

Emergence and Creativity

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Abstract

Emergence is the appearance of novel entities that in one sense or another could not have been predicted from what came before. We outline a number of different conceptions of emergence: of formal structures, of material structures, of functions and organizations, of new perspectives. Epistemic emergence involves the creation of new points of view: the evolution of new sensors in biological evolution, the addition of new measurements and observables in scientific models, the creation of new concepts and meanings. In art, epistemic emergence can involve formation of new "ways of seeing", new interpretive paradigms. We distinguish two modes of creating novelty: combinatoric (new combinations of existing primitives) and creative (new primitives). Although combinatoric systems may differ in numbers of possible combinations, their set of possibilities is closed. "Creative" systems, on the other hand, have open-sets of possibilities because of the partial- or ill-defined nature of the space of possible primitives. We discuss classes of adaptive and self-modifying cybernetic robotic devices in terms of these two kinds of processes. We consider material systems constructed from genetically-directed pattern-grammars. Although spaces of accessible structures are closed, function spaces can nevertheless be open. Works of new media art can be considered in terms of this combinatoric/creative framework, whether they explore an existing space of possibilities or whether they enlarge such spaces.

Varieties of emergence

Emergence entails the creation of something fundamentally new – something that could have have been foreseen in terms of what came before. Emergence = fundamental novelty. Novelty by itself does not rise to the level of being emergent if it is simply an extension of previous events. A new winning lottery number or a new record temperature on a given day do not rise to this standard. On the other hand, the appearance of self-producing, self-sustaining, living organisms on the earth was clearly an emergent event.

In the last decade emergence has re-emerged as a topic of widespread discussion (Clayton & Davies, 2006; Gregersen, 2003; Morowitz, 2002). Much of our current discussions of emergence revolve around the concept of new macro-patterns arising from micro-processes. Mathematical examples involve chaos, fractals, and new patterns that arise in cellular automata. Physical examples of this sort of micro-macro dynamics include the appearance of whirlpools, the swarm-behavior of flocks of birds, the formation of termite nests, and the synchronization of fireflies. But emergence is broader than simply the creation of new structures or behaviors. It also includes the formation of fundamentally new organizations of matter – life – and the formation of fundamentally new informational processes – nervous systems and minds – and the concomitant appearance of a new aspect of the world – conscious awareness.

My shorthand for the full scope of emergent processes is Form-Matter-Life-Mind-Consciousness. The full gamut of emergence encompasses new forms, new material structures, new organizations, new functions, new perspectives, and new aspects of being. New forms arise in our mathematics in new systems of relations and more powerful logics (Piaget, 1980), as well as from the unfolding of the consequences of rules operating on symbols. Major emergent transitions in the history of the physical universe include the formation of particles, atoms, and molecules, the appearance of molecules and macromolecules on the micro-scale, and the formation of stars, galaxies, and black holes on the macro-scale. One can even ask if the physical laws and even time itself are fundamental emergent aspects of the early universe.

Life arises from qualitatively new modes of organization in which networks of chemical components regenerate themselves and their organizations ("autopoiesis", (Maturana & Varela, 1973)). Primitive organizational closure results, as networks continually re-create themselves and persist through time. Nonequilibrium thermodynamics tells us how such self-sustaining complex material organizations are energetically possible (Denbigh, 1975; Prigogine, 1980). Self-producing metabolisms evolved generalized coding mechanisms that permitted reliable inheritance of blueprints for proteins that serve as the structural elements and enzymatic controls of cells (Barbieri, 2003). The emergence of this informational, molecular memory mechanism permitted radical complexification of structures and functions through evolutionary mechanisms of inheritance, variation, and natural selection (Reid, 2007)ba. Symbiotic co-evolutions produced qualitatively new cooperations between proto-organelles, cells, and groups of cells that led to multicellular organisms. Morphological evolution produced hearts, gills, lungs, backbones, legs, arms, teeth, strong jaws, thick skulls and a host of other structures.

Qualitatively new functions appear over time. Emergence of new functions accompanies the appearance of new structures. One can imagine a set of "universal" functions of living systems (Miller, 1978) that includes categories of matter-energy transactions (e.g. digestion, metabolism, storage, distribution, excretion), structural functions (support, scaffolding, leverage, enabling space), organization (self-production and reproduction), informational functions (e.g. sensing, analyzing, pattern recognition, memory, anticipation and planning, communication, decision-making, learning), and action (physical movement, secretion). Over the course of evolution, in every species lineage, there is the possibility that each of these functionalities may be refined, expanded, or transformed.

