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Article

Entropy generation, Brain Dynamics, and Thomas Aquinas

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Abstract

Entropy and entropy generation are fundamental quantities in the analysis of complex systems. Indeed, they have been proved to be the key in the understanding of many different phenomena and of practical applications in engineering and science. They represent the fundamentals of most modern formulations of both equilibrium and non-equilibrium thermodynamics. In the last twenty years, entropy and entropy generation have been better understood in fundamental aspects and a great number of applications have been developed in classical engineering and new scientific area problems. In this paper, starting from these results, the entropy generation approach is presented as a powerful method of analysis of the brain function, in looked at in the light of the moralistic and philosophical arguments of Italian philosopher and theologian Thomas Aquinas.

Introduction

Small systems are interesting devices in nanotechnology, where motors with dimensions of less than 100 nm are built and used inside of cell wherein *bio*logical (*chnops*ological) motors convert chemical energy into useful work inside the cells.[N1] Danish-American cellular physicist Irvin Richardson, in 1968, proved analytically the fundamental role of dissipation in *bio*logical (*chnops*ological) systems and this theoretical result has been confirmed by all the experimental investigations on these small systems: the small systems dissipates energy continuously, so they operates in non-equilibrium states.[1]

In non steady states, some properties of the systems change in time due to thermal fluctuations that, in small systems, can be described by means of control parameters, the variable fixed when the others are allowed to fluctuate.[2]

The analysis of these large fluctuations brought Australian chemical physicist Denis Evans and theoretical chemist Debra Searles, in 1994, to introduce the fluctuation theorems, which state that: 'in a steady state system heat is continuously produced and transferred to a bath.'[3] This represents the need of interaction between the system and its environment from which irreversibility necessarily occurs.[4]

From the explicit mathematical expression of this result, it has been pointed out that small systems are more probable to deliver than to absorb heat, which is completely lost.[5] Non-equilibrium systems have been proven to be characterized by irreversible losses of energy from the system to the environment: these results suggest to consider the thermodynamic approach to irreversible open or closed systems to evaluate the stability of the steady states of brain.[6] This actual result is argued here to be in accordance with the approach of Italian philosopher and theologian Thomas Aquinas and his 1272 concept of mind-body intention, a perspective which is summarized well by American cellular researcher Walter Freeman, in his 2008 article 'Nonlinear Brain Dynamics and Intention According to Aquinas', as follows:[18]

> "The philosophical foundation from which the sciences grew is accessible through the work of one of its originators, Thomas Aquinas. The core concept of intention in Aquinas is the inviolable unity of mind, brain and body. All that we know we have constructed within ourselves from the unintelligible fragments of energy impacting our senses as we move our bodies through the world. This process of intention is transitive in the outward thrust of the body in search of desired future states; it is intransitive in the dynamic construction of predictions of the states in the sensory cortices by which we recognize success or failure in achievement. The process is phenomenologically experienced in the action-perception cycle. Enactment is through the serial creation of neurodynamic activity patterns in brains, by which the self of mind-brain-body comes to know the world first by shaping the self to an approximation of the sought-for input, and then by assimilating those shapes into knowledge and meaning."

In short, energy or rather 'force', as James Maxwell correctly defined things in 1847 at the age of 16:[21]

> "The only thing which can be directly perceived by the senses is force, to which may be reduced light, heat, electricity, sound and all the other things which can be perceived by the senses."

impacts our senses and our bodies are moved through the world. Aquinas, supposedly, in the late 13th century, intuited this logic of nature, in some sense, without having scientific instruments, more than philosophy, to model it. Herein we will expand on this early insight through the lens of thermodynamics.

In this direction, the following, to give some terminology reference usage basis, is the author's human thermodynamics variables table, which gives the author's perspective as to how he sees thermodynamic variables correlating and or equating to terms, entities, and or concepts in the humanities:

Thermodynamics	Humanities
Particle	Brain cell
Heat lost	Communication
Energy stored	Memory
Entropy	Information lost

Engineering thermodynamics results

The stability of a complex system can be measured in terms of a certain dimensionless parameter and when such a parameter exceeds a certain critical value, the system is no longer stable against small perturbations.[7] In phenomena out of equilibrium, irreversibility manifests itself because the fluctuations of the physical quantities, which bring the system apparently out of stability, occur symmetrically about their average values; the statistical physics allows us to link the probability and the frequency of occurrence to control quantities related to entropy generation.[8] The entropy generation in complex systems can be evaluated as the sum of five components:[9]

1) Thermal flux driven temperature difference;
2) Diffusion current driven by chemical potential gradients;
3) Velocity gradient coupled with viscous stress;
4) Chemical reaction rate driven by affinity;
5) Dissipation due to work by interaction with the environment.

