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Deposited in *Repositório ISCTE-IUL*:

2018-08-09

Deposited version:

Publisher Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Eloy, S. & Duarte, J. P. (2012). Transformation grammar for housing rehabilitation: from a specific to a general grammar. In 30th International Conference on Education and research in Computer Aided Architectural Design in Europe, eCAADe 2012. (pp. 471-478). Prague: eCAADe.

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# Transformation Grammar for Housing Rehabilitation

## *From a specific to a general grammar*

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**Abstract.** *This article focuses on the use of both shape grammar and space syntax as tools to identify and encode the principles and rules behind the adaptation of existing houses to new requirements. The idea is to use such rules as part of a transformation grammar-based methodology for the rehabilitation of existing dwellings. The developed grammar is a specific grammar to inform the rehabilitation of a particular type of building in Portugal – “rabo-de-bacalhau”. In this article the goal is to explore how the “rabo-the-bacalhau” transformation grammar can be transformed in a general rehabilitation grammar in order to inform the rehabilitation of various types of housing buildings.*

**Keywords.** *Multifamiliar housing building; shape grammars; transformations; housing rehabilitation.*

## INTRODUCTION

The goal of the presented research is to rehabilitate the existing housing stock to meet the new needs of dwellers in the current information society and the consequent need for the integration of Information, Communications and Automation Technologies (ICAT) in living areas. The outcomes of the research are the definition of design guidelines and a rehabilitation methodology to support architects involved in the process of adapting existing dwellings, allowing them to balance sustainability requirements and economic feasibility with new dwelling trends such as the incorporation and updating of ICAT and the need to solve emerging conflicts affecting the use of space prompted by the introduction of new functions associated with such technologies.

In addition to defining a general methodology applicable to all the building types, the study focuses on a specific type, called “rabo-de-bacalhau” (“cod-tail”), built in Lisbon between 1945 and 1965

for which a specific methodology has been generated. Both shape grammar and space syntax were used as part of the rehabilitation methodology as tools to identify and encode the principles and rules behind the adaptation of existing houses to new requirements.

This article focuses on the use of the specific transformation grammar to inform a general transformation grammar capable of encoding the principles and rules behind the adaptation of different types of existing houses to new requirements.

## SHAPE GRAMMAR AND SPACE SYNTAX

Shape grammars were invented by Stiny and Gips (1972) more than thirty years ago. They are “*algorithmic systems for creating and understanding designs directly through computations with shapes, rather than indirectly through computations with text or symbols.*” (Knight 2000) The process generated by shape

grammars is not a deterministic one since it enables multiple designs to be generated, based on a single language but determined by different choices.

Space syntax was conceived by Bill Hillier and Julienne Hanson in the late 1970s as a tool to help architects understand the role of spatial configurations in shaping patterns of human behaviour and to estimate the social effects of their designs. In their theory, space is represented by its parts, which form a network of related components.

In this research, shape grammar is used as a tool to define the methodology for rehabilitating existing types and space syntax as a tool to evaluate spatial properties of the existing and proposed dwelling designs. The combination of a shape grammar with an analysis tool such as space syntax offers the possibility of producing rehabilitation projects that conform to the requirements stipulated by the inhabitants and the specifications set by the architect. In this context, space syntax is used to determine the universe of valid solutions generated by the grammar and to validate them in terms of social properties.

## **TRANSFORMATION GRAMMAR FOR HOUSING REHABILITATION**

We propose a new type of shape grammar, called transformation grammar that was developed to adapt existing dwellings to new requirements. As shape grammars, a transformation grammar is a set of rules that apply step-by-step to existing shapes to generate a language of designs. The proposed transformation grammar is a type of shape grammar that enables architects to transform dwellings, instead of generating new ones, in the same design language.

Within this context, the concept of transformations in design explored by Terry Knight in her study on stylistic changes in different periods was used as a starting point (Knight 1989; 1994). This work, however, proposes a different approach, in that it aims not to understand how rules evolve from a original “rabo-de-bacalhau” grammar through an adapted

“rabo-de-bacalhau” grammar but the principles and rules that enable original dwellings to be adapted to new design that meet new lifestyles.

