Peer Review

Review of: "The Information Theory of Self-Organization Phenomena in Thermal Systems"

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In this work, authors study the single Brownian motion and the multiple-particle system motion as well, by using Information Theory,
the article tries to show an ambitious theoretical framework unifying Information Theory, Thermodynamics, and Complex Systems.

By appealing to the framework of the maximum entropy principle and Bayesian inference, authors find a relationship between local randomness and global probability distribution.
Also, authors present the interesting concepts
such as "Energy as Encoding" and "Information Temperature" to clarify
how energy distribution determines information structure.

Besides, in the context of out of equilibrium open systems,
authors define the concept of "Equilibrium Flow" in order to give an explanation of self-organizing behaviors

I think that the article pursues very interesting and ambitious physical issues. Indeed, as authors explain, they try to give new perspectives for understanding
the dynamics of Complex Systems.

However, I think that, on one hand, work hypothesis are not well established and consequently, on the other hand, results are not properly demonstrated.
As authors affirm in the conclussion section: the work primarily provides theoretical insights without extensive empirical validation or detailed mathematical proofs.

Such a declaration does not leave any doubts that this work must be deeply revisited and complemented with more detailed and accurate theorem´s demonstrations.

I want to emphasize that the objective of the work is valuable and deserves to be studied. However, there is still much work ahead.

I suggest to Qeios to reject this work.

Below I give some arguments on which I take my decision of rejecting the article.

1: The following sentence is not clear, it should be rethought and rewritten:

We introduction of concepts such as "Informational Temperature"
seeks to quantify the frequency and intensity ofinformation exchange,
further elucidating the interplay between energy and informational dynamics.

2 - Theorem 1 is not demonstrated in a general way properly.

3 - What does the conditional entropy mean?
I think this quantity should be defined on theorem 2 subsenction.

4 - On Eq. 8 what do Hcond and I(x,y) mean?

5 - Before Eq. 8 authors refers to entropy at time t and joint entropy:
first: I cannot see an entropy formula depending explicity on t but on x and y.
I suppose that time dependence appears through x and y. Anyway,
wouldn´t it be more properly to write H(t)?
Second, in my opinion it is not clear what the joint entropy is.
Authors should clarify this point.

6 - After Eq. 8 authors affirm that ´´ ...Brownian motion maintains not only its characteristic random diffusion but also a structured propagation of information across space and time.´´
It is a very poweful statement. Authors propose an interesting explanation about it.
However, I think demonstration is not complete from a analytical point of view. Something is missing.

7 - From reading the paper and interpreting a restricted random process,
is it possible to think that there is a transition between a Markovian process
to a non-Markovian process? If so, the dynamics changes abruptly. I find it surprisingly
because of you just propose a symmetric random walk. Please, could you explain this?

8 - What is the difference between H and S?

9 - On page 10, the authors introduce the information temperature by affirming that it represents the frequency of sample information exchange between systems. What systems are they referring to? Indeed, at the beginning of the subsection ´´ 4.1.2. Information Temperature´´ the authors affirm that the information temperature ´´ represents the frequency and intensity of information exchange within a system.´´
So, on one hand, information temperature needs two systems to be defined, and on the other hand, it is an exchange measure within a system. It is not clear at all.

10 - Eq. 21 is a very interesting result. I wonder, does Tinfo depend on time?

11 - On page 14, subsection ´´ 4.2.3. Explaining Self-Organizing Behavior in Complex Systems´´, what do capability threshold and loss value mean?

12 - On page 14, subsection ´´ 4.2.3. Explaining Self-Organizing Behavior in Complex Systems´´, the authors talk about model transitions from low to high energy states.
Why do they affirm such a statement? Do they know the energy spectrum of such a system?
If so, I think it should have a reference at least.

13 - Theorem 3, Equilibrium Flow Systems Follow the Fermi-Dirac Distribution, is not clear at all.
Why do out-of-equilibrium open systems follow a Fermi-Dirac distribution?
Eq. 35 is not clear. Where did the authors take this equation from?
Why did the authors take the derivative of the supposed Lagrangian with respect to P(E) equal to zero?

14 - Theorem 4, ´´ Self-Organized Criticality of Equilibrium Flow Systems´´, is not demonstrated properly.

Typos or syntax errors:

1 - Typo: On subsection 3.1, the title is ´´Definition´´.

2 - Typo: On page 5, just below Eq. 1, there is a typo: ...withs(x,t)=1indicating...

3 - Typo: After Eq. 19, it should be written: ´´ ...Tinfo represents...´´

Declarations

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Potential competing interests: No potential competing interests to declare.