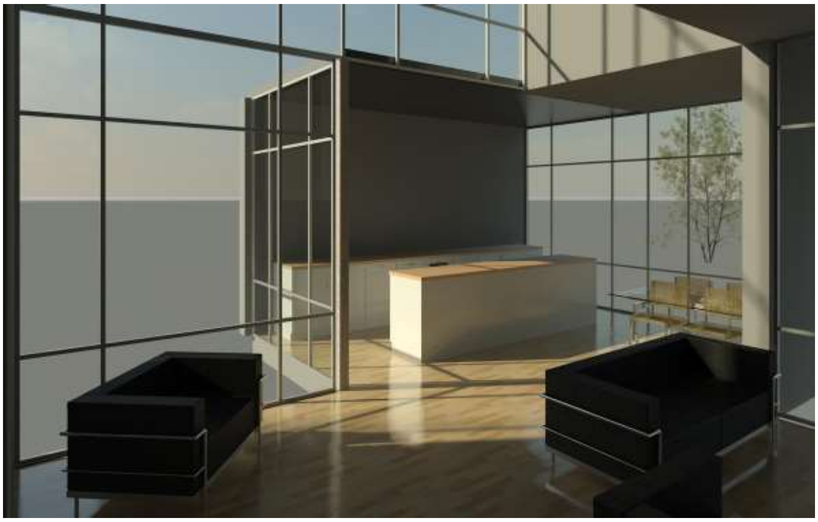
South



West

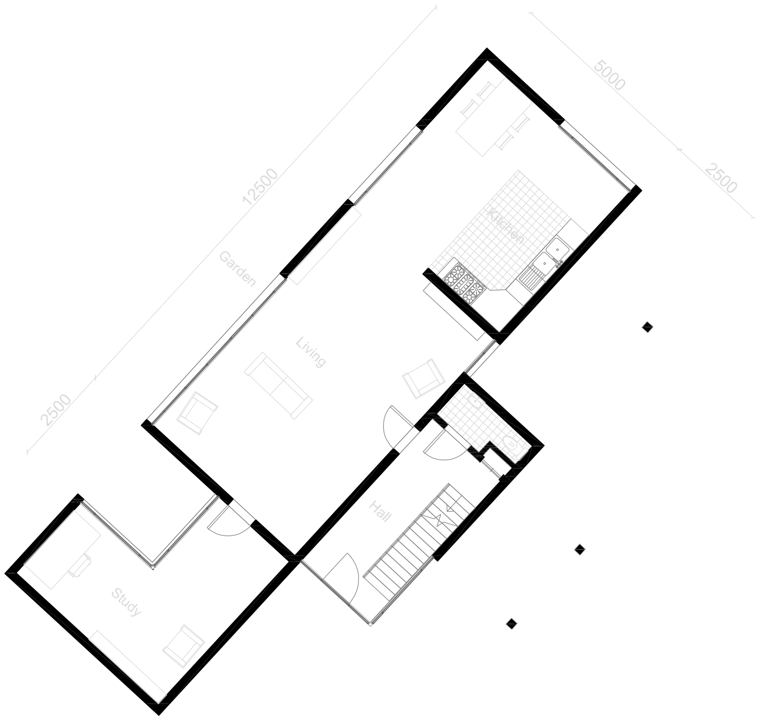
House B

Impressions



House C

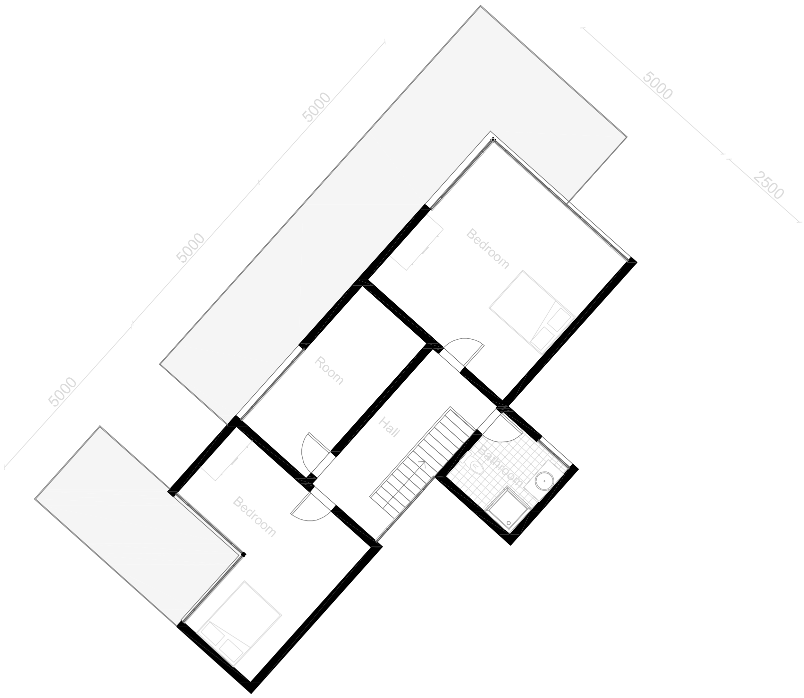
Floor plan: level 0



Where the characteristic jagged corners added to the definition of the spaces, the linearity in this plan provides a more straight-forward space. Strategically placed walls and windows help define the living room and kitchen.

House C

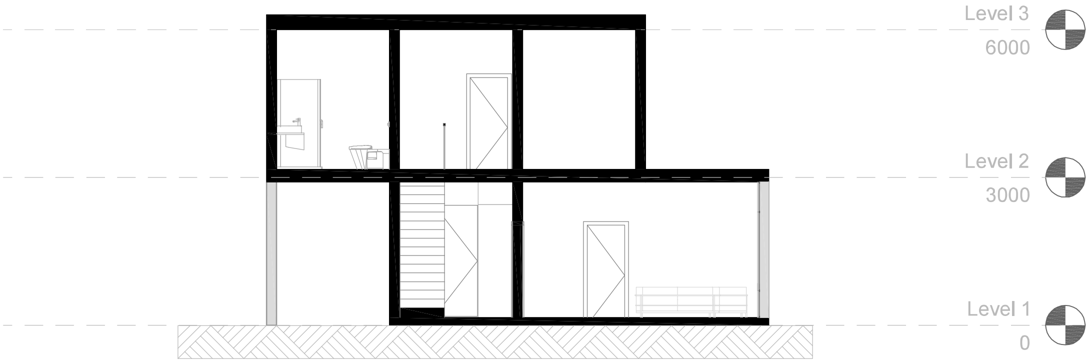
Floor plan: level 1

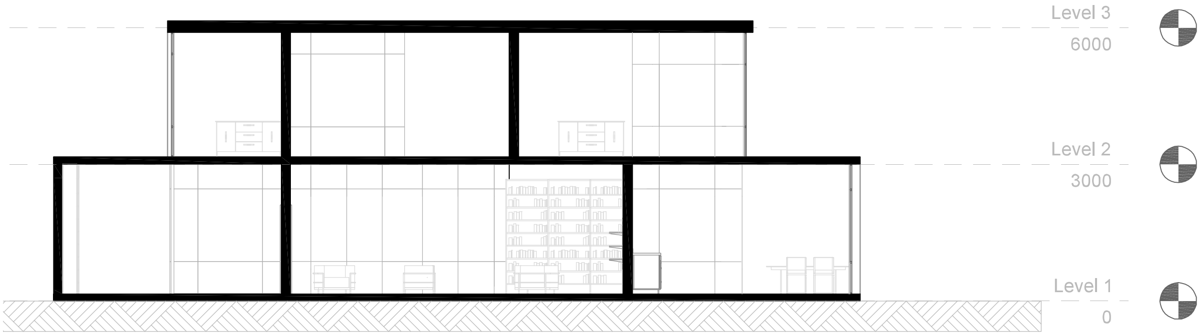


In this plan, a void could have been placed against the outer north wall, however regarded from the ground level, the ideal place would be adjacent to the spare room. Obviously, this room preferably receives daylight, discarding that option. Additionally, the morphology of the house with its two shifted linear floors is one of its strengths. This is impaired by extending the living room to the second level to create a void.