Also work done by Colakoglu (2005) explores a grammar that induces a type of transformation since it includes both the rules for generating traditional Hayat houses and the rules that enable the generation of these type of houses but conforming to a contemporary context. Again, our work does not aim to infer rules from the original dwelling layouts neither rules to design new contemporary adapted “rabo-de-bacalhau” dwellings but to transform the original dwellings into new ones.

The proposed transformation grammar enables a rehabilitation solution for a given dwelling to be generated based on compositional principles defined by transformation rules. These rules are derived from knowledge acquired in previous stages of the process.

The transformation grammar is parametric because of the variety in the shapes and dimensions of the rooms found in existing dwellings. By using parametric rules we can encode varying features of shapes so that a greater variety of shapes can be matched to the left-hand side of the rule and then be transformed by the right-hand side.

In addition to the shape of an architectural space, which is defined by the position of the construction components, it is essential to consider the functions that will be carried out there. This implies that if we want to apply a shape grammar to architecture, functional predicates have to be introduced into the language of the grammar, otherwise we may be considering an architectural problem as if it were a “shape game” (Mitchell, 2008: 197). Thus the activities that may take place in a space or the function for which it was conceived are inseparable from the design process. These spaces and relations constitute “predicates to satisfy” (Mitchell 2008: 212) and their design requires rules able to relate shape to the position in space of the functional attributes.

## **“Rabo-de-bacalhau” transformation grammar**

To define a housing rehabilitation it is first necessary to determine both the functional and ICAT programmes for specific family profiles and, secondly, carry out the rehabilitation work by adapting the programmes to the existing building and vice-versa. These tasks are proposed to be systematised within a general rehabilitation methodology which encompasses two steps (Figure 1).

However, the use of a specific case study allows the methodology to be extended further. By using a specific building type, a transformation grammar can be developed for this particular building type, therefore producing a specific methodology for “rabo-de-bacalhau” rehabilitation. This part of the rehabilitation methodology encompasses also two steps.

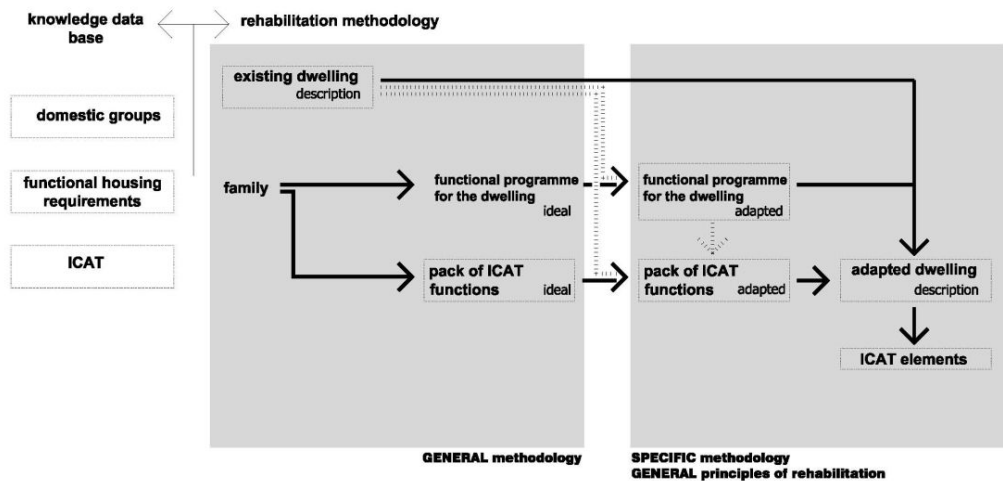
Prior to the first step in the general methodology a knowledge database was created, which contains the knowledge required to perform the proposed rehabilitation: domestic groups; functional housing requirements; ICAT. This data constitutes the knowledge database for the methodology rep-

resented on (Figure 1). With this knowledge and a set of algorithms and rules which determine how to act on the information, a particular dwelling can be rehabilitated for a particular family.

Considering the general methodology two steps are needed: i) gathering data of the household profile and the description of the existing dwelling; ii) using the household profile to determine the ideal functional programme for the dwelling – following Pedro’s (2000) and Duarte’s (2001) work on the housing programme – as well as the ideal pack of ICAT functions.

