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Could Long-Term Stability Last Forever?

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Abstract

The subject of the present paper is to prove that the recently introduced conjecture of boundedness puts a ban over the view of stability as asymptotic property. This result comes in sharp contrast with the prescription of the traditional thermodynamics and statistical physics which consider the existence of equilibrium as asymptotic property of all systems. The difference commences from the use of infinitesimal calculus as the basic implement for modelling by the latter while the primary premise of the conjecture of boundedness is sustaining the energy/matter/information permanently bounded and finite. The latter property overrules the infinitesimal calculus as the major implement of modelling because, among all, it is proven that the traditional one suffers unsoluble difficulties.

Keywords

Long-Term Stability, Equilibrium, Infinitesimal Calculus, Boundedness, Decomposition Theorem, Certain Information, Universal Mechanism for Collapse

1. Introduction

The major goal of the present paper is to prove that long term stability of any complex system never is their asymptotic property: that is, it cannot last forever. This assertion is in fundamental contradiction with the central conjecture of the traditional thermodynamics and statistical physics, namely the conjecture that stable equilibrium has it's asymptote so that the corresponding system arrives at it in finite time interval and stays there forever regardless to the initial conditions and irrespectively to the boundary ones, and regardless to the structure, functional properties and environment where the system is put in. However, an unforeseen so far flaw of the traditional conjecture is that, if so, the total amount of energy and matter involved in maintaining the stable asymptote gradually and permanently increases in the course of evolution eventually and inevitably reaching infinite values. The latter consideration holds for any asymptote since the cumulative effect of its maintaining always reaches infinite and ever-increasing values in the time course, despite the fact that it could involve only finite amount of energy/matter/information at each and every step of evolution. A few paragraphs below it are demonstrated that the convergence of corresponding indefinite integrals does not help solving that problem.

Consequently, the above considerations immediately imply that, if it would be possible to maintain each and every system in stable state arbitrary long time, the Nature would turn to be a giant perpetuum mobile such that each and every its constituent also would be a perpetuum mobile.

It is worth noting that the above conundrum provokes a cascade of questions some of which are: if all systems, both natural and tailor-made inevitably turn unstable in due time, are there any early warning signs for their collapse and if so, for which systems are they available? Does a universal mechanism for "dying out" of any system, even the best organized and the most stable one, exist? Is it possible to define the "life-time" of each and every system? Further, is there universally available operational protocol such that to provide answers to the above mentioned questions?

Let us start with the obvious fact that infinite systems are excluded from the present consideration because, being infinite either in size, and/or in energy/matter necessary for functioning as such, it takes infinite amount of energy/matter to sustain a system not only asymptotically but at each and every instant. Thus, the obvious consequence is that only systems of finite size and such that their construction and functioning involve and exchange only bounded amount of energy/matter at each and every step of their evolution are the appropriate candidates for being subject of present consideration. This premise renders the primary importance of taking into account explicitly the size of each and every constituent viewed as boundary conditions, and its permanent interaction with the environment viewed as highly non-trivial interplay with the corresponding initial conditions. It is worth noting that this highly non-trivial interplay suggests that there exists a specific spatio-temporal domain where the corresponding unit evolves in a stable way. The intuitive clue hints that whenever the size of any spatio-temporal domain is bounded, it takes bounded time of a system to cross the boundaries of that domain regardless to the direction and nature of its motion (ballistic or diffusive).

In more familiar terms, the role of boundary is that, though restraining the motion to stay within a domain by means of reflection back from it, the reflected flow of matter/energy interacts with the bulk and thus eventually the boundary turns overcome and certain amount of matter/energy "leaks" beyond. In turn, the latter changes the functional properties of the system within the domain which in turn provokes another "break" in the boundary restraint. Thus, eventually a system approaches moment of functional instability and eventually collapses.

The tacitly presupposed assumption in the above consideration is that the boundaries are supposed not absolutely rigid and forever intact. The crucially important consequence of the withdrawal from intactness of the boundary in the above example is that stability turns out not to be asymptotic property. To prove the latter is the subject of the present paper.

