Enformation Theory — Part V:
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From *Pinwheels* to *Wheels of Life*[⋆]

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Abstract. The cyclicity theme studied before is extended in the spirit of *extreme enformation pursuit*, and it turns out that systems can further be abstracted in *frequency domain* with appropriate mathematical tools. This makes it possible to escape traditional thinking patterns, and there may even be need for a *new kind of science*. There are new challenges ahead: *one truly has to abandon centralized thinking.*

1 Introduction

Previously, different points of view have been employed for studying enformation theoretic system models. Now, finally, let us *immerse* in the systems, living it all, seeing things from inside, after all couplings have been completed.

It was observed earlier that in the enformation theoretic systems, the basic cycle structure is defined through the implicit feedback loop between the system and its environment, the momentary system state being defined in terms of vector x, and the experienced environment being defined by vector $\tilde{u}$. — But how to find the balance of signals? According to what has been observed we can assume that, given the mapping matrix Φ,

$$x = \Phi^{\mathrm{T}} \tilde{u}. \tag{1}$$

The problem is that $\tilde{u}$ finds its steady-state value only together with x:

$$\tilde{u} = u - \Phi x, \tag{2}$$

Should one just iterate and hope for convergence? — Of course not; there are still the same strict reasoning guidelines available. Again, one has to study *what is possible* and *what is optimal* in natural systems, thus finding more and more delicate structures.

Dynamics is the key to really reaching the *added value*. In Part IV it was concluded that the faith of evolving systems is to go in cycles; in such fractally vibrating worlds, there exist more appropriate thinking aids than what have been used this far. To reach intuition on this issue, one has to go to the very basics, to the simplest cycles.

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2 Beauty lies in details

Only the static world after convergence of dynamics was studied before, or the steady-state values $\bar{x}$ and $\bar{u}$. Of course, this is an annoying flaw, as dynamics in all levels has been emphasized.

And, indeed, it pays off to be pedantic here; as it turns out, the kernels of behavior, the basic mechanisms, are repeated and reflected also in the big picture, and fresh intuitions can be gained that can be utilized to extend the analyses. This dynamicity aspect is specially important when systems operate on their limits and there are transients taking place all the time. *To understand the big, study the small*.

Abandoning the stationary solutions a *Pandora's box* is opened, however: there are many ways to reach the same asymptotic stationary state. But there is again the same strong guideline available: *optimality pursuit*. The key forward is to extend the view again; there are similar-looking mathematical patterns when one goes to *probability distributions*, allowing one to discuss *optimal* dynamics.

> The *Ensemble Kalman Filter* is an iterative implementation of the probability density function estimate update problem: given an estimate of the *pdf*, called the *prior*, and the *likelihood* of some new data, find the new enhanced estimate, or the *posterior*. The *Kalman Filter* is known to be the optimal update strategy for Gaussian data; the *ensemble* formulation means that the distribution is stored implicitly in the form of compressed "virtual data", or in *state vectors*. Using the familiar notation, the goal now is to find a set of model vectors x so that the conditional Gaussian probability for some given data u
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> $$p(u|x) \propto \exp\left(-\frac{1}{2}\,(u-\Phi x)^{\mathrm{T}}\,R^{-1}\,(u-\Phi x)\right) \qquad (3)$$
>
> would be maximized; there is uncertainty in the model that is revealed in terms of the covariance R. The best result is reached when one updates each x for given u as
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> $$x^{\text{posterior}} = x^{\text{prior}} + C\Phi^{\mathrm{T}}\left(\Phi C\Phi^{\mathrm{T}} + R\right)^{-1}(u - \Phi x^{\text{prior}}) \,. \qquad (4)$$

Formally, this should be interpreted so that all x collectively correspond to all u as a distribution. In (4), the model uncertainty (the sample covariance $C = \mathrm{Cov}\{x^{\text{prior}}\}$) is projected into the space of data u, employing the covariance of the reconstruction Φx^{prior}. However, for practical reasons one would like to implement robust matrix inverses in the lower dimension, even with the cost of less "optimal" estimates. The projection mapping can approximately be moved to the other side of the inversion:

$$x^{\text{posterior}} - x^{\text{prior}} = C\,(C + r)^{-1}\,\Phi^{\mathrm{T}}\,(u - \Phi x^{\text{prior}}) \,. \qquad (5)$$

