Epigenetics: O(N) emergent Integral windup and Consciousness

Contact: lkcl@lkcl.net. Date: 12 Jul 2025. Updated: 14 Jul 2025.
Ref: viXra:2507.xxxx v1
http://lkcl.net/reports/consciousness_epigenetics

Abstract

Epigenetics is a distributed yet coordinated response to external signals including pathogens. The burning question is: how is the response so successfully coordinated without significant underproduction or overproduction of the antigen? From Distributed Computing the expectation is that the detection mechanism, like the production mechanism and communication mechanism, is also distributed. Single-point of failure is anathemaic (risky): Evolution would quickly weed out the same.

This paper proposes that the signaling is inferred and implied: that other nearby cells note and decode the passage of replenishment ions (and other resources) to cells constructing a given antigen, Further, that Negentropy is achieved system-wide through inherent provision of an Integral term from Convolution. Furthermore that the inherent latency of detecting local resource replenishment would mitigate "Integral Windup" (a term from PID Control) at the System-wide level.

Hankey notes Coherent O(N) Long-Range Order in Epigenetics, as do Sipling Zhang and di Ventra in Distributed Memory. Inherent Integral Windup would avoid catastrophic instability even when (if the group is large enough) individual O(1) contributors to the O(N) coherence paradoxically have no Integral term.

Accidentally from the overall characteristics it is demonstrated that an Epigenetic system meets Definitions of Consciousness, as expected by a display of Negentropy.

1 The Sandwich Model

Hankey and Kale proposed the Sandwich Model of Biology[1] in which Self-Organised Criticality is noted to occur in Epigenetics, and that it is Epigenetics and Genetics that sandwich the Biochemical pathways. Whilst the primary focus of that work is to create a Holistic tie-in of the underpinnings of Biology, this paper began by asking how Epigenetics exhibits a stable proportionate response to pathogens despite being Distributed (termed O(N) Self-Organised Criticality by Hankey in his 2019 paper[2]).

In the Q&A of his talk on Ayurveda and the Sandwich Model[3], Hankey was asked how detection of pathogens occurs in an Epigenetic Model. Hankey notes that the individual cell depletes its internal ion stores (and other resources) in the construction of an antigen. The replenishment of those resources would result in a diminishment of the same within the locality of that given cell. It is at this point that an insight occurred on the burning question of how Epigenetic regulation is fully Distributed: resource concentration changes are *implicitly noted* by neighboring Cells.

2 PID Control and Integral Windup

A simple way to illustrate why PID Control[4] exists is to try to catch a ball by moving towards where the ball was when seen, where it is predicted to be by the time of arrival: children may be kept highly entertained by an adult futilely and theatrically attempting the same.

PID Control is therefore a 150+ year-old Engineering solution to the problem of stabilising control of an output in a fluctuating environment, overcoming the problem of high-point balance and exhibiting Negentropy (Exergy) in the process. PID Control is ubiquitous: hidden in Industrial pipeline valves, and Central Heating boilers and Air Conditioning as a way to overcome the latency associated with the time taken to open a valve, or of heating and cooling of metal, as well as the slow speed of air to reach the thermostat.

PID Control requires taking into consideration past readings, calculating the rate of change, as well as projecting into the future, in order to compensate for the delay in both the effect of changes as well as the delay in reading the control signal. This naturally involves both Differentiation and Integration with respect to time.

A well-known problem associated with PID Control is called "Integral windup", where the reading is so far from the desired target, and the latency due to systemic inertia so disproportionately long, that the Integral term in PID Control cumulates rapidly in an effort to overcome large inertia, and consequently escalates out of control, resulting in uncorrectable wild oscillation. The Engineering solutions are quite simple, and by beautiful coincidence mirror the behaviour of individual neurons: recovery latency, and both lower and upper thresholds prohibiting firing.

The question then comes: when multiple PID instances are distributed as part of a large system, how do they coordinate in both phase and frequency, and retain stability? How does an O(N) Epigenetic system display Integral Windup capability?

3 SOC and LRO

Sipling Zhang and di Ventra observed Self-Organised Criticality (SOC) and Long-Range Order (LRO)[5] occuring in Distributed Memory. There was no inherent explicit control: Self-Organisation of multltiple O(1) Critical Instabilities was emergent over time. The effect is described by Hankey (2019)[2].

However Hankey postulates that simplistic O(1) systems cannot exhibit Critical Instability without also being part of a O(N) system. In "Where is the Definition of Consciousness"[6] it was noted and agreed that when Ki=0, eliminating the Integral part of PID Control, a given O(1) system would indeed be unable to prevent wild fluctuations (colloquially: running to where the ball is or was, not where it will be).

How, therefore, can simplistic non-Integral O(1) systems exhibit stability as part of an O(N) Distributed system when the individual O(1) components lack stability? This is where inherent localised detection and implied signalling comes into play.