In a nutshell, it will be proven that stability holds only until a system evolves so that to stay within specific margins, called by the author thresholds of stability and never reaches either of them. Indeed, in order to sustain its stability intact, a system should make a smooth "U-turn" back on reaching either threshold. At this point, however, the traditional modelling of the evolution needs major revision because, as proven next, it suffers an up to now unforeseen inherent contradiction. Indeed, the traditional science asserts that the notion of smoothness is adequately modelled by means of infinitesimal calculus. Consequently, the latter defines the notion of smoothness as a lack of restraint over the number of significant digits necessary for characterization of an information unit and/or the distance between nearest points. Yet, the price of that conjecture comes as follows: each smooth exertion of a "U-turn" takes infinite number of steps, accordingly infinite energy/matter and time for its substantiation. The unforeseen so far point is that convergence of the corresponding integral(s) suffer(s) inherent contradiction, namely: the lack of restraint over the number of significant digits means that the smaller the infinitesimal number is the more energy/matter is involved/exchange for its substantiation regardless to whether it is a point and/or distance. Thus, though the integral over the information units converges, at the same time, the integral over the energy/matter involved in providing that convergence diverges. Thus, convergence is mathematical property which, however, is inappropriate for modelling real processes.

In order to overcome the problem, the author has put forward a new approach grounded on the conjecture [1] that the evolution of stable systems involve/exchange only finite and bounded amount of energy/matter at each and every state/step at its execution. In turn, this brings about a restraint over the values of each information unit characterizing a point and/or step; that is, their values are bounded and finite, e.g. number of significant digits is always finite and bounded both from below and from above. It is worth noting that that restraint is a fundamental property which must not be associated with imperfections of resolution and/or insufficiency of our current knowledge about a given process.

It is worth noting that, to the author's knowledge, neither of the traditional or latest approaches put restraints over the values of information means. Thus, all sorts of modeling share the same property of the infinitesimal calculus, that is, the lack of restraint over the information means. In turn, the lack of restraint makes possible the execution of a smooth "U-turn", even though a model is described by, for example, a discrete mapping. To compare, both infinitesimal calculus and all current approaches render execution of a smooth "U-turn" available but optional (*i.e.* it depends on the concrete modelling) while the conjecture of boundedness puts a ban over execution of each and every smooth "U-turn" for a fundamental physical reason.

Now the major difference with the traditional approaches becomes apparent. To compare, the latter prescribes existence of stable equilibrium as asymptotic property because a system is open to make a smooth “U-turn” on reaching either threshold (to remind: a smooth “U-turn” implies tangential approach to a threshold). On the contrary, the conjecture of boundedness [1] renders the approach to any threshold to be always non-tangential and thus the execution of a “U-turn” inevitably to go some beyond either threshold. However, going beyond either threshold, inevitably makes the corresponding system to experience certain damages, either in its structure and/or its functioning. This opens the door to further malfunctioning and on exerting other “U-turn(s)” eventually to collapse.

In a nutshell, the exertion of a “U-turn” turns out to be the demarcation line for our understanding of the future evolution of any system. To remind, the smoothness of a “U-turn” sets the generic property of stability to be its holding forever. On the contrary, the setting of boundedness renders the generic property of the execution of each and every ”U-turn” to be always non-tangential which in turn makes stability rather transient property, that is, it lasts only until the first “U-turn” is completed.

It is worth noting on the analogy between the above consideration and the mentioned in the beginning example about the role of boundary conditions viewed as either absolutely intact (traditional approach) or viewed as having specific margins (thresholds of stability) such that their overcoming is available.

Outlining, the major suggestion of the approach put forward by the author and called by her boundedness [1], is that the long-term stability holds intact only until reaching either of its thresholds for the first time. Now the following questions stand: are “U-turn(s)” inevitable and are there early warning signs for their execution? The corresponding considerations and the answers to these questions are presented in the next section.

Then, in Section 3, the consideration about how the functional organization of a complex system should be organized so that to “prolong” its “life-time”.

A very important and, to certain extent unexpected, outcome is the opportunity to extract confident information even about the evolution of systems, the information about whose behavior is uncertain and/or incomplete. The corresponding considerations are presented in Section 4.

