Using Interactive Evolutionary Computation to Generate Creative Building Designs

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Abstract

In this paper we describe how we have exploited Evolutionary Computation (EC) to generate creative building designs. The algorithm has been implemented to create a design tool for architects called Design Inspiration system (DIS). The interactive design inspiration tool is able to generate initial design concepts of architectural plans. Our approach illustrates what we regard as an ideal strategy towards an organic architecture that is inspired from living organisms and not concerned with architectural style. The current capabilities of the system are demonstrated by the example of designing a library building.

The paper ends by describing a comprehensive experiment with a total of 28 volunteer architects as a cognitive performance measurement tool, capable of accurately positioning participants' performance using the design system.

Introduction

Although there is much evidence of the utilization of evolutionary and adaptive computing technologies for system optimization there appears to be little recognition or investigation of their design exploration and search capabilities. Such capabilities support their appropriate integration with conceptual and preliminary design processes to support search within predefined design spaces whilst also allowing exploration in less well-defined areas that lie outside of initial constraint, objective and variable parameter bounds [1]. Noguchi has pointed out the necessary requirements of design imagination support. It is thus important to make designers realize the missing elements, factors, or methods in their designing process, not to support them to make an easy output [6]. Suwa stated that design sketches are not just images but they can inspire designers with new ideas in process of design [5]. DIS is a design tool for architects developed by Multimedia Engineering Lab at Kagoshima University. The aim of DIS is innovation in architectural design by exploiting and exploring new algorithms from computer science. In particular we are interested in applying ideas from Evolutionary Computation (EC) and Artificial Life (ALife) to architectural design. In addition to designers' own interpretations for the system outputs, DIS can help make new design concepts and explore new architectural forms. DIS provides more opportunities to enhance and support designers' creativity.

Interactive Evolutionary Computation (IEC)

Interactive evolutionary computing relates to partial or complete human evaluation of the fitness of solutions generated from evolutionary search. This has been introduced where quantitative evaluation is difficult if not impossible to achieve.Evolutionary Design is derived from biological principles, specifically those of the theory of natural selection. Interactive genetic algorithm (IGA) is defined as a genetic algorithm that uses human evaluation. These algorithms belong to a more general category of Interactive evolutionary computation [7]. Aesthetic Selection is a general term for methods of evolutionary computation that use human evaluation. Human evaluation is necessary when the form of fitness function is not known .The number of evaluations that IEC can receive from one human user is limited by user fatigue which was reported by many researchers as a major problem [7]. In computer bimorphs, ring of 18 possible mutants, of which a representative six are drawn in (Figure.1). Each member of the ring is only one mutational step away from the central bimorph, it is easy for us to see them as children of the central parent. A child differs from its parent at only one gene, all mutation occurs by +1 or -1 being added to the value of the corresponding parental gene. The shape of each child is not derived directly from the shape of the parent. Each child gets its shape from the values of its own nine genes (influencing angles, distances, and so on) [2].

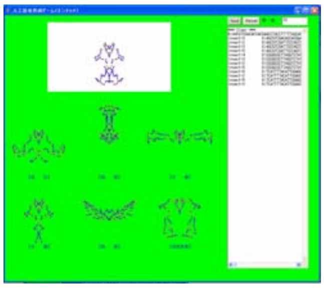


Figure 1 Biomorph

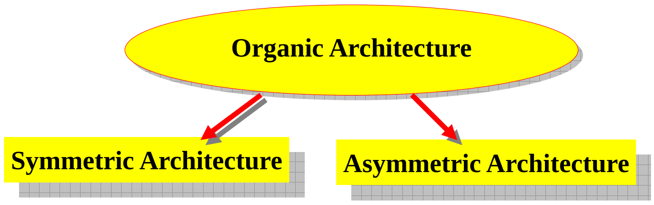


Figure2 Distinction in design

System Implementation

In our system, organic architecture is divided into symmetric and asymmetric architecture (Figure 2)[3][4]. Design Inspiration System (Figure 3) is designed to generate asymmetric architecture designs (Figure 5,6) and based on BioArchitect that we developed in 2006 to generate symmetric architecture forms(Figure 4) [3][4].

