A Parametric Process for Shelters and Refugees' Camps Design

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Many situations related to natural environment and human activities increase the risk related to housing and create a demand for rapid post-disaster solutions. The solutions implemented by both the non-governmental organizations (NGOs) and the local and national organizations should fulfill the requirements of the temporarily displaced populations. However post-disaster design faces many challenges in its process making the response always more complex. At the same time, computer-based design is a growing approach in both architectural practice and research. The research described in this paper aims to help in finding solutions to design issues by addressing the potential of computer-based architectural design support. It is applied to shelter and camp development and takes into account physical, contextual and climatic parameters. The outcome is a design process for shelter and camp, which has been validated by a parametric prototype experiment in a case study. This should support humanitarian teams and contribute to enhancing the quality of design as well as to reducing the time required for the design and construction processes.

Keywords: *Parametric architecture, Generative design, Humanitarian design, Computer aided architectural design*

1. INTRODUCTION

Currently, factors related to natural environment and human activities increase the risk relating to housing. These factors create a demand for a rapid, sustainable and effective post-disaster response. This response is a collection of interventions during and after crisis based on previous experiences (Santos et al. 2013), either to answer the direct need of the displaced population or to focus on a long-term process of development. Still, the solutions implemented by NGOs, the local and national organizations most often target to meet the emergency needs of the displaced population. Criteria such as time reduction, resources conservation, safety and cost should also be taken into consideration. The unpredictability and diversity of cases in addition to the different locations as well as the culture and tradition of each region make the response more complex (Balcik et al. 2010).

However, the need of sheltering is increasing. In addition to that, the average lifespan of camps is 10

years while families can remain up to 17 years. Poorly organized camps are often transformed into slums with harsh living conditions, thus the interests of anticipating camp planning at the urban scale. Moreover, the refugees' camps planning should be performed as soon as possible during the intervention process rather than to wait for calm or stable periods (Corsellis and Vitale 2005).

2. PARAMETRIC GENERATIVE DESIGN

The application of computational design is increasing in the Architecture, Engineering and Construction industry. "Parametric Modeling" reflects recent trends in computing design in academic research and market innovation. It allows the designers to control the generation of visualized 3D objects from an overall logical computing script or scenario (Davis et al. 2011). They embed mathematical formulas, constraints and control functions to derive a geometric model from series of input data through a generative process. The characteristic of this approach is that it produces more than static geometry, i.e. a model with a collection of primitive shapes (Fernando et al. 2012).

Parametric design and humanitarian field

In disaster and crisis, the need for shelter is increasingly significant and the design must meet multiple constraints (technical, sociological). Therefore, the design should not only take into account physical parameters (such as gross area, height or structure), but also the contextual and climatic parameters (e.g. site conditions, culture of inhabitants, tradition, climate etc). Generation tools can be the optimum solution for meeting this increasing need by implementing different types of parameters.

Only few applications related to design computing have appeared in the humanitarian design field. One of the studies focused on the application of the digital architecture in low-tech reconstruction of the Solomon Islands (Yeung and Harkins 2011). This study targeted a set of tools needed to start with the latrine by identifying appropriate parameters. An-

other example was the application of digital architecture to humanitarian design in the case study of a post-earthquake case study in Haiti (Benros and Granadeiro 2011), when automated systems were developed to create houses. This example focused on a set of construction drawings as the resulting documentation. Jinuntuya focused in his research on the use of digital tools and a game 3D virtual environment engine for decision-making support system (Jinuntuya and Theppipt 2007) for humanitarian needs. Another way to integrate the community in the design process for low cost housing design was the development of an application user interface (Wutthikornthanawt and Jinuntuya 2011). This interface was created for non-CAD users and has the advantage of being able to import information from different concerned fields with integrated real-time cost estimation. Sener has also proposed a parametric system to randomly arrange container shelters within a given site (Sener and Torus 2009) for an immediate answer to post-disaster relief. Recently, the research of Gonçalves (Gonçalves 2014) was based on grammars and configuration modules starting from an initial shape, and allowing the development of the original form to generate shelter housing. The generation process followed by this previous example is interesting in terms of mass production as was also shown in the research of Deborah for the reconstruction of post-earthquake Haiti (Deborah et al. 2011).