Semiogenesis involves the emergence of informational processes, in which special, configurational constraints rather than energy gradients switch the behavior of systems (Barbieri, 2007; Cariani, 1998; Hoffmeyer, 1996; Howard H. Pattee, 1969; H. H. Pattee, 1972; Queiroz & El-Hani, 2006). Perhaps the most rudimentary informational constraints involve the coding of proteins by more stable sequences of nucleic acids that act as molecular memories. With the evolution of nervous systems, the sensory flux is transformed into neuronal activity patterns that can then flexibly switch behavioral responses. "Neural codes" are those aspects of neuronal activity that are used by the nervous system for informational functions, e.g. to coordinate between perception and action. Mind arises from the organization of neuronal activity that subserves informational functions. The mind is the informational organization of the nervous system. We will take up the relation of mind and consciousness in a moment.

Epistemic emergence

Epistemic emergence involves the appearance of new perspectives, new windows on the world. When new sensory organs evolve in a lineage of organisms, those organism acquire a new means of sensing and interacting with the world. The evolution of smell, taste, touch, vision, and audition amplify the kinds of distinctions an organism can make on its environment. And there are many more sensory

systems besides these: balance, pain, temperature, body position and internal state, electroception, magnetoception. Effectively the epistemic *umwelt* or "life-world" of the species (Uexküll, 1926) becomes enlarged in its dimensionality whenever a new sense organ is formed or elaborated in a new way. Color vision amplifies vision; echolocation amplifies audition; chemical analysis amplifies smell and taste.

Epistemic emergence also occurs in technological evolution. All technology is prosthesis. All technology involves the amplification or augmentation of biological functions. We construct measuring instruments, such as thermometers, Geiger counters, microscopes, telescopes, and spectrophotometers, that serve as new kinds of sensors. By interposing such devices between our own senses and the world, we can change the relationship of our internal sensory states vis-à-vis the world. In effect we are temporally changing the external semantics of our sensory organs to enable us to access new aspects of our environment. On the action side, we interpose artificial effectors that amplify and augment our muscles: bicycles, cars, trains, planes, rockets, cutting, lifting, and digging machines, chemical processors, and devices that allow us to communicate over vast distances.

To the extent that a system can choose its own sensors, it has the capability of choosing the basic categories of how it will view the world. In effect, such a system attains a limited degree of *epistemic autonomy* – that system is no longer strictly limited by the sensors that were given to it initially. Another organizational closure is attained when lineages of organisms evolve the means to construct their own sensors. While the organizational closure of autopoiesis at the origins of life enabled the organism to control its own internal structure, this organizational closure enables the organisms to control their own epistemic life-worlds.

New internal sensors can also be created within nervous systems. One can think of concepts as new distinctions that are made on internal representations. Arguably, every new concept increases the effective dimensionality of a cognitive system, since it permits another way of parsing the world. It becomes possible to conceive of neural networks that create emergent conceptual perspectives by the adaptive formation of neural assemblies.

On sociocultural scales, new perspectives, systems of interpretation, or "paradigms" can appear. In art, new techniques of producing artworks and new "ways of seeing" can appear. For example, over the history of Western painting, there has been a succession of styles and interpretations, each constructed from different sets of visual elements and techniques. At some junctures, new perspectives about art itself emerged, radically altering the interpretation of what art itself means (Hughes, 1991).

Up to this point we have surveyed emergence in the material realm, emergence of dynamical organizations, emergence of informational processes, and emergence of new perspectives. None of this yet requires any mention of conscious awareness. We believe that the essential functionalities and operations of primitive observers and actors can be captured with a semiotic framework of measurements, informational coordinations, and actions.

Consciousness

A description of the world in terms of form, material, organization, and information is still incomplete because it does not acknowledge the experiential dimension of conscious awareness. In this sense, consciousness is a transcendent property of the world (and there may be yet others of which we are only dimly aware (Clayton, 2004)). Consciousness, in my opinion, requires recognition of yet another aspect of the world that is not reducible to form, matter, life, or mind (as we have defined "mind", in informational, not phenomenal terms). It is clear that the structure of our awareness depends (I think

entirely) on the organization of some aspects of neuronal activity in our nervous systems. Not all neural activity produces, in Gregory Bateson's phrase, "a difference that makes a difference" in our awareness, but everything in our awareness is a concomitant of appropriately-organized neuronal activity. In my view, the structure of our experience is isomorphic to that of the neural codes, both in the dimensions that our experience takes, but also the specific qualities of that experience.