2. Boundedness Conjecture and Universal Protocol for Collapse

The major conjecture of the present paper is that the evolution could develop in a stable way only when a system evolves so that to stay within specific thresholds of stability never reaching either of them. Next the elucidation why the author’s approach sets the role of reaching either threshold so crucial for the collapse of any system, even the best ones in construction and functioning, comes. The core of that approach turns out to be the following conjecture: it asserts that all natural phenomena involve/exchange only bounded and finite amount of energy/

matter in each state and/or step. The major consequence is that this assertion puts a general restraint over the values of the information units used for modelling the corresponding phenomena. Put in other words the major conjecture reads: the phenomena subject to the conjecture of boundedness evolve so that the corresponding rates and amplitudes are constrained within specific for each and every process, system and environment margins, called by the author thresholds of stability. At this point the major novelty comes: due to that restraint, on reaching either threshold, neither system can make a smooth "U-turn" because it approaches the corresponding threshold always in non-tangential way. Thus, the execution of any "U-turn" always goes some beyond either threshold. However, doing that, the corresponding system certainly experiences specific damages either in its structure and/or its functioning. This opens the door to further malfunctioning which on exerting other "U-turn(s)" eventually brings collapse.

Let us now consider how to confirm mathematically the above described setting.

The major breakthrough of the author's idea is to consider the above mentioned setting as general operational protocol not as law. To elucidate the latter difference, let us remind that the notion of a law implies establishing of a stable relation among specific variables characterizing a given process which re-occur the same on repetition. On the contrary, the notion of operational protocol implies existence of a stable pattern which stays intact in an ever-changing environment. Yet, the ever-changing environment is where all natural systems "live" and interact. To compare, controlled environment is available for only few model systems such as ideal gases and/or other tailor-made systems such as computers and other electronic devices whose energetic needs are supplied artificially. Yet, systems like Internet, power and water grids etc. are put in semi-autonomously changing environment just because different users plug to them semi-randomly. That is why the matter about stability of the behavior of a system in an ever-changing environment is of primary importance.

Next it is demonstrated that the successful modelling is rigorously derived from the proved by the author and called by her the decomposition theorem. The latter proves that each system, put in an ever-changing environment and subject to boundedness of rates and amplitudes, exhibits the same type decomposition of the power spectrum of each time series characterizing its behavior. More precisely, it is proven that the power spectrum of each and every time series comprises 3 parts, namely: a specific to a system discrete pattern, universal continuous band of shape $1/f^{\alpha(f)}$ and components which commence from the thresholds. Since the derivation of that decomposition is grounded on the boundedness of rates and amplitudes alone and does not require any knowledge about the nature and origin of a system, neither about its dimension, size and or other specifications, it can serve as the major implement of a universal operational protocol for modelling the behavior of such systems.

Crucial for our considerations is the major outcome of the decomposition theorem which proves that stable and predictable behavior is available only when the specific discrete band and the universal continuous band of shape $1/f^{\alpha(f)}$ are additively superimposed. That additivity ensures that the specific for the system information encapsulated in the discrete band stays intact and thus could serve as the major specific characteristic of the corresponding system which does not change in an ever-changing environment. This happens because the additivity of those bands prevents development of emergent phenomena and thus sustains robustness and stability of the discrete pattern.

However, the things become different with regard to the components in a power spectrum which come from thresholds: emergence of new phenomena is unavoidable and started going on at the execution of the first "U-turn". The inevitability of those phenomena is grounded on the facts that: 1) simultaneous additivity of all three bands is impossible since, if otherwise, the components which come from thresholds would belong either to the discrete or to the continuous band. To elucidate this consideration better let us remind that the lines in a power spectrum are permutation sensitive: any permutation yields a new pattern. 2) the ubiquity of the non-tangential approach to a threshold, (a "U-turn" in the setting of boundedness) is the one which launches the emergence and development of new phenomena, each of which is associated with specific "leak" beyond the corresponding threshold. Remember the "leaking" beyond the physical boundaries at the example given in the Introduction; 3) each line in a power spectrum is characterized by bounded means of information and thus each new phenomenon emerges in a specific bounded time interval set by the concrete path to approach the threshold.

