Review of: "Infodynamics, a Review"

Pengfei Su[1]

1 Fudan University

Potential competing interests: No potential competing interests to declare.

Topic: Would It Be Possible to Construct a Unified Theory of Complexity Evolution That Explains Both Useful Information and Free Energy?

Professor Klaus Jaffe has published an insightful paper that reviews various topics relating to Infodynamics. Building upon the findings from his previous publications on relevant themes, he gives fairly comprehensive descriptions of many concepts relating to information and Infodynamics, and sets forth his views on useful information, how to increase its emergence, and the interesting interactions between useful information and free energy.

While this is not a green-field academic topic, Professor Jaffe's presentation in this paper is vividly informative. My review below will summarize its discussions into three key aspects; I find that the arguments in his second proposition are quite convincing, while his first and third propositions deserve much deeper explorations. That is to say, Professor Jaffe has raised good points about useful information (**Φ**) and free energy (**F**) and their interactions, but is yet to reach the threshold for any ground-breaking discovery about their inner mechanisms. I sincerely hope my review below might pave the way for some collective research efforts towards a more comprehensive theory on useful information (**Φ**) and free energy (**F**) within the context of complexity science.

Key Point 1: Vast Diversity in the Concept of "Information"

A key proposition of this paper is that there exist many sides and dimensions to the concept of information, and they do not necessarily conflict with each other. The paper lists various angles from which information can be understood, e.g., the opposite of thermodynamic entropy (*negentropy*), the element that serves to produce free energy (useful information), *enformation* (a kind of structural information), *intropy* (memory of historical information), and the degree of aging of information (information senescence). In conjunction with such descriptions, the paper cites the passages of such scientists as Salthe, Dompere, Ceruti, Rubin, Vopson, and the author himself. The paper stresses in particular the multidimensionality of the concept of information, based on such factors as different methods for encrypting information, different resolution levels of information, "fuzziness" of information, different functions being served by information (in teleological senses), and the variegated features of information when viewed from inter-disciplinarian perspectives… It is stressed that these many different definitions of information could be reconciled with each other in their workings.

The above discussions suggest that the concept of information is extremely kaleidoscopic and diversified, so much so that I started to surmise that we might now be at a stage similar to where the scientific community stood in the 1830s in the face of the then emerging concept of energy. Would it be possible for us to arrange all such concepts of information into some better organization? To what extent might such different forms of information mutate between each other without losing their total balance in the process? Does information entropy (in Shannon's sense) coalesce, relax, and fluctuate along some invisible baseline within a given complexity system? Could we eventually arrive at some sort of law of conservation of information? What inferences will we have to draw if we find that information, if left alone, will keep on increasing or decreasing on a universal scale? These topics are worthy of deeper exploration. And in order to arrive at some meaningful discoveries on information mutation, researchers might have to expand the time horizon of their search, given that cosmic and natural evolutions sometimes unfold at glacial speeds; besides, the current diversified concepts of information must, in the first place, be assorted, re-categorized, and somewhat cleaned up, in the same way the scientific community cleaned up the caloric theory and redefined some older concepts (e.g., *vis viva*) in the early nineteenth century before arriving at the law of conservation of energy.

In addition, this paper's citations on the above topic of informational diversity seem to focus on scientific literature that contains the key word *infodynamics*, but some other contemporary commentators seem to have addressed relevant topics as well (George Ellis 2008, Paul Davies 2010, David Krakauer 2014, Sara Walker 2016). A somewhat broader scope of literature review might produce a more comprehensive coverage of contemporary developments in this area.

