# A QUANTITATIVE FITNESS FUNCTION FOR AN EVOLUTIONARY ALGORITHM THAT GENERATES DIGITAL SURFACES

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Form design in Architecture has conventionally been a process where aesthetic criteria supercede all others. It is only after a form has been artistically ` created' that more ` concrete'design steps consider performance based criteria. At these steps, performance evaluation may lead to form revision but, the influence of performance on form is indirect. As the architectural design process evolves, aided by computation, the integration of quantitiative *and* subjective performance is extending to the realm of form design. In this paper, we describe how Genr8 (Hemberg 2001), an architect' sdigital surface (i.e. form) design tool based on Evolutionary Computation (EC), handles its form evalution. Thus, Genr8 is a contribution not just from an architectural perspective but, from an EC perspective, it demonstrates one means of resolving the elaboration of a fitness function in a domain with subjective factors.

Genr8 was developed by the Emergent Design Group (EDG) at MIT in 2001. Genr8 creates digital surfaces with the aid of an algorithm called Hemberg Extended Map L-Systems (HEMLS). HEMLS are based on the more familiar Lindenmayer-systems (L-systems) (Prusinkiewicz and Lindenmayer 1996) that have successfully been used to produce realistic images of trees and plants. The digital surfaces are created through a reactive growth process that takes place in a simulated environment. This gives the surfaces an organic quality. More details are available in Hemberg (2001).

An evolutionary algorithm (EA) (O'Neill and Ryan 2003) helps the user find interesting forms. In an evolutionary algorithm, each member of a population (in Genr8' scase, a surface or form) must be evaluated and assigned a fitness. This fitness score is then used in a fitness based selection phase of the algorithm. Assigning fitness to anything that has artistic or creative qualities has always been a complicated issue (Bentley 2001) Should quantitative criteria that can be assessed very quickly be used, or should the user be involved interactively to provide subjective ranking? The latter approach eliminates the task of algorithmically defining fitness, but it introduces a new problem; human fatigue (Sato and Hagiwara 2001). Assigning fitness is a tedious, repetitive and inconsistently performed task and it limits the population size as well as the number of generations that can be used.

In Genr8 the fitness function is metaphorically a steering wheel that helps the user guide the evolutionary search. It is automated to allow a larger

portion of the search space to be explored. Genr8 uses a parameterized fitness function relating six features of a digital surface. The user chooses a target value, $t_i$, and a weight, $w_i$, for each feature. In order to calculate fitness, each feature is assessed (yielding a value $s_i$) and compared with the user specified target values. As shown in Equation (1), the fitness is a weighted sum of the absolute values of these differences.

$$\text{Fitness} = \sum w_i \left| t_i - s_i \right| \qquad (1)$$

The six fitness criteria are:

- **Size**. This criterion measures the size of the surface in the *x*-*y* directions.
- **Symmetry**. The symmetry measure gives a rough idea of the symmetry.
- **Soft boundaries**. This criterion can be used to allow the surface to grow through the boundary wall at a fitness penalty.
- **Subdivisions**. This criterion measures how articulated the surface is.
- **Smoothness**. A local measure of how the variations in the *z*-direction.
- **Undulation**. A global measure of the variations in the *z*-direction.

Understanding the meaning of the numerical values of the target values is not direct. One must develop intuition via experience with Genr8 that yields a feel for how the parameters contribute to the fitnesses of surfaces. The user is able to intervene periodically to tune the parameters of the fitness function. An accommodating aspect of these features is that they map many to one with fitness values implying that a large number of surfaces that will fulfill a given set of fitness criteria.

Genr8 has been used in the graduate program Emergent Design and Technologies (Emtech) at the Architectural Association (AA) in London for two years. Experience from the AA work has shown that Genr8 can successfully be used for design activity that focuses on functional form and that the parameterized fitness function significantly increases the size of the search space that can be investigated.

## References

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