COMBINING SHAPE GRAMMAR AND GENETIC ALGORITHM FOR DEVELOPING A HOUSING LAYOUT : Capturing the Complexity of an Organic Fishing Settlement

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Abstract. Many settlements like the fishermen's habitat have developed organically and embody the complex relation between land characteristics, functional activities and social aspirations. However, the recent rehabilitation and planning projects, constrained by technical and inscriptional rigidities, have become relatively fixed, formal and monotonous. This research attempts to harness and integrate some of the qualities of organic design process into computer-aided design. The two complementary fields of Shape Grammar and Genetic Algorithm have been converged for this purpose.

1. Introduction

This project proposes a generative model for a layout of a fishermen's settlement. It attempts to capture the complexities of an organic solution and apply it to the housing design decisions. Shape Grammar is used to extract the style and aspects of organically evolved fisherman's housing settlement and explore alternatives. Genetic Algorithm is used to evaluate the generated design for its functional and usability values and identify the fitter solutions. To get a complete and useful solution, context-specific physical aspects, socio-cultural expectations and the functional requirements are addressed in the proposed computer-enabled design process.

2. Design Knowledge—Fishermen's settlements

A general study of the fishermen's settlements revealed a very distinct pattern of hierarchy of spaces. A gradual transition of private space at the household level to semi-private spaces around the houses, to public spaces like community centres/ work areas is a common feature in all the settlements. Majority of activities during the day such as work/ relaxation etc., are done in groups and occurs mostly in and around the beach. The public space around the beach is used for storing fishing implements, drying of fish, selling of fish, relaxation and even for sleeping during summer nights. Most communities have a very strong preference to religious

activities and a temple/church/mosque forms the major community space. The other common community spaces are schools and commercial areas. The dimension and value of public space around the community space varies, depending on the activity. In most settlements a highway/a connecting road acts as a major constraint to the settlement growth. Commercial activity along the periphery of the road forms an informal community space in most settlements. The fishing commune's survival is linked with effective co-operation and interaction within the community. This reflects greatly in their settlement layout. The house is the only private space used by the household in the community. The land use immediately outside the house follows a traditional pattern of multiple and mixed land use, wherein no rigid hierarchy of ownership of land is practised. The primary units which are the houses, are arranged randomly along meandering pathways, connecting the beach and the community spaces (Figure 1).

Figure 1. Layout plans of various fishing settlements.

2.1. REHABILITATION PROPOSALS

The designs proposed by the government and a few agencies for the rehabilitation of fishermen colonies are rigid and lack sensitivity to the social aspects. They ignore

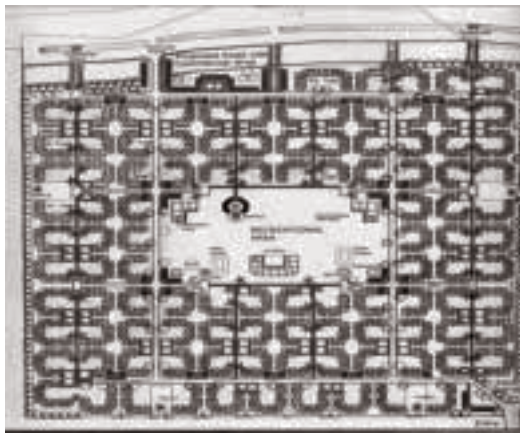


Figure 2. A conceptual layout plan for a fishing village in Chennai.

the design knowledge available through existing settlement and life patterns (Figure 2). This proposal criticizes this approach and tries to incorporate some of the objective and the subjective design knowledge learnt from the organic settlements.

