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EMERG. HOUSE 4ALL: A SENSITIVE APPROACH INFORMED BY NEW DIGITAL TOOLS

Alexandra Paio
Department of Architecture and Urbanism, School of Technology and Architecture,
ISCTE - Instituto Universitário de Lisboa
ADETTI-IUL, Lisbon Portugal
alexandra.paio@iscte.pt

Vasco Moreira Rato
Department of Architecture and Urbanism, School of Technology and Architecture,
ISCTE - Instituto Universitário de Lisboa
DINAMIA'CET-IUL, Lisbon Portugal
vasco.rato@iscte.pt

Joaquim Reis *
Joaquim.reis@iscte.pt

Filipe Santos *
filipe.santos@iscte.pt

Pedro Faria Lopes *
pedro.lopes@iscte.pt

* Department of Information, Science and Technology, School of Technology and Architecture,
ISCTE - Instituto Universitário de Lisboa
ADETTI-IUL, Lisbon Portugal

Abstract

The paper presents the progress of a multidisciplinary team who is collectively working on an integrated design tool to generate humanized urban and self-built tailored incremental housing. The ongoing project called "Emerg.cities4all" goal is to develop a system that could use the revealed cultural, social and spatial dynamics involved in the genesis of informal settlements (favelas, musseques and caniços) to autonomously generate adequate housing designs while simultaneously generating all the information needed to direct fabrication. This research explores grammar-based design and digital fabrication systems to provide modular, adaptable and affordable housing. Emerg.cities4all research project suggests that computing and fabrication algorithms are paving the way to achieve new design paradigms for low-income populations.

Keywords: self-built housing, generative design, shape grammar, CPLP, digital fabrication, bottom-up approach

Introduction

Even knowing that the right to adequate housing is recognized as a fundamental right to people's life since 1948 (UN 1948), the current situation does not allow the achievement of adequate shelter for all in urbanizing areas (UN-Habitat II, 1997). Informal settlements and self-built housing are the predominant mode of urban habitation production, arising as survival mechanisms to answer for the deficit and as a consequence of the rural exodus that happens in all the major cities in the world. According to Brazilian data, São Paulo has more than 1.500 *favelas* and 60% of the city housing is self-built (Barda, 2010).

Recently, the governments of the Portuguese-speaking countries have sought to address the housing needs by launching state conventional mass housing programs to overcome the housing needs. Brazil and Angola have launched major current housing programs in the world, called "My Home, My Life" (*Minha Casa, Minha Vida*) and "National Housing Construction Program" (*Programa Nacional de Construção Habitacional*). The aim is to build about 1 million houses for low-income population in each country. Although these housing programs bring some facilities to low-income families, they tend to exclude future residents from the participation in the decision-making process about their own houses. The large massive repetitive housing blocks offer identical typological dwellings that are inadequate to the cultural, social and economic conditions of their inhabitants (Fig.1). According to Erguden (2001, p.1) "design of dwellings and neighbourhoods [have to] reflect and protect important elements of values and culture". Specific social-cultural aspects play an important part in the preference shown by families in building their own homes (Kowaltowski, 2005), creating a typological affinity (Aguiar, 2011). The complexity of these issues, as well as the actual environment of economic constraint, call for different approaches. Advanced digital technologies can emerge as a possible solution to a social and economical sustainable and integrated design (Larson et al., 2001). Technological evolution based on scientific knowledge in design and production, coupled with recent cultural and economic shifts, renewed interest in the processes involved with prefabrication and self-built housing. A link between the computational power of parametric design and the construction technology of CNC (computer numerically controlled) and prefabrication suggests a new building paradigm for architects and urban planners (Alvarado & Turckienicz, 2010; Boza, 2009). As Kieran and Timberlake (2004, p. xii-xiii) put it

> (…) mass production was the ideal of the early 20th century. Mass customization is the recently emerged reality of 21th century. It proposes new process to build using automated production, but with the ability to differentiate each artifact from those that are fabricated before and after. The ability to differentiate, to distinguish architecture based upon site, use, and desire, is a prerequisite to success that has eluded our predecessors. With the information control tools we now have we are able to visualize and manage off-site fabrication of mass customized architecture.