Key Point 2: How to Increase Useful Information

Along with discussions on the diversity of the concept of information, this paper provides detailed suggestions on how useful information can be increased, and such suggestions come in two different batches. First, the paper uses the examples of academic journals and online academic forums to advance the view that useful information is more likely to emerge where the publisher strictly performs its gate-keeping duty by means of high rejection rates (e.g., above 90% at certain top-tier journals, 40.9% at Qeios) or deletion rates (e.g., 60% at wikipedia.com). Next, the paper gives high praise to the method of sexual reproduction regarding its numerous techniques for maintaining information quality, which result in the "best balance between innovation and conservation of genetic information". By then, the reader should find quite convincing the paper's argument that there do exist feasible methods to "select useful information and separate it from noise". But are there any logical connections between the above two categories of methods for improving useful information? Is the sexual reproduction method a more advanced, sophisticated application of the high-rejection-rate method employed by scientific journals? The author does not expound on any commonality between them.

Discussions on useful techniques for improving useful information might serve as valid topics of separate research articles, and the author stops short of going into details here. Next, he turns to a much grander topic which could not possibly be fully addressed in a single article either, i.e., the synergy between useful information (**Φ**) and free energy (**F**).

Key Point 3: Synergistic Chain Reaction between useful information and free energy

After covering various background topics as listed above, we are now approaching the most valuable theme of this paper. It is around this theme that the author provides his views on the underlying mechanisms of complexity systems, i.e., there exist synergistic chain reactions between useful information (**Φ**) and free energy (**F**): **F** requires **Φ**, while **Φ** requires **F** for the emergence of **Φ**. The paper posits that **Φ** and **F** need each other in order to grow; that**Φ** and **F** are mutually dependent and mutually reinforcing.

While such propositions sound very plausible, the relationship between **Φ** and **F** becomes fuzzy if we put it to stricter scrutiny. We will find that useful information increase (ΔΦ>0) does not necessarily accompany increments in free energy (ΔF >0). For example:

- The evolution from the Australopithecus ape to the primitive *homo sapiens* brought about a tremendous increase in the amount of **Φ** available to our ancestors, but not much increase in its muscular power.
- The evolution from an early CenozoicCenozoic **artiodactyla** to a modern blue whale experienced a tremendous increase in the amount of **F** available for use by the animal (presumably by hundreds of times), but it was not accompanied by much increase in the amount of **Φ** at the disposal of the animal.
- The information content (hence **Φ**) as contained in a sunflower plant (in terms of its biological complexity) is higher than that of the sun, while the **F** amount as contained in the sun overwhelmingly exceeds that of a sunflower at an astronomical level.

If useful information and free energy are often present with each other concomitantly, that is because they concurrently belong to a bigger complexity system, whose emergence was caused by a variety of natural laws (including the principle of free energy minimization). *Concurrence* of **Φ** and **F** does not necessarily imply *causation* between them, while this pair (**Φ** + **F**) is probably part and parcel of an emergent bigger system. The "incremental" increase of both **Φ** and **F** might be just the outcome of an evolutionary process that is of a much broader range than biological evolution in its Darwinistic sense. For example:

- A cannon gun possesses much stronger fighting power than an ancient catapult (i.e., stone slinger) because the former was a product of early modern weapon upgrading, which involved both more sophisticated engineering designs (i.e., more **Φ**) and more destructive gunpowder (i.e., more **F**). It would not be academically significant to discuss whether/how more complicated cannon design drawings caused stronger gunpowder, or whether/how stronger gunpowder caused more complex design drawings. Our understanding of the evolution of cannon guns would be meaningful only if it were put into the context of the early modern European military revolution (i.e., a higher degree of societal complexity at large).
- Similarly, an automobile engine possesses much more **F** than a horse because the former is the product of the Second Industrial Revolution, which involved the application of both the internal combustion engine (i.e., more **Φ**) and petroleum mining and refining (i.e., more **F**). It would not make sense to discuss whether/how the internal combustion engine design caused the use of gasoline, or whether/how gasoline use caused the emergence of the internal combustion engine. Our understanding of the invention of the automobile engine would be more meaningful if it were put into the context of the Second Industrial Revolution (i.e., a higher degree of societal complexity).

The cause for the author's omission in mentioning any underlying mechanism that supports both **Φ** and **F** might have been embedded in the second paragraph from the end of the article's main text, where the author acknowledges that "*in complexity system science, the exact mechanism by which information creates free energy is still nebulous*". Despite such uncertainty, it is now high time that the scientific community set out to explore this significant topic, behind which there might lie some sort of intellectual Holy Grail awaiting our discovery.