On the other hand, the infiltration of a parametric approach into an urban context was carried out within different projects and researches. Steino shows in his research (Steino and Veirum 2005) the capabilities of a parametric design approach in urban design through a case study. According to him, urban components share a similarity that can be defined parametrically. Aspects such as density, functions, forms, and spaces, can be translated into parameters. This approach can help to evaluate different scenarios and to reach the optimum solution. Thus, the infiltration of a parametric approach in urban design can lead to a sustainable result (Saleh and Al-Hagla 2012). In his research, Saleh examines the

use of a parametric approach in sustainable urban development. The case study developed in this research was the generation of an Arabian city by taking into account constraints such as wind and solar envelopes. Saleh identifies different components such as traffic, density and zoning that can be linked to urban design.

This brief state-of-the-art shows that:

- The contextual, climatic and ethnographic conditions that have an impact on the design process were not taken into consideration as structured sets of constraints, both regarding shelter and camp design.

- The humanitarian "urban design" (i.e. refugee camp scale) was not fully addressed in previous research efforts.

- A parametric system has the potential to be used as decision-making support in humanitarian design.

3. RESEARCH METHODOLOGY

This work is based on the previous recovery of post-disaster process by humanitarian groups. It was validated through an experimental phase with humanitarian partners. In particular the Shelter Research Unit (SRU) of The International Federation of the Red Cross (IFRC) was involved in the design process and in the identification of pertinent problems, as well as in the determination of essential parameters affecting the shelter and camp design. These parameters are translated into algorithms in a 3D modeling software allowing by this the experimentation of the prototype.

Identification of parameters. Problem solving requires the analysis of similar projects in similar crisis situations to extract the list of specific variables, as well as the identification of shelters and camps parameters (physical and contextual) and relations between them.

Among the list of identified variables, parameters are chosen for the design and modeling demon-

Figure 2
Shelter model provided by the Red Cross, Haiti 2010

strator. The chosen parameters are specified according to their importance in the shelter and camp design. Pertinent components are specified with external partners with an experience in the design of humanitarian housing.

Generative algorithm and their implementation. The generation of solutions that fit design requirements involves the identification of an accurate algorithmic resolution and formulas. Basic algorithms are implemented in a 3D modeling parametric software in order to create the physical model with a list of criteria and constraints to be taken into account.

Experimentation. The utility has been assessed with the IFRC expertise and in particular the SRU. This validation helps to reconsider the parameters used and to verify the methodology implemented in the process of humanitarian design for shelter and camps.

4. PARAMETRIC DESIGN PROCESS

This work assumes that the constraints and requirements in the design of the shelters and emergency camps can be connected to parametric digital design approaches. Variables and parameters proposed in the paper reflect the constraints defined at the level of both shelters and camps.

Shelter's design process

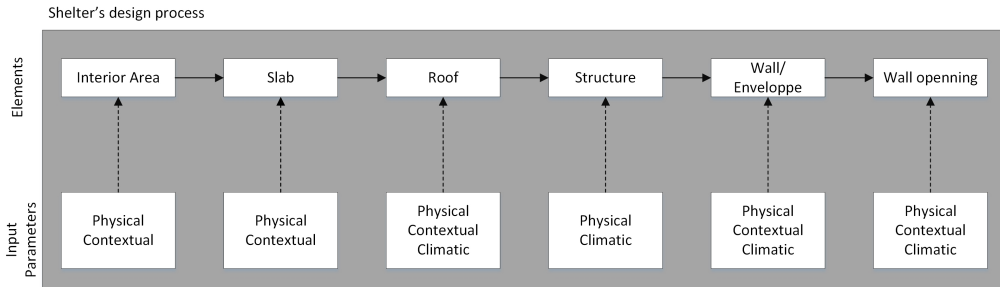| | Interior Area | Slab | Roof | Structure | Wall/ Enveloppe | Wall openning |

