Evolutionary algorithm for timber shelter optimization.

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Abstract

The present paper describes an approach to wood as an alternative construction material and the formal search of typologies which combine a secure and efficient structure with an architectural based definition of dimensions and geometry. The outcome, given by a genetic algorithm is intended to be used as a concept to develop shelter solutions for the village of Jametla, located on the coast of the state of Jalisco, in Mexico.

Keywords: multi-objective optimization, security, shelter, timber construction, hurricane.

1. Introduction

Natural disasters are a growing threat and have increased significantly in the past few years. The New England Journal of Medicine published that natural disasters between 2000 to 2009 have increased three times when they compared between 1980 and 1989 and 80% of this growth is due to climate-related events (Debarati, 2013).

The state of Jalisco, where the village of Chamela is located, was ranked number 5 out of 32 states prone to cyclone hazards according the Mexican water committee (CONAGUA, 2012).

In addition, Chamela also presents a high marginalization and poverty index, ranked 6,619 in a national context, and increase in illiteracy (PDZP, 2013). This reality is reflected in an increasing emigration indicator from “balanced” (lapsed from 1995-2000) to “elevated expulsion” (lapsed from 2000-2010) category.

This combination of both a tendency to natural disasters and extreme poverty levels, is the case of Chamela but also of many other coastal villages. Therefore, this paper can apply to contexts which are like the one we’re presenting and we aim for it to be useful in future hazards or disasters, mainly focusing in hurricane disaster zones.

A transitional shelter is a rapid, post disaster household that can be upgraded or re-used in more permanent structures (IFRC, 2011). One of the main problems in designing and building a transitional shelter is that, given the nature of a shelter, these are built without having architectural considerations. In some cases, transitional shelters are built to develop a rapid household but comfort is not considered.

In a hurricane post disaster zone, a few factors come into account when designing and building a shelter since heavy winds and rain are likely to happen.

Many of the structural considerations that should be considered to design a safe shelter can go against comfort for users. As an example, as the shelter surface (walls and roof) are increased, the stress in the structural elements of the shelter will increase, but will have a greater area. In these cases, like this one, it is useful to use evolutionary algorithms to search and explore different possibilities.

2. Pareto frontier

In multi-objective optimization, a Pareto frontier is a set of nondominated solutions, being chosen as optimal, if no objective can be improved without sacrificing at least one other objective (Reddy, 2015). The set of Pareto optimal solutions is very helpful in evaluating and visualizing the behavior of multi-objective optimization design variables since it can be possible to observe the tradeoff between multiple design variables into multiple objectives.

3. NSGA-II

A NSGA (Non-Sorting Genetic Algorithm) is a popular non-domination based genetic algorithm for multi objective optimization (Seshadri, n.d.).

For the optimization of this transitional shelter the algorithm developed by Aravind Seshadri was used as a base and modified to meet the requirements of this article.

A total of seven objective functions were considered to try to find an optimal solution for a timber shelter that would be built as a rigid frame using a fixed topology.

The first block (5 functions) were architectural objectives. The last two where structural objectives.

Block 1: architectural functions contains these parameters:

1. Total area must be at least 18 m2 and at least 3 meters long for the width to ensure it can be a useful area.
2. Length must keep a harmonic proportion to the width.
3. Height must be proportional to length and height as well as like most the town's houses.
4. Total area must be capable of a future subdivision into smaller or more private areas, such as a room.
5. The volume of interior space must be as big as possible

Block 2: structural functions contains the following parameters:

1- Mass: the total mass of the structural elements.
2- Lateral displacement: The maximum lateral displacement of the nodes.

Both structural objective functions were developed using local parameters for timber properties and wind load estimations. The codes used were:

- Normas Técnicas Complementarias Para Diseño Por viento, for wind análisis.
- Evaluación del Comportamiento de Tres Maderas (Bustamante, n.d.).

Since a tradeoff is made when a design variable is changed, a series of plots were developed to observe the behavior of the objectives for different values of the design variables. The next figures show some of the tradeoffs between different elements of the population.