Related work

There are reasons to consider that diversity and adaptability yield a better match between the building environment and the life it shelters (Habraken, 1987). Variety is an indispensable requisite for freedom and authentic culture and without them, people's needs cannot be satisfied (Turner, 1976) (Fig. 1). As Gonzáles and Donath (2003, p.2) put it the

> *(…) user-design and self-built housing strategies correspond to non-paternalistic support methods that are not only capable to provide more diversity of dwellings than conventional mass housing programs, but also a bigger sense of appropriation and identification of the dweller with their own habitat.*

The United Nations is also increasingly recognizing that informal settlements dwellers must play an active role in improving their own living conditions (UN-Habitat, 2003). The call for local user participation in planning and decision-making process represents a key factor to the success of social-cultural inclusion. Self-built informal urban housing carries local wisdom, while formal housing programs aspire to erase the local logic and recodify the old paradigms. According to Mehrotra (2010, p.xiii)

> (…) it seems to be about the tactics and innovations which the urban poor and marginalized people have to offer. That is, their ability to absorb recycles, provide services, establish networks, celebrate, play and essentially extend the margins of the urban system to new levels of robustness. (…) is about invention within strong constraints with indigenous resources with the purpose of turning odds into a survival strategy – often a sustainable strategy.

The act of housing production has to be understood as a process instead of a static end product, and the housing as an open system (Habraken, 1972). Several approaches have been done to support an alternative to mass housing production. Customized mass production housing was proposed by SAR-group headed by John Habraken (1979), but the result has been limited. The MIT Group created the “instant house”, based in shape grammar. Sass incorporates rule-based processes with fabrication (Sass, 2005; Cardoso & Sass, 2008). Other important work in this area is the integrated planning support system for low-income housing in Chile by Dirk Donath and Luis González (2006). This preceding works suggest that processes of incremental and self housing can be an alternative to massive construction. The housing attributes of socio-cultural adaptability and of economic appropriateness are increasingly important for the adjustment of homes to the lifestyles of families.

Figure 1. Diversity to repetition. Favela, São Paulo, Brazil; Programa Minha Casa Minha Vida, Brazil (from: Google earth, www.casavivacorretora.com.br)

Over the past decades, shape grammar has been adopted as a powerful means of analyzing and generating designs languages (Stiny & Gips, 1972). As a method, shape grammar supports the analysis of the form-making logic and has proved to be strong in the shape description, interpretation, classification, evaluation and generation (Stiny & Mitchell, 1978; Brown, 1997). As well as providing a gateway to define parametric designs shape grammars (Duarte, 2001; Duarte et al., 2007). In addition, there is a variety of tools that have been developed to provide an interface with shape grammars formalism (Chase, 2005). Following this potential, shape grammar was adopted as the basic method to this research.

Research Methodology

To address this research challenge, the following methodology was used to develop the generative computer-aided planning support system for humanized urban and self-built tailored and incremental housing to low-income populations: (1) analyzing precedents; (2) design a computational tool to generate design and generate fabrication using shape grammars (SG); (3) and implement/evaluate the system in field.

Studies in cognition and human behavior have demonstrated that analyzing precedents in design is an efficient strategy to solve new problems. The Human being does not inherit concepts but the ability to build these through a description retrieval mechanism (Hiller & Hanson, 1984). The bottom-up approach offers a way of controlling the design and the emergence, based on the dependent behaviour of its parts. In this approach, larger scale problems are solved by solving the small-scale ones (Duarte et al., 2007). Three scales of information are explored: urban design, housing and construction system. However, this paper only addresses the first two.

