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An evolutionary view on function-based stability †

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† Presented at IS4SI 2017

Published: 8 June 2017

Keywords: Evolutionary view, stability, functional structural dispositions, functional relations, constraints, The 2nd Law of Thermodynamics, The Principle of Stationary Action, Evolution, Selection, Information processing

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How can things become stable? This is a difficult question to answer, but we should nevertheless try, because of the answer´s importance for life, for us.

Admittedly the question sounds too broad to try to find an answer, but largely this is because we tried to find a universal answer, a universal answer instead of an evolutionary one. The large advantage of the evolutionary view is that reductionism is "only" needed to find the possible base for a phenomenon which is analyzed and which could as well be a relatively modern phenomenon, and afterwards from this base ideas can be developed further; relatively modern refers to modern estimated from the duration the phenomenon influences developmental and evolutionary processes compared to the total duration of the evolutionary process on Earth. A possible base to describe phenomena is to analyze

motion (processes),

acceleration of motion (including positive as well as negative acceleration) and

(changing) *distribution functions*

which seem to be essentially involved in the phenomenon´s appearance. This still sounds challenging, but science has a long and successful tradition of describing and investigating motion and matter, namely: physics. Momentum changes and static as well as dynamic distribution functions are its topic. By the way: physics in the last decades started to find descriptions for non-linear and non-conservative processes of motion and stabilities emerging out of deterministic "chaos", too. But this was just to mention future potential for understanding, since in the following we will focus on maintenance of stability in systems which already gained it.

When a physical base for phenomena which involve motion, changes of motion and distribution functions, has been found, automatically the question of stability is important. Physical models allow comparing parameters in the form of initial conditions regarding their capacity to model an *observable* phenomenon. A phenomenon like that can be observed as a material object respectively a material structure characterizing an object or as a type of motion the character of which can be captured with a mathematical formula. In both cases stability is essential, otherwise observability was not warranted.

Developing this approach further, an evolutionary view means that to understand stability and stabilizing effects we have to focus on processes which enable and maintain motion structures and configurations, which allow them to gain stability. Starting from this, we have to rely on a more general interpretation of selection. It is proposed construing the one-line evolution definition of Darwin, namely "descent with modification" [1] together with Mayr´s "(...) differential perpetuation of genotypes"[2] - definition for selective processes:

An evolutionary view on systems focuses on the *differential perpetuation of stable states and stability of states.*

The more per se stable elements an object comprises, the more probable it becomes that an object´s associated elements gain a function for the object, especially regarding its long-term stability. What about stability in general? The most direct contribution to stability of objects in physical environments is to not obey the 2nd Law of (Statistical) Thermodynamics' drive to expand distribution over all calculable degrees of freedom and energy levels which are available in the surroundings of the object. Instead, a stable object obeys the 2nd Law of (Classical) Thermodynamics, and elements belonging to the object only perform non-virtual work, if mutual differences between them or differences between them and particulate objects surrounding the object can be evened out transforming part of their energy into heat, exchanging heat. How is local disobedience to (distribution-) entropy maximization, in the form of stationarity of a distribution function inside a surrounding different distribution function possible? When can the dissolution of objects, the immediate dissipation of all of a structure´s configurational energy into kinetic energy and heat be energetically unfavorable? The basis for understanding this has been laid 1776 beginning with Maupertuis´ discovery of a mechanism of action [3]. Literally. The work of several others, prominently of Lagrange, Hamilton and Feynman [4,5,6] developed the Principle of Stationary Action into a form which puts it into the position to give an answer to both of the above questions. It is a basic principle, too.

It is true that the 2nd Law of Thermodynamics is underlying the expansive tendency of evolving systems to flatten distribution functions, reaching out for available energy levels. Whenever the existing physical distinctness between an object's elements can be reduced through absorption of locally available energy to evade or rid constraints, the drive for increase of entropy will make it happen. But whenever expansion is favored, *motion is needed to realize it*. Energy is needed to change velocities. When motion becomes constrained, certain non-equilibrium distribution functions can be stabilized. The Principle of Stationary Action (subsequently called PSA) underlies the constraining of motion on a path to certain paths which make action stationary.

We introduce a pictorial example to show the interplay between structurally stable positions of rest and a stabilizing principle for the motion in between them: An aggregation of non-interacting but touching balls lies on the ground. The 2nd Law predicts that there exist many more possibilities to distribute the balls, e.g. when external forces happen to transfer energy to temporarily change their velocity, than possibilities to bring the balls back to a state of touching each other. Therefore the balls will tend to become moved away from each other over time, if there is nothing to reverse their directions of motion or to stop their motion. Now we zoom out of the aggregation and view the surroundings. We see that the balls are lying at the edge of a half pipe with a steep wall surrounding them from the side opposite to the edge. They are at an extremal position, but nevertheless stationary through the structure. When kinetic energy becomes transmitted to them (e.g. via a blast), the balls immediately move according to the direction of the pulse. Eventually this blast is strong enough to bring all of them over the edge, even if some of them initially got moved in the opposite direction and were reflected at the steep wall before that happened. After surpassing the edge, their potential energy (which was stored as long as their position was stabilized by lying on a plane area and missing motional energy) transforms into kinetic energy enabling them to travel on a path to reach a state of minimum *stored energy transformable into motion* again. They arrive at the next point in the half pipe where the curvature is zero. But as you know, since the area of zero curvature inside a half pipe structure is limited, the probability that the balls will be in an aggregation touching each other again is proportional to the available area compared to their size and is rather high.