Here, $r = \Phi^{\mathrm{T}} R \Phi$ is the *a priori* model covariance (because $\Phi^{\mathrm{T}}\Phi = I_n$; see Part III). Letting the originally discrete-time pdf estimate update process become faster and faster, the difference between the posterior and the prior becomes the *derivative* with some time constant τ_x:

$$\frac{dx}{dt/\tau_x}(t) = G\,\Phi^{\mathrm{T}}\,\tilde{u}(t), \tag{6}$$

where

$$G = C\,(C + r)^{-1} \tag{7}$$

is a symmetric, positive definite speed adjustment matrix (vanishing for zero reconstruction error). Now the static model (1) has changed into an almost identical dynamic Kalman filter form that also models its environment. The model is lossless, there is no dissipation, with system states acting as pure integrators. This dynamic formulation is a major step forward.

3 Models in frequency domain

When extending the view to truly large scale systems, one thing that becomes clear is that the number of subsystems increases proportionally as compared to the number of actual inputs, or fresh resources. This means that it is *other subsystems* that have to serve as inputs to each other. As the subsystems operate on the same emergent level, on the same time scale, the dynamic considerations become necessary when trying to capture their interactions.

The subsystems acting as inputs raises a question: the inputs themselves are also dynamic now, being governed by similar differential equations. The increase in x activity is sucked from another subsystem u, and assumedly bigger contribution in (6) has to be visible also here; the loss can be approximated as

$$\frac{d\,\tilde{u}}{dt/\tau_u}(t) = -\gamma\Phi G\,x(t), \tag{8}$$

where $\gamma > 0$ is perhaps some adjusting factor. To get rid of the other variable, apply further differentiation to (6):

$$\frac{d^2x}{dt^2/\tau_x\tau_u}(t) = G\Phi^{\mathrm{T}}\,\frac{d\,\tilde{u}}{dt/\tau_u}(t) = -\gamma G\Phi^{\mathrm{T}}\Phi G\;x(t). \tag{9}$$

This expression now characterizes the lossless coupling between the subsystems. By experimenting, one can recognize that there is a class of signal forms that fulfills this expression:

$$x(t) = A\sin\left(\sqrt{\frac{\gamma}{\tau_x\tau_u}\,G\Phi^{\mathrm{T}}\Phi G}\;\;t + \psi\right), \tag{10}$$

the expression inside the square root being positive definite. There are also unattenuated harmonic oscillations taking place between the subsystems, defining a set of *resonators*. Frequencies of the resonators are determined by the coupling strengths in ϕ and the time constants, tighter coupling resulting in higher frequency. The system dynamics is autonomous, and the external inputs can only affect the initial values, determining the free parameters, or the amplitudes in A and the phases in ψ.

When differential equations are integrated as an integral part in the system model, it seems that the possibility of simple static calculations is lost. However, this increase in complexity does not take place, when one steps up to *frequency domain,* where it is assumed that individual signals are irrelevant, and it is only the resultant group behaviors or wave fronts that are of importance; in steady state, then, it is *frequencies* and their *phases* that count.

Now the linearity of model structures is nicely rewarded: there are strong tools available for analysing signals in frequency domain. The mathematical tool to manipulate and analyze systems with linear differential equations is the *Laplace transform* (or *Fourier transform*). Applying this transformation, differential equations change back to static algebraic equations, but the signal-domain variables become substituted with frequency-domain ones. *Vibration patterns* can efficiently be studied directly in frequency domain.

There is one essential difference: frequency domain signals are *complex,* as the amplitudes and phases both count. But this is not a problem now, as complex numbers can readily be used in the cybernetic models when all transposed expressions are substituted with Hermitean ones.

When the system is based on such oscillators, there are no balances at all in the systems, and the adaptation that is based on balance values cannot be implemented. However, the vibration patterns are stationary after they find their balance; learning can be carried out directly in frequency domain, where the signal activities have to be changed to signal amplitudes. In both cases, in frequency domain as well as in time domain, averages of the squares are related to "information energy", and discussions presented in Part I still hold: the adaptation of structures is based on enformation pursuit. When adaptation is carried out directly in frequency domain, the model parameters become complex-valued, meaning that they are phase-sensitive.