House C

Section AA' & Section BB'





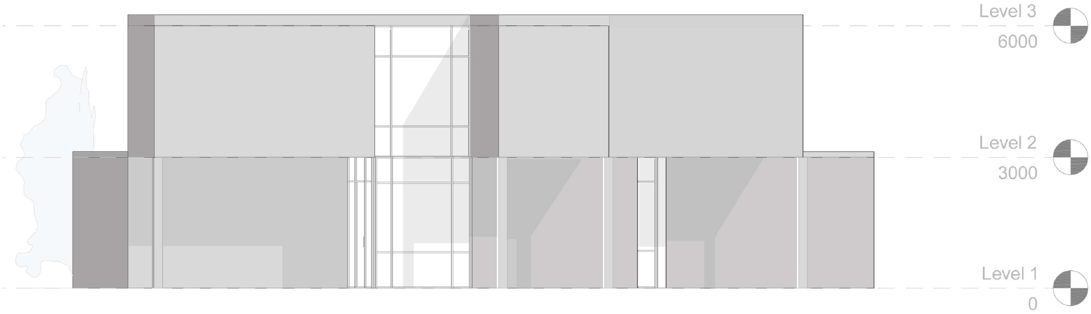
House C

Elevations

North

East

West



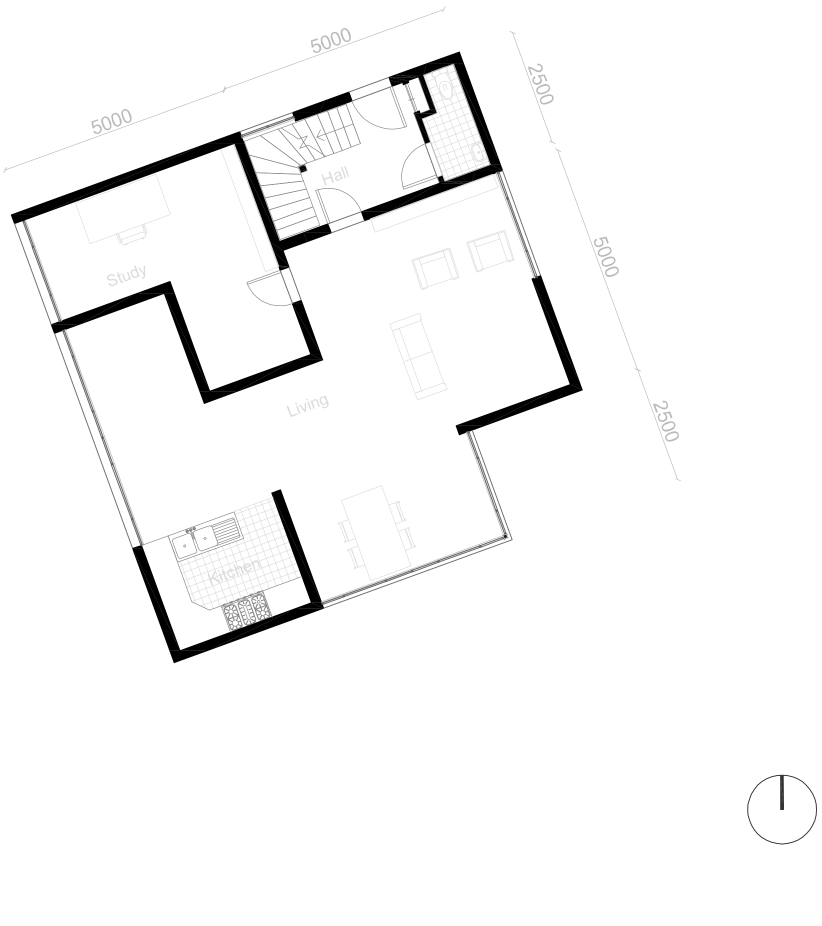
South

House C

Impressions

House D

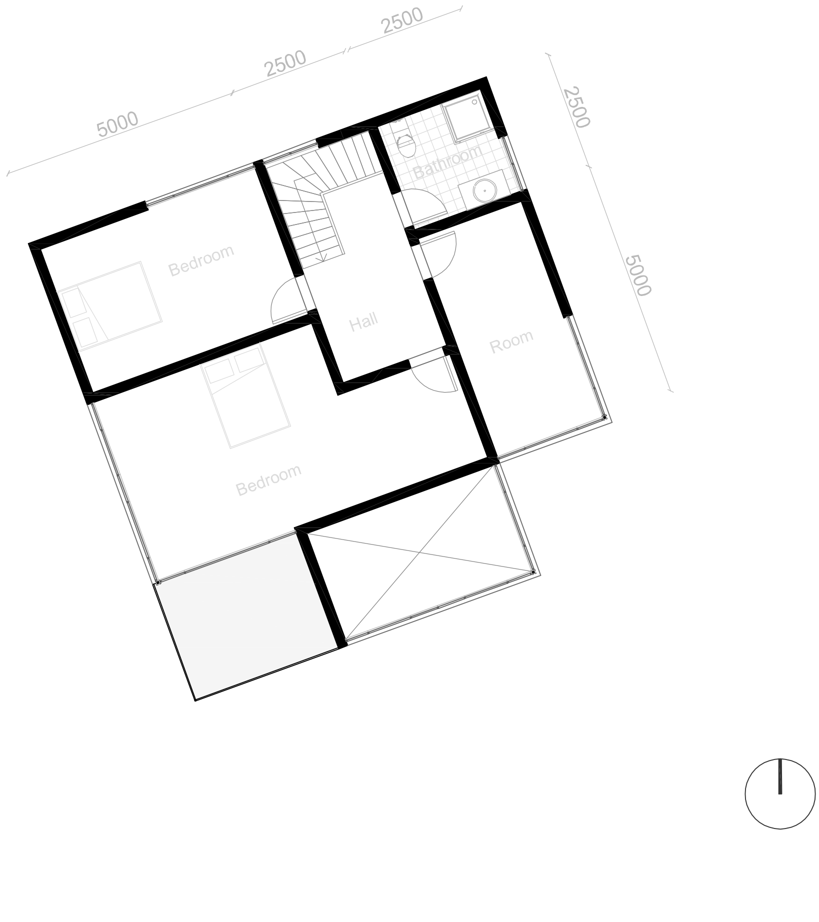
Floor plan: level 0



The approach to let the outer shape define the spatial focus in the plan does not really apply here. When removing all inner walls, the remaining space is a square, which is the only spatial focus. However, it is preferable to keep the walls from the study to ensure a quiet, secluded working space. In addition, the walls from the hallway are also preferably kept, to form a buffer between the entrance of the house and the privacy of your living room. When placing these walls, the square shape has completely disappeared. However, with the walls of the study and hallway placed, this shape forms a new base for the same strategy, which resulted in this plan.

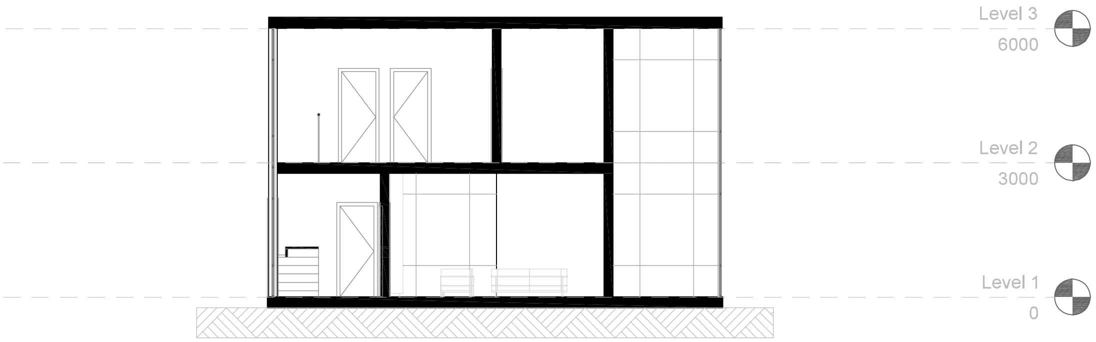
House D

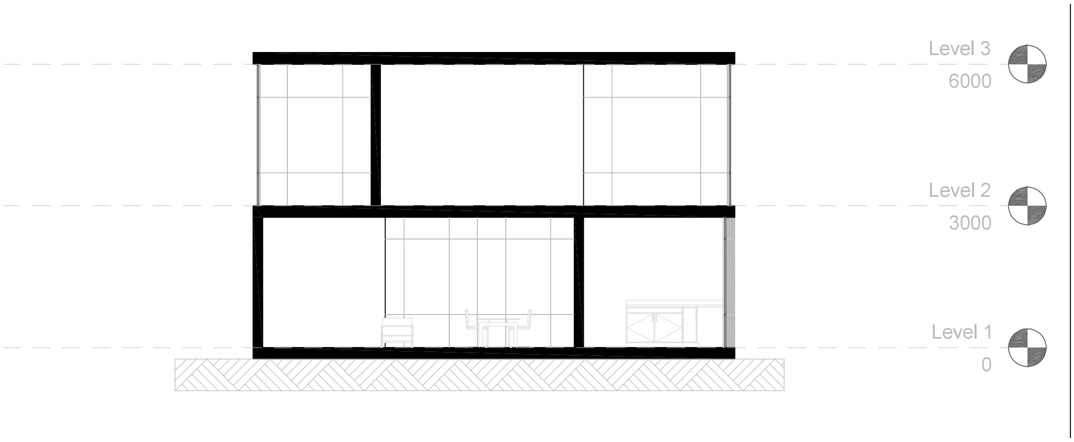
Floor plan: level 1



House D

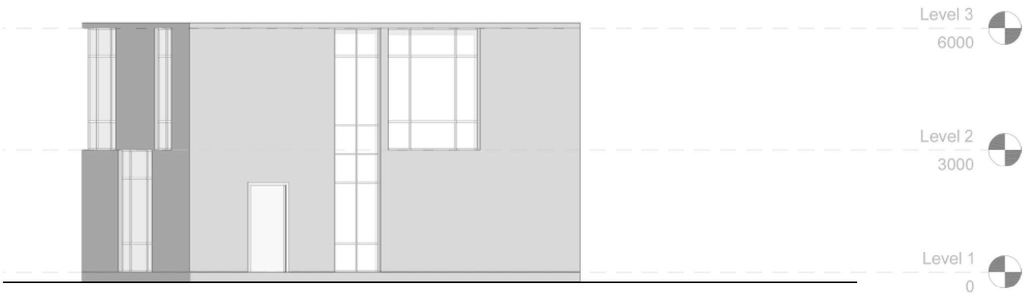
Section AA' & Section BB'



