An Information Theory Application to Bio-design in Architecture: *UnSESUS*

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This research translates info-biological principles into the design of architecture; more specifically, it reviews the use of the Gestalt approach (GA) and Free Energy Principle (FEP) in bio-design, and asks: "how can Artificial Intelligence (AI) learn from bio-intelligence to facilitate designs that are sustainable and aesthetically interesting?" This research illustrates its argument with a design experiment: Unattended Solar Energy Smart Urban System — *UnSESUS.*

Architecture stands at the convergence of art and tectonics—the art of creating built environments that immerse and guide our everyday lives. In our information age, media platforms often interface between architecture, its users, and their exchanges, and have the potential, beyond entertainment, to satisfy both sustainability and aesthetic desiderata by taking into consideration users demand and comfort through the collection of data. AI may help to accelerate and automate exchange processes as the content that users create deep learns from itself. For instance, digital platforms often perform content personalisation with AI—using system information to distribute information—a self-organisational strategy.

With millions of years of evolution, nature is a master in self-organisation. It is a system that is adaptive and efficient, and it is sustained through the rapid exchanges of all sorts of information, from DNA to languages. Even though the word "information" is a noun, it is in fact a process—a construct that arises in the context of trying to understand our complex environment. How should we create information? Is information a form of energy or a pattern extracted from stochasticity? In raising these questions, this research rethinks the relationship between information, biology and architecture, in order for us to better understand our AI tools for design—from generative algorithms to predictive analysis.

There is an increasing amount of biological research that tries to understand bio-intelligence using information theory, which helps us in applying mathematics as a language for describing complex systems—from organisms to organisations—and potentially enables us to capture them computationally (Friston 2019). More specifically, GA and FEP study how entropic information is fed back from the interior to exterior of a system in an iterative manner. The former argues that "individuals are aggregates that preserve a measure of temporal integrity, i.e., 'propagate' information from their past into their futures," where we may begin to describe the performance and qualities of an individual by the variation in their "degree of environmental dependence and inherited information," which is a measure of entropy (Krakauer 2020). The latter argues that individuals have access to information through their individuation. The "consideration of how an individual maintains the boundary that delimits itself"— the *Markov blanket*—is the key to studying self-organisations (Ramstead 2018). Thus, biological systems tend to minimise entropy—the average level of disorder or surprises in some information—through active inference.

Active inference is what intersects between info-biology and AI, it is how an individual "uses an internal generative model to predict incoming sensory data" (Friston 2019). This research extrapolated three main points of how an individual—be it a set of building components or an energy system—can perform active inference using AI: negentropic, preemptive, and network design. It exemplifies this approach with a design experiment—*UnSESUS*—based on self- sufficient (i.e. perpetual) networks.

UnSESUS aims at tackling three issues: 1) distribute infrastructural power (not every building has the same solar capacity); 2) minimise energy dispersal (i.e. entropy) through active inference and preemptive designs; 3) leverage between aesthetic, microclimatic, and structural concerns. *UnSESUS* couples form-finding for Carbon NanoTube (CNT) backed solar cells (CNT can be produced as flexible and conductive thin films to be placed over building facades as light harvesting materials) with a personalisation feedback system using sudoku gameplay (a combinatorial game as a distribution strategy to resolve the hierarchical structure in time and demand factors for solar energy).

In *UnSESUS*, negentropy is the minimization of energy dispersal, where a "solar swarm" installation is proposed based on the Hadley cell, which transports energy polewards for more equal distributions. Negentropy is equally important for the information that represents energy exchanges to minimise uncertainty and maximise efficiency using active inference (i.e. AI with Markov models), and facilitate a smart energy system that is not reactive but preemptive—it acts before demands/climatic conditions are realised. The immediate advantage is a reduction in energy absorption by the power grid, which is usually obtained from carbon fossil. Thus, the system becomes environmentally friendly (Miozzo, et al., 2013). The design of media platforms facilitates information exchanges between users. The network design based on sudoku brings the users and the solar installation together.

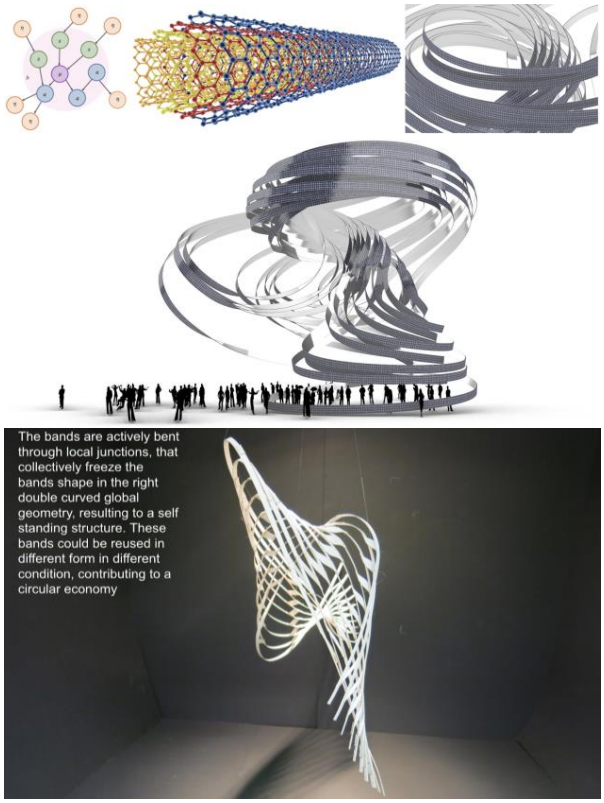

Fig. 1. (a) Markov Blanket (Ramstead, 2018). (b) CNT (AZoNano, 2013). (c) (d) CNT solar cells arranged in a Solar Swarm structure. (e) A self-standing physical model.

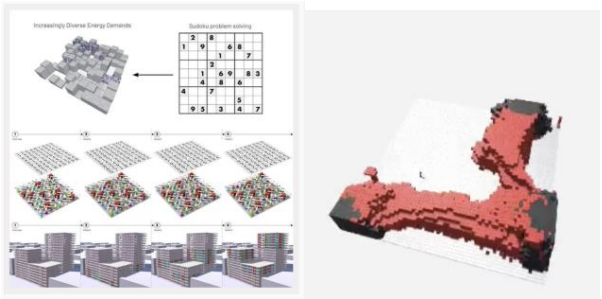

Fig. 2. Sudoku as a networking strategy that brings together the solar installation and a network of users; a pix2pix neural network was trained to translate between pixels and voxels.

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Biographies

Provides Ng, **Baha Odiabat**, and **David Doria** founded *Rational Energy Architects* (@R.E.Ar_), which is an architect/researcher collective based in Hong Kong, Frankfurt, London, Jordan, and Brazil that invests in using irrational numbers to rationalise energy use through architecture and urban design. R.E.Ar collaborates with talents across geographical, cultural, and disciplinary boundaries, searching for tools that fall between the established fields of expertise.