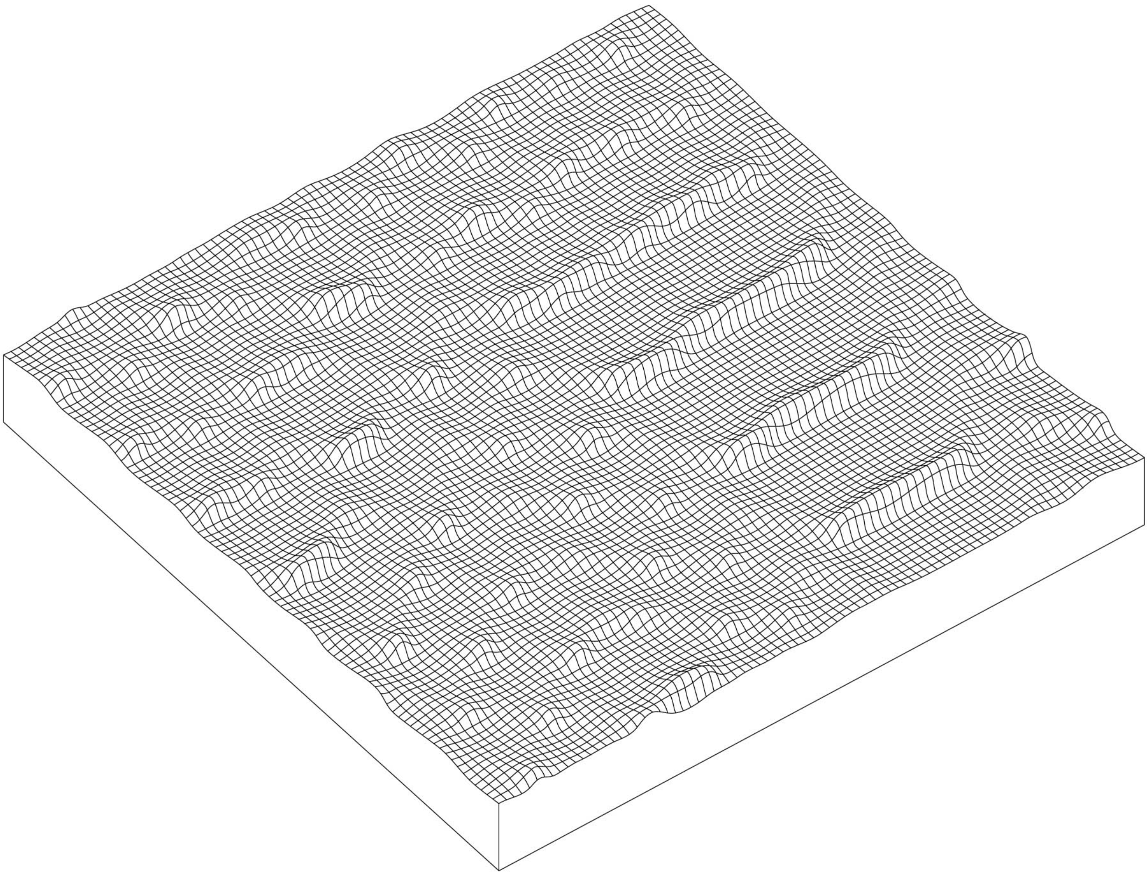
**Proceedings of the New Academy of Artistic Sciences**

# εὕρηκα




an object by

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## Foreword

The origin of εὕρηκα, a CNC milled object, is a partial nonlinear differential equation as given in 1. The dynamics of the specifically chosen equation are structurally equivalent to neural networks and to chemical reaction diffusion systems. One dimension of the object represents a linear array of oscillators; the second dimension, its time development.

$$
\begin{aligned}
\frac{dU_n}{dt} &= -m_1 + V_n(t) - 0.8V_n(t) + a + K_U(U_{n+1} + U_{n-1} - 2U_n) \\
\frac{dV_n}{dt} &= m_1 - V_n(t) + K_V(V_{n+1} + V_{n-1} - 2V_n) \\
m_1 &= \frac{m_2 U_n(t)}{1 + U_n(t)} - \frac{m_3 U_n(t)^2 V_n(t)}{(0.81 + U_n(t)2)(0.8 + V_n(t))} \\
m_2 &= 20 \\
m_3 &= 23 \\
a &= 0.324 \\
K_U &= 2.0 \\
K_V &= 1.201
\end{aligned}
\tag{1}
$$

The selected snapshot of the simulation shows chaotic amplitude oscillation as well as the spontaneous emergence of synchronized oscillation. The self-induced excitability of such a medium of dynamic units is often found across various systems. The phenomenon of formation and decay of synchronous movements, however, is not restricted only to equations of motion describing nature.