Shelter design process

The shelter design process is a linear process. It was essential to identify this process (Figure 1) to understand the logical order in which information concerning these various elements is defined and thus inserted in parametric modeling methods. For this paper, a "transitional shelter prototype" (Figure 2) was developed with parameters based on the Red Cross standards and prototypes for shelters (Saunders 2013). The degree of flexibility and the allowed elements to be controlled have been defined in the parametric model. Adjustment of the elements and parameters will give the ability to obtain the desired prototype according to the criteria set. A modelling process was developed by identifying possible relationships between different elements of the shelter, and by defining the specific phase for the implementation of the parameters in this process. The process begins with the number of people expected to live inside the shelter. This parameter enables to derive the requested surface shelter through the usual area per capita. According to RC standards, the minimum area by person should be >2.5 square meter: this will define the interior area of the shelter needed by each family. The process continues with all the further implemented construction parametric elements based on the interior surface. The slab and extensions as well as the roof and the structures are deducted thereafter through the contextual and climatic parameters. The structures and the envelope of accommodation are chosen by deducting the roof. The roof has a key role in customizing shelters indeed. The importance accorded to the roof as an essential element in the design stems from the fact that this form can also be the indicator of the typology of the region "Contextual parameter" and an answer to the local climatic conditions.

Camp design approach

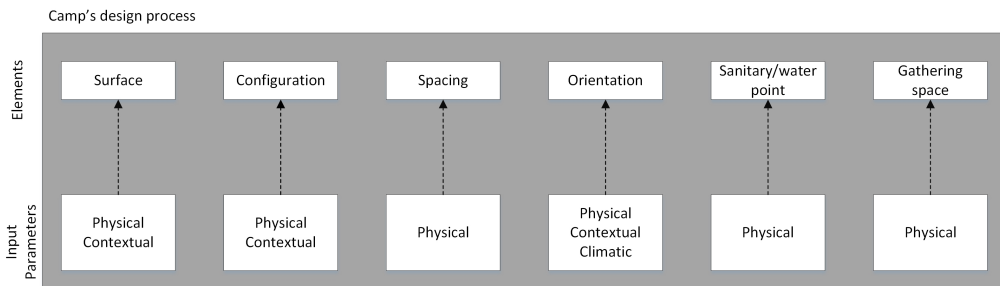Emergency camps design (Figure 3) is a more complex and non-linear process often addressed through

Camp's design process

the logistics issues raised. New concepts, requirements and ideas will constantly be introduced and planners should be prepared to adjust accordingly. The camp design should be linked to the types of solutions envisaged for sheltering which must be conform to standards. The authors propose a multicriteria approach rather than a so-called "iterative design process" and identify the parameters and relationships between the pertinent elements in the camp. These relations were combined to define a conceptual model. The camp design process is then validated in a parametric experiment. The prototype was developed by defining the following elements: main camp configuration based on cultural and contextual criteria, mobility nodes, roads and distance between shelters, interior roads, height of shelters and distance between them, the location of different resources (gathering place, water and sanitary points, gathering area, school and religious buildings etc).

Parameters

The parameters identified are based on a list provided by the Red Cross (Sanders 2013). Parameters were classified according to their types in order to choose the pertinent parameters at the good step during the design process. We can identify three types of parameters: (1) contextual parameters related to living conditions and culture, (2) climatic parameters related to climatic conditions and weather, (3) physical parameters related to the forms, geometries and dimensions.

The identification of parameters shows that physical parameters can be easily expressed numerically, while contextual and climatic parameters are more complex to be be translated into qualitative or numerical values.

Note that the elements of the shelters and the camps can be affected by physical, contextual or climatic parameters at the same time, climatic and contextual parameters may have direct influence to a physical elements.

Parameters included in the shelter's design process. In order to define the design structure of the shelter, a decomposition with specific components is essential. These components represent the building elements, such as walls, columns, beams, roof, and wall opening. Relations between these components are defined and maintained along the design process. Components can have the same parameters, but they can also serve as entries to other components by transferring the data (geometrical or numerical) to them (table 1).