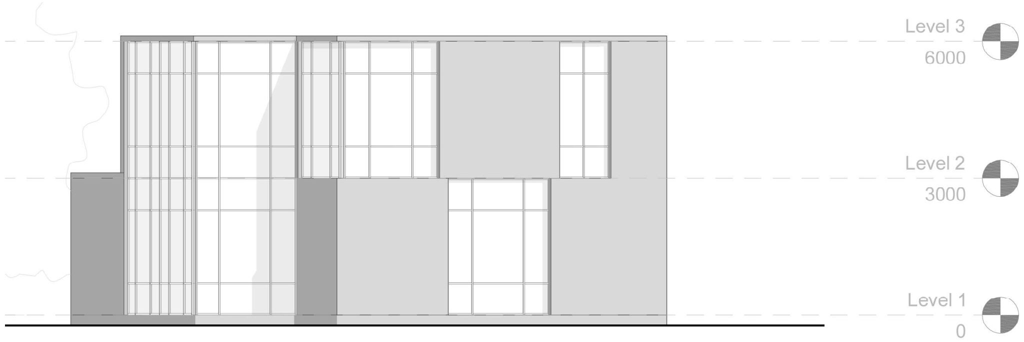


House D

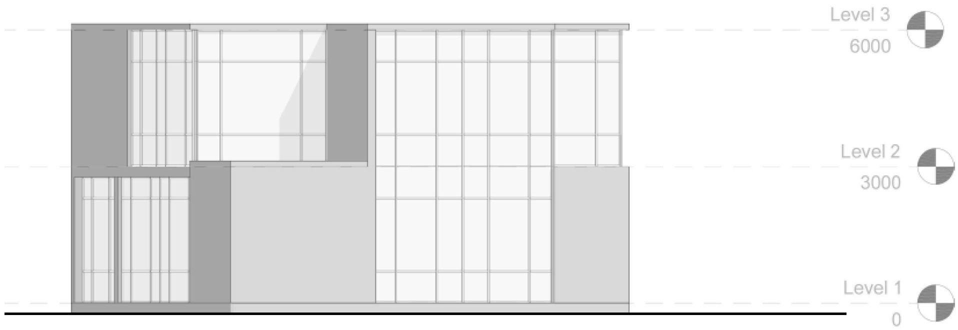
Elevations



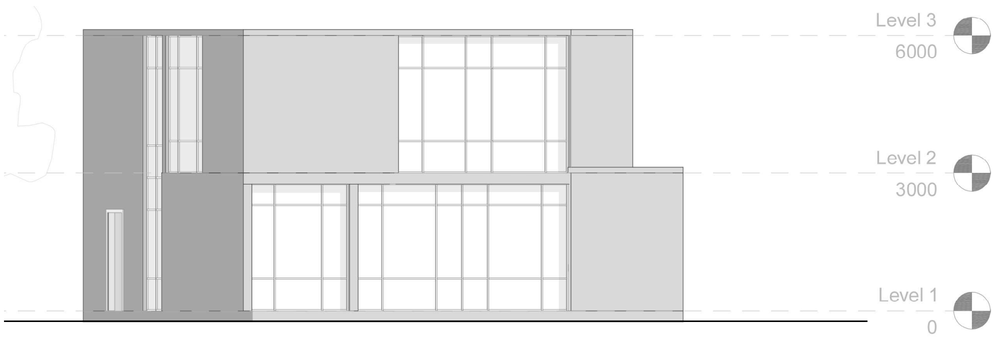
North



East



West



South

House D

Impressions

The Interpreter

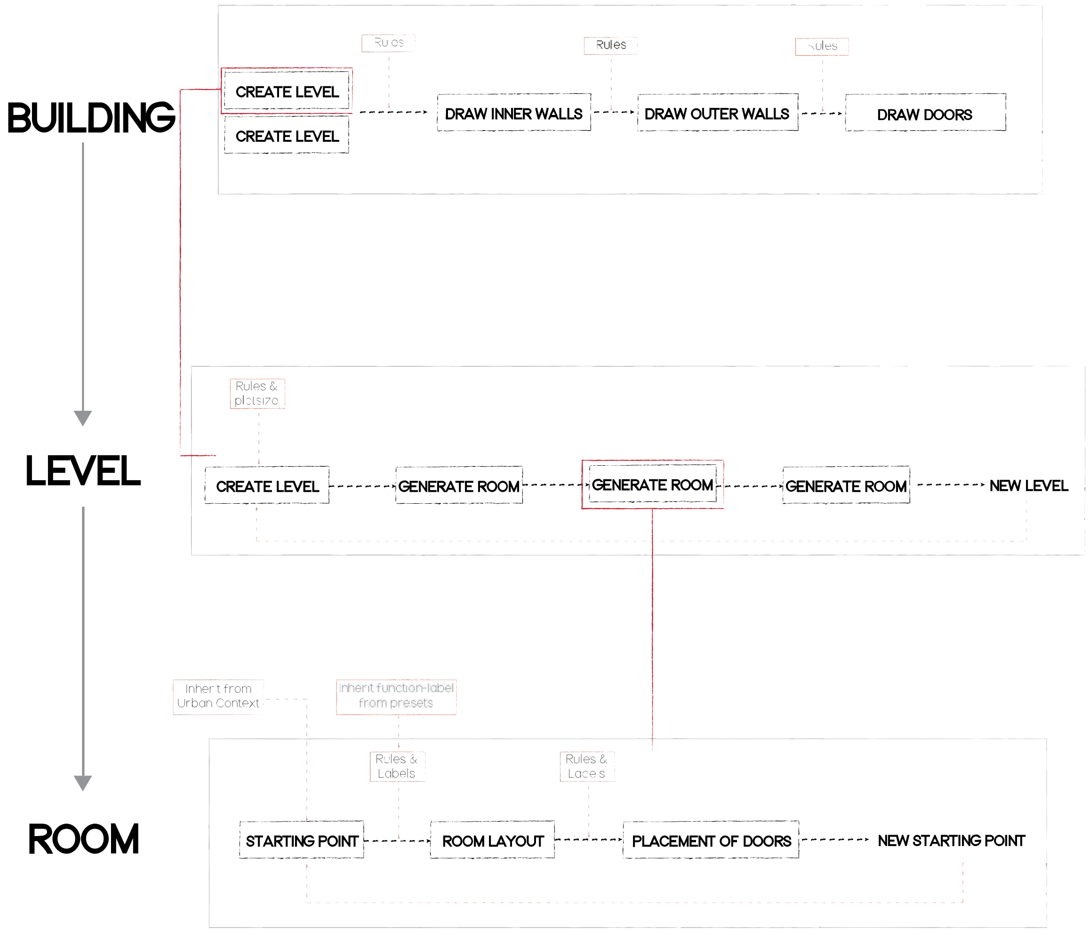


Fig 54. Interpreter structure

Introduction

The interpreter

A shape grammar is often accompanied by a computer program, or a so-called 'interpreter', that is capable of recognizing and transforming the shapes according to the rules of the grammar. Although such a program or an interpreter is not a necessary part of a shape grammar, it is a valuable addition. Using a computer to generate the solutions provides much more results in a significantly smaller amount of time. Creating an interpreter also ensures the accuracy of your rules: a computer does exactly what you tell him to do, nothing more and nothing less, there is no cheating or skipping steps to reach the solution you desire.

In this chapter, the interpreter created for this grammar will be described. The representation of the grid in the interpreter and how the recognition of shapes is ensured will be discussed, as are the differences in approach and structure between the grammar itself and the interpreter.

The interpreter structure

The structure of the interpreter is the same as the grammar itself. The order of creating floors and spaces remains. To execute the rules and create the spaces a different approach is used.