In this example, the possibilities to distribute the balls into a state where they are not touching each other, can easily be less than the possibilities of a "touching state" and the non-touching states will also very likely be states of limited duration (e.g. during single balls being on their way to reach the minimum energy). The conditions seem to be turned upside down. Nevertheless the 2nd Law is strongly valid and affecting the balls. To confirm this, just imagine throwing a firecracker into the setting. This amount of energy would most certainly suffice to immediately accelerate the balls into distribution (and possibly would even suffice to accelerate the elements of some of them into dissolution of the ball structure).

The example was chosen to show two important aspects for the physical basis of function-based stability in evolution: First, *the 2nd Law of Thermodynamics always holds, whenever a constraint to reaching a flatter energy level distribution* (including the introduction of external energy into a system of lower energy, e.g. due to an increase in temperature of its surroundings) *is removed, entropy will increase. Motion can become constrained following the Principle of Least Action, if energy to overcome constraining is* (locally and/or temporally) *not available.*

Second, it was chosen to make the PSA as an important aspect for evolving stable systems together with the 2nd Law, more easily comprehensible. Modeling of the PSA is based on the calculus of variations and therefore not easy to grasp immediately. In the example, starting and final position of the motion were chosen to be at the same time the resting positions of the motion and relatively stable extrema. This is not necessary to apply the action principle, but it shows how structures influence stable motion -due to the PSA- when different positions inside a (in the example: gravitational) potential field make motion start with enhanced potential energy, E_{pot} compared to kinetic energy, E_{kin}. The elements necessary to apply the PSA contained in the given example:

- *The starting point A and the endpoint B*. The action is calculated on the path connecting A and B.
- *The paths connecting a starting point A with endpoint B* along which potential- and kinetic energy transformation takes place; the *Lagrangian function* $\mathscr{L}$ **(x,** v**,** ***t*)**, which depends on coordinates (**x**), velocities (**v**) and time (**t**). It gives the observably taken (classical) path, if the action [kgm²/s i.e. energy times time or alternatively momentum times distance[1]] is kept stationary. It determines the path as a mathematical functional. In the example, the path integral over $E_{kin} - E_{pot}$ makes the action stationary on its path, leading to Newton´s laws of motion for energy transformation *during time* of travel from A to B: One of the balls starts to move with enlarged E_{pot} and so from A to B it has to increase velocity from the beginning of its motion on, until E_{pot} has diminished to a point that E_{kin} can reduce again, to keep action stationary. Because the potential energy is high from the start, the ball increases kinetic energy when traveling downwards and when potential energy is lowest, kinetic energy reached its maximum. With high kinetic energy, the ball can´t come to rest in accordance with the PSA, so it is driven (constrained in freedom) to reduce E_{kin}, continuing travel again, leading to another increase of E_{pot} given by the half-pipe structure. The next oscillation between a starting point A´ and B starts (E_{pot} and E_{kin} diminished by friction reducing the speed). This goes on, until the kinetic energy is low enough to not suffice to drive the ball out of its stable minimum E_{pot} position again. The Lagrangian takes the simplest form which is consistent with the symmetries. (In the example, translation invariance is disturbed by the structure determining differences in E_{pot} along positions on the path).

When an object reached a stable resting position and does not have enough kinetic energy to move as a whole, only its interior elements or random external events can influence the perpetuation of its existence. When an object is instead in motion, the 2nd Law drives it to distribute inside available space and the *PSA constrains sudden changes* in velocity which would happen at the expense of being

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[1] Actually this is only one of two versions of the PSA. The corresponding (MAUPERTUIS) action principle focuses on the spatial aspect of motion along a given trajectory between two points by searching for the path which connects A to B as well, but for a given fixed energy. This enables a comparison of changes in momentum inside conservative systems to find the path with least traveling time

exposed to potential energy acting on the object with increasing strength. As such, the PSA also has a "path-distinguishing function (…) stationary on realizable paths" [7]. This is nicely shown by Feynman for particles whose motion can be described using a wave function to model their probability amplitude in QED [8]. Feynman already hints at the fact that the PSA also lies behind Fermat's famous principle that light selects the path of least time and that interference is an important concept behind path selection. To explain the dynamics behind it would lead too far away from the presentation´s focus, but reading QED and [9] is strongly recommended to deepen understanding of the far reaching influence of the PSA. For understanding the calculus, reading [10] is recommended.

The stationarity of distribution functions given the PSA is not a function of elements inside an object per se, since the PSA is a Natural Law like the 2nd Law of Thermodynamics in evolutionary processes. Nevertheless one can easily imagine that there exist combinations of configurational or structural energy and motion types which support the further stabilization as well as there exist relations which weaken the influence of the PSA on stabilization. Some relations lead to an increased probability that they will be maintained, others lead to a decreased probability that they will be maintained, the latter ones often because they enabled the dissolution of the object expressing them. For relations of the former type, it is proposed to speak of *functional relations* or *functional structural dispositions* inside objects which maintain a separation between distribution functions of their elements and distribution functions of elements *outside* for a longer duration. Objects which comprise such functional structural dispositions (or short: functions) which allow them to be maintained inside their surrounding environment will be called *systems* in a publication which will further develop the ideas which have merely been touched here in a theory of *information processing systems evolving*.

An evolutionary view on *information processing* would allow viewing the emergence, the conservation and the further development and last but not least: the communication of functional relations. Functional relations as they develop out of interrelations between physical processes influencing motion obeying the 2nd Law and the PSA. Functional relations as they transform the possible size and complexity of systems as well as functional relations which increasingly gain influence on the structure and stabilizing properties of their own environments. Functional relations that enable the storage and processing of the information on the constraints necessary to built a self-stabilizing unit with the capacity to reproduce the complex relationships which underlie its own existence… Differential perpetuation