Analyzing precedents

Developing designs with informal rules means to understand how agents work together. They are self-organized structures that are sensitive to the inside logic of the spontaneous process by which they grow and to their codified rules (Grilo, 2010). In other words, these processes are generated on the basis of a mutual interaction between self-planning and self-organisation, which gives rise to complex functional configurations. According to Mehrotra (2010, p.xii) "patterns of occupation determine its form and perception. It is an indigenous urbanism that has its particular 'local' logic. It is not necessarily only the city of the poor, as most images and discussions of informal city might suggest; rather it is a temporal articulation and occupation of space which not only creates a richer sensibility of spatial occupation, but also suggests how spatial limits are expanded to include formally unimagined uses in sense urban conditions". Based in this statement, the emerg.cities4all research suggests that is necessary to begin with an analytical grammar since it enable to analyze how existing informal settlements and houses are generated and what cultural, social and spatial dynamics are involved in their growth. We believe that the adaptability and evolutiveness characteristics of their houses as well as the social relations of these inhabitants have some degree of quality and positive aspects to be retained in each case/grammar rules to be introduced into the system (Paio et al., 2011). As Habraken (1988, p.2) refers, “the culture, the social patterns, and shared preferences of a people are expressed in the house form itself”.

Informal urban settlements and previous social initiatives for cities with low-income housing in Portuguese-speaking countries have been examined in order to establish the key parameters to urban and housing design and the initial input data and knowledge for the computer system application. With respect to urban and housing design the key parameters are geographic, climatic, ecological, cultural, social, economic and technical. The variations of each house subsequently will be affected by each of the land lot’s ecology, social, cultural and economic specificities. With respect to the computer system application it is further necessary to identify and classify two kinds of knowledge: local knowledge and expertise knowledge. The first is related to informal rules, and the second generates solutions based in the inferred informal rules.

In order to analyze the rules of the informal genesis morphology, three case studies were defined: (1) *Favela São Judas*, São Paulo, Brazil; (2) Airport neighbourhood, Maputo, Mozambique; and (3) *Marçal*, Luanda, Angola. The definition of case studies had in account several variables: topography (plan or hill), the socio-spatial urban relationships, levels of density and centrality (consolidated, expansion and new), and size of settlements (small, medium or large). These analyses allow us to define some preliminary conclusions. The *favela* morphology is a built map of social relations and is dictated by the geometry of its specific topography. Looking at *caniços* in Maputo, Mozambique, the implantation strategy is the imposition of a square grid on a plain site. So, the street follows a straight line, sometimes interrupted by an unexpected construction, a public space or an improvised ephemeral structure, suggesting a kind of emergence, proper of the outskirts. Finally, *musseques* in Luanda, Angola are defined by major orthogonal arteries unoriginal from the city of Luanda. Then, a fractal composition of secondary streets deriving from those arteries. The morphology of the informal settlements, the construction of its streets, urban walls, alley, define concise territorial units, with urban and social logic that inspire different types of land occupation and density, and consequently different levels of urbanity. Highlighting the urban block it is possible to define two types. In the first, the inside of the block is composed of a twisted walls and pedestrian access following property limits. The small open spaces are street markets and community meeting points. In the second, the lots go to the block boundaries that match with streets. Green spaces are subsistence agriculture or family socializing patios.

The typical selft-built housing is in a constant state of construction, expanding to accommodate distant relatives and friends that are drawn to the city. Families can cover multiple buildings, or one may also find multiple families in a single dwelling. The housing type of each informal settlement is a reflection of a specific set of parameters (geographical, cultural, social, economic), by the percentage of lot occupancy and followed by the definition of the main areas of housing and its spatial and social relationships (Fig. 2).