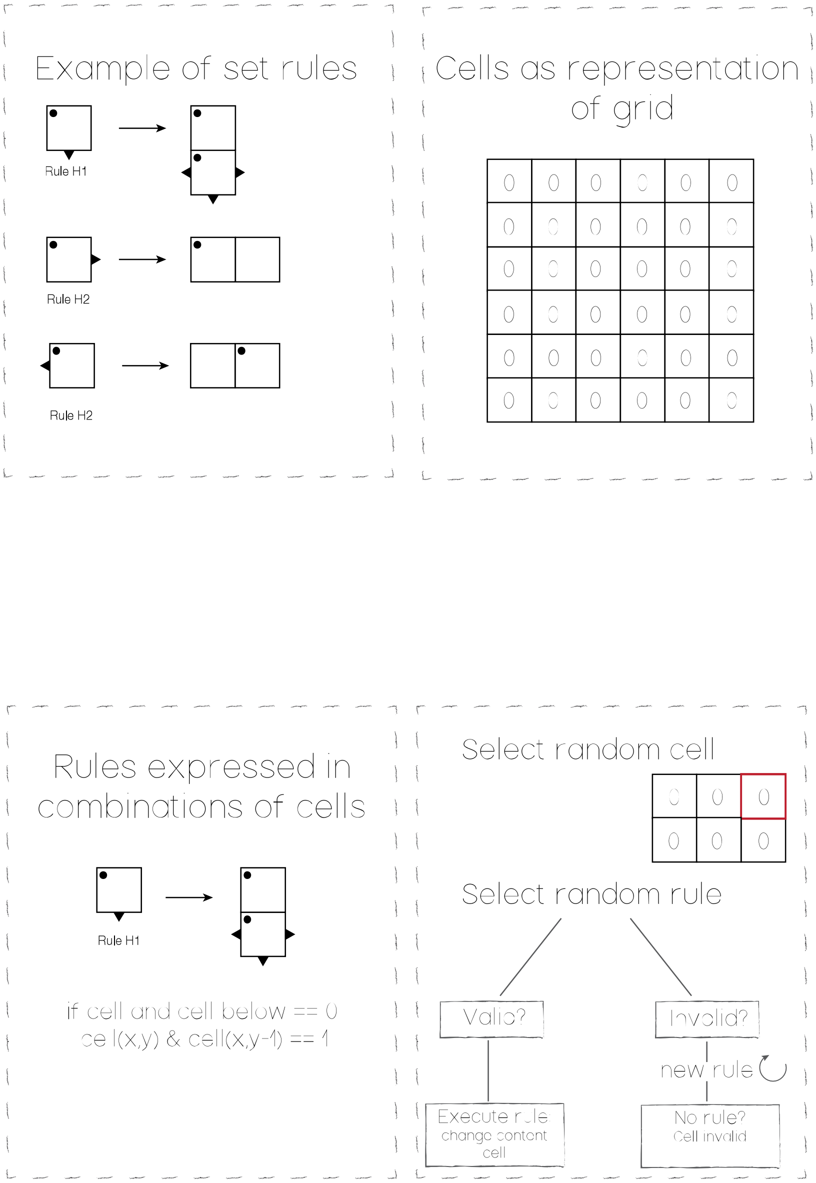


Fig 55. Representation of rules in the script

From grammar to interpreter

The manner in which the shapes are represented in the interpreter is of significant importance. The interpreter should be able to recognize the shapes easily, but the shapes should also be able to contain information on functions and a relation between different shapes and functions.

This interpreter works based on a grid of cells, where each cell has a x-y location and a content, similar to a table. Each cell in this grid is a representation of a grid-cell of the grammar. As previously stated, each cell has a content. This content tells you to which shape a cell belongs.

In a grid grammar, the rules are basically expressions of combination of cells. In the starting situation, each cell has a value of zero. For a rule to be executed, a certain condition has to be met. When a cell is chosen for a rule to be applied to, it is first checked whether these conditions are truly met, for instance if an adjacent cell is available for a transformation.

The order in which the spaces on a level are created is predetermined. The starting space is always the hall. Its starting point is given, derived from the context. This starting point is the first cell on which a rule can be applied. Due to the spatial demands of the particular space, a set of rules is available for this space to be generated. Starting with the first cell, one of the rules is chosen and applied, assuming all required conditions are met. Once the end-condition of a space is reached, the space is finished. If there is a new space starting from the created space, every surrounding cell are gathered in a list, from which the starting cell of the adjacent space will be chosen. After every space is created, the spaces are drawn.

Learnings

Learning from creating a shape grammar

When I first came in contact with the concept of shape grammars in an earlier project, a grammar not of a language of words but of a language of design, I was intrigued. Seeing the Palladian villas, you realize they are connected through a similar style or design language, but the idea of a set of rules, a grammar, that you can apply to create new designs in that same language roused my interest. Now, as was previously mentioned, Shape Grammars were initially invented by Stiny and Gips (1972) with the intention of use in both an analytic nature as well as a design nature. The use of Shape Grammars in an analytical context has been widely and more thoroughly researched. Using the design of a Shape Grammar as a design method has proved to be more challenging. The aim of this project was to research how shape grammars could be used, not as an analytical tool, but as a method of design. In other words, how the architectural design process is translated to the process of creating a shape grammar. In order to do this, I attempted to create a shape grammar through design myself. During this process, I encountered numerous obstacles and problems, which offered insight into the process of designing a shape grammar, used as a design method. This chapter describes these obstacles, providing a better understanding of the process and how to approach it.

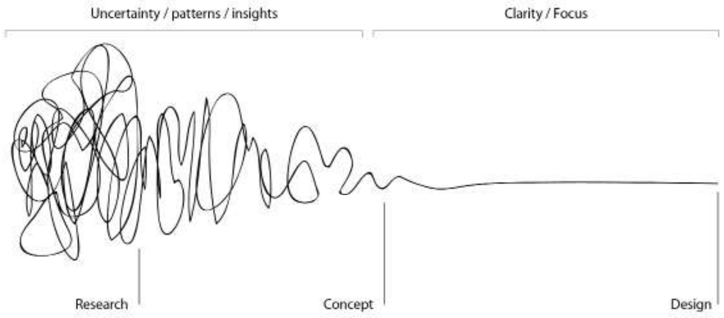
The grammar of a language teaches us the rules and structure of a language. It tells us how to construct a sentence. But what does a Shape Grammar tell us about the design language it is supposed to represent? What information do we gain by using shape grammars? Remarkable is the fact that in the abundance of articles written on this topic, only a few argument the reason or purpose for using Shape Grammars. Argued is that using Shape Grammars "can be used for educational purposes to better understand structure and composition" and "it helps us to discover principles behind the design" (Trescak, Rodriguez & Esteva, 2009) or that they "reveal general strategies and create a knowledge base for understanding particular architect's compositions." (Tepavčević, Stojaković 2012) What exactly do we understand about the designs?

These arguments remain vague, However, apparently this explanation is adequately satisfying and the focus in the majority of the articles is on the capabilities and possibilities of the grammar instead of the value of the grammar in its use. The rules of a Shape Grammar often are only small fragments that are meaningless outside their context of the whole grammar, they become unreadable as insight into style or language. The transformation of one single shape is insignificant in the sequence of the generation of an entire design. However, in the process of creating the grammar it is much easier to see the connection between one single rule and its place in the whole of the grammar. So the process of creating the grammar offers a great deal more information and understanding than studying a completed shape grammar.

To comprehend what information of a design language a shape grammar represents in its rules is key to designing a shape grammar. What do the rules of a shape grammar tell us about the style or design language of the designs? There is one shape grammar that describes not one but three different styles. They believe that a grammar does not "fail its descriptive, analytical, and synthetic purposes" when it is not exclusive of a particular style. (Benrós, Hanna & Duarte, 2012) But how can a grammar describe multiple design languages? This depends on how you interpret the word 'grammar'. What does a grammar represent in the case of a design language? It is easy to use the grammar we know from our language of speech. However, architecture is very different and incomparable to language. In architecture, we often speak of a certain 'style'. A frequent occurring description of style is as follows: "An architectural style is characterized by the features that make a building or other structure notable or historically identifiable. A style may include such elements as form, method of construction, building materials, and regional character." (Juarez, 2015 or Wikipedia) J. Michael Gerzso describes similarities between language and architecture. For instance: in language, it is clear what the units of a sentence are, and how they constitute a sentence.

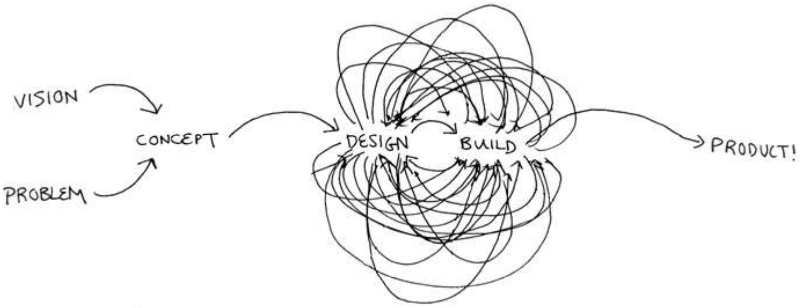
In architecture, it is also clear what the units of a building are and how they constitute a building. As to the meaning of a sentence, it is often apparent what a sentence means, and again, in architecture, a building has "meaning", however it has meaning in an entirely different manner. Last, when groups of sentences have recurrent syntactic patterns, they are referred to as a language. In architecture, some groups of buildings have recurrent patterns and are referred to as having a similar architecture or style. (Gerzso, J.M. 2003) The grammar of a language does not describe style. However, when using a language in a particular way, patterns are created which offers a sense of style. (Emdanat & Vakalo, 1996) Which underlying architectural structure could be captured in the rules of a shape grammar remains difficult to determine. Perhaps these rules are just a sequence of transformations, eventually leading to a design, multiple designs.

Although it seems unlikely that the rules of a shape grammar teach us something about a design language or style of a building, researchers claim that working with shape grammars, developing grammars, proves to be valuable. (Knight, 1991) According to Terry Knight, "The process of developing, or designing, a grammar is no different and no less creative, thoughtful, or challenging than any other design process—it involves numerous changes and refinements, guesswork, and imagination. The more knowledge a designer has about grammars—in particular, the behaviour of rules, how rules may be changed, the consequences of such changes, the differences and similarities between different grammars—the more likely it is that an interesting and productive grammar will be achieved in a reasonable amount of time." – T.W. Knight, in Shape Grammars: Six Types (Environment and Planning B – Planning and Design volume 26, pp. 15-31) The process of analysing a series of buildings offers you much knowledge about the designs you are analysing. Through dissecting every shape and space, comparing the existing designs in order for you to derive your rules from recurring spatial patterns or similarities, you familiarize yourself greatly with the designs. However, when you create an original shape grammar, i.e. not a grammar based on the analysis of existing designs, the formulation of rules is more challenging. There are several problems in the formulation of an original grammar. Firstly, in order to the capture an underlying structure of a design, this structure obviously needs to be present in the design. In the early stages of a design process, this is often not the case. The design process is often quite the opposite of structured. One could say that there is a certain structure present in the form of different stages in the design



process: a problem is introduced and you start collecting information. You analyse this newfound knowledge and start brainstorming about possible approaches towards a solution. When a suitable approach is chosen, the careful elaboration of this approach leads towards a beginning development of a design. You sketch, make models, whichever way suits you best, and try to find the right way to apply your analysed approach in a sketch design in order to solve the problem at hand. When you are stuck, you go back a few steps and try to revise your chosen approach with the information you gained during the elaboration of your sketch-design. This process of zooming in and out during the design process continues constantly. However, within the boundaries of this general structure, every architect works in his own way.