To go further in the transformation of a “rabo-de-bacalhau” dwelling two more steps are needed: i) the definition of the adapted functional programme and the adapted pack of ICAT; ii) the description of the layout of the adapted dwelling and of the ICAT elements. To perform these two steps the existing dwelling, the ideal functional programme, and the ideal ICAT pack are used to derive a description of a compromise or adapted solution based on the existing dwelling. Since the solution is influenced by the existing morphological structure, it is necessary to transform the description of the ideal solution ob-

Figure 1  
General and specific rehabilitation methodology.



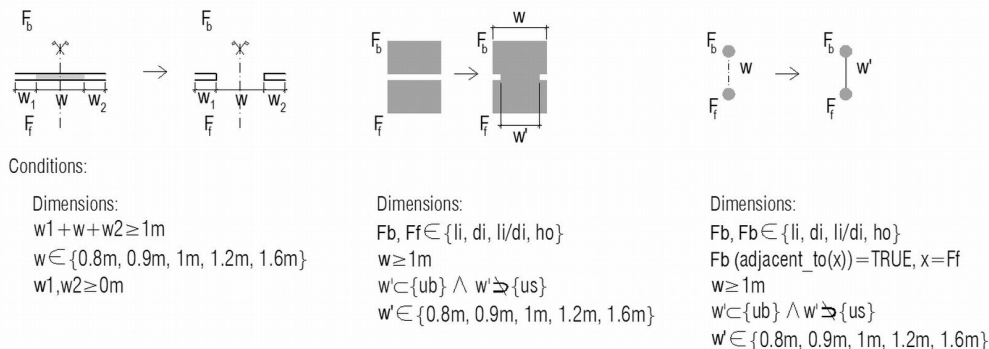


Figure 2  
Different ways of representing rules: left - using lines (walls); middle - planar surfaces (rooms); right - nodes (abstraction of rooms) and arcs (connections) forming graphs. Besides the dimension conditions (shown in the image), there are functional conditions that are not shown as they are the same in each of the three hypotheses.

tained with the two steps of the general methodology into the description of the adapted solution.

The proposed grammar is a compound grammar defined in three algebras U02, U12 and U22 and is augmented by labels in the algebra V02 and weights in the algebra W22 (Figure 2).

Different ways of representing dwellings and the transformation rules of the proposed rehabilitation methodology were considered for the current grammar. Traditional floor plan, spatial voids and graphs representation are used as a compound grammar to manipulate complex problems in the transforma-

tion rules (e.g. area, existence of windows, shape, among others) (Figure 2).

The last stage of the rehabilitation methodology for “rabo-de-bacalhau” dwelling includes two steps, first the chosen of an appropriate dwelling and then the adaptation of the dwelling. The adaptation of the dwelling includes 10 steps listed in (Table 1). These steps may be divided into three different stages, firstly the preparation of the design (step -1), secondly the functional adaptation of the dwelling (step 0 to step 7) and thirdly the integration of ICAT components (step 8). At the end of each step there is

Step	Action	Rule number
-1	Preparing the floor plan	-1.1 to -1.5
0	Define kitchen / according to the chosen strategy	0.1 to 0.6
1	Assignment of hall	1.1 to 1.2
2	Define private area (if functional programme has 2 or more bedrooms, if not go to step 3)	2.1 to 2.19
3	Define social area (if functional programme has 2 or more bedrooms, if not go to step 2)	3.1 to 3.17
4	Define circulation	4.1 to 4.5
5	Define service area	5.1 to 5.4
6	Define storage spaces	6.1 to 6.5
7	Adapt shape	7.1 to 7.7
8	Integrate ICAT	8.1 to 8.13

Table 1  
Steps of the “rabo-de-bacalhau” transformation grammar which have to be followed to do the adaption of a dwelling.

Figure 3

On the left a sample of an original dwelling; on the right several possibilities of transformation generated by the transformation grammar (four transformations according to strategy 2, one transformation according to strategy 1 and one transformation according to strategy 3).



a rule which changes to the next step if the previous conditions have been met.