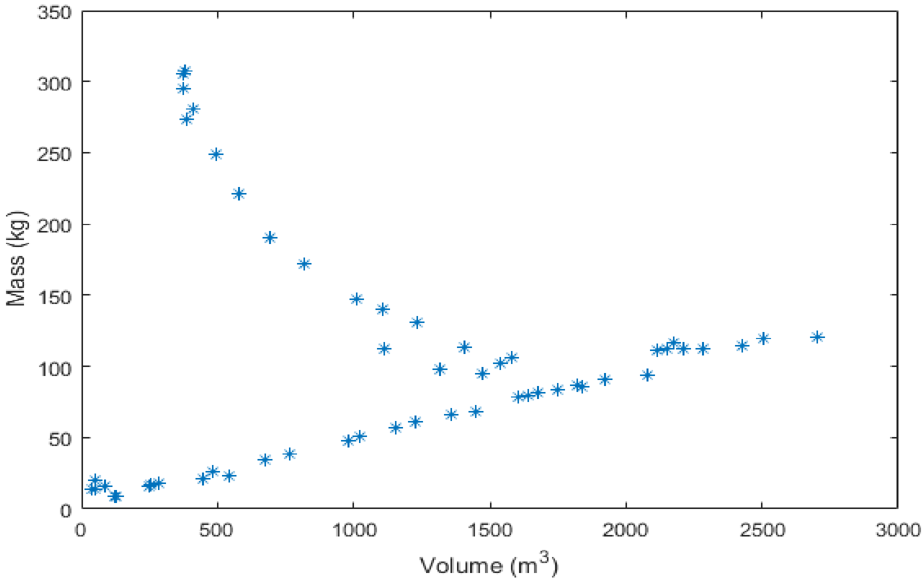

Figure 1: volume vs mass of the shelter.

The previous figure shows the tradeoff between volume and total mass of the structure. Increasing the volume increases the mass, but there are cases where the increase of the mass does not increase the volume. This is likely to be due the stress distribution in some of the geometries.

Another interesting interaction found between the objective functions was between volume, area and node displacement.

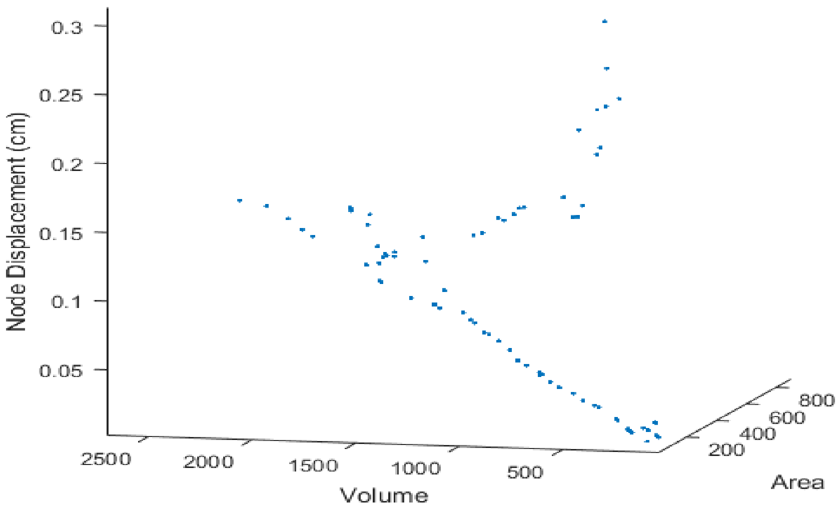

Figure 2: Volume vs Area vs Node displacement.

It can be noticed that the distribution is similar in figure 1 and figure 2. This might be because mass and node displacement are directly related because the load vector is the same for a given geometry,

4. Conclusions

The search for endowing comfort to shelters tends to come to a secondary part in a post-disaster context. The priority is commonly limited to the minimum budget, minimum of dimensions for a “dignified” home. Ideally the program will consider a more comfortable and pleasant geometry without necessarily involving a raise in cost and material. It defies the idea that architects and designers are luxury reserved for the upper class.

The sole exercise of combining architectural and structural values at the same level forcing neither one to overcome the other is an accomplishment by itself. It’s an exercise we rarely practice and in more practical terms is nearly impossible.

The idea of giving architectural features a numeric value and turning it to a function is also an interesting practice that tends to be complicated since a quantitative value must be assigned to a qualitative variable.

One important aspect that was noticed is that evolutionary algorithms can help in looking for different solutions. In this case, only one topology was used to search for different geometries to achieve the different goals, but it could be more useful to develop an algorithm that can evaluate also different topologies to have an even bigger search space.

5. References

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