My working hypothesis is that a particular organization of neuronal activity is required for that activity to change awareness (Cariani, 2000). To become aware of them, neuronal signals need to be actively regenerated and amplified in neuronal circuits so that they build up past a threshold level and persist. This hypothesis is analogous to our conception of the essence of living organization as a network of components that regenerates its parts and their relations. Here, we envision an "autopoiesis of neuronal signals", a set of neuronal signals that regenerates itself in neuronal circuits to form a stable, resonant, informational state. We believe that informational integration in "global workspaces" (Baars, 1988) is realized via signal regeneration processes (working memory is signal regeneration) and it is for this reason that the coherence, continuity, and unity of the global workspace is mirrored in our awareness. General anesthesia and seizures abolish awareness not necessarily by suppressing activity in particular neurons, but by disrupting the coherence of the signal regeneration process. If this hypothesis is correct (and we believe that it is empirically falsifiable once we are able to understand the nature of the central neural codes), then conscious awareness is a relatively recent development in the history of the universe because it depends on (nervous) systems that can regenerate their own signals.

As we mentioned earlier, it is conceivable that matter, energy, and time may be emergent aspects of the universe. There is also the fundamental question of whether consciousness itself is an emergent aspect of the universe (Broad, 1925; Clayton, 2004). If awareness depends on the evolution of nervous systems, then, aside from parallel developments elsewhere in the universe, a new transcendent aspect of the world has appeared in the last half-billion years. Alternately, panpsychists such as Spinoza and Leibnitz have argued that some sort of awareness, albeit simple and fleeting, has always existed in all material things (Skrbina, 2005). In this view, although nervous systems are complex, coherent organizations that permit much more variegated and sustained experiential realms, these complex phenomenal realms are not different in kind from those associated with the individual biological and physical components that subserve them. Although I tend to agree strongly with the emergentist view, why only regenerative, circular-causal informational organizations should support awareness remains a deep mystery. In a sense panpsychism is no better in this regard in that it pushes this mystery into the ultimate nature of the world, but in making matter and consciousness integral, complementary aspects of the world from the very beginning (if the world indeed has a beginning), the perspective does gain a certain economy of explanation, and I cannot yet rule it out.

Emergence and creativity: combinatoric vs. creative novelty

In the realm of art and technology, conceptions of emergence have some utility as *heuristics for creativity*. If emergence is fundamental novelty, then an understanding of processes that lead to emergent events, structures, functions, and perspectives can be used to design artifacts that realize these processes to create fundamental novelty. We can use emergent processes to amplify human creativity and to design and construct semi-autonomous artificial systems that are themselves creative.

We humans often build complex systems by identifying a set of parts and use rules to recombine those parts into new aggregates. The building blocks are the "primitives" of the construction system, and their combinations define the possibilities of that system. The primitives in question depend upon the discourse; they can be structural, material "atoms"; they can be formal "symbols" or "states"; they can be

functionalities or operations; they can be primitive assumptions of a theory; they can be primitive sensations and/or ideas; they can be the basic parts of an observer's model. To say that an entity is "primitive" relative to other objects or functions means it cannot be constructed from combinations of the others, i.e. its properties cannot be logically deduced from those of other entities. Thus, in this way of thinking, simple combinations of "lower-level objects" do not create "higher-level primitives" because the higher-level systems can be decomposed into yet lower-level objects (atoms).

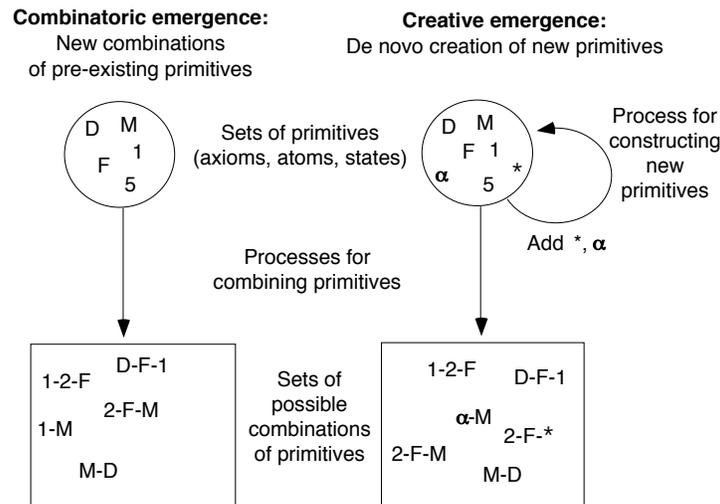


Figure 1. Combinatoric vs. creative emergence. In combinatoric emergence, new combinations are formed from a fixed set of primitives. In creative emergence, new primitives (α , $*$) are formed, permitting the space of combinations to expand.