Now, it seems that the nature of the implicit lowest level loops and the explicit high level loops of nature (as studied in Part IV) is *oscillation patterns and spectra*. Extending to the frequency domain is a natural continuation to the previous discussions, because one can now complete the optimality pursuit: *all enformation over all time scales becomes available*. The frequency thinking can couple the low level and the high level; what is more, *it can also couple separate systems*. Different entities define their characteristic chords, together hopefully constituting a (Pythagorean) *harmony of spheres!*

4 Systems of systems

In frequency domain, one has a completely new set of concepts and intuitions available for interpreting system behaviors. The monadic oscillators make it possible to speak of things like *resonances* and *synchronization* among systems; they can become *coupled*, and *unattenuated enformation waves* can constitute *fields*. It is no more about mere hierarchical filtering of data, it can be *ubiquitous interaction among systems*. As a concrete example of new possibilities, *holographic memories* and the like can perhaps get implemented. — But, here, study still wilder views.

Before, it was assumed that data was the general means to become visible in the world, always the same at all levels; now the *system structure has been collapsed*, so that there are universal characteristics, frequency spectra (data again), that describe all systems, and specially their interaction with the environment; systems can see each other. And, specially, systems can see *themselves*, modeling their own operation: some kind of "systemculus" (in the spirit of *homunculus*) is created, and some kind of model of *self* can be formed. As there can be a "collapsed infinite descent" of system models, qualitative changes are possible, something that cannot be explained in a fixed form — finally, perhaps some kind of *implicit consciousness* emerges.

All semantics that is needed is captured in the fields of enformation. In the beginning, it was assumed that nature observes itself, collecting information in models, but this is no more enough: nature *experiences* itself. Human is not needed to give interpretations, meaning or purpose to change the observations to *perceptions*; no external mediators are needed, the "knowing of knowing" emerging from inside. The vibration fields permeate everywhere, causing the unexplainable holistic experience of wholeness and "being there"?

The above scenario cannot be possible without a flexible enough substrate to carry the fields. The monads must act like radiating "antennas" that make it possible for systems to interact even if they are not spatially next to each other. The claim here is that exactly such thing is accomplished by the nervous system, for example: the signals there are electric, and the electric charges propagating in monadic loops, indeed, because of the laws of physics, they give raise to electromagnetic fields.

However, when looking at the complex systems in our everyday surroundings — what on earth are such fields that would make it possible to reach higher level "system systems"? True, there is no physical substrate to implement *morphic fields*. What can nature do, yearning for more information and models?

Nature has created the *man* to implement the most difficult models and controls. Humans have the explicit consciousness to realize "allocybernetic" systems, boosting entropy production. But what is more, the human's role is to implement the *aether* to make intersystemic fields possible. The morphic fields must be *emulated* in one's own brain; one has to recognize the "vibrations" of nature, in the Eastern spirit. A human must recognize (more or less explicitly) one's place in the eternal continuum of cycles in one's work, in one's family, in one's culture, and in nature. The neocybernetic sincere selfishness gives way to *altruism* as a system-level survival strategy. Humans are the nature's way to implement the Hegelian *consciousness of nature*. Only if such aether becomes existent, best possible interaction and maximum enformation transfer through the universe becomes possible, and "visibility" through the (cyber)spaces is reached.

What happens when the organization of enformation proceeds and the fields start further modeling and organizing themselves? — Gods were not needed to make the world exist in the beginning, but such more-than-humans higher understanding must emerge again to keep the ever more complex system structures up and running ...

5 Towards a "new science"

In Part I, it was observed that new conceptual thinking tools, like concepts, are needed, to capture the essence of enformation theoretic systems. But that is not enough: it is now time to get rid of the conceptual constraints and look in the direction of new mental freedoms.

