Performance-based parametric design explorations: A method for generating appropriate building components

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Performance-based parametric design explorations depend on formulating custom-designed workflows that require reading, writing, interpreting and manipulating databases, as part of the design process. The possibilities of customization and parameterization offered by the user-friendly interfaces of advanced building-performance simulation software and digital design tools have now enabled architects to carry out performance-based design explorations without the help of simulation experts. This paper presents a customized workflow methodology to explore design alternatives for producing shading devices that can optimize daylight, while blocking out excessive solar heat gains, in an office building in a hot and humid climate. The design alternatives were generated by evolutionary algorithms in accordance with daylight performance requirements and simulated to assess their shading and daylight efficiencies.

Keywords: genetic algorithms, design strategy, generic design, simulation, environmental design

Performance-based or performative design is defined as the synthesis of two digital design processes; namely, geometry-generation and performance-simulation (Oxman, 2006). Performance based models are generated to comply with predetermined performance objectives; thus, performance becomes the determining factor for form and geometry generation (Oxman, 2008). This generative design process depends on variants which are parametrically defined in relation to the design problem, while the evaluation of the generated solutions depends on the simulation of different parameters; such as social, cultural, ecological or economic (Kolarevic & Malkawi, 2005). However, generative design explorations and performance simulations are complex and time consuming processes due to the large number of design parameters and their inter-relationships; practically, it is not possible to handle them without the aid of computational tools.

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Renner and Ekárt (2003) state that genetic algorithms provide an alternative to traditional design exploration techniques by simulating the mechanisms found in genetics; they transpose the notion of natural evolution to computers and imitate it by first generating a population of individual members and then

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finding the fittest ones through a multidirectional search. In this technique each member of the population is assigned a fitness value by incorporating a fitness function into the genetic algorithm, which in turn indicates how well the solution performs with respect to the design problem. Individuals closer to the fitness value are kept and new ones are generated either by mutation, crossover, or reproduction from the fit ones, and are tested again (Renner & Ekárt, 2003).

Genetic algorithms can be used together with parametric modeling techniques to generate optimized building forms based on a performance driven geometry. In other words, the two digital tools can be brought together to produce high performance design solutions; such as the performance based design of a long-span roof that was optimized for solar heat gain and daylight transmittance (Turrin, von Buelow, & Stouffs, 2011), or the geometric form of an energy efficient building that helped reduce its heating and cooling loads (Li, Lin, Lv & Peng, 2013). Instead of generating the entire building form, some researchers have simulated the performance of individual building components; such as high performance shading devices for critical facades. Reducing undesirable solar gains without cutting out useful natural light is an important design strategy for providing controlled indirect daylight in buildings, especially in cooling dominated climates (Tavares, Kinsel, & Silva, 2006). Especially, in office buildings where artificial lighting systems account for as much as 30% of their energy consumption, providing natural light can greatly improve their energy performance (Linhart & Scartezzini, 2011). However, enlarging windows to let in more sunlight leads to excessive heat build-up. In order to resolve both the need to avoid overheating and glare, and the need to provide natural light in building interiors, complex shading devices have to be developed (Schuster, 2006). To this end, Palmero and Oliveira (2010) have simulated the impact of horizontal and vertical layouts for rectangular external louvers, and Tzempelikos and Athienitis (2007) have simulated the design of motorized exterior roller shades. While Choi, Taekyoung, Euisoon, Gensong, and Janghyun (2014) have gone a step further and used a genetic algorithm for the parametric design of rectangular louvers by changing the four parameters; i.e. angle of rotation, spacing, projection length, and inclination; and simulating the thermal performance of each generated louver design to find the best performing option.

In order to design a high performance building architects need to integrate performance measures for the generation and evaluation of the building form, starting from the conceptual to the detailed design stage. The search for alternative solutions for buildings that inherently have multiple design criteria can be speeded up by using computational design procedures; however, most architects do not have the wherewithal to utilize and integrate digital tools into the workflow of their design process; they depend on other specialists to achieve this aim.