One can thus envision creative processes that simply recombine fixed primitives vs. those that somehow create new ones. Emergent novelty can be generated in two ways: *combinatoric emergence* and *creative emergence* (Fig. 1). In a similar vein Lloyd Morgan (Morgan, 1931) distinguished "emergents" from "resultants": emergents being the result of novel creation, resultants, of novel combination. Both kinds of emergent orders are built up from basic sets of possibilities that constitute the most basic building blocks of the order, its "primitives." Emergence then entails either the appearance of new combinations of previously existing primitives or the formation of entirely new ones.

Generating combinatoric novelty

Genetic algorithms for evolutionary design are clear contemporary examples of combinatoric emergence. Here a genetic language specifies how primitives of a system are to be combined into complex productions, and a selective process guides the generation of new combinations of primitives. Genetic algorithms, as their name implies, were inspired by biological evolution (Fogel, Owens, & Walsh, 1966; J. Holland, 1998; J. H. Holland, 1975). A clear example of a genetic algorithm that generates graphical patterns is the Blind Watchmaker program of Richard Dawkins (Dawkins, 1987). In the Dawkins' program a set of genetic symbol-strings codes for graphical elements and parameters (lines, line properties, orientations). The set of primitive graphical elements and the rules for their combination constitute a "pattern-grammar", and the resultant forms can be called "productions". The

symbolic gene-strings correspond to organismic genotypes, the elements and rules of the pattern-grammar correspond to mechanisms of gene expression and developmental construction, and the productions correspond to organismic phenotypes.

Using the genetic algorithm, the computer generates a set of graphical designs from the genes of many individuals. Human "critics" examine the designs and evaluate them according to some set of criteria. These could be purely subjective judgments based on their own aesthetics, utilitarian goals, or some other criteria. Here the human critics play the role of natural selection. Their "fitness" judgments determine which designs will be allowed to survive and reproduce. Once a subset of the designs is chosen for the next generation, the computer randomly mutates and recombines their genes, and produces the next generation of patterns. If this evolutionary process is iterated many times, and the critics are consistent in their tastes, then the average fitness of the designs in the population will tend to improve, i.e. those designs will better please the critics.

The genetic algorithm mirrors many of the essentials of Darwinian evolution. My shorthand for this is evolution = inheritable construction + evaluation + selection + variation + proliferation. There are inheritable genetic patterns that reliably guide developmental construction processes to phenotypes with different functional properties. These phenotypes are evaluated according to their ability to survive and reproduce, such that only a subset of them are selected to produce the succeeding generation. Variation is achieved by mutation, sexual recombination, and genetic shuffling, and a new set of individuals is proliferated.

This evolutionary process involves an expansive phase in which many possibilities are generated (variation + proliferation) and a contractive phase in which critical selection of "adequate" or "best" possibilities is made. The expansive phase is the reign of the imagination, of free and open creation, while the contractive phase is the realm of sober clarity and rigor. In science, hypothesis creation is such an expansive phase, where arguably, "anything goes" (Feyerabend, 1973), whereas empirical testing and falsification is the contractive phase where hopes and visions are separated from "reality", i.e. consistency with observations (Popper, 1959). One conceives of many possibilities that are then narrowed down by "what works".

A pattern language or grammar can be formulated in any domain (e.g. architecture and design, (Alexander, 1964)), and many such evolutionary generative strategies have been applied in music and the visual arts. A genetic algorithm need not be used to explore the space of possibilities that a particular pattern-grammar affords – other search methods may be as good or better in particular circumstances. What is critical is that the primitive elements and the combinatorial rules yield a rich set of possibilities that are capable of producing patterns of high desirability (or utility or "fitness", however conceived).

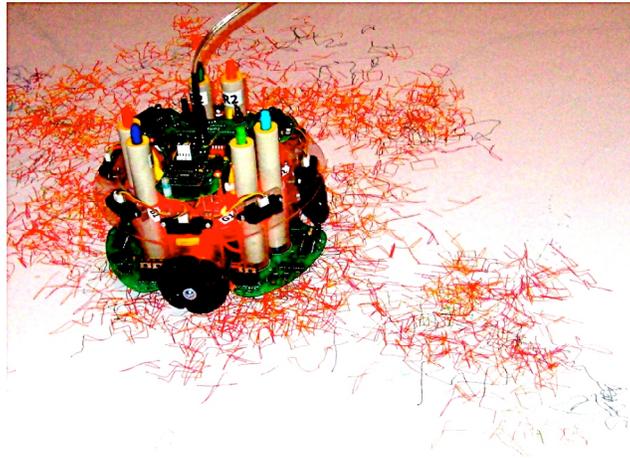


Figure 2. The Robotic Action Painter of Leonel Mours.