For the complex systems at the stationary states, the entropy generation has been proven to be always an extremum.[10] This result has been used in solid state physics, in two-phase flows, in the optimization of magnetic refrigeration, in economic analysis of production systems and in *bio*logical (*chnops*ological) systems and in many other applications in chemistry and *bio*chemistry (*chnops*chemistry).[11]

Last, starting from the consideration that all the natural systems need to reach the stability in the least time, recently it has been proven that:[9]

1) If the system does not grow in space, but evolves only in time, then its entropy generation results maximum: this means that the small system changes its internal configuration;
2) If the open system evolves also in space the entropy generation results maximum or minimum due to the prevailing of the time or spatial term respectively: this means that the small system changes the values of its control quantities.

Brain as thermodynamic device

The interaction between environment and brain is sensory impressions and changes in brain states. Human brain interacts with the environment with exergy flows. Consequently, perception can be studied as a transduction phenomenon of the energy exchanges, between the senses and the surroundings, in neural signals. This process can be developed only if there exists a physical representation of information as an energy flow, which means that a person can manage his or her sensations only if a scheme of representation has been made in his experience, i.e. they are able to realize the transduction of energy flows in neural signals and to represents the information collected.[12] Consequently, when a new energy exchange occurs, the brain system follows the thermodynamic paths which allow the individual to rationalize the perception, consuming the exergy associated to the signal and growing its entropy generation.[Q5]

When a disease or a lesion occurs, the brain can increase or decrease the entropy generation in order to maintain specific neural structures and functions.

This nondeterministic behavior of the brain can be described by the variation of the brain entropy generation in relation to the energy changes.[13] As a consequence, memory consists in the activation of the neural path, in order to disperse exergy, increasing entropy generation. This approach can be useful to study the brain and its disease, both neurological and psychiatric, but also related to learning. Indeed, the processing of external stimuli increases the entropy generation with the consequence that any cognitive process increases the entropy generation, of a quantity proportional to the information collected. This can be experimentally obtained and it is useful in the analysis of the brain performance, to its developments and of the study of the diseases related to it.[14] Indeed, the following are known:[15]

1) Core body temperature is a fundamental parameter in brain neurodegeneration: temperature changes the entropy generation variations;
2) *Bio*chemical (*chnops*chemical) processes show a preferred direction in relation to heat exchange, conditioned by temperature: this preferred direction can be determined by the entropy generation extremum principle;
3) Brain dynamic homeostasis is in accordance with the second law of thermodynamics: the second law is the fundamental of the extrema entropy generation principle for the open and closed systems.

Any neurotransmitter produces variation in dynamic states related to homeostasis and this determine the entropy generation variation in specific brain region: this influences the functions related to the specific brain.[Q6] Consequently, the entropy generation analysis of the brain regions allows the neurologist to obtain information on the behavior of those regions; indeed, from the previous three points, the entropy generation analysis allows to state that:

1) Brain temperature change brain homeostasis and neurotransmission with the consequence of region-specific brain dysfunction;
2) Chemicals determine neurobiological changes.

These two results can explain some experimental facts, as, for example, the schizophrenia relation between the man behavior and the abnormal neurotransmission on brain neural network and the effects of a neurotransmitter on the chemical reaction cascade.[16]

Thomas' approach to brain

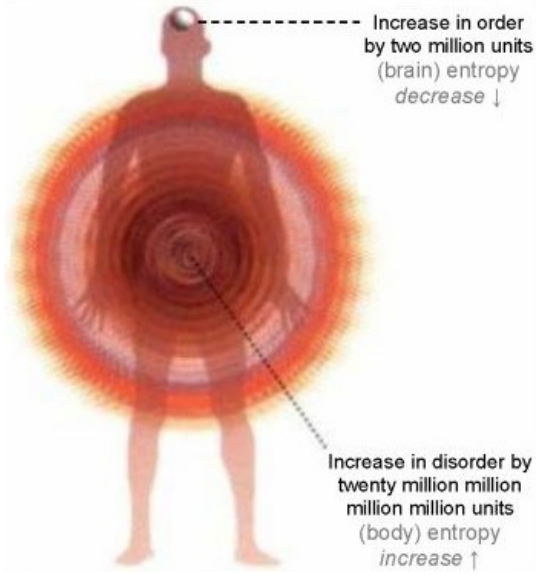
The thermodynamic approach to brain underlines how the brain can be consider a thermodynamic device. From a theological point of view, it is interesting to underline how Italian theologian-philosopher Thomas Aquinas introduced a logical method of investigation of man, even if in the 13th century he could not have the scientific knowledge useful to express his intuition.[Q7] The author believes that the intuition of Thomas can be formalized by irreversible thermodynamics.

Thomas' ideas, as presented in his 1272 *Summa Theologica*, according to the author, represent the philosophical basis of brain engineering thermodynamic.[17] Indeed, while thermodynamics allow us to understand the brain functions, Thomas' philosophy allows us to give a human and ethical approach to the scientific results: Thomas' ethics are based on natural behavior and this is what make them so interesting from a scientific point of view.[Q8] Moreover, he reactively existed (*lived*) before the Protestant reformation and the Catholic counter reformation, so it is an original Christian approach, before any schism. Last, this general approach can be also accepted by any other religion because of its analytical basis and historical fundamentals.[18]

Thomas' *Summa Theologica* introduces the distinction between matter and intellect. Matter has unique and individual actual forms that are not accessible to knowledge, while intellect has sets of forms, abstracted from matter, which do not exist in matter.[18] Intellect can know only the forms of material things. Thomas, in respect to the theory of the soul, states the following:[19]

> "Whether the human soul is something subsistent? It must necessarily be allowed that the principle of intellectual operation which we call the soul is a principle both incorporeal and subsistent. For it is clear that by means of the intellect man can know the natures of all corporeal things. Now whatever knows certain things cannot have any of them in its own nature, because that which is in it naturally would impede the knowledge of anything else."