When looking closer at the human's quest for understanding nature, it is *natural philosophy* that is the upper category model above the constraints and freedoms of *science*. Today's science is just one possibility for organizing knowledge; and if understanding *life* seems to oppose scientific principles, a step ahead is necessary. Perhaps one should look beyond *scientific cartesianism?*

Let us try to *bootstrap a new science*. — As was observed before, one needs to change the viewpoint: rather than studying the system as an object, the *system itself* is the active observer and manipulator of its environment. And this rethinking has to be repeated throughout the universe; everything is subjects and everything is objects to others. One has to continue the *Copernican revolution*: the human is no more needed as the center of the universe, the observer and the active subject to make world an organized whole. — On the other hand, the observed world is relative to the observer; in the spirit of "general reality theory", *human is again the center of one's subjective universe!*

The dichotomy between *mind* and *matter* (or subject vs. object) is also obsolete in its current form. However, *dualism might be coming back* in another form: remember that enformation determines the stable attractors, or the structures, for matter to reside in. — And there is yet another of Descartes's ideas that need to be renewed to read: "I think therefore the *world* is". In the optimizing world the existence of the simpler is the only motivation for the more complex to exist; the outer world must be real.

Today's *correspondence* in science may be giving way to *coherence* once again. There are no one-to-one causalities or relationships, or, at least, they are less relevant than the *pancausal* ones. If phenomena are studied one variable at a time, as in contemporary science, the "wave functions" collapse and the *essence* escapes. One needs to admit the observer effect, or the coupling between the subject system and the object system; one has to *immerse* and apply some kind of *multivariate methods* for analysis to reach a *gentle touch*.

Taking another philosopher, one could also say that Immanuel Kant's *transcendental idealism* need not restrict our world any more. Kant says that mental functioning is anchored in space and in time; however, fields are not bound to exact signal locations, and, in a way, frequencies address both the past and the future in current time. Computation has to be ubiquitous. Perhaps Kant just did not have the necessary mathematical tools, like the frequency domain methodology, available to widen his thinking?

What comes to other modern tools to be used for doing the "new science", one has to mention some kind of *emulators* (or *emergence simulators*) to make it possible to enter the new "data world". To create general models that do not apply to just a single case, to find general principles of complex (living) systems, one has to receive observations from different kinds of *possible worlds*, not only from the current implementation ... One has to supply the appropriate environmental conditions and apply some kind of *Monte Carlo method* to generate fresh data about "alternative futures" to be operated on, to make it possible to reveal the potential degrees of freedom. Tools are needed to see *the world of data*, or, indeed, *the world as data*.

It needs to be emphasized that despite the phantastic visions above, it is not about some kind of *holism*. On the contrary, everything is *extremely reductionistic*: it is assumed that *everything is reducible to data*.

Despite the adopted *extreme empirism*, it seems that, suddenly, *rationalism* is striking back. It is not whatever data analysis, but there are strict guidelines to follow: the hypothesis is that the data is to be fit against the neocybernetic model structure. For example, the discussions in this paper are based exclusively on the properties of the model. Wilson's *consilience* among scientific cultures may be a step nearer, when relevance-based methodologies can be applied to combine different terminologies and approaches.

Albert Einstein once said that *the most incomprehensible fact about nature is that it is comprehensible*. Perhaps this is because the nature's complexity is based on very simple underlying models that are just repeated over and over again? Perhaps even the fine tuning of cosmos need not be explained in terms of some anthropocentric mysticism but on the universal controls becoming ever more polished? — As shown by enformation theory: if you optimistically *believe* that the world can be modeled (in Part I), then it truly *can*. In the spirit of *Gaia hypothesis*, where the marvellous stabilizing feedbacks are (jokingly) interpreted so that it must be the goddess that protects the earth, one could propose the *Pallas Athene hypothesis*: the good goddess guards the believing researchers so that their sincere efforts are not wasted, the final dead end will never be reached.

Speaking of researchers, it seems that today's scientific community has departed from the original ideals: it is not necessarily the scientific ideals that rule the behaviors, but the cyberneticity of the social system. A complete regeneration seems to be necessary there.

— Even though the "births" were emphasized in the beginning, there is too long a way to the absolute bottom; one had to start half-way, assuming that "nature observes and collects information". Now one is back there — however, the cycle has changed to a *spiral*: one can perhaps even claim that "nature perceives and collects experiences". It is now possible to *stay* on that level, and build further, creating consistent theories. As Ludwig Wittgenstein has said, after some level of understanding has been reached, one has to abandon the "ladders" anyway.