In this exhibition roughly half of the installations systematically explore combinatorial spaces to generate patterns that are visually or conceptually interesting. I place in this category a number of works: Ultra-Nature (Miguel Chevalier), The Mutations of the White Doe (Nicolas Reeves), Tumbling Dream Chambers (Boredomresearch), youTAG (Lucas Bambozzi), Spore (Will Wright/Electronic Arts), Bacterias Argentinas (Santiago Ortiz), Pix Flow #2 (LAB[au]), RAP3- Robotic Action Painter (Leonel Mours).

Combinatoric Novelty and Closure

Combinatoric emergence assumes a fixed set of primitives that are combined in new ways to form emergent structures. This is very compatible with the way we often think about structure spaces, where parts can be combined to form larger structures. Thus in biological evolution, new genetic DNA sequences arise from combinations of pre-existing nucleotides, codons, and codon-sequences. Microevolution entails generation of novel combinations of genes; new genes arise through novel combinations of nucleotide sequences. Likewise, new, emergent structures are thought to arise from novel combinations of previously existing molecular, cellular, and organismic structures.

This strategy for generating variety from combinations of relatively small set of primitive parts is a powerful one that is the basis of the systematicity of human and computer languages. Digital computers are ideally suited for generating combinations of symbol-primitives and logical operations on them that can then be evaluated for useful, interesting, and/or unforeseen formal properties. Correspondingly, in the realm of adaptive, trainable machines, directed searches optimize combinations of pre-specified features and actions (i.e. feature-action mappings, classifications). What formally distinguishes different kinds of trainable machines, such as neural networks or genetic algorithms, are the structures of the respective combination-spaces being traversed, and the rules that direct the search processes through them. In artificial life contexts, genetic algorithms using generative pattern grammars search through complex quasi-organic structure spaces or find more optimal percept-action coordination strategies for simulated robots and organisms. In both types of applications, search spaces are large, but nevertheless closed.

Combinatoric novelty is a dynamic, creative strategy insofar as it constantly brings into being new combinations of elements. However, its use of fixed sets of primitive elements mean that the set of

possible combinations is closed (albeit very large). In the example of Fig. 1, one cannot create new alphabetical letter types simply by stringing together more and more existing letters (the left hand process) – the new notations must be introduced from outside the system by external agents or processes (right side).

Generating new primitives (creative novelty):

It is usually easier to give examples of qualitatively new functions than examples of qualitatively new structures. In our opinion, the most salient examples of the creation of new primitives involve the biological evolution of new sensory capabilities. Where previously there may have been no means of distinguishing colors, odors, or sounds, eventually these sensory capacities evolve in biological lineages. From a set of primitive sensory distinctions, one can list all combinations of distinctions that can be made with those primitives, but there are always yet other possible distinctions that are not on the list. For example, we cannot combine information from our evolution-given senses (sight, hearing, smell, etc.) to directly detect low intensity electrical or magnetic fields in our midst (as is achieved by electroceptive fish and some migratory birds, respectively). Creation of the ability to sense these fields through biological evolution, or artificial construction of measuring instruments (magnetometers, field strength sensors), thus adds new primitives to the set of perceptual distinctions that can be made.



Figure 3. "Roots" by Roman Kirschner was inspired by Gordon Pask's electrochemical device.

Artificial devices that create new perceptual primitives have been built. A perspicuous example is an electrochemical device that was constructed by the British cybernetician Gordon Pask in the late 1950's (Bird & Di Paolo, 2008; Cariani, 1993; Pask, 1958, 1959, 1960, 1961). In this exhibition, the installation "Roots" was Its purpose was to show how a machine could evolve its own "relevance criteria." The structure of the heart of the analog device itself was hopelessly ill-defined. Current was passed through an array of platinum electrodes immersed in an aqueous ferrous sulphate/sulphuric acid equilibrium, such that iron dendritic filaments grew to form bridges between the electrodes. By rewarding iron structures whose conductivity contingently varied with environmental perturbations, the set of structures

could be adaptively steered to improve the sensitivity of the whole. Pask's device acquired the ability to sense the presence of sound vibrations and then to distinguish between two different frequencies. In effect, the device had evolved an ear for itself, creating a set of sensory distinctions that it did not previously have. Albeit, in a very rudimentary way, the artificial device automated the creation of new sensory primitives, thereby providing an existence proof that creative emergence is possible in adaptive devices.