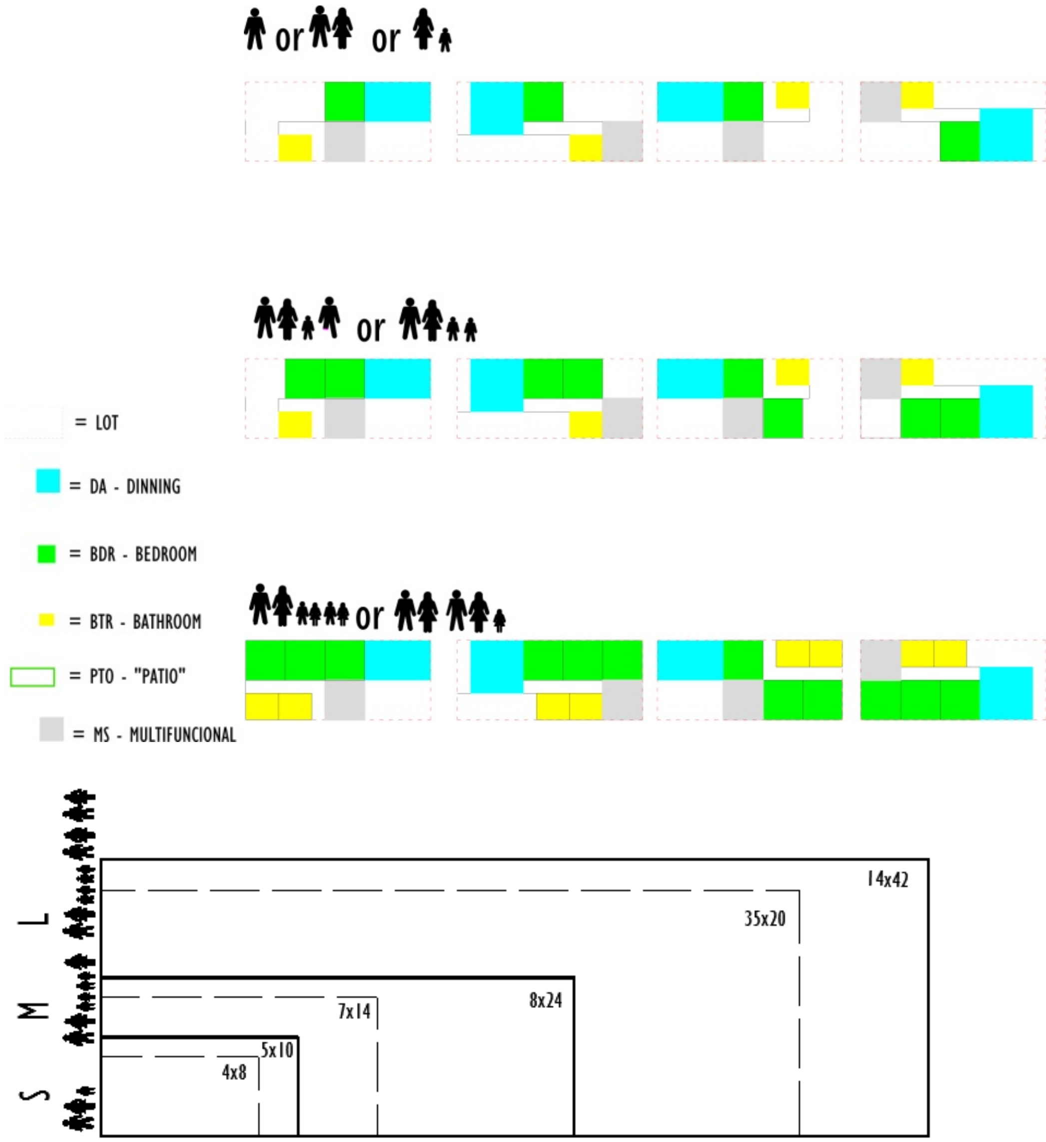

Figure 2. Incremental housing typologies (from: Linhares et al., 2011)