The proposed methodology seeks to produce rehabilitated designs that are “legal projects” because they are in the transformation language and “adequate projects” because they satisfy the a priori set of user requirements. (Duarte 2001) According to Duarte, a grammar applied to an architectural problem must satisfy two functions: it must create or transform an object within a specific language and it must create objects that satisfy requirements stated at the outset. (Figure 3) shows several dwelling layouts based on the same original dwelling and that fulfill different a priori set of user requirements.

### **General transformation grammar for housing rehabilitation**

This research proposes both a general methodology that can be applied to different building types as well as a specific methodology developed from the previous one but specific for the “rabo-de-bacalhau”. The methodology developed is a general rehabilitation methodology because it can be used in different building types by applying the main steps of the methodology. Although, when all the steps of the methodology are applied it is a specific methodology applicable to the “rabo-de-bacalhau” building type.

In order to fully apply this methodology to all the multifamily housing building types the shape rules as to be revised and all the specific aspects of “rabo-de-bacalhau” buildings has to be generalized so that a larger scope of buildings could be reached.

In the definition of the transformation grammar rules were divided into different groups according to the nature of the work involved: i) rules for the assignment of functions to rooms; ii) rules for permuting room functions; iii) rules which add walls to enable rooms to be divided and wall openings to be eliminated or reduced; iv) rules which eliminate walls to enable rooms to be connected or one room to be enlarged; v) rules for changing the stage in the derivation; vi) rules for preparing the floor plan; vii) rules for integrating ICAT elements.

These groups of rules were used for “rabo-de-bacalhau” buildings. Nevertheless, they reflect all the types of actions involved in rehabilitation works which means that all the major aspects of rehabilitation works are already implemented in the grammar. Considering that the major aspects of rehabilitation works are already implemented in the grammar its generalization as to do, in an initial phase, with a more complete and embracing parameterization of shape.

A generalization of the grammar would begin by the use of the same general framework of rules and then proceed to the integration of specificities

of different building types – considering different construction constrains, different functional organizations, among other parameters.

The development of a more general transformation grammar is done by extracting from the “rabo-de-bacalhau” grammar its methodological structure and rule types and using this information in the definition of a more general grammar that can be applicable in the development of other specific transformation grammars (Figure 4).

However, this generalization of the grammar as to consider some aspects that allows the rehabilitation of other building types. The integration of knowledge about different construction methods will lead to different demolishing/constructing restrains and the analyses of the functional characterization of other buildings may lead to more strategies of rehabilitation as well as to different hierarchies within the grammar structure.

As for the “rabo-de-bacalhau” transformation grammar, a more general transformation grammar will encompass three different stages: the preparation of the design (step 1); the functional adaptation of the dwelling (step 2 and 3); the integration of ICAT components (step 4). For each one of these steps there are specific types of rules which are applied to each one of the expressed requirements: constructional, spatial, and topological, among others. For “rabo-de-bacalhau” dwellings the rules were designed to answer its functional and constructional restrains. If different buildings are to be rehabilitated using the same transformation grammar some changes has to be implemented. (Figure 4) shows what steps and rules of the general transformation grammar can be fully used and stresses which of them need to be update to accommodate differences for each one of the different building types.