From this statement, it is possible to argue that Thomas understood that stimuli onto receptors, and into the brain, cannot represent the memory.[Q4] Even if the brain were to collect them, the brain could not know anything. A very important quantity of the energy spent by the brain is used for habituation, in order to attenuate the continuous noise to the senses. Brain learns only what is useful. From a thermodynamic point of view, it increases its entropy generation. Here, to give some comparison, we might recall English astronomer Stephen Hawking's 1996 diagram and commentary the subject of learning and entropy:[20]



"Reading this book will have increased the amount of ordered information [decreased entropy] in your brain. However, during the same time, heat released by your body will have had a much greater effect increasing the disorder [entropy] in the rest of the universe."

—Stephen Hawking (1996), *A Brief History of Time*

Thomas introduced the term *participated being* as the partner of *form*. Today it is called function and its value is related to the *cooperation*, today called network.

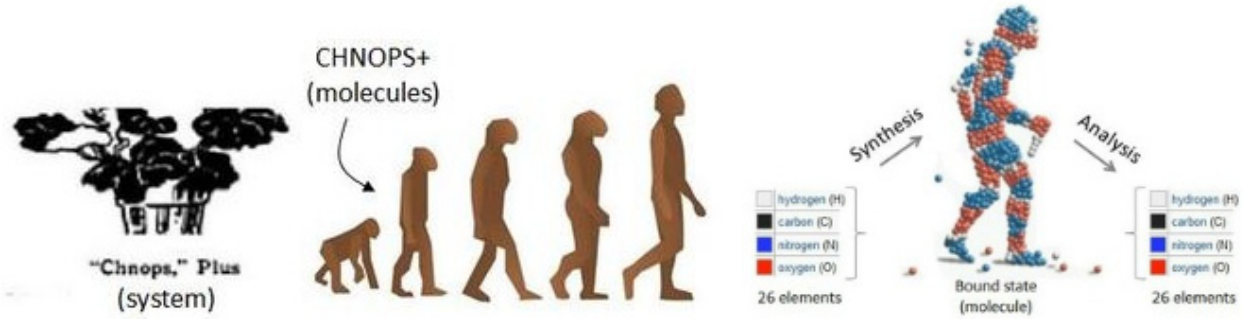
This brief summary of the intuition of Thomas was analyzed in 2008 from a philosophical point of view, as mentioned, by American cellular researcher Walter Freemam.[18] Here we wish to point out that Thomas understood the complex structure of the brain.

Conclusions

The brain is a complex system, open and continuously under energy and exergy exchange. Entropy generation is a thermodynamic quantity proven fundamental in the analysis of complex systems. Consequently, this can be used in the analysis of the brain and of its diseases, too. Thomas thought on the brain underlines as he understood the brain as a complex system and also its behavior in functions. Entropy generation allows to describe these functions. Consequently, Thomas' ideas can represent a philosophical approach to human consequences of the engineering thermodynamic approach. Indeed, thermodynamics allow us to understand brain functions, but it does not give us any philosophical basis.[N2] Thomas' philosophy allows us to give human and ethical approach to the scientific results, starting from the actual knowledge of engineering thermodynamics.

Notes

N1. (a) All *bio*-related terms, synonyms, and antonyms have been editorially redacted, per 2012-initated JHT life terminology upgrade protocols—on the basis that "chemistry does not know the word life" in the famous 1938 words of English physiologist Charles Sherrington—into physical and chemical thermodynamically neutral terminology, such as depicted below:



(b) eoht.info/page/Life+terminology+upgrades

(c) eoht.info/page/defunct+theory+of+life

N2. This is the author's prerogative; German physicist Gustave Hirn's 1868 *Philosophical Implications of Thermodynamics* is one counter example to the author's statement; German polyintellect Johann Goethe's 1808 statement that "the moral symbols of the natural sciences are the elective affinities discovered and employed by the great Bergmann" is another more accurate counter example.

Editorial questions

Q1. What is the author's definition of "entropy"?
Q2. What is the author's definition of "entropy generation"?
Q3. What does the author mean by "theological approach"?
Q4. What is the author's position on the theory of the soul in terms of thermodynamics?
Q5. What is the author's definition of 'exergy'?
Q6. Please provide an example of a specific neurotransmitter variation, e.g. serotonin, dopamine, oxytocin, etc., that can be used determine entropy generation?
Q7. What does the phrase: "From a theological point of view …" mean? From a God point of view? From a Christian point of view? From a soul theory point of view?
Q8. What exactly is "Thomas' philosophy" for those of us who don't know?

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