Fig 56. Representation of the design process



But however the design is conceived, there are often many aspects or details that fall into place further along in the design process, creating a solid general structure in the design. This makes it difficult to translate a design process into the process of creating a shape grammar, which could be considered a description of an existing structure. Secondly, every rule in a shape grammar holds explicit information. This could be seen as one of the qualities of designing with shape grammars: you need to explicate your design intentions. If something is missing in your designs, it is because it was not in the rules. The more explicit your design intentions are, the easier they can be investigated, revised and adjusted. However, in the beginning of your design process, your intentions are still being formed and developed. As an approach to this problem, you could first develop your design to a certain level of detail, where you have a better understanding of what your design intentions are, and how to explicate them in rules. However, you would first be designing and then analysing your own plans, which makes it resemble an analytical approach for a grammar rather than using the creation of a shape grammar as a method of design. The third problem is starting with your rules. In the creation of the grammar in this graduation project, this proved to be a very challenging part. How do you begin? Where do you begin? How do you decide what the first shapes are, the first transformations of these shapes? You need to determine what kind of grammar you wish to use. There are different kinds, as discussed in the beginning of the book. The choice

Fig 57. Representation of the design process of grammar influenced how you make your rules. However, you do not need to restrict yourself to one type of grammar. There are cases where a combination of rule-systems is applied to maintain a higher level of freedom in designing. (N.M. Verkerk, 2014) And then you begin, focused on transformations in accordance with your grammar-type. In the case of this project, this was a trial and error method. Start exploring with shapes and rules, spatial relations or transformations. Try to find something that inspires you, patterns, shapes, anything, and just start trying. In a 'normal' design project, what are the first lines you draw based on? You try to find inspiration or guidance, from the project location or other projects, and then you start sketching and trying, and possibly (probably) failing and trying again. What makes this process more complicated is that it is harder to imagine the possibilities of your results in the first stages of rule-creation, or how your results relate to the aims and goals of your project. They are but fragments and it takes some time and effort to get to a point where you can compare your results to something architectural.

The part where you go from abstract shape transformations and relations to form a connection to your project assignment is necessary but tricky. Knight claims "At some point in the process of developing a grammar -- if not at the start – a connection must be made between rules that describe spatial form, and the goals of a project that may describe anything from function to meaning to aesthetics and so on. Making this connection is not an easy task because shape grammars are in general unpredictable. Seemingly simple rules can produce surprisingly complex results." (Knight, 1999) Once you have managed to make this connection, the process gets relatively easier, you have a new focus: trying to implement the specifics of the project assignment in your rules. Eventually, you want your grammar to only generate results that comply with your intentions. The more confined and framed your rules and results are, the better your grammar.

Duarte states: "Shape grammars are simultaneously descriptive and generative and so they can be used as an analytical tool to describe the formal structure of a corpus of existing designs, to determine whether other designs are in the same language, and to explain how to generate new designs. They can also be used as a synthetic tool to create new languages of design. In both cases they facilitate the automatic generation of designs." (Duarte & Beirão, 2010) However, in order to really benefit from this asset of using shape grammars, an 'interpreter' proves to be convenient. An interpreter is a tool, or program, that provides the automatic generation of the designs of your shape grammar. This contributes to many results in a small amount of time. This abundance of results offers the possibility of choosing between different results, which is valuable. The process of evaluating the various results forces you to consider your intentions. In constantly reviewing your results and comparing them to your intentions, the extend of your rules becomes more evident. The design process of creating a shape grammar requires you to consider architecture from a different perspective.

Another advantage from using a shape grammar interpreter, is that it will only produce valid results. If the results are invalid, it means that your rules are invalid, or lacking. A shape grammar is capable of objectively considering every possibility constructed within the boundaries of the given rules. In my opinion, architects, or human beings for that matter, will always have a preference. This preference, consciously or unconsciously, is derived from years of experience, or perhaps just personal taste. This conscious or unconscious preference, or maybe it is just our instinct, causes us to reject some possibilities immediately. This is often a good thing, since we recognize a bad result straightaway, for instance a space that would be too small and too long to be comfortable. However, it is possible that results that seem unfit at first could lead to a valuable and good design in a way we could not have expected. Through using a shape grammar, these results would never be falsely discarded, provided that they meet the requirements of the specified rules.

Considering this property of shape grammars, there can be two different objectives when using shape grammars as a design tool or method. When wanting to fully exploit the potential of the asset of unbiased results, you want to have as insignificant rules as possible. The results of the grammar offer a mere incentive for possible solutions that one could not have thought of himself. The preconceptions we have obtained through study, tradition or personality, impede our ability to review results equally objectively. When one uses a grammar with the objective of being an unbiased design generator, an incentive, it becomes a doodle, or a sketch.

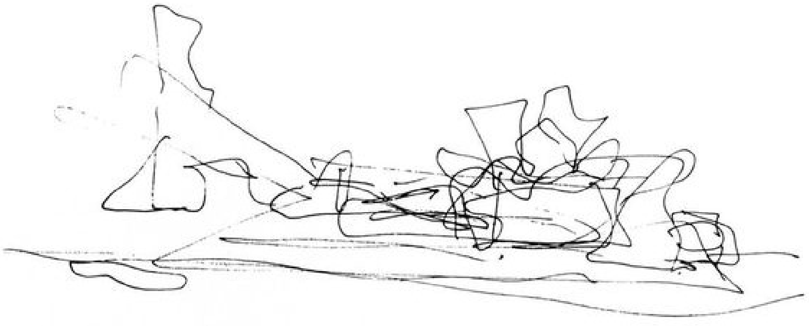


Fig 58. Concept sketch of the Bilbao Guggenheim by Frank Gehry

Once you are inspired by the results created by the very few rules you determined, you, as the architect, take over the design task. Naturally, you always have the ability to take over the design process when you disagree with the results, or if they are disappointing or unsatisfactory. Nobody forces you to keep inventing new rules when you just want to finish the designs yourself, or to keep everything in the finished results from the grammar. As the architect, you have every right to change every bit you disapprove of. These changes could be accommodated in new rules, but that is not required.

Another objective for creating a shape grammar is to aim towards a specifically characterized set of results. In this case, the rules need to be carefully chosen. One needs to have a very clear design goal in mind from the beginning. An example of such a design project, is Alvaro Siza's mass-housing project in Malagueira, Portugal. Duarte created a shape grammar on these designs, however Siza developed this plan with generative characteristics for the design of 1200 dwellings. He laid the groundwork and more than thirty-five layouts were designed. However, despite the potential of Siza's design system, it proved difficult to carry out. The designers working for Siza had trouble understanding and following his rules since they were never explicitly determined. Despite of its generative nature, Siza's potential to customize these dwellings on such a large scale was never fully reached. When Duarte made the Malagueira House Grammar based on Siza's designs, he succeeded in translating the generative design system into a shape grammar. All of Siza's intended rules were implemented in the grammar, which is extremely detailed.

Conclusion

Conclusion

This project investigated the use of shape grammars as a method of design. Since the introduction of shape grammars in 1972 for both analysis and design, mainly analytical grammars were studied. It is difficult to create an original shape grammar, because you have no clear end-point and everything is possible. When you create an analytical shape grammar, you do not have a series of buildings within the same style to base your grammar on and thus a clear end-point.

In order to relate the architectural design process to the process of designing a new and original shape grammar, I created an original grammar myself. First, I familiarized myself with the basics of shape grammars and studied three analytical grammars: The Palladian Grammar (Stiny & Mitchell, 1978), The Prairie House Grammar (Koning & Eizenberg, 1981) and the Malagueira House Grammar (Duarte, 2001). Based on the general understanding of shape grammars developed through this research, I chose the grid-grammar used in the Palladian grammar as a grammar-type for this project. I wanted to experiment with using the creation process of the grammar as a design strategy and let the results trigger me. The strong generative properties of the grid-grammar as well as the variation possibilities of the grid-size increase its originality, motivated me to choose this type for my grammar.

I formulated an assignment in the form of a mass-housing project to frame and support the design of my grammar. This assignment was drafted with the intention of creating a grammar with defined and elaborated rules, capable of generating results of architectural quality. However, I also wanted to exploit the fact that a shape grammar generates results impartial and unprejudiced, providing an opportunity to surprise you with the results, possibly creating results that you would never have come up with yourself. In this case, you want to confine the rules as little as possible and avoid using detailed and specific rules. During the process of this project, I did not realize that I was working towards to different and very contradictory goals. This ambiguity made it difficult to form rules for the grammar.

As previously stated, I wanted to experiment with using the creation process of the grammar as a design strategy and let the results trigger me and refine the rules through a process of trial and error. I tried to design in rules to ensure that it would not become an analytical grammar. This has kept me from defining a clear architectural vision for the houses to be created, which also complicates the formulation of rules.