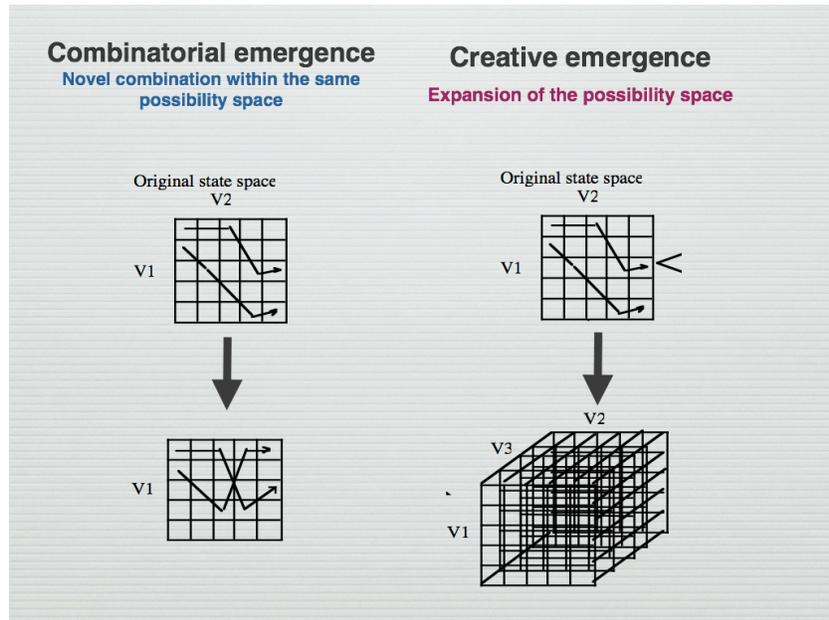


Figure 4. When a new primitive is created, the effective dimensionality of the possibility space increases.

Evolvable Cybernetic Systems

Pask's device is a special case of a broader class of devices that are capable of modifying their own internal structure in open-ended ways. One can formulate a taxonomy of possible cybernetic devices and their creative capacities (see(Cariani, 1989; Cariani, 1992, 1998; Emmeche, 1994)) and (de Latil, 1956). These robotic devices consist of sensors and effectors coupled together by means of computational coordinative modules with well-defined internal symbolic states (Fig. 4). These devices have an evaluative part that directs the construction and modification of the hardware that subserves faculties of perception, cognition, evaluation & reward, and action. This hardware includes sensors, effectors, and the internal computational mechanisms that mediate sensorimotor coordination by implementing particular percept-action mappings. The evaluative part contains memory, learning, and anticipatory mechanisms for measuring performance, changing percept-action mappings, and adaptively modifying internal structures to improve performance. A methodology has been developed to distinguish between these functionalities and to determine when a new measurement, computation, or action is created. We believe they capture the basic operational structure of the observer-actor.

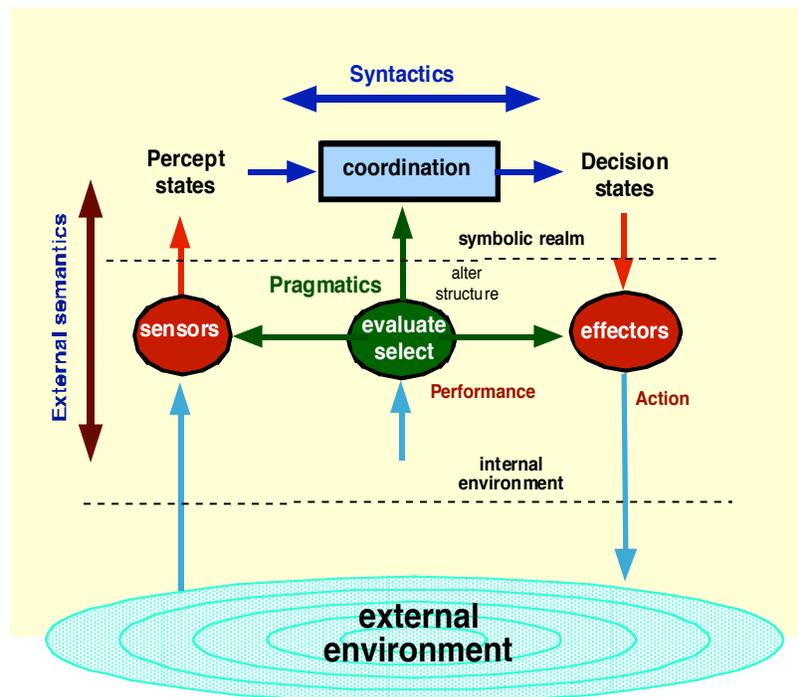


Figure 5. The semiotics of self-constructing cybernetic devices. Semantics are relations of internal states to the external world, involving causal linkages through sensors and effectors. Syntactics are rule-governed relations between internal states. Pragmatics are relations of internal states to goal states, and involve mechanisms that steer behavior and/or self-construction in order to better achieve them.