3. Shape Grammar

The distinct and deliberate pattern of hierarchy of spaces wherein a gradual transition from private space at the household level to semi-private spaces around the house to public spaces at the beach and around the community centres, is the feature that

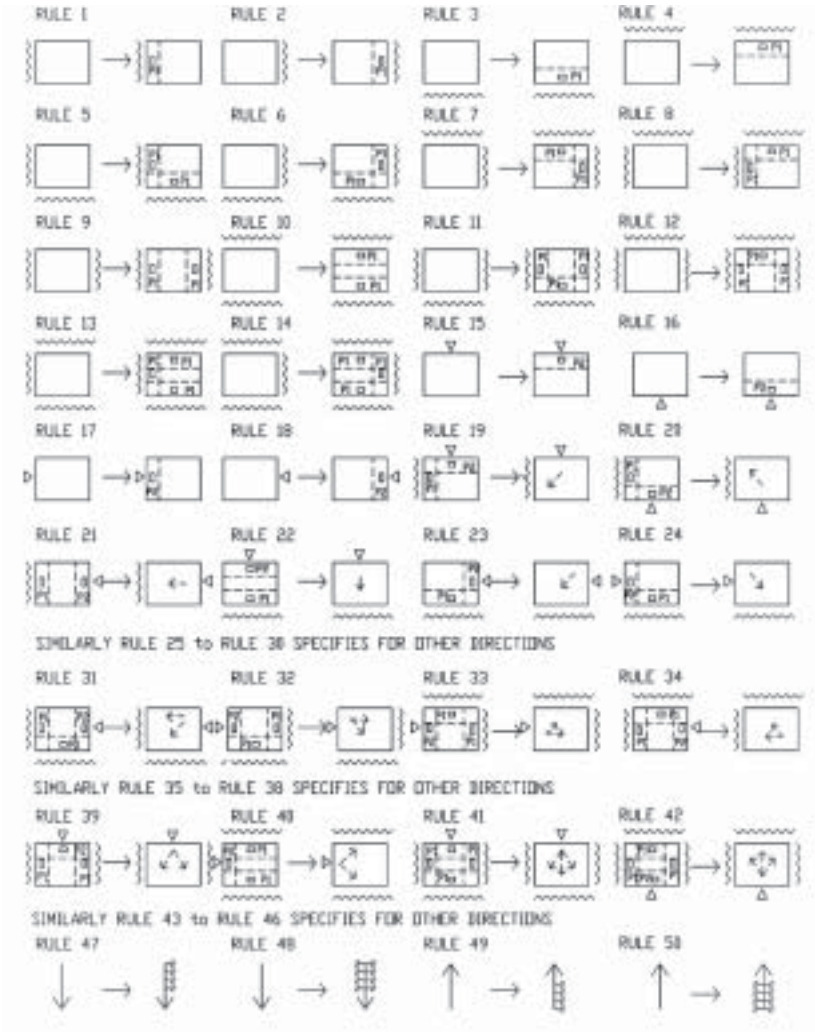


Figure 3. Shape Grammar.

enriches an organic settlement. This design knowledge is abstracted into a Shape Grammar and acts as a source for the derivation of designs, controls and guides the design process and allows the designer and computer to evaluate the results of designing (Figure 3).

Rule 1 to Rule 14 specify the positioning of the beach with respect to the site and the public space around the beach. Rule 15 to Rule 18 specify the positioning of the community centre and the space around it. Rule 19 to Rule 46 specifies the path offshooting from the community centre to the beach. Rule 47 to 50 specify the placing of the primary units along each side of the pathway.

4. The Shape

The geometry of the shape generated within the set boundaries are evolved by a simple addition rule. The model consists of a set of simple rules and restrictions which function continuously and generate a complex shape randomly. The result varies on different runs because the addition rules are randomized. The randomization is restricted by a rule so that the solution lies within the expected space of solutions.

4.1. SHAPE UNIT

It is a simple square unit of usable space comprising four line entities, (Figure 4) the size of which determines the complexity of the resultant shape. The user handles the value of the shape unit which may range from a minimum of 1.5m (a pedestrian pathway) to 4.5m (average size of a dwelling). All usable space can be represented as a single shape unit or a combination of shape units. It is arranged in an array at restricted points chosen randomly. Since the array points are chosen randomly, it opens up more possibilities. The single square unit is defined on the basis of its centre point and its four vertices.

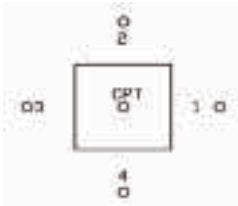


Figure 4. Shape Unit.

4.2. ORGANISATION OF SPACE

In this context a shape is defined as the geometry generated by the random array arrangement of shape units. The four adjoining centre points are also associated with the shape unit and form the potential points where proliferation might occur.