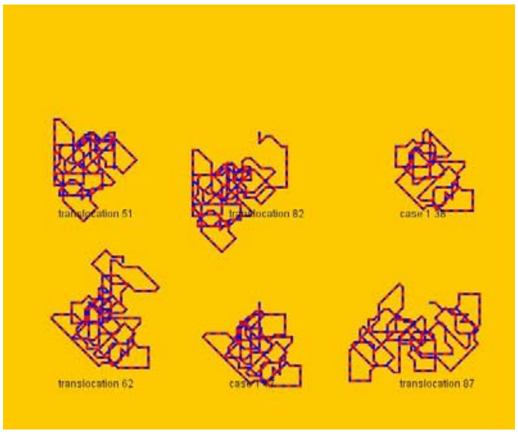


Figure 3 DIS

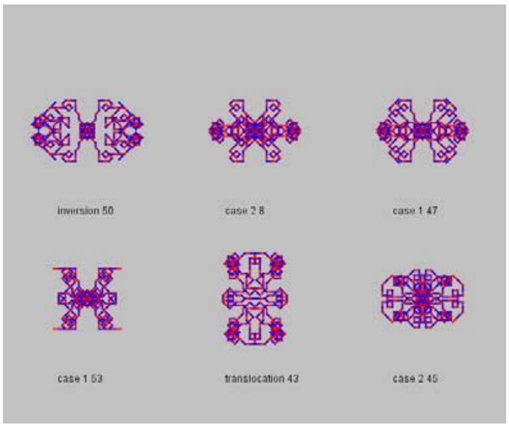


Figure 4 Bioarchitect

Both of BioArchitect and Design Inspiration System are inspired from computer bimorphs developed by Richard Dawkins in his work of " The Blind Watchmaker"(Figure 1), and the possible mutants, of which a representative six are shown in the system interface. The Interactive evolution consists of endless repetition of reproduction, which takes the genes that are supplied to it by the previous generation, and hands them on to the next generation.

Genotype-phenotype distinction

The genotype-phenotype distinction refers to the fact that while genotype and phenotype of an organism are related, they do not necessarily coincide. The genotype of an organism represents its exact genetic makeup, that is, the particular set of genes it possesses. Two organisms whose genes differ at even one locus (position in their genome) are said to have different genotypes. The term "genotype" refers, then, to the full hereditary information of an organism. The phenotype of an organism, on the other hand, represents its actual physical proper ties, such as height, weight, hair color, and so on. The mapping of a set of genotypes to a set of phenotypes is sometimes referred to as the genotype-phenotype map. In DIS (Figure 3), the individual is represented by an array of four types of strings for initializations `A', `C', `T', and `G' that are used to represent the DNA. In general, a string `A', `C', `T', and

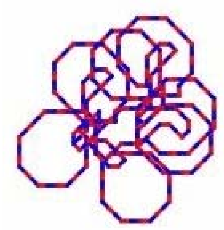


Figure 5 Sample output 1

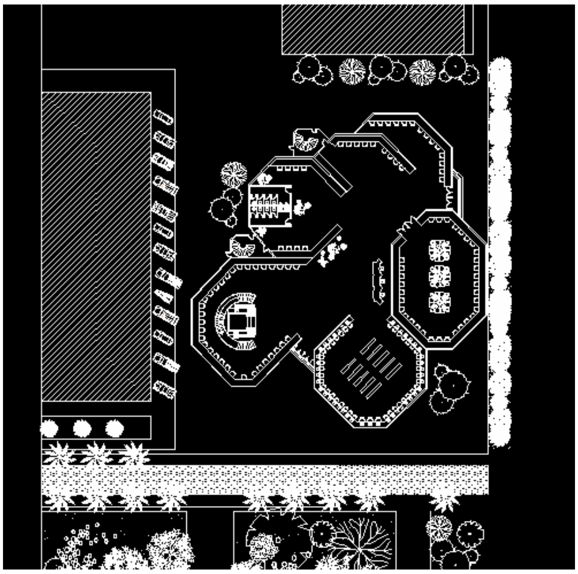


Figure 6 Sample output 1 drafting

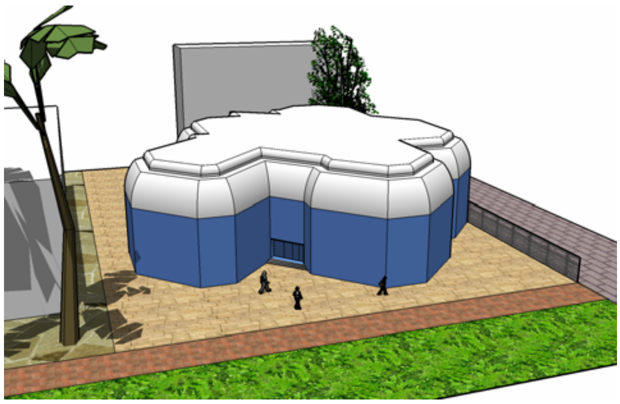


Figure 7 Sample output 1 (exterior 3d view)