This article points out that the interactions between useful information (in the Aristotelian sense of “form”) and work-producing free energy (in the Aristotelian sense of “function”) cut across numerous academic disciplines and might serve as connecting bridges uniting many areas of science. Here, Professor Jaffe calls for the creation of a more generalized information theory covering different scientific disciplines, and I cannot help but applaud his suggestion. If we take his logical arguments further afield, we might infer that we need a Grand Unified Theory of Complexity Evolution covering **Φ** and **F** in all significant subjects based on generic concepts. However, Professor Jaffe did not go that far, and he mentioned in this article the task of quantifying **Φ** and **F**. However, a meaningful initial step in exploring such a GUT is more likely to be insightfully qualitative rather than rigidly quantitative. It will be helpful to make some general projections towards the future path onto the construction of such a unified theory.

A major challenge to constructing a synthesized theory of emergent complexity is its sheer breadth and depth. Accomplishing this task will take a well-coordinated committee of Renaissance-man academics talking to each other in mutually-intelligible academic jargons from very different disciplines. The committee members will be able to articulate complex theories in plain language and mutually bridge their gaps in advanced frontier research areas, aiming at creating an eventual scientific symbiosis.

A unified theory on complexity-based **F-Φ** increase will call for a deeper and broader understanding of various scientific laws. The neo-Darwinian theory of biological evolution might need to be expanded to achieve perspectives into much broader areas. It will be worthwhile to also explore whether broader scenarios of application might be found for the Gibbs free energy criteria ($\Delta G = \Delta H - T\Delta S < 0$), which calls for free energy minimization. From time immemorial, it has been the spontaneous workings of, *inter alia*, the Gibbs free energy criteria that drove forward numerous chemical reactions and created significant increases in both **F** and **Φ** (instead of **F** creating **Φ,** or **Φ** creating **F**). Without primordial chemical evolution (induced by the free energy minimization principle), LUCA (let alone Darwinian evolution or human society) would not have existed. In a broader sense, can we discover coarse-grained rough equivalents of the free energy minimization principle in other scientific disciplines as well? For the moment, we cannot completely rule out such a possibility yet.

Our research on a unified theory of complexity-based **F-Φ** increase will not take off until we have seriously revisited the significance of the Second Law of Thermodynamics, which, after all, is a scientific law of statistical (rather than dynamical) nature. While we do not intend to dispute this law’s present applications, some scholars (in addition to Prigogine 1977) have formulated theories to explain a vast range of entropy-decreasing phenomena in far-from-equilibrium environments.[i] More importantly, it might be helpful for us to put aside for a short while the Boltzmann notion of entropy (i.e., the total number of possible microstates) and reconsider the very original concept put forward by Clausius in 1872 in his argumentative paper (i.e., entropy being the measurement of the degree of *disgregation* of physical bodies).[ii] The very concept of “*disgregation*” might connect us to a broader scope of observable natural phenomena in which common patterns of evolution might be discovered in multiple realms.

I hope the above ideas could be helpful for our exploration of a unified theory on emergent complexity and **F-Φ** increases. The endless evolutionary cycles occurring over the last 13.8 billion years at different layers of our universe have created fascinating complexity that contains increasing levels of **F** and **Φ**. I will be interested in discussing with serious researchers how to construct a unified theory on the fundamental laws of complexity evolution, and I can be reached by email at pfsu1@hotmail.com .

[i] Kauffman, S. *Is There a Fourth law for Non-Ergodic Systems That Do Work to Construct Their Expanding Phase Space*? Entropy 2022, 24, 1383. https:// doi.org/10.3390/e24101383

[ii] Pellegrino, E.M; Ghibaudi, E; Cerrut L. *Clausius' Disgregation: A Conceptual Relic that Sheds Light on the Second law*. Entropy 2015, 17, 4500-4518; doi:10.3390/e17074500