The centre points around all the shape units are stored as a list and choice is made randomly at any of these centre points and the shape unit is placed on it.

4.3. RESTRICTIONS

The random choice of the centre points is bound by certain restrictions which control the proliferation process. Some of the restrictions can be modified by the user while others cannot.

4.3.1. Prohibit Overlap

It prohibits two units from occupying the same centre point. This function is evoked every time a point is chosen for placing the shape unit. The centre points of the placed shape units are saved in a list. If the centre point is already in the list of placed shape units, it prohibits the placing of the shape unit in that particular centre point.

4.3.2. Boundary

It allows proliferation only within the specified boundary. A boundary could be specified based on the physical requirements. Proliferation is allowed only on the centre points which are within this boundary.

4.3.3. Connections

Connections if required are established on the periphery of spaces. Certain spaces function only when they are physically connected to another space, e.g. pathway. This function connects the two adjacent shapes at the point where they come in contact.

4.3.4. Size

The size of the space generated is restricted by the user input. The site characteristics, extent, activity and population are criterians which define the size of the open spaces.

6. Evaluation Criteria

6.1. OPTIMAL USAGE OF SPACE

This function calculates the area of the built-up space, and usable open space comprising the public spaces and the pathways. Area of unoccupied space farther away from the pathway and behind the dwelling units is considered as dead space. The percentage distribution of the area of each space is tabulated for each alternative. The lesser the unused dead space, the fitter the solution.

6.2. CONNECTIVITY

Effective connectivity between spaces is ensured by this function. Five shortest pathways connecting two spaces are calculated and the pathways generated are checked for their length. The solutions with shorter pathways are graded as high.

6.3. THERMAL COMFORT

The generated solutions are checked for their thermal values also.

6.3.1. Western walls

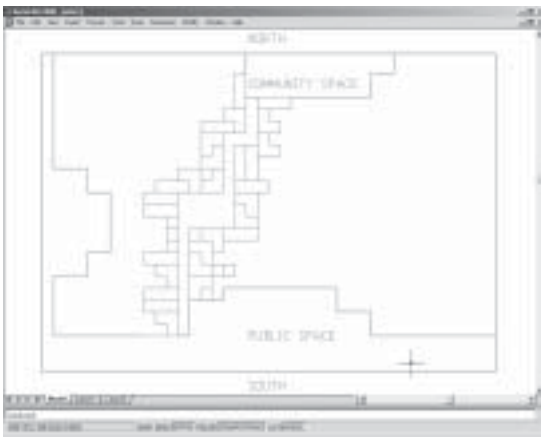
The area of wall surfaces exposed directly to the western side is calculated. This is to ensure that heat gain inside the dwellings is minimized.

6.3.2. Solar Protection

Solar protection can be increased by mutual shading of buildings. The lower altitude of the west sun allows buildings to be separated around 1.5 to 2 times the height of the building giving shade. The height of the dwellings is assumed and the solar protection calculated.

These objectives determine the fitness of the solution. A new generation of solutions could be produced by considering a parent from the generated family of solutions. The highly "fit" solutions are chosen as parent for further reproduction with greater probability. Each design solution has an associated ''shape code". A shape code in this context is a list that encodes the sequence of centre points chosen for the proliferation of the shape units. This shape code is taken as the genotype and crossover/ mutation performed to give a next generation of solutions.

7. Demonstration example



Public space is generated along the 2 sides facing the beach and the community space is generated around the community space. A pathway connecting the two spaces is flanked by the random arrangement of the dwelling units whose area is fixed but the shape varies randomly.

The solutions generated on different runs can be viewed simultaneously with their respective fitness evaluations. The user could select the best solution as the parent for the next generation of solutions.

Figure 5. Demonstration example.

8. Conclusion

The use of such a tool at the early design level will have a number of advantages:

- The physical and socio-cultural requirements are captured by the shape grammar, resulting in more empathetic design solutions to the context.
- The randomized proliferation of the occupied units results in an unanticipated geometry of spaces.
- Genetic algorithm uses the fitness function to choose the 'best' solution and makes sure that the objectives of the design are satisfied.
- The tool does not generate in and of itself. Human intervention in judging and selecting the various possibilities it generates enhances more control.