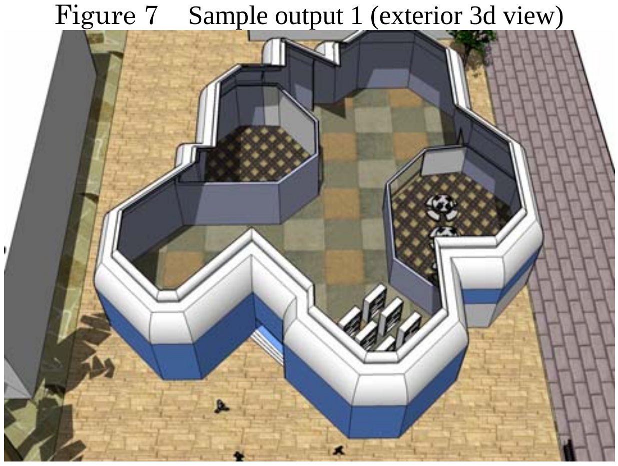


Figure 8 Sample output 1 (interior 3D view)

`G' of the individual is considered as a gene. The gene row is GENOTYPE, and the new design generated from GENOTYPE to be PHENOTYPE. Conversion from GENOTYPE to PHENOTYPE occurs from starting point according to the gene structure. DIS is a very creative tool because the total amount of genetic difference from the original ancestor (Figure 5,6).

Empirical Research Methodology

Interviewing and questionnaires with architects from multicultural backgrounds

A task of designing Kagoshima university library building was given to 19 Japanese architects working at TojoSeki architecture firm in addition to 9 architecture students from Kagoshima University as a cognitive performance measurement tool, capable of accurately positioning participant performance using SIA. Participants included architects from multicultural backgrounds such as Japan, USA Jamaica, Vietnam, China, Australia and the United Kingdom.

Usability Questionnaire

In order to evaluate the system, and describe the participants' performance towards the implementation of SID, they responded to each question of usability questionnaire. The results were then converted into percentage. The questionnaire is available at 7 questions. Each of the questions had rating scales ascending from 0 on the left (Figure 13) to 7 on the right and anchored at both end points with strongly disagreed and strongly agreed. The options used by the scripts include:

- Overall, I think the system is user-friendly.
- The system speeds up my design process and reflects my sense of space.
- The system produces creative designs that are guided by my own interaction
- This system supports my imagination and helps me to find what I am looking for in a very short time.
- It was easy to learn to use system. The interface is very simple and well designed to help designers.
- I became productive quickly using system because I can work on several high quality designs simultaneously.

The main assessment criterion is to check whether the system can produce creative designs guided by user interaction .As shown in figure 7, the illustrated 3D graph shows that the system helped to produce creative designs and forms in a very short time span. Design samples (Figure 5,8) were selected to be processed into AutoCAD architectural plans (Figures 6 and Figure 10) then into three-dimensional drawings (Figures 7,8,11,12).

Summary

Artificial Creativity demonstrated by the interaction between genetic algorithms and the architect using DIS suggests that creativity in organic architecture can result from a combination of (Logical/Mathematical) and

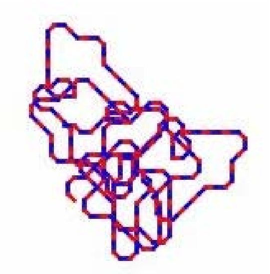


Figure 9 Sample output 2

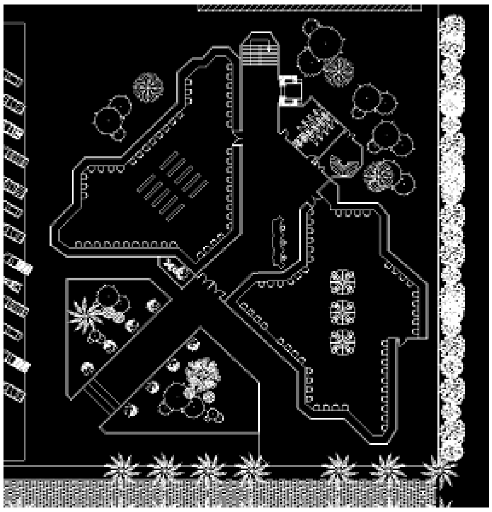


Figure 10 Sample output 2 drafting

Figure 11 Sample output 2 (exterior 3d view)