By giving form to abstract concepts, εὕρηκα has a poetic potential reaching beyond the representation of the dynamics as a mathematical formula.

For this volume of the proceedings of the New Academy of Artistic Sciences, we are happy that εὕρηκα inspired three essays covering topics such as the origin and meaning of the dynamical phenomena of synchronization, their connection to creativity and the relationships between artistic practice and scientific thinking.

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# Dynamic Unfolding in Space and Time

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A living organism, its organs, and the activity of its cells and molecules unfold in space and time. Would this unfolding be random, there could be no life. Would it be fixed and predetermined, there could be no life. It is the emergence and evolution of structure that defines a living process, for good and for bad. Science tries to capture the essence of such structure in mathematical equations. The equations then form part of our understanding. We find that structure is created spontaneously in networks, active units linked through permanent interactions. Structure changes when the interactions change flexibly. Flexibility is the result of a balanced interplay of activation and inhibition. The object εΰρηκα by Grond Vaillant and Weber [1] represents a segment of dynamic evolution of one specific equation [2] as it evolves in space and time. Although the equations (the rules) are fixed the resulting pattern is not. Activation and inhibition find a balance between random and fixed behavior. A balance that is nevertheless unstable and gives rise to transitions. The transition displayed here is from an alternating arrangement of short-lived spots to a period of longer-lived stripes and back again. Both are a combinations of oscillations (named after the German physicist Eberhard Hopf [3]) and stable stripes (named after the British mathematician Alan Turing [4]).

On the one hand, the equations prove that only the local interactions need to be nonlinear and that the network itself is capable of creative transitions. The process is self-organised. No interference from the outside is required. On the other hand, the model is susceptible to interaction with the outside world; perturbed transitions can be induced, in the direction of randomness or in the direction of more ordered patterns. It is now believed that such induced transitions may explain cognitive processes in the brain and at the same time form the basis of mental disorders. Both an epileptic fit and a stroke of genius appear as a related process of organisation that is inherent in the interacting net of neurons. Dynamic unfolding in space and time is the key to understanding both.

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# Creativity in Design Processes and Neural Correlates

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According to Herbert Simon [1] everyone designs who devises courses of action aimed at changing existing situations into preferred ones. Designing is an activity that starts with the identification of a need or idea for producing a change in the world, and involves the generation of solutions or plans that will bring this change about this change. The peculiarity of design is that although there is on the one hand a driving need or idea for change, on the other hand, neither the means for generating a solution nor the criteria for evaluating it are given. Studies of designers at work show that design involves an iterative process of analysing and defining problem formulations (a set of design requirements) together with the solutions that will satisfy these requirements. This led to the conceptualisation of design as a co-evolution between a problem space and a solution space [2]).

On this basis, the crucial moment of illumination or insight that characterises creative resolution of a problem marks the recognition of a correspondence between problem and solution spaces.

We hypothesise that from a neuro-cognitive perspective, design creativity seems to involve a process that leads to a coordinated, synchronised, cognitive response to a task. In this sense, the moment of defining (or recognizing) a design solution marks a transition from a situation where there are disparate neural representations and schemata of action, to a situation where these different schemata become congruent. We currently explore this hypothesis with functional magnetic imaging and electroencephalography studies [3].

This moment of illumination thought as a synchronized neural network has found a convincing representation in the object εὕρηκα by Grond Vaillant and Weber [4]. It is also a motivating example of how artistic and scientific boundaries may criss-cross to provide new research insights and a common ground for collaborative working.

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# Performative Logic in Complex Systems Research

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**Abstract.** Sciences are governed by propositional logic. In the arts, performative logic prevails. In this short note a fruitful negotiation between science and art within the field of complex systems research is outlined. We bring forward arguments for the advantage to adopt performative logic in nonlinear dynamics and pattern formation.
**Keywords:** performative logic, propositional logic, complex flow, subject-object dichotomy, epistemic thing

## 1 Rationality

"…the passion between the sexes is necessary and will remain nearly in its present state." Thomas Robert Malthus expressed this postulate only 211 years ago in his 'essay on the principle of population' [1]. What sounds strange to our ears today was an enormous progress in rationality. Malthus adopted Newton's analytic approach to dynamical systems: the temporal change of a system's state is a function of the very same state. In other words, he searched for a driving force – fertility, in this case – intrinsic to the system under investigation. He concluded that a population left to its own resources obeys a geometric growth. [1] A familiar case is bacterial growth by means of cell division, $x_{t+1} = 2x_t$, with $x_t$ being the population size at time $t$ and $x_{t+1}$ being the subsequent size after cleavage. The duplication after each time step quickly blows the system's resources. The exponential growth of human population is not substantially different. However, "food is necessary to the existence of man," according to Malthus' second postulate, and "subsistence increases only in an arithmetical ratio." From the simple fact that "the effects of these two unequal powers must be kept equal," he concluded an increasing impoverishment of mankind.