This research started with the question:

"How does the architectural design process translate into the course of developing a shape grammar?"

There is no definite answer to this question. However, through the course of this project, I developed an understanding of the process of creating a shape grammar and have determined several recommendations for the approach of designing an original shape grammar:

- In order to design with shape grammars, you need to familiarize yourself with the general theory to develop a certain affinity for this subject. It takes time before you get accustomed to the techniques and develop a finesse for working with them;

- Determine your goal: why do you want to use shape grammars? What aspects of its generative properties are most important in your project? A clear goal and thus how you wish to use the shape grammar makes it easier to evaluate your results;

- A shape grammar is basically a description of a structure. In the process of creating a design using shape grammars, you need to design in a conventional way. Develop a clear vision for your architecture. Once you have established this, analyse your designs and define your underlying structure or system. Then try to translate this into rules.

- Starting the process is challenging. Try to find something that inspires you, patterns, shapes, anything, and just start trying. Experiment with spatial compositions.

- Making the transition from experimenting with abstract shapes and rules regarding their transformation to results representing architectural designs with a specific program is a difficult part of the process. Forming clear design intentions can help with this transition.

Even with these suggestions, it remains a challenging process because it is very different from what we are used to. But that is also exactly what makes it valuable. It challenges you to approach the design process and architecture from a different perspective.

Reflection

In the preface, this research is introduced as an attempt to create a grammar. This is exactly what it is. When looking at the created grammar, it is just a small beginning of a grammar. A lot of thought is put into the structure of this grammar: where can I derive information from, what kind of information can help frame the grammar without impairing the generative possibilities. This resulted in a structure of contextual, morphological and typological input from the location and users. The possibilities that this system provides, have not nearly been exploited, or even used. It did help in providing a framework for developing rules or constraints. The process of developing a feeling for shape grammars and trying to fully understand what designing with shape grammar entails, took a lot of time. As regards to the subject of shape grammars, my feeling has been ambiguous from the start. On the one hand, I was intrigued by the idea of a grammar describing a design language, an underlying structure declaring what 'style' represents. On the other hand, I have always been sceptical towards shape grammars, and how to design without analysing a series of buildings you already know has a structure. But this ambiguity resulted in an interesting process, a continuous inner-battle and compelling discussions. The programming of the interpreter for this grammar was also very challenging, but rewarding. Creating such a program requires a different kind of creativity in combination with objectivity which results in an interesting process. From frustrating to exhilarating in a matter of seconds.

Even though I feel that this grammar is far from completed, with basically only four rules that are extremely primitive and superficial, It created results that offer a possibility of promising and interesting designs. In addition, the process, which was actually more important for me than the actual grammar itself, was very enlightening and rewarding. It taught me a different way of looking at designing, using a different approach. Letting go of how I used to handle a problem and formulating an entirely new path to a solution. In finding an answer to my research question, "How does the architectural design process translate into the course of developing a shape grammar?" I have gained a lot of insight in the design process, both for the design of a shape grammar as the 'conventional' design process. Without completing the grammar, for me, the research is complete.

Acknowledgements

I would like to thank my tutors, Maarten and Aant, and fellow students, Stijn, Sander and Marjolein, for the pleasant, amusing and interesting weekly sessions. Thanks to Bauke de Vries, for his sharp questions and refined comments during the presentations. Thank you Lijsterbes, for listening to my babble about programming and support especially in the last weeks.

A special thanks to Moniek, for every cup of coffee, every break and every discussion. You were my outside inside-man and helped me to make this research what it is now.

And lastly, thanks to Erik, for knowing exactly what I needed when I needed it.

Bibliography

Literature

Stiny, G. and Gips,J. "Shape Grammars and the Generative Specification of Painting and Sculpture", in C.V. Freidman, ed., Information Processing 71 (North Holland, Amsterdam, 1972), pp. 1460 – 1465

Stiny, G. "Two exercises in formal composition", Environment and Planning B 3 (1976): 187 – 210

Stiny, G."Introduction to shape and shape grammars", Environment and Planning B7 (1980a): 343 - 351

Stiny, G. "Kindergarten grammars: designing with Froebel's building gifts", Environment and Planning B3 (1980b): 409 – 462

Knight, T.W. "Applications in Architectural Design, and Education and Practice", Report for the NSF/MIT Workshop on Shape Computation (1999)

Stiny. G., Mitchell, W. "The Palladian Grammar", Environment and Planning B5 (1978): 5-18

Duarte, J.P."Towards the mass customization of housing: the grammar of Siza's houses at Malagueira", Environment and Planning B: Planning and Design volume 32 (2005):347 – 380

Koning, H., Eizenberg, J."The language of the prairie: Frank Lloyd Wright's prairie houses", Environment and Planning B8 (1981): 295 –323

Galivanes, J., Mandow, L. , Pérez-de-la-Cruz, J. & Ruiz-Montiel, M. "Shapes, Grammars, Constraints and Policies", SHAPES conference (2011)

Benrós, D., Hanna,S. & Duarte, J.P. "A generic shape grammar for the Palladian Villa, Malagueira House and Prairie House", Design Computing and Cognition DCC'12 (2012)

Knight, T.W. "Shape Grammars: six types", Environment and Planning B: Planning and Design volume 26 (1999): 15 – 31

Knight, T.W. "Shape Grammars: five questions", Environment and Planning B: Planning and Design volume 26 (1999): 477 - 501

Knight, T.W. "Designing with Grammars", CAAD futures Digital Proceedings (1991): 33-48

Verkerk, N.M. "A general understanding of shape grammar for the application in architectural design", Graduation Thesis TU Delft (2014)

Benrós, D., Duarte, J.P. & Hanna, S. "A new Palladian Shape Grammar", International journal of architectural computing (2012): 521 - 540

Knight, T.W. "Applications in Architectural design, education and practice", (1999) Cambridge: Massachusetts Institute of Technology

Stiny, G. "Shape, Talking about Seeing and Doing" (2006), Cambridge, Massachusetts: The MIT Press

Eloy, S. & Duarte, J.P. "Inferring a shape grammar: Translating designer's knowledge", Artificial Intelligence for Engineering Design, Analysis and Manufacturing 28 (2014): 153 - 168

Trescak, T., Rodriguez, I. & Esteva, M. "General shape grammar interpreter for Intelligent Design Generations", Proceedings of the Computer Graphics, Imaging and Visualization conference (CGIV'09), volume 6: 235–240

Emdanat, S.S. & Vakalo, E.G. "Shape Grammars: a critical review and some thoughts", In Design & Decision Support Systems in Architecture. DDSS. Spa, Belgium, (1996)

Tepavcevic, B. & Stojakovic, V. "Shape Grammar in contemporary architectural theory and design", Facta universitatis - series Architecture and Civil Engineering 10(2):169-178 · January 2012

Chase, S.C. "Using logic to specify shapes and spatial relations in design grammars", Workshop Notes, Grammatical design, Fourth International Conference on Artificial Intelligence in Design, Stanford University, USA, 22 June 1996

Duarte, J.P. & Beirao, J.N. " Towards a methodology for flexible urban design: designing with urban patterns and shape grammars", Environment and Planning B: planning and design. (2010)

Liew, H. "Descriptive conventions for shape grammars." ACADIA 2002: thresholds. Proceedings of the 2002 annual conference of ACADIA (2002)

Gerzso, J. M. "On the Limitations of Shape Grammars: Comments on Aaron Fleisher's Article "Grammatical Architecture?" Proceedings of the 2003 Annual Conference of the Association for Computer Aided Design In Architecture (2003): 279-287

Figures

[Frank Lloyd Wrights Prairie House] [Photograph]. (n.d.). Retrieved from http://fmclip.com/frank-lloyd-wright-inspired-house-plans_1/

[Frank Lloyd Wrights Prairie House] [Photograph]. (n.d.). Retrieved from https://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwi7vcWjv8zOAhWFExoKHVzGAacQjxwIAw&url=http%3A%2F%2Fliceocuneo.it%2Fdutto%2Fwp-content%2Fuploads%2Fsites%2F35%2FWRIGHT-in-Word.docx&bvm=bv.129759880,d.d2s&psig=AFQjCNHLHPpQFZI6u-T4YKKg5Kv7cwCSKWQ&ust=1471662232810112

[Frank Lloyd Wrights Prairie House] [Photograph]. (n.d.). Retrieved from http://www.mcnees.org/architecture/prairie_arch_images/flw_henderson_hse_elmhurst_1206_nw_remc.jpg

[Housing Prototypes] [Photograph]. (n.d.). Retrieved from http://housingprototypes.org/images/evora-unit-types-dwgs%2025.gif

[Malagueira Houses] [Photograph]. (n.d.). Retrieved from http://images.adsttc.com/media/images/54c8/bd58/e58e/ce45/7a00/018f/large_jpg/d.jpg?1422441811

[Malagueira, Evora] [Photograph]. (n.d.). Retrieved from https://portuguesearchitectures.files.wordpress.com/2014/05/c3a1lvaro-siza-malagueira-c3a9vora.jpg?w=397

[Villa Rotonda] [Photograph]. (n.d.). Retrieved from http://architectuul.com/architecture/villa-capra-rotonda

P Duarte, J. (2001). Customizing Mass Housing -A Discursive Grammar for Siza's Malagueira Houses (Dissertation). Retrieved from https://dspace.mit.edu/handle/1721.1/8189