Such cybernetic systems can be described in terms of semiotic categories: syntactic, semantic, and pragmatic dimensions. Syntactics describes rule-governed linkages between signs that are implemented in computational, coordinative portions of devices. Semantics involves the relation of signs to the external world, i.e. causal linkages between internal symbolic states and the world that are mediated by sensors and effectors. Finally, pragmatics involves the purposes for which signs are used: their relation to embedded goal states. Pragmatic relations are implemented by internal evaluation-reward mechanisms that adaptively steer or modify internal device linkages to better achieve embedded goals.

Within such a framework one can envision devices with both mechanisms that switch between existing sets of possible internal states (combinatoric emergence) or mechanisms that adaptively construct new hardware (e.g. new sensors, effectors, internal states) capable of creating new functional primitives (creative emergence). Table I summarizes possible types of adaptivity vis-à-vis combinatoric and creative emergence. In the syntactic realm, creative emergence produces new signs (symbols, internal states). In the semantic realm it produces new observables and actions that make new contingent linkages between internal states and the outer world. In pragmatic realm, it produces new evaluative criteria (new goals).

Each functionality (sensing, effecting, coordinating) can be either be fixed, subject to combinatorial search, or capable of *de novo* creation of new primitives (Table I, above). In this scheme, combinatoric creativity involves new combinations of pre-existing input and output states, sensors, effectors, and goals. Creative emergence requires going outside of the set of existing functionalities to modify material structures ("hardware") in a manner that can create new states, new sensors and effectors, or new goals.

To the degree that a system has control over its own structure and functions, it attains a degree of freedom vis-à-vis both its environment and its own history. When a system can add to its own states and state-transitions, as in a growing automaton, it achieves some degree of computational autonomy. When a system can construct its own sensors, it attains a degree of epistemic autonomy. When it can construct new effectors it attains a greater autonomy of possible actions. Finally, when the system can construct its own set of evaluations and embedded goal states, it becomes self-directing.

Dimension	Primitives	Stable systems Fixed structure	Combinatoric systems Search/optimize existing possibilities	Creative systems Add possibilities Evolve
Syntactic	States Computations	Deterministic FSA's (fixed machines)	Change computations (trainable machines)	New states & rules (growing automata)
Semantic	Measurements Actions	Fixed sensors, effectors	Search combinations of existing sensors & effectors	New measurements and/or actions (epistemic autonomy)
Pragmatic	Goals	Fixed goals	Search combinations of existing goals	New goals (creative self-direction)

Table I. Combinatoric and creative emergence in cybernetic devices

Open-endedness

We argue that combinatoric systems are closed, while systems that create their own primitives are open-ended with respect to their current set of primitives. This is because the process for generating new primitives is undefined – if it were defined, it would be part of the combinatorial rules, and we would simply see the system as a larger combinatorial system. A simple example is helpful in conveying the differences between closed vs. open-ended realms. The set of all 6-digit sequences of numerals 0-9 is well-defined and contains 100,000 elements, which can be enumerated. The set of all sequences of 6 arbitrarily defined objects, however, is ill-defined, because the number of possible objects is indefinite. As a result this latter set is unbounded, ill-defined, and open-ended – one can always augment the set by specifying 6 more objects, but this process of specification is left undefined. In the first case, the primitives are exhaustively described by their token-types; consequently, the set is well-defined and closed. In the second case, the space of possible primitives themselves are not well-defined, and therefore the set of possibilities is ill-defined and open. Like the set of all possible distinguishable objects, the set of possible measurements (observables) and actions that can be carried out respectively by sensors and effectors is ill-defined and open. Likewise, the set of possible meanings and interpretations is open. As a consequence, biological organisms and artefacts that are capable of evolving new sensors and effectors (both external and internal) have an open-ended set of possible ways of interacting with the world and with themselves. Further, I think this implies that the space of possible epistemic life-worlds, *umwelts* (Uexküll, 1925), is open-ended.

Creative emergence and art

I think there are two major ways that art can produce creative emergence. The first way is art that creates autonomous objects that themselves independently evolve new primitives. This creative emergence may or may not be explicitly intended or stated by the artist – it may even be a completely unexpected occurrence.

A sound installation piece by Simon Penny, "Sympathetic Sentience" that was constructed in 1995 comes to mind (http://www.ace.uci.edu/penny/works/symp_sent/sympathetic_sentience.html). The work consisted of a set of elements that sense sounds in their environments and reproduce the sounds that they hear with a delay. The sonic space of the installation complexifies over time as the sounds reverberate through the elements. The "Bacterial Orchestra" by Martin Lübke & Olle Corneer, in the exhibition, is an interactive sound installation constructed along similar lines.