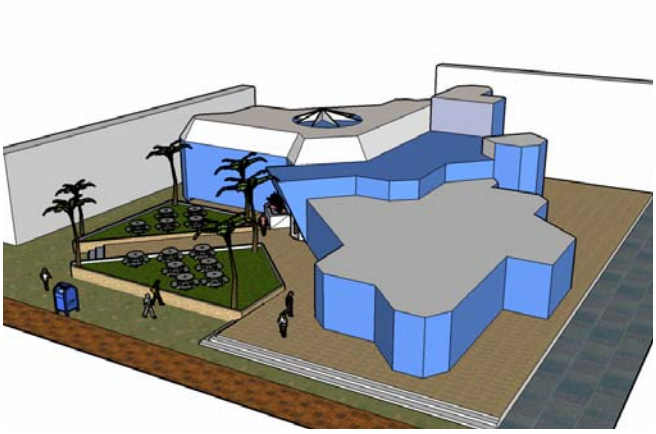
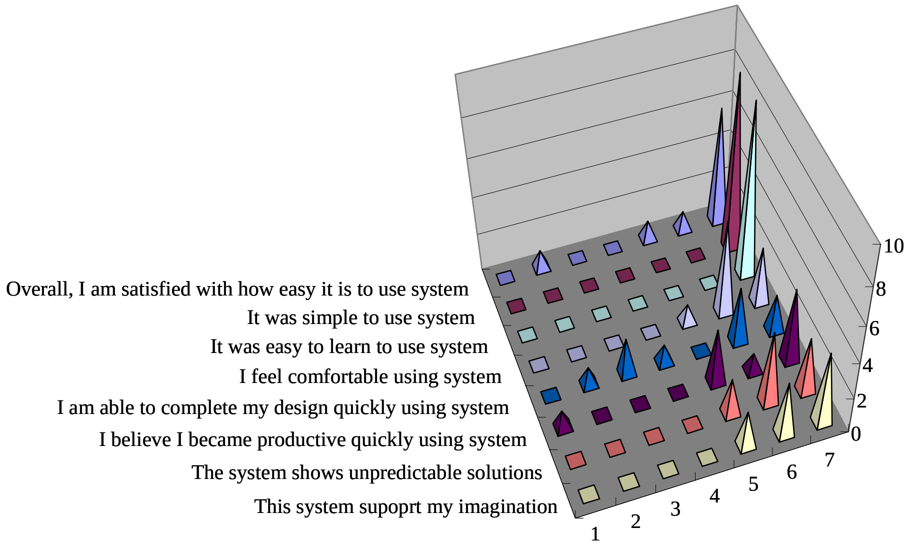
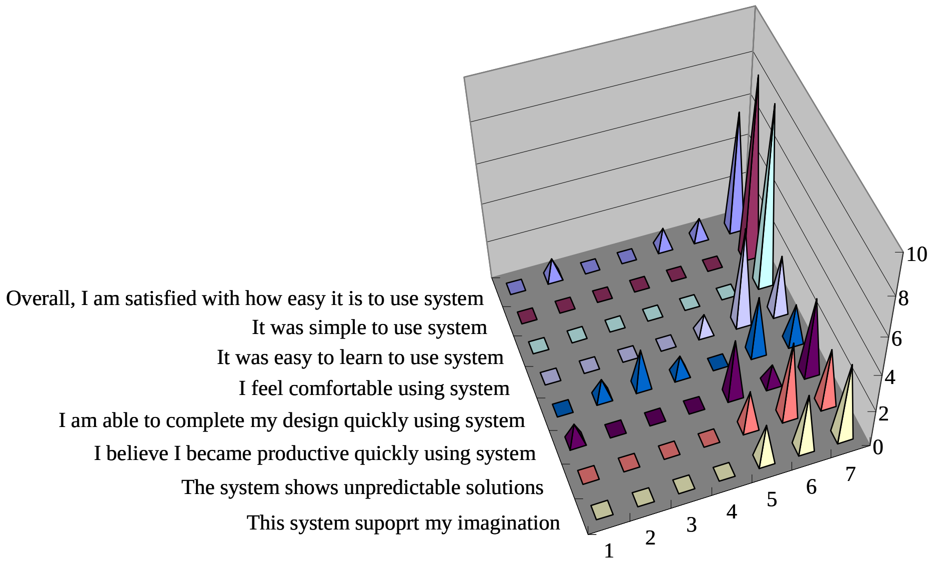


Figure 12 Sample output 2 (exterior 3d view)



(a) From students.



(b) From professionals.

Figure 13 Usability questionnaire results

(Visual/Spatial) intelligence regardless of the socio- cultural the background of the designer or a particular style. The creative input from the architect is still essential. The difference is that architects will have to concentrate on generic ideas and leave specific instances to the computer and the environment. In the computer-based design future, the generic idea will be encapsulated in a genetic language and DNA.

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