Research Directions: Biotechnology Design

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Community Paper

Keywords: Bio-inspired design, product design, complex systems, generative design

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Complexity by Design

A nature-inspired approach to generative product design

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Submission Type
Paper

Extended Abstract (300-500 words)

Living systems are intrinsically complex at many scales, as are other natural and artificial systems such as volcanoes, cities, computer networks, or the stock market. Important complex dynamics are also found at the intersections of the natural and the artificial, such as the effect of drugs on human physiology, or the impact of human activity on the environment.

From the scientific point of view, complex systems are characterised by the interaction relationships among their components, and have dynamical properties such as self-organisation, non-linear behaviour and sensitivity to critical parameters. In many relevant cases, a complex system can be strongly adaptive, in the sense that it spontaneously adjusts to perturbations or changes in its environment (or in its internal parameters) showing robustness and resilience (Bak, 1996; Bar-Yam, 1997).

In contrast to an increasingly complex world, design and engineering have classically aspired to predictable and flawless product behaviour. Users expect simple functional cause-and-effect relationships and unsurprising linear responses from most man-made artefacts (Norman, 2011).

One of the main challenges that Design as a discipline currently faces is to better define its role in the relationship and integration of man-made products and complex natural and artificial systems.

Ultimately, any man-made product integrates and interacts in various intentional and unintentional ways with society and the environment, from the origin of its constituent materials to its disposal. Considering only the product's primary functions, this integration with complexity can take different forms, at different stages of its lifecycle. A product can be designed to act as a mediator between the user and a complex system, creating a predictable and manageable interaction. An automobile, for example, is used by a human to navigate a complex network of roads and other moving vehicles. A product can also be a modulator of a complex system. Vaccines or brain implants, for example, interact with and take advantage of the properties of complex dynamical systems in the human body (Krakauer, 2019). Man-made products can also be complex systems with useful emergent behaviours themselves (Minai, Braha and Bar-Yam, 2006), as in the case of autonomous vehicles or artificial intelligence chatbots. A product can also be the result of a complex design process. Product design may include and take advantage of processes and methods that are complex systems themselves. The application of generative design algorithms or the use of collaborative design methods, for example, can give rise to "emergent products" as a result, although these products may not function as complex systems in themselves.

Here, we propose the development and testing of a set of

generative algorithms that can be integrated into the creative design process.

Our approach draws directly on a set of biophysical mechanisms that can generate functional dynamics and organised form as emergent properties of the system (e.g. regulatory networks, reaction-diffusion, surface instabilities).

In contrast to linear parametric approaches, these generative processes behave as complex systems, leading to non-linear responses to changes in parameter values. In this way, we can perform rich and unpredictable explorations of possible variants that are capable of meeting a predefined set of design requirements and constraints.

In proof-of-principle applications we discuss how form and function are associated in these emergent morphologies, and highlight the essential creative role of the designer in the process.

Connections references

Vijayakumar V, Cogdell C, Correa I, et al. How do we grow a Biodesigner? Research Directions: Biotechnology Design. Published online 2024:1-4. https://doi.org/10.1017/btd.2024.1

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