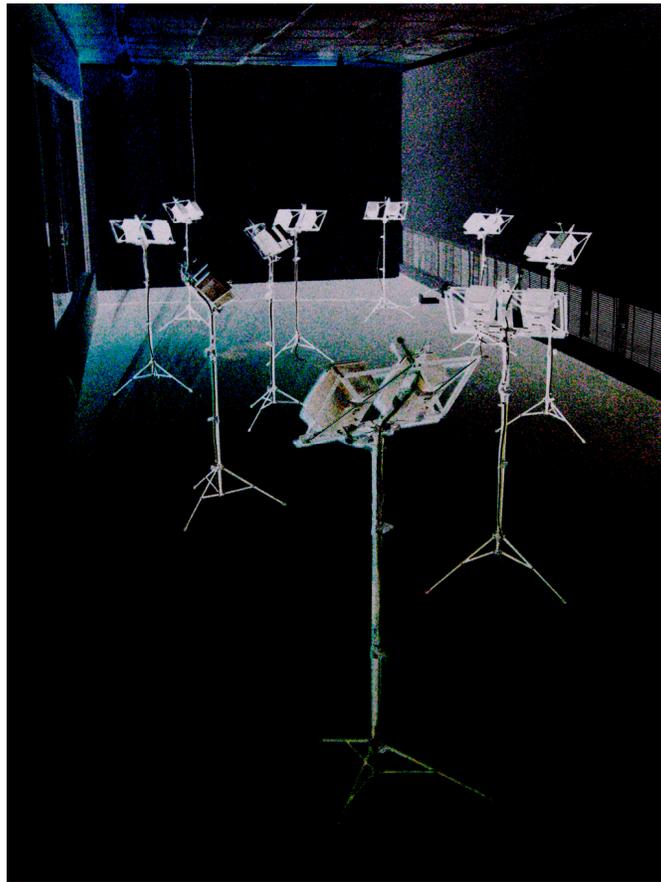


Figure 6. The Bacterial Orchestra (Martin Lübke & Olle Corneer)

For me "Sympathetic Sentience" is highly reminiscent of how I think about neuronal pattern-resonances in the brain, as a set of unfolding interactions between sets of neuronal assemblies that are emitting the own annotative signals. A triggering sensory event thus generates a process of semantic elaboration and eventual convergence to a stable set of pattern resonances that becomes the final "meaning" of the event. The signals continue to reverberate and to regenerate themselves within the network in a manner that parallels the autopoietic model of consciousness that I alluded to earlier.

There are several pieces in this exhibition that are potentially creative-emergent in this sense – they have enough richness and autonomy in their dynamics that it is difficult to draw a clear boundary of their possibility spaces. In this group I include: *The Bacterial Orchestra* (Martin Lübke & Olle Corneer), *Performative ecologies* (Ruairi Glynn), *Roots* (Roman Kirschner), and *Canções Submersas* (Vivian Caccuri).

The second mode of creative emergence is that an art piece can provoke new ideas, meanings, and perspectives in its audience. One thinks of Duchamp's 1917 urinal *Fountain* as a striking example of an inert, found, common object that nevertheless can have transformative effects in audiences. All of the works in the exhibition have the potential for this kind of emergent provocation, but we found *Bachelor -The Dual Body* (Ki-Bong Rhee), *Performative ecologies* (Ruairi Glynn), *I/VOID/O* (Sandro Canavezzi), and *Reler* (Raquel Kogan) evocative in this respect.

In practice, in the context of art and aesthetics, it can be difficult to assess whether new primitives have been created either in an artefact or in the audience. Much art is left ambiguous either by design or chance. For most new media art, an art object or performance is either compelling to its audience or it isn't, and this is usually independent of the means that generated it. For better or worse, I think of art as aesthetic engineering, the goal being to design objects and performances that move people in some significant way. Thus we see combinatoric and creative emergence as means to an end, two paths to the goal of making art that is compellingly meaningful to its creators and its audience.

Creative-emergent generative processes does not in any way guarantee "better" artistic productions, however one wants to define this. If the right primitives are judiciously chosen in the first place by the artist, then a search for new primitives in some ill-defined space of possibilities may take a good deal of time and effort and the result may not necessarily be an improvement. Such is the risk of exploration and experimentation! The one advantage of creative-emergent processes is that it can liberate one from stifling and mined-out conventions, and in so doing it can bring new worlds into being.

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