Outlining, the break in additivity commences from the emergence of any new phenomenon and is characterized by the emergence of a new line(s) in the corresponding power spectrum. The importance of the latter emergence is that it turns out impossible to maintain any longer the discrete pattern stable and intact because the new phenomenon starts its development immediately after it's commence due to the interaction with the entire system. The emergence and development of a new phenomenon could be traced by monitoring the development of the new line(s) and the changes it makes to the power spectrum. Since the exclusive property of the execution of a "U-turn" is the persistent non-tangential approach to either threshold, it is certain that it produces specific damages either to the structure and/or functioning. So, the execution of "U-turns" serves as a general protocol for launching destructive phenomena which eventually yields collapse. Further, the collapse is inevitable and happens in a finite time interval since any "U-turn" inevitably happens in a specific, yet finite and bounded spatio-temporal time interval.

Summarizing, each and every system, whose behavior is subject to the boundedness of rates and amplitudes, is subject to unavoidable collapse which occurs even for best organized and functioning ones. However, establishing of the "lifetime" of each system is mathematically decidable with certainty only for the time periods before the first new line emerges. This is so because the break in additivity between a discrete pattern and a continuous band renders the individual properties extremely sensitive to the specific and highly non-trivial interplay between already developed and newly emergent phenomena for each item, system, individual etc., the. The high sensitivity makes the evolution after the first "U-turn" subject to individual circumstances which, to a much extent, appear as unique ones.

Now, a question comes: whether it is ever possible to "prolong" stability by other means? This question is suggested by our daily experience about the role of medicine: for example, most of people take dietary supplements in order to keep their health in a good shape as long as possible. But, the author's interest is focused on the following subject: does a universal protocol governing the interaction of different units, systems etc. exist and could it help to "extend" stability? That issue is the subject of the next section.

3. Protocol of Compatibility and Early Warning Signs for a Change

Let us start with establishing how to model interactions in the setting of boundedness. Up to now, the traditional modelling is grounded on the idea about linear superposition among interactions. It conjectures that the total interaction consists of linearly superposed interactions among clusters of two, three, etc. numbers of units. However, the corresponding approach suffers of so far unavoidable infrared and/or ultraviolet catastrophes, a fact which is in conflict with the energy saving law.

Further, the idea about linear superposition is also in conflict with the idea of boundedness since linear superposition does not put bounds on the partial and/or total energy/matter involved and/or exchanged in any point.

In order to resolve the above conflict, the author has conjectured withdrawal from the principle of linear superposition and instead she replaces it with the primary role of saving boundedness of the involved and/or exchanged matter/energy. The later implies that the interactions are non-linear and non-homogeneous throughout a system and both in space and in time. Since different functional units, modules etc. in a complex system have different thresholds of stability, the interplay between the corresponding units makes some new phenomena emerging from a local "U-turn" to affect other unit(s) without the latter to reach their own thresholds. Thus, an alternative to inevitability of destructivity of a "U-turn" arises and this is adaptation. A few paragraphs below it is consider whether an emergent line implies adaptation or destruction.

At this point the question stands: how different units should be organized so that to provide stability of the discrete pattern as long as possible? The answer is given by the put forward by the author conjecture about a bi-directional hierarchy of interactions [1]. Its major idea asserts that the response of a system could be strengthened and its "life-time" prolonged when the response is diversified so that its functioning to be a subject to the called by the author protocol of compatibility [2]. Diversification is substantiated by means of letting only specific units to response to a given stimuli; for example, our vision responses to visible light, but not to temperature etc. The exclusive property of the bi-directional hierarchy is that the diversification of the response goes via the organization of the functional units in functional hierarchical layers so that the boundedness is self-maintained on each and every level. The latter is substantiated by means of the following: the outcome of each level serves as environment for the others. The bi-directionality comes from the fact that the "environment" for each given level comes both from lower and from the higher levels and thus generally it goes simultaneously both bottom up and top down.

Now the general operational protocol, called by the author "protocol of compatibility", comes into consideration. Its major value is that it provides general rules for establishing bi-directional hierarchy.