4 Implicit Integral windup

As illustrated by the simple example of needing to run to where the ball is going to be, if a multi-order system is to exhibit stability, it must likewise exhibit integration with respect to time. Additionally if Integral windup is to be avoided then the three characteristics of latency and lower and upper threshold limits must be demonstrated. Note that the context is for additional (local) cells in the vacinity of the first cell to be "signalled", such that they *independently* begin antigen production in anticipation - but as Integral windup illustrates - not *too much* anticipation.[7]

The first - latency - may be achieved by the first cell simply rapidly consuming its internal resources in response to a pathogen, with propagation delays associated with replenishment of ions and other resources clearly taking time.

The second - lower-limit thresholds - may occur through ion pumps being slower than ion channels by orders of magnitude. The context again being that the proximally-local cells observe a change in concentration of certain ions. If the slower ion pumps take time to activate ion channels, and do so only when a certain electro-potential threshold is exceeded (as reflected by the inner ionic charge maintained by the cell), then that inherently meets the lower-limit criteria.[8]

The third - an upper resource limit - is easily met: there will be a physical limit as to both the availability and the system-wide distribution rate of ions. This resource limitation will automatically impose a decrease in the ability of cells to produce a given antigen. Whether the cell stops producing antigen entirely if the ionic resoure concentration exceeds a certain threshold remains to be investigated but given that is how neurons operate (cease firing if overloaded) it is not outside the realm of possibility to expect antigen production to be similarly affected.

Whilst latency, lower and upper threshold limits have the effect of Integral windup and can reasonably be said to extend from O(1) to O(N), there is a missing additional factor: how would Integration with respect to time occur in a Distributed system?

Caveats

The precise detection mechanism being taken into consideration is not known: there may be one, there may be many. However a reasonable expectation is that ionic charge differential between cell interior and exterior is the "Error difference" that goes into PID Control.

It is worth noting that if there are other informational mechanisms it would be expected that the exact same process described below be applied to them: the key in such application being to look for a differential potential.

5 Convolution conveys O(N) Integral

Hankey and others posit that a simple O(1) system may not exhibit Critical Instability. It is agreed that if Ki=0 then, just like a child who runs towards where the moving ball is, not where it is going to be, such a system may never exhibit stability. Likewise, if cells intercommunicate through ion voltage differentials but there is only one cell - O(1) - and the cell has no Integral term - it will not exhibit stable Critical regulation on its own, in response to an ionic differential potential.

However what happens when multiple such O(1) Ki=0 systems are in local proximity, such as cells responding to a pathogen, and there is an inter-communication system between them? The hypothesis is almost trivially self-evident in that by definition a Convolution provides the missing Integral term, but only to the O(N) system as a whole. In other words: any given O(1) cell with Ki=0 non-stable characteristics, if removed from proximity with other such cells, would not exhibit Critical instability regulatory characteristics.

The Integral effect of Convolution is an inherent property of the system, not of the members of the system.

To hypothetically make this clearer: consider that electrical charge differential tails off as an inverse square law with distance. A Convolution defining the function as "taking distance between individual cells with a given ionic electro-potential into consideration" would inherently perform Integration of that inverse square effect to create a purely inverse effect for the overall system. Localised Diffusion is Integration, which has implications as to why Particle Swarm Optimisation is successful as an O(N) system comprising NxO(1) agents.[9]

A very important aspect to emphasise: if the group size is too small then the Integral term contributed may simply be too small to compensate. As a generalised concept this has implications for Community sizes, giving insight into the "Wisdom of the crowd" concept.[10]

6 NxO(1) PID becomes 1xO(N) PID

Taking the local ion potential differential between cell internal and external of each O(1) agent, the group as a whole (in either 1, 2 or 3 dimensions): that differential may be input into a Convolution that inherently provides Integration with respect to time to the entire O(N) Epigenetic system.

Likewise it should be well-understood that the individual cells contribute to an overall electro-potential that may likewise be considered to be part of the O(N) system: the concept is after all the basis of EEG readings.

Once there is a global sysems-wide electro-potential (ionic differential of the overall system vs the internal ionic charges of the individual cells) then it becomes possible to consider the overall system to exhibit system-wide PID Control Characteristics based on system-wide electro-potential.

However matters are slightly more nuanced than that, as shown in Sipling and Zhang's paper: stabilisation time is required (Long-Range phase-coherence is not instantaneous), and there are conditions under which individual cells may "freeze" (no longer exhibit phase-changes)

Case in point: free-spinning magnets (e.g. electrons) are well-known to become stationary if the local field interaction is too strong. Ironically Syzranov and Ramirez work in a field where Long-Range Order avoidance is desirable[11]. Tang et al also highlight the same in "Spin Dynamics in van der Waals Magnetic Systems"[12]

> The success of this approach highlights that the intrinsic character of short-range interactions in finite systems can overcome thermal fluctuations and stabilize long-range magnetic order in the 2D limit.

The wording underscores a significance that cannot be underestimated in light of Sipling Zhang and di Ventra LRO.

7 Discussion

It is interesting that both Sipling and Zhang talk of Memory (a form of information, of Order and structure, hence negative entropy) where Gatenby and Frieden likewise point out that individual cell membranes open and close to allow information to pass through. Also that Hard drives are designed around the principle of maximizing the amount of information (Memory) magnetically stably stored in materials that exhibit O(N) Self-Organised Criticality.