Kindergarten grammar Eight variations of one spatial relation [Illustration]. (n.d.). Retrieved from http://grape.swap-zt.com/

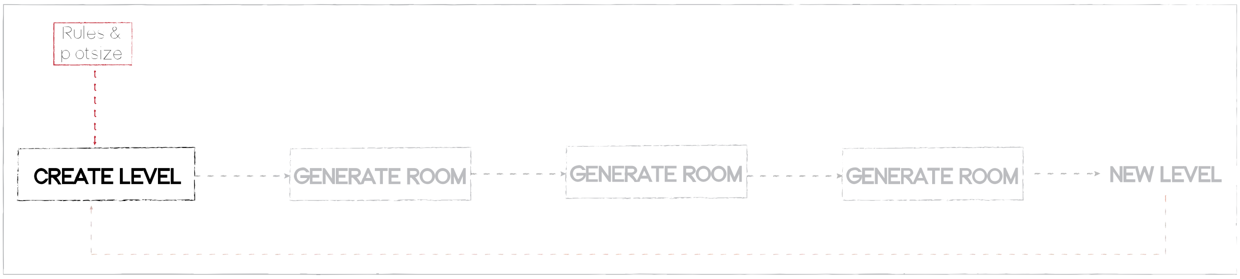
A Rosbach, H. (2007, July 11). A Villa at Finale of Agugliaro in Italy. Designed by Andrea Palladio [Photograph]. Retrieved from https://en.wikipedia.org/wiki/Villa_Saraceno#/media/File:VillaSaraCeno2007_07_11_1.jpg

Stiny's Shape Grammars [Illustration]. (n.d.). Retrieved from https://github.com/bitcraftlab/Coding-Gestalt/tree/master/04-rewriting-grammars

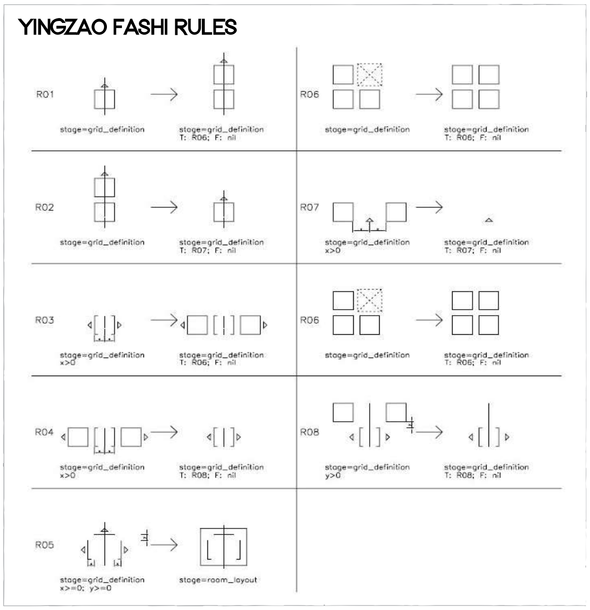
Typical group of 2-story patio houses [Photograph]. (n.d.). Retrieved from http://housingprototypes.org/images/evora%2032.jpg

Appendix

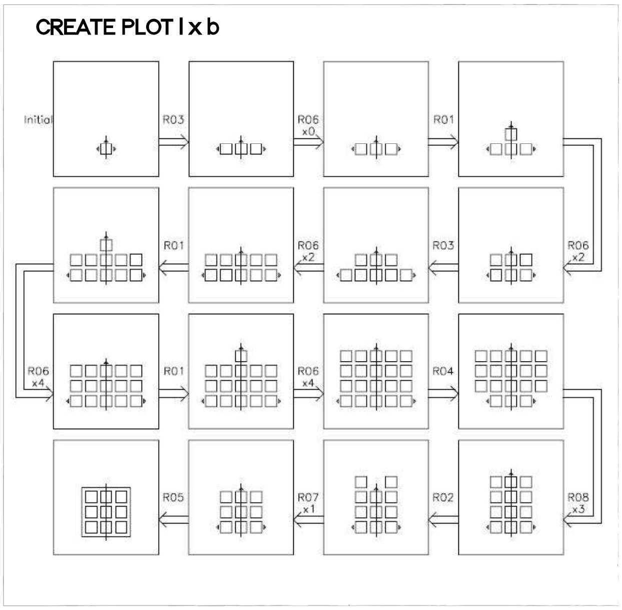
The rules of the created grammar



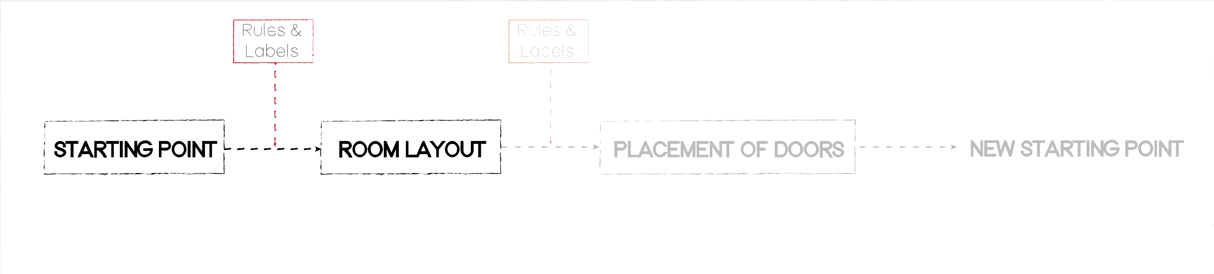
Rules &
plotsize
CREATE LEVEL
GENERATE ROOM
GENERATE ROOM
GENERATE ROOM
NEW LEVEL



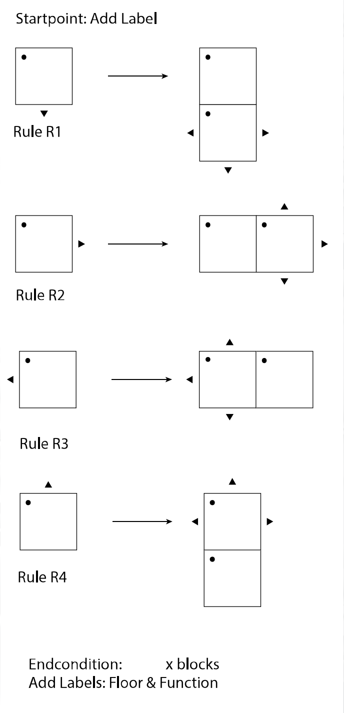
YINGZAO FASHI RULES
R01
R02
R03
R04
R05
R06
R07
R08



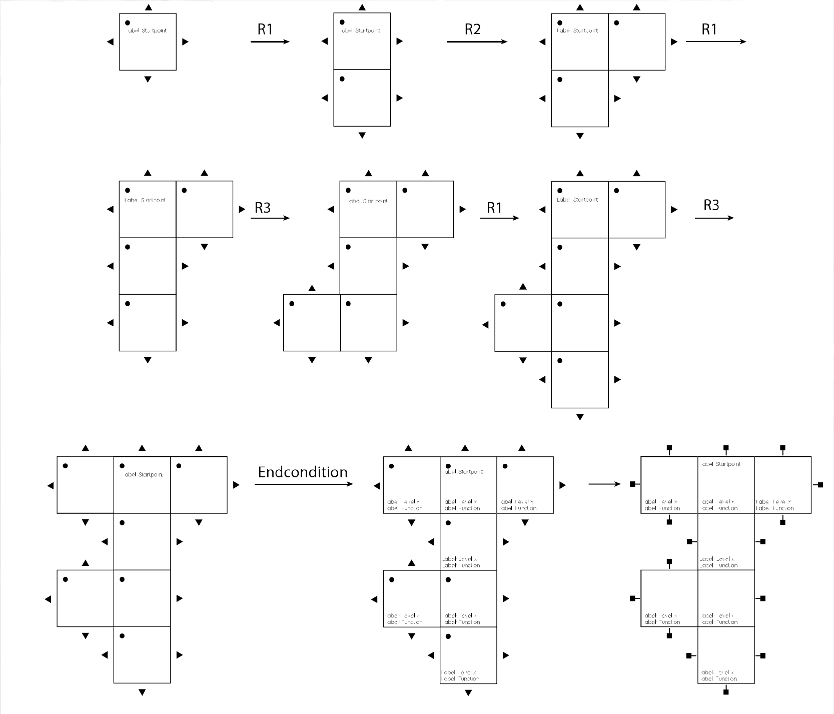
CREATE PLOT l x b
Initial
R03
R06 x0
R01
R06 x2
R03
R06 x2
R01
R06 x4
R01
R06 x4
R04
R08 x3
R02
R07 x1
R05



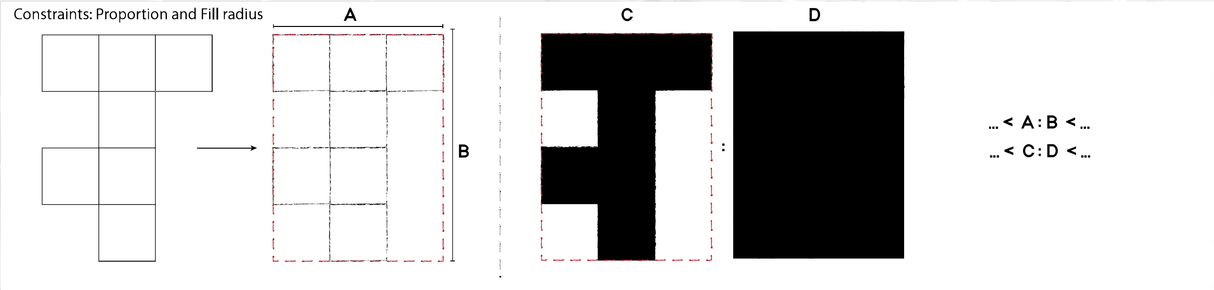
Rules &
Labels
Rules &
Labels
STARTING POINT
ROOM LAYOUT
PLACEMENT OF DOORS
NEW STARTING POINT