The general protocol of compatibility comprises two interconnected rules which come as follows: the first one asserts that in order to postpone emergence of a new phenomenon as long as possible, the lower and higher level discrete patterns must appear as closer as possible to be in overtone positions to a given discrete pattern.

An obvious consequence of that rule is that, because the functioning of all units is interconnected, the emergence of a new phenomenon of any single unit affects all others. This is characterized by emergence of specific new lines in the power spectra of each unit. Yet, now different functional units and hierarchical levels are subject to highly a non-trivial interplay among mutual interactions, remember the major conjecture about non-linearity and non-homogeneity of interactions so that to save energy/matter bounded, which makes some of those interactions to turn from originally destructive to adaptive ones.

However, as proven in [3], it is mathematically undecidable whether the newly emergent line(s) means adaptation and thus eventually prolonging stabilization, or it triggers malfunctioning of the entire system which eventually brings almost immediate collapse. At this point, the role of other knowledge comes of decisive importance: Thus, with the primary knowledge that the collapse of a system and/or unit is generally unavoidable, could and when other appropriate knowledge helps the stabilization of the entire system and in this way to "prolong" its "life-time"? Obviously, the answer to this question is subject to each concrete case. For example, the EEG and EKG time series of an ill person exhibit specific deviations from an established standard but it is the medical knowledge which prescribes the appropriate for a given case medicines.

The second part of the protocol of compatibility is provided by the following rule: the processes at each hierarchical level should be organized so that all of them to share the same "strip" of energy/matter involved/exchanged. Thus the functioning of specific units (self)-organizes in a stable system (hierarchical level). The major value of the second part of the protocol of compatibility is that it puts under control any increase of a quantal error regardless to its origin and location by means of not allowing it's growth over the thresholds as long as possible. Consequently, the "interactions" among hierarchical levels stay under control as long as possible.

Put in a nutshell, along with the straightening of the response by means of its diversification, the two rules of the protocol of compatibility provide that other levels emergent phenomena appear as small disturbances to a given level ones for a longer time. However, it is crucially important to stress that, though being prolonged and the response strengthened, the total life-time of a system turns again to be finite and bounded.

An exclusive property of the protocol of compatibility, viewed as a protocol of stable (self)-organization, and the boundedness, viewed as universal protocol for stable functioning, is their self-consistency. It is worth noting the major exclusive property of that self-consistency: that is the property that the decomposition theorem holds for each and every so organized system and /or hierarchical level. The major consequence of that holding comes as follows: since the author considers only systems of bounded finite size, the hierarchy of functional levels has its lowest and its highest one, a fact which makes the collapse unavoidable.

Further, the emergence of a new line(s) in a power spectrum appears as a generic type of early warning sign(s) for a change. However, it is mathematically undecidable whether the emergence of a new line in any power spectrum is an early warning sign for adaptation or for fast collapse even for systems subject to the protocol of compatibility.

The "life-time" of any system could be prolonged and the response enhanced by means of highly specific for each system and environment interplay between the general means of "the protocol of compatibility" and other appropriate for each and every given system knowledge.

And last but not least, the "protocol of compatibility" serves as a criterion for demarcation between stable systems and "bunches" of units. Indeed, only systems subject to that protocol stay stable and predictable in a definite period of time that is, until reaching a threshold for the first time. On the contrary, for a "bunch of units", that is systems which are not subject to that protocol, it does not exists a definite period of time when any of them evolves in a stable and predictable way.

4. How to Get Certain Information from Uncertain Data

Let us start with establishing what certain information is.

The novelty of the author's approach lies in the suggestion that stable functioning of a system is modelled by means of "locking" the values for matter/energy/information involved and/or exchanged in every instant and throughout the system within specific margins called by the author thresholds of stability. This restraint commences from the basic assumption of the theory of boundedness, that is: the hypothesis about primary role of keeping boundedness of energy/matter involved/exchanged in each step. As it is demonstrated in the previous sections one of the far going consequences is the one which asserts that stability is rather transient phenomenon than asymptotic one.