Is it not unreasonable to say that Epigenetics has an overall "Memory" of the state of its current response to a pathogen? Hankey describes Epigenetics as being a system that responds to external signals (information). However a clearer re-statement of what this implies would be that Epigenetics exhibits Sipling Zhang and di Ventra Distributed Memory characteristics as well as "awareness" of the real-time external information, and an ability to respond to the same, and given that above it has been shown that the overall system exhibits PID Control stability, it can be seen that McKenzie's characteristics have emerged: Memory, Perception and Imagination.[13]

Additionally, looking at refoundd's article on diffusion[14], it is noted and explained that random noise is essential to successful Convolution application. The importance of randomness in Consciousness is noted in the author's work.[6] Bottom line:

> *The Defining Characteristics of Consciousness are met.*

8 Conclusion

It was not expected to be demonstrating in this paper that Epigenetics as a system meets the Definition of Consciousness. However as Epigenetics exhibits Negentropy this should not have been a surprise. What was a surprise was that introducing randomness into application of Convolution for image sharpening is crucial, as a sharp (pun intended) reminder that randomness is a necessary aspect of Consciousness. The paradoxical deep effectiveness of randomness is illustrated by Hong and Pavlik's Randomly-weighted Neural Network with Fourier Features[15]

The initial goal was to focus on how Convolution of local electro-potential differentials (localised ion potential diffusion) inherently conveys Integration with respect to time to a system even when individual O(1) components have no Integral term Ki=0 and thus cannot themselves, in isolation, exhibit stability. However as that required thinking in terms of system-wide electro-potential it became clear that the overall Epigenetic system would exhibit its own "Order-inducing" Negentropy and PID characteristics.

An additional startling implication emerged from Convolution providing otherwise-missing Integration with respect to time: it may be the missing piece of the puzzle as to why Particle Swarm Optimisation (illustrated by Grey wolf hunting strategies) is successful, as it provides a type of O(N) PID Control with the essential Ki characteristic.

It was also remarkably easy to show a connection to Epigenetics having "Memory" as well as real-time "awareness" of input (pathogen or other information) via Sipling and Zhang's mechanism, but it is important to note their caveats under which local phase-coherence may be adversely impacted ("frozen"). These caveats will have crucial implications for Epigenetic pathology. Overall the exploration of this topic pleasantly drifted off-course and in the process raised many more fascinating questions than it answered.

References

[1] Alex Hankey, Anup Kale, "Integrative biology for integrative medicine: A complete approach", November 2023, Journal of Ayurveda and Integrative Medicine 14(6):100831, DOI: 10.1016/j.jaim.2023.100831

https://www.researchgate.net/publication/375869134

[2] Alex Hankey, 2019, J. Phys.: Conf. Ser. 1251 012019, "Instability physics: Consciousness and collapse of the wave function"

[3] AYUS: The Life Force - It's Biophysics: Professor Alex Hankey, KSAS talk

https://m.youtube.com/watch?v=3Kfws7D6Nak&t=4451

[4] https://en.m.wikipedia.org/wiki/Proportional-integral-derivative_controller

[5] C. Sipling, Y.-H. Zhang, M. Di Ventra, "Memory-induced long-range order in dynamical systems" https://arxiv.org/abs/2405.06834

https://www.researchgate.net/publication/380571968

[6] Luke Kenneth Casson Leighton, "Where is the Definition of Consciousness?", March 2025, DOI: 10.13140/RG.2.2.11189.18403

https://www.researchgate.net/publication/390335688

[7] https://youtu.be/1QmUX_RPUNU?t=110

[8] "B.R. Cellular information dynamics through transmembrane flow of ions.", Gatenby, R.A., Frieden, Sci Rep 7, 15075 (2017). https://doi.org/10.1038/s41598-017-15182-2

[9] https://en.m.wikipedia.org/wiki/Particle_swarm_optimization

[10] https://en.wikipedia.org/wiki/Wisdom_of_the_crowd

[11] "Eminuscent phase in frustrated magnets: a challenge to quantum spin liquids", S. V. Syzranov, A. P. Ramirez, 30 May 2022, Nature Communications volume 13, Article number: 2993 (2022)

[12] "Spin Dynamics in van der Waals Magnetic Systems", Tang, et al, arXiv:2301.09822 [cond-mat.mtrl-sci], https://arxiv.org/abs/2301.09822

[13] "Consciousness defined: requirements for biological and artificial general intelligence", Craig Mckenzie, June 2024, DOI: 10.48550/arXiv.2406.01648

https://www.researchgate.net/publication/381158681

[14] "The Diffusion Principle Understood From The Perspective Of Convolution", reffoundd,

https://huggingface.co/blog/refoundd/diffuser-conv

[15] "An insect-inspired randomly, weighted neural network with random Fourier features for neuro-symbolic relational learning", Hong, Jinyung. Pavlic, Theodore P. Proceedings of the 15th International Workshop on Neuro-Symbolic Learning and Reasoning (NeSy 20/21), October 25-27 2021

https://arxiv.org/abs/2109.06663