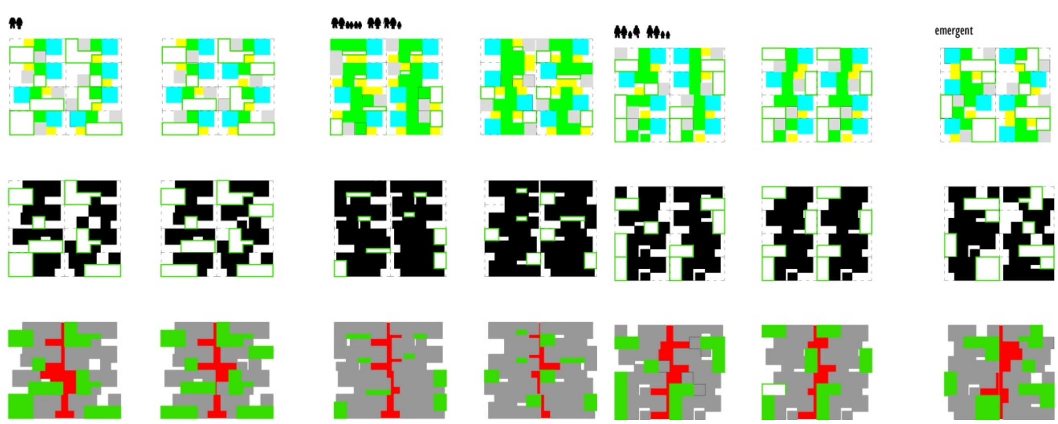

Figure 3. Urban scale

The major conclusions from their lifestyle and architectural processes for the development of a grammar are: (1) rooms inside dwellings are contiguous, leaving no space for circulation areas; (2) rooms have minimum areas and as a consequence maximum segmentation; (3) dwellings grow by the means of their family necessities, for example, household changing number (Linhares et al., 2011); (4) inhabitants value the exterior space, spending more time outside than inside their homes, generating greater experiences of community living, exploring the soil for subsistent farming or even washing and drying their clothes. For example, in the *musseques*, the patio has great importance in the African housing living (Louro, 2009). The enclosed walls patio is the social family space and has a direct connection with the meal-preparing space (Fig. 2); (5) several economic activities are carried out at the house, including a multiplicity of types of shops, services and small manufacture (Aguiar, 2011); and (6) the dwellings originally circular matrix, becomes one rectangular room, moving progressively to the division between living room and bedroom and after increasing the number of rooms in proportion to the number of floors. This basic knowledge has been essential to infer rules based on the existing practices and to consider new possibilities of creating living environments (Fig.3).

A computational tool to generate design and fabrication using shape grammars

The second stage is based on the assumption that it is possible to generate self-built tailored incremental housing design solutions and fabricate them by a computational generation tool supported in a descriptive method as the Shape Grammars (Stiny, 1980). Grammar formalisms deal with an algorithmic process of design. A particular house type can be parameterized, tailored and encoded by shape grammar defining a design system. The use of parametric shape grammar allows for the manipulation of shapes and functions creating operable design alternatives, adding diversity and automatically generating fabrication for rapid prototyping machines (Botha & Sass, 2009).

From the analysis of the case studies it was created a demand for better solutions that meet the needs of socio-economic conditions, having in account the size, financial conditions (minimum salary) and the type of the family group. The building system has been developed based in a wood 3D shape grammar. Due to space limitations, this paper describes only the grammar for generating the basic house layout.

In the first phase, the parameterization of the minimum unity was executed, which corresponds to the maximum limit of construction per household. The first element to emerge in the house is the dining area characterized for being the space where the family meets for the daily meals. Related to this space, the bedroom emerges where one or two people can fit, according to a generic distribution, although it could in exceptional cases take three to four people.