6 Conclusion: back to beginning

As was observed, everything goes in cycles — there is no actual beginning or end, or some real conclusion here. Also *understanding*, being based on enformation theoretic principles, evolves in cycles. The neocybernetic metaphor is a good basis for *constructivism*: the *reader's mental constructs* are being built gradually from where they were before, too.

Indeed, it would perhaps be instructive to carry out the next iteration loop starting again from Part I with the emergence of *cognitive mental models* rather than some physical structures in mind. — For example, how could one explain in this case, on the level of cognitive concepts, in a plausible way, the basic learning law

$$\bar{x} = Q\,\mathcal{E}\left\{\bar{x}\bar{u}^{\mathrm{T}}\right\}\bar{u}, \tag{11}$$

where $\bar{x}$ is the internal and $\bar{u}$ is the external state, the mapping matrix $\mathcal{E}\left\{\bar{x}\bar{u}^{\mathrm{T}}\right\}$ between them being the "thing" that has been learned? — First, it is the constructivistic basic idea that the old experiences determine how the new observations are filtered and new structures are built on previous ones. And in which direction does the learning take place here — yes, the formula can be interpreted in terms of *motivation*: when something has earlier been accomplished often and successfully, one is willing to go farther in that direction. How about emergence of more sophisticated structures? — Does it not sound appealing that when you are able to apply acquired enformation to filter data, this ability is something like *knowledge* or even *wisdom*? — Rather intuitive interpretations, regardless of the simple outlook of the formula, after all.

The neocybernetic view makes it possible to see *concepts* or *categories* as stable dynamic attractors among the "flows" or tensions in "ideasphere", being somehow *relevant* in their environment, defining a *grounding* of semantics based on enformation. And when the whole path is completed, *mental states can be seen as being characterized in terms of standing waves.*

Such high-level models that reside in ideasphere are, indeed, not limited to exist within only a single brain, and the world models can become intersubjective. There can exist *intelligent societies*, distributed models among groups of people, if the communication among the atomic minds is complete enough (if they see the same data). The *systems thinking* in one mind can change to a *thinking system* as seen from outside.

The age-old dilemmas in artificial intelligence can be seen in a new perspective. The AI propositions have been typically *hermeneutic* symbol systems; in the neocybernetic models, however, the environment is tightly coupled in the representations. First, the constructs are now learned rather than preprogrammed; but the models are also two-directional, so that controlling, or somehow affecting the environment is an essential part of the control loop. After all, the role of the mind is to implement models and controls to change the world. What is more, the infinite convergent loops in the model make it perhaps possible to understand the leap from the subsymbolic to the symbolic, the semantics following the constructs from below; such models may combine the worlds of symbolic AI and numeric approaches (like neural networks).

Again, there is the dualism — *consciousness* is to information what *life* is to energy: it inevitably emerges in the evolutionary quest for enformation as complexity cumulates.

— All these wild scenarios are just untested hypotheses — but many pieces seem to fit nicely together. And other similarly wide views are available in some other domains. For example, it seems that the world of *molecules* can better be understood when their interactions are interpreted in terms of structured spectra, explaining their very delicate affinity properties (see [1]).

IDA Symposia support *papers that go beyond established technology and offer genuinely novel and "game-changing" ideas, whilst not always being as fully realised as papers submitted to other conferences*. This paper has been submitted keeping the above promise in mind.

IDA 2012 also *will include an important and still emerging class of problems: the analysis of data from networked digital information systems ...*

The presented approach seems to be well suited for modeling distributed network systems. For example, in the paper *SAMPO Mills: Neocybernetic Grounding of Ontogenesis* (available through [1]) a sketch is presented how the *PageRank algorithm* (being also based on eigenvectors) could perhaps be extended applying the neocybernetic principles: this time the semantics (as revealed by the enformation flow) is visible in user activity, every page being hungry for more "clicks".

References

1. *Neocybernetics — Pragmatic Semiosis by Complex Adaptive Systems.* Research pages accessible in Internet through http://neocybernetics.com.