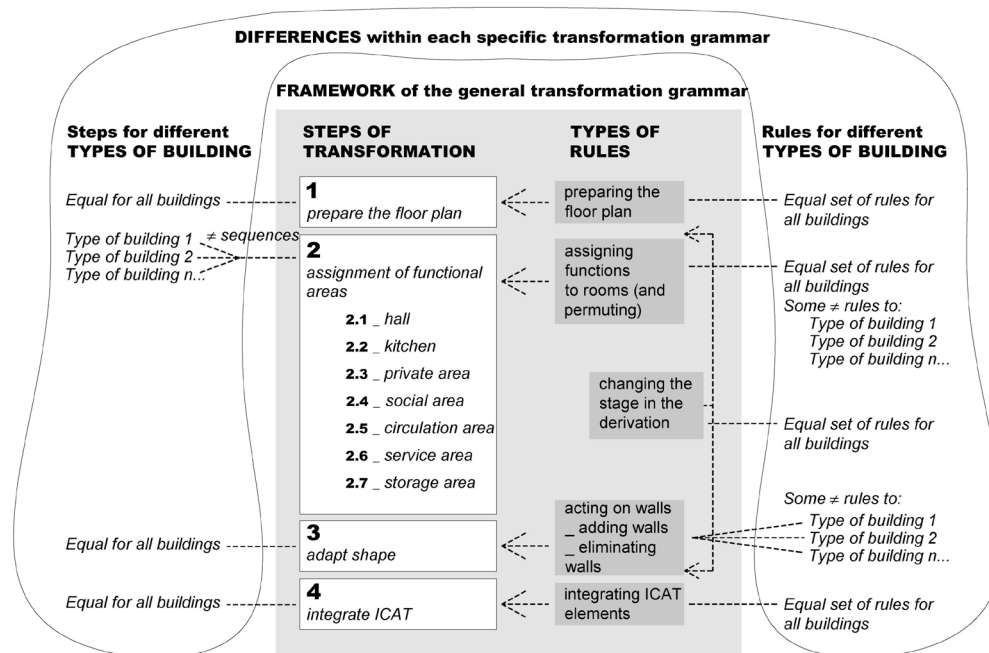


Figure 4  
Framework for the general transformation grammar with the sequence of steps and types of rules and the specificities that have to be introduced when generalizing the grammar to other types of buildings.

Step 1 of the transformation grammar is the preparation of the floor plan in order to begin the dwelling transformation. The rules included in this step enable the following actions: i) generating a compound representation by adding dots, arcs and surfaces to the floor plan (these actions will enable the generation of different forms of representing spaces); ii) adding labels to the existing rooms (labels are used to characterize rooms); iii) adding weights to the existing walls (weights are used to characterize the construction system). The existing rules for “rabo-de-bacalhau” buildings include all the possibilities of compound representation as well as all the classifications required for the labels. Weights were used to define the constructional constraints and materials of “rabo-de-bacalhau” buildings. When addressing different constructional constraints and different materials and systems other weights have to be defined to incorporate e.g. concrete walls (instead of columns), light partition walls and non loadbearing brick walls, among others.

Step 2 of the transformation grammar consists on the assignment of functional areas to the existing areas of the dwelling. The “rabo-de-bacalhau” grammar starts by locating the kitchen and, in accordance with the chosen strategy, the kitchen can be assigned to two different positions. According to this specific grammar, after assigning the kitchen position the next step is the assignment of the function hall. When other building types are to be transformed other sequences of assignment functional areas need to be defined and validated.

When it is necessary to make adjustments to spaces Step 3 is activated. This step includes rules that allow for 5 types of actions with various possible effects: connecting spaces; separating spaces; creating or changing circulation; expanding spaces; changing the position of a door by eliminating and then adding a wall. However all the defined rules for “rabo-de-bacalhau” dwellings may be applicable to other dwelling types, some new rules may need to be added in order to correspond to specific geometries or morphological requirements. These new rules may be integrated in the general grammar be-

cause they are abstractions of geometries and they can be applicable to more than one building type.

Step 4 allows for the integration of all the major technology devices needed for the domestic system. Although the aim of the previous steps was to transform a dwelling using rules that work with the existing elements, Step 4 intends to integrate new elements into an already defined dwelling and therefore uses rules for adding devices. As the conditions to incorporate technologies relates to the room's functions and the wall's positions, the use of this rules in different building types is also possible.

## DISCUSSION

Unlike traditional rehabilitation processes executed on an individual case basis for each family/dwelling combination, this article proposes a methodology to support a process which clarifies decision-making and speeds up the project. The benefit of the proposed methodology is its ability to impose a very precise and systematic form of intervention.

The use of a transformation grammar as a tool for transforming existing dwellings enables shape transformation to be managed within dwellings to create a systematic and methodical process that can encompass all the valid transformation rules for a given dwelling.

This article shows an application of a transformation grammar to a specific building type - “rabo-de-bacalhau” - as well as some approaches to the use of the transformation grammar in a general context of rehabilitation.

The generalization of the transformation grammar would use the same general framework of rules and integrate specificities of different building types, e.g. considering different construction constraints and different functional organizations.

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