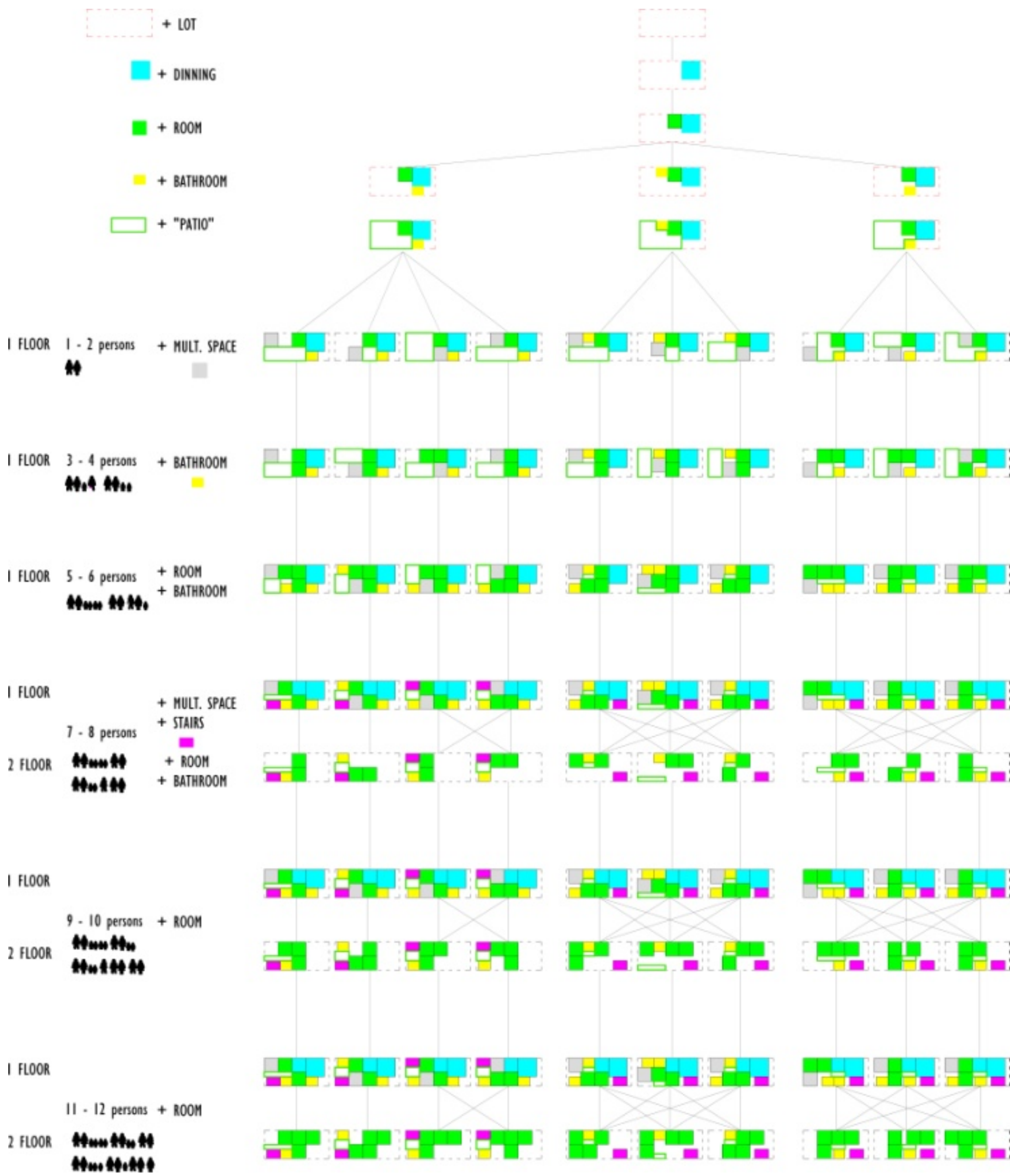

Figure 4. Tree diagram to illustrate the derivation of some modular,adaptable and evolutive grammar (from: Linhares et al. 2011).

The generative process continues with the bathroom and the multifunctional space; this latter may assume one of the following functions: office, commercial space, and living room or storage space; it can also be transformed into a bedroom according to an adaptive rule. It is still necessary to refer to the public purpose of this space, and consequently its location restrictions, having always to be located as close as possible to the main street. This is one basic condition for the case of office or commercial functions (Fig. 4).

The tree illustrates some of the many possible solutions for the house, where the elements that constitute the space are the consequence of the application of fixed rules, adaptive and evolving, according to the logic of the number of inhabitants per services and bedrooms – it evolves according to the number of inhabitants and the number of floors.

The limit of 7 to 8 people gives origin to a new floor, and the respective staircases, which appear in the limits of the construction extremities. In the two floor house even more combinations may be generated, with the 1st floor keeping its shape and the 2nd floor possibly changing (Fig. 5).

After establishing the parameters and producing the shape grammar, it was reproduced one example of derivations to show one type of dwelling for a household with 3-4 persons (Fig. 5).