Table 1
Parameters of shelter

Elements	Parameters	Parameters category		
		Physical	Contextual	Climatic
Interior area	Nb of person	x	x	
	Area per person	x	x	
	Coefficient	x	x	
Slab	Offset Slab		x	x
	Extrusion of slab	x	x	
	Extension	x	x	
Roof	Type of the Roof	x	x	x
	General Height	x	x	x
	Extrusion of the roof	x	x	x
	Extension of the roof	x	x	x
Structure	Distance between columns	x		x
	Disposition of columns	x		x
Opening	Door	x		
	Window	x	x	

Parameters included in the camp's design process. A decomposition of camp's components is essential when extracting the elements of the camp, such as road, lots, sanitary, spaces, dimensions, green spaces, gathering spaces (table 2).

Table 2
Parameters of camp

Elements	Parameters	Parameters category		
		Physical	Contextual	Climatic
Site	Form	x	x	
Roads	Width	x		
	Evacuation road	x		
Specific elements	Sanitary	x		
	Water Point	x		
	Green Space	x		
Shelter position	Specement between shelters	x	x	
	Rotation of lands		x	x
	Shelter additional PAD		x	
	Rotation of shelters	x	x	x

5. VALIDATION

Implementation

Shelters and camps parameters used for assessing our research propositions are implemented in a 3D modeling software allowing the generation of the prototype taking into account parameters and constraints. Grasshopper and Rhino 3D are used in our study. The choice of Grasshopper and Rhino 3D is justified by the ability of these software systems to easily design and manipulate algorithms based on visual objects and defining the constraints and parameters. The prototype developed deals with parameters and constraints that can be expressed numerically or geometrically. However while physical parameters were easily expressed, other parameters for the climatic and contextual variables could not be defined by numbers. For handling this kind of parameters, we defined scenarios, the objective was to create scenarios taking into account these parameters and translate them into numerical algorithmic formulas. In this project, the acceptable values of parameters are defined and are manually introduced into Grasshopper. These parameters are linked to Rhino 3D allowing the visualization of the physical model. This model can be controlled by the parameters included in Grasshopper giving the ability to choose the final desired model.

The figure 4 shows the overall generation of the shelter design process. The parameters used for the shelter are implemented in Grasshopper, where we can manually modify the values. For each element of the shelter, a sub-process were created allowing the generation of a 3D geometry which can be used as an entry for other element. Each element of the shelter is developped by a sub-process and related to other elements. The figure 5 is an example of the implementation of the roof parameters.

At the camp level, the scenario experimented in this case considers a flat land. For that, a module is proposed which divides each parcel into four different surface plots where the surfaces of plots are proportional to the shelter surface. The four surfaces can vary proportionally, respecting defined limits. Each surface is hosting one shelter. The plots can change according to the shelter's surface. In addition, formulas were developed to give each shelter a different height, allowing by this a dynamic non standard camp. Similarly, the second part of the work focuses on the camp development of previously cited elements (figure 6).

Assessment

The proposed system presents an opportunity for future development with NGOs interested in the humanitarian design taking into account selected physical and contextual parameters. Even though limits and constraints were fixed in the model, this does not prevent a certain level of flexibility; parameters can be modified according to the given scenarios. These limits were necessary in the definition of margins, thus reducing any unacceptable form they may be having.

To test and evaluate the effectiveness of this system, the prototype was confronted with experts from both the humanitarian field and architectural and urban design. The review is done thru different ex-
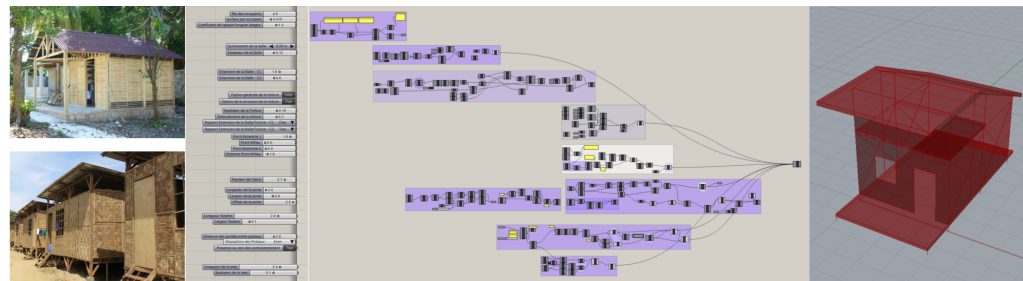