## 2 Chaos

Forty years later, the balancing effect postulated by Malthus found its mathematical description as what is today called Verhulst equation [2]. This differential equation reads: $\frac{dx}{dt} = rx(1-\frac{x}{C})$. The exponential fertility term $rx$ dominates the growth for small populations. For larger populations, the population size is limited to the environmental capacity $C$ throught the saturation term, $-\frac{x}{C}$. An ecosystem consists of many interacting species

[1] In the continuous case it is equal to exponential growth.

mathematically represented, for example, by a network of coupled Verhulst equations where $C$ for a given species is determined by the size of another population. Such coupled dynamical systems exhibit extremely complex dynamics occasionally producing chaotic oscillations - it is deterministic, yet unpredictable. The variation of a single parameter, e.g., the value of the fertility rate $r$, yields a cascade of alternating period and chaotic modes.
This phenomenon absorbed the attention of numerous scientists for many decades and still affords surprises with respect to its dynamics. Chaotic dynamical systems like the logistic map are classic in nature but at the same time show typical features from quantum mechanics (QM). The system in its chaotic mode left alone can be seen as a container of eigen-dynamics like the wave function in QM. An external interaction leads to a collapse of the system (the 'wave function') into one of its eigen-dynamics, for example, a periodic oscillation. A synchronisation takes place which is almost as puzzling as the collapse in QM. It is a promising candidate to explain Maturana's postulated 'structural coupling' as a basic characteristic of autopoietic systems.

## 3 Alchemy Strikes Back

Mathematical analyticity hits the wall when confronted with chaos. Without good instict, for example, of how to design and to interpret computer simulations, one fights a losing battle. Objectivity, held in high esteem by the sciences, is a past remedy. A performative logic is making up for a delay [3]. Physical involvement - particularly of the researcher - gains in importance. Artistic approaches start to be taken seriously beyond their often unspeakable reduction to didactics and illustration. A physical, performative engangement with the 'epistemic thing' [4] becomes inevitable. In a time when art practice has increasingly taken on the quality of research, one risks to lose the experience of 'what-is as being' (*Seiendes als Sein*), in Heidegger's language, and one instead looks upon the world as 'standing reserve' (*Bestand*), as is the case in the sciences [5]. We agree with Barbara Bolt when she claims to preserve an art beyond representation [6]. Beyond that, we even attempt to adopt Bolt's pledge almost as it stands for the sciences. In other words, where the arts risk 'reification' (*Verdinglichung*) the sciences gain performative power through a flirt between the two cultures.

Compared to the brave engangement of artists in research, the engangement in the opposite direction is still shy. However, the series of "International Conferences on Flow Interaction cum Exhibition/Lectures on Interaction of Science & Art (SCART)" initiated and organized by hydrodynamicists and held in Hong-Kong (1994), Berlin (1997), Zurich (2000) and New Brunswick (2005) proves that there is growing interest, especially in the fields of complex flows, to open the methodology towards artistic modes of knowledge production. Proceedings of the $3^{rd}$ conference are available where an amazing spectrum of performative approaches in flow dynamics is presented by both scientists and artists [7].

We particularly promote a performative approach in any investigation of retroactive systems where we consider performativity to be indispensable. Retroactive systems usually change their behaviour at one's cognizance, i.e., they are essentially self-referential. A social system is the most striking example; another one is the human brain. Those systems exhibit nonlinear dynamics whose complexity even transcends (invariant) chaos and generates permanent transience or chaotic itinerancy. Such a contingent world with non-repeatability and ongoing phase transitions demands for a suspension of the strict dichotomy of a model and modeled system.

## 4 εὕρηκα

From a synergetic perspective it doesn't matter so much whether an equation of motion is interpreted as biological or chemical species or electro-magnetic potentials. It is less the field of application and more the class of dynamical modes that counts. The dynamics that form the basis of εὕρηκα by Grond Vaillant and Weber [8] has been originally introduced within the context of chemical reaction-diffusion systems [9]: it is a chain of diffusively coupled oscillators and structurally equivalent to predator-prey or symbiotic behaviour or a network of coupled neurons. The oscillating modes of the elements synchronise to a global coherent pattern that propagates over the network. Aesthetic sentience to a large extend depends on synchronization processes, too. Therefore, it is a fallacy to believe in objectivity in such a case. The model is no longer a pure representation – it is presencing (*"es west an"*, cf. [5]). The object-subject dichotomy is annihilated. The performative approach to science is essentially an aesthetics of reception. Following Thomas Malthus we might say that 'the passion between researcher/artists and epistemic thing is necessary and will gain importance in its near future state.'

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