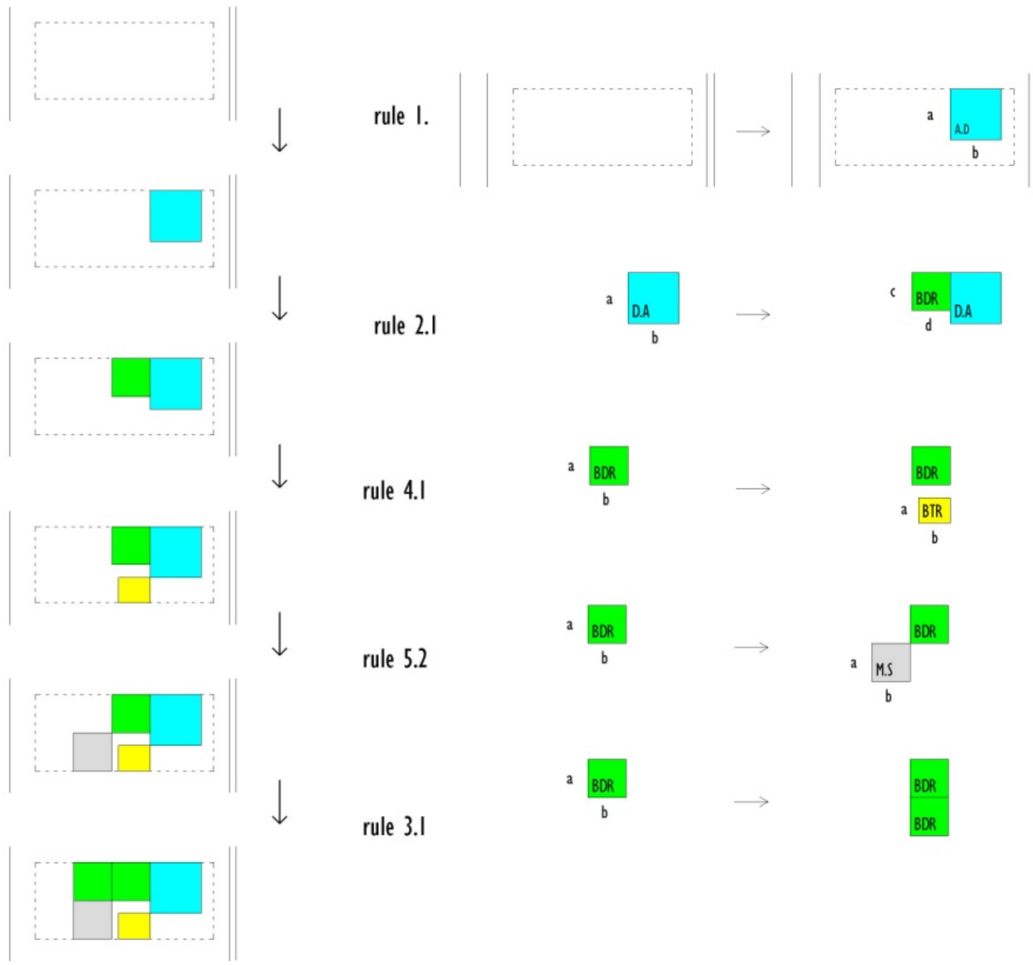

Figure 5. Example of one derivations for 3-4 people and applied shape rules (from: Linhares et al. 2011)

Implement/evaluate the system in field

The final stage of this research will be to test and evaluate the software. It will include a self-builder dweller or a family sitting in front of a computer in a local association interacting with the interface, filling some text-boxes with descriptive data and menus to choose the layout typology and send it to digital fabrication tools.

Discussion and Conclusion

The paper shows only a part of the on-going research. The aim is to create software to design and fabricate tailored self-built housing for low-income population in Portuguese-speaking countries based in the lesson that we cannot impose our own habits and processes to these communities. Grammar design facilitates the process of analyzing, describing and applying rules systems that define languages of design at several scales. They have their own quotidian life styles and habits, meaning that for creating this specific architecture we needed to learn with them. On the other hand, this new design tool can deal with complex issues such as self-evolution, self-adaptation and formal diversity on architecture and urban design. This paper suggests that the advanced digital tools can be a sustainable solution to solve social problems. The main challenge of our approach is the ability to integrate flexibility and adaptability, supporting a larger number of conditions and constraints and being able to evaluate and control outcomes. These are important features, especially because the huge number of data and reasoning processes involved.

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