Figure 4
Overall process for the generation of the shelter prototype

periments describing different scenarios created instantly by modifying the parameters to test the ability of the design process to answering scenarios similar to real cases.
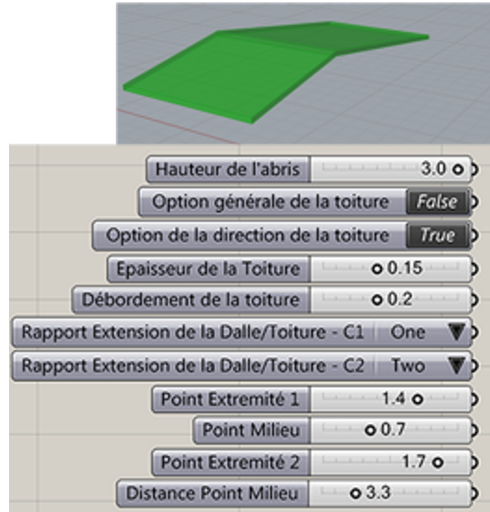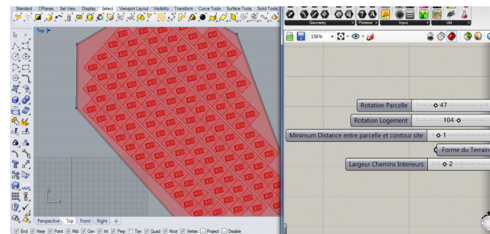
6. DISCUSSION

The shelter process can be criticized in real cases, where the mass production and rapid prototyping are considered the best answer for post-disaster reconstruction. Personalizing the shelters according to some parameters (including the area of interior surface) will help accelerating the mental recovery of beneficiaries (Lawther 2009). The validation shows that the design process developed for shelters and the planning of the camps can be adapted to possible real cases. The practitioners in the validation found that the prototype process is adaptable to real case assessments, and that such approach will help potential users in emergency design in term of flexibility, collaboration and time economy.

7. CONCLUSION AND PERSPECTIVE

This paper describes the research carried out to investigate the potential application of computational design to assist humanitarian design. It attempts to explore the capacity offered by the parametric modeling in the design of emergency shelters and camps in order to help architects and humanitarian in decision-making, and it attempts as well to explore the limits of this technology. It starts with developing a design process for the shelter and camp. This process is based on the idea to personalize each shelter according to the size of the family, taking into account some cultural and contextual parameters. The main result of this paper is a prototype of parametric shelter and a model of a camp based on the Red Cross standards. The prototype is linked to a set of parameters and constraints with contextual and climatic impact. Another part of this work was to define a list of recurring parameters, to be used to model a shelter and an emergency camp. Three types have been identified: physical parameters, contextual parameters and climatic parameters. It thus was necessary to identify, with the external partners, the relationships between parameters and variation margins of values as well as the elements to be controlled.

The research field is delimited by the identification of parameters for modeling a prototype shelter and a layout of a camp. This prototype is inspired by the shelters designed by the IFRC following disasters in several regions. In addition, the design at the scale of a camp is proposed using some relations identified between the designed camps and shelters. Aspects related to construction materials cost and bills of quantity are not taken into account in this part of the research even if they are important in the humanitarian field. Future research should focus on

these points. This paper is part of a future project attempting to answer humanitarians' needs by providing a decision-making support system in the design of shelter and emergency camps, taking into consideration multi-contextual conditions.

ACKNOWLEDGEMENT

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