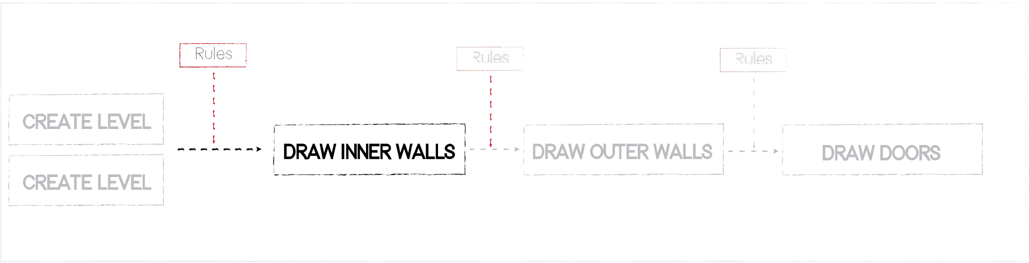
Startpoint: Add Label
Rule R1
Rule R2
Rule R3
Rule R4
Endcondition: x blocks
Add Labels: Floor & Function

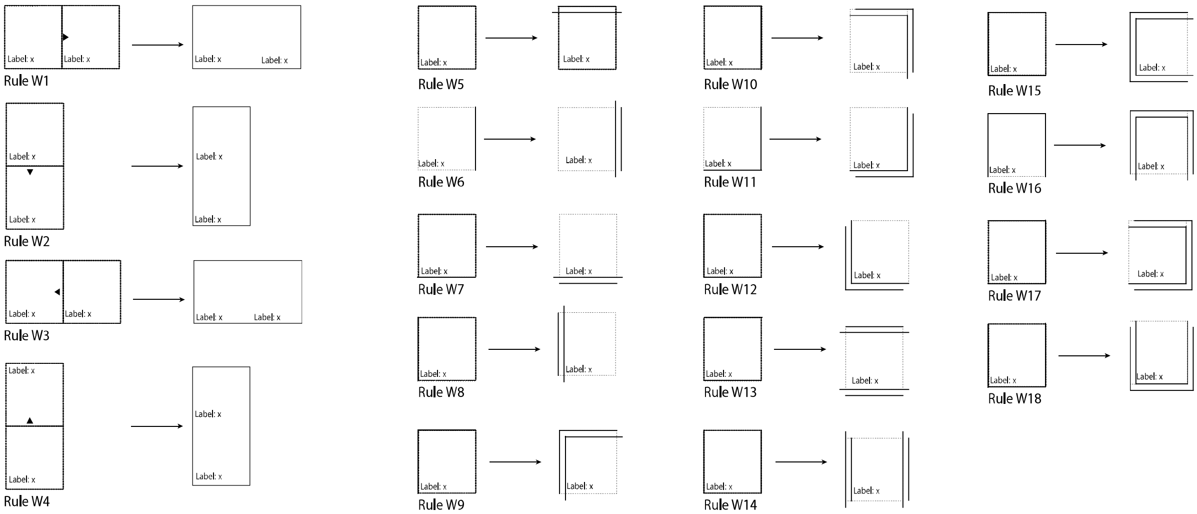


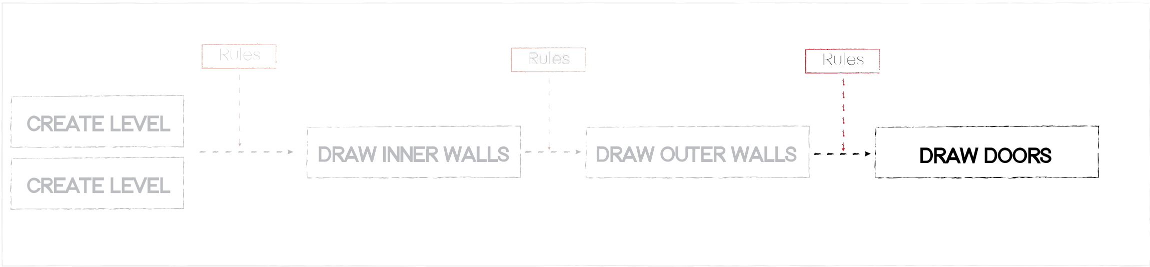
R1
R2
R1
R3
R1
R3
Endcondition

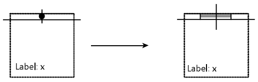


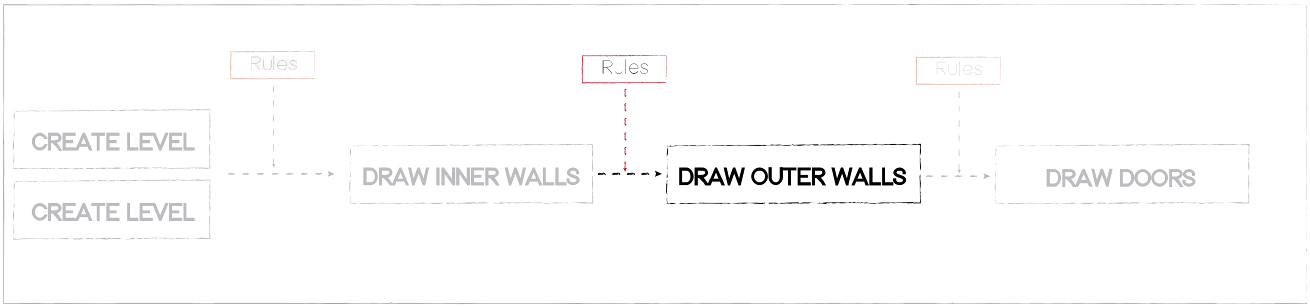
Constraints: Proportion and Fill radius
A
B
C
D
... < A : B < ...
... < C : D < ...

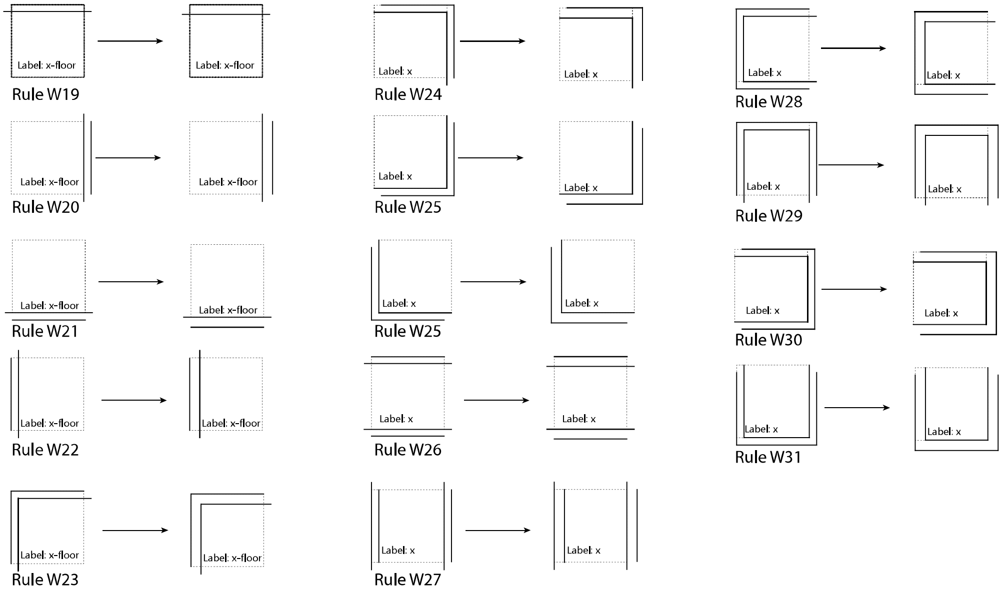

Rules
Rules
Rules
CREATE LEVEL
CREATE LEVEL
DRAW INNER WALLS
DRAW OUTER WALLS
DRAW DOORS


Rule W1
Rule W2
Rule W3
Rule W4
Rule W5
Rule W6
Rule W7
Rule W8
Rule W9
Rule W10
Rule W11
Rule W12
Rule W13
Rule W14
Rule W15
Rule W16
Rule W17
Rule W18


Rules
Rules
Rules
CREATE LEVEL
CREATE LEVEL
DRAW INNER WALLS
DRAW OUTER WALLS
DRAW DOORS


Label: x
Label: x
Rule D3


Rules
Rules
Rules
CREATE LEVEL
CREATE LEVEL
DRAW INNER WALLS
DRAW OUTER WALLS
DRAW DOORS


Label: x-floor
Rule W19
Label: x-floor
Rule W20
Label: x-floor
Rule W21
Label: x-floor
Rule W22
Label: x-floor
Rule W23
Label: x
Rule W24
Label: x
Rule W25
Label: x
Rule W25
Label: x
Rule W26
Label: x
Rule W27
Label: x
Rule W28
Label: x
Rule W29
Label: x
Rule W30
Label: x
Rule W31