An immediate consequence of that reminding is that the evolution of each process and each system put in an ever-changing environment is modelled by means of monitoring its behavior for a given period of time. The exclusive property of the boundedness conjecture is that the values of the members of the corresponding time series belong to the same specific bounded both from above and from below "strip" of discrete values. Thus, when a system is put in an ever-changing environment, the time series in study comprises some, probably most of all available values from the corresponding "strip". It is important to stress that the obtained sequence is not random because each its member is defined by the current environment and the previous member(s). Yet, an exclusive property of those sequences is that all members in each one appear of equal significance in their contribution. So, a question comes: which member is the true and the certain one? An intuitive answer is that this could be only that information, which stays intact in an ever-changing environment.

An immediate interpretation of the above consideration comes as follows: Does the decomposition theorem holds for the case when factors such poor resolution, human reluctance to say true to some questionnaires etc. persists? The answer is positive and comes as follows: the proof of the decomposition theorem does not involve any knowledge about the nature and the concrete values of the members in the time series under study. The only necessary knowledge is that about their permanent boundedness. Thus, it holds also for time series whose members comprise uncertain/incomplete and even false information let alone they stay bounded within the original thresholds.

Thus, as long as the decomposition theorem holds, there is knowledge obtainable with certainty and that is the information encapsulated in the corresponding discrete pattern. More precisely, each discrete pattern carries the information about stable spatio-temporal landscape of causal relations [3] which characterize a given system.

It is worth noting once again that the information encapsulated in a discrete pattern is certain, although the members of the corresponding time series could comprise uncertain/incomplete (even false) information. The only necessary condition for obtaining certain information is that the uncertainty of information in each and every member of a time series not to exceed the original thresholds.

Thus, an immediate consequence of the above generalization of the decomposition theorem is: again the appearance of a new line in the power spectra suggests that some threshold is reached. And again it is mathematically undecidable whether the new line(s) is early warning sign for adaptation or for collapse. And again, the role of other knowledge turns out to be of primary importance.

5. Conclusions

The major outcome of the considerations presented in the present paper commences from the withdrawal from the infinitesimal calculus as the basic implement for modelling the dynamics and the evolution of complex systems. The infinitesimal calculus suffers inherent contradiction which comes as follows: the smaller the infinitesimally numbers are, the larger the amount of energy/matter involved in their substantiation is. On the contrary, the conjecture of boundedness puts specific restraint over the amount of energy/matter involved in substantiation of any state and/or step in evolution of each and every system. Hence, the information characterizing the functioning of a stable system turns out to be restrained into a specific "strip" of values.

The new conjecture comes at price: it is that stability turns rather transient phenomenon since the stability is well-defined only until the first "U-turn" is executed. The decisive role of reaching thresholds is that the withdrawal of infinitesimal calculus renders any approach to either of the thresholds non-tangential; hence, the exertion of a "U-turn" goes some beyond the corresponding threshold thus causing specific damages to a system. Then, the stability of a system has a well-defined life-time which is the time before the first "U-turn" happens. To compare, the infinitesimal calculus makes "U-turns" smooth which in turn provides the stability to last arbitrary long time.

Yet, it is worth noting on an exclusive advantage of the conjecture of boundedness which comes as follows: a design which puts under restraint the available values characterizing the corresponding processes into operational "strips" each of which stands for a given hierarchical level, renders the maximum possible stability towards any accidental growth of any quantal error wherever and whenever it occurs. To compare, any lack of restraint over the current values makes the corresponding "software" vulnerable to accidental growth of a quantal error which inevitably is accompanied with the corresponding "hardware" malfunctioning such as overheating, sintering etc.

Summarizing, the major conclusion drawn from the present paper is that the stability never could be asymptotic property that is, it cannot last forever. Yet, with the primary knowledge about the inevitability of collapse in mind, along with other knowledge specific to a given system, the lifetime of a system could be prolonged and/or strengthened. Further, the knowledge about the principle of compatibility and the mathematically non-decidability of early warning signs viewed as parts of a universal protocol for functional organization, along with appropriate specific knowledge, could serve as guiding lines for our understanding of natural systems and for a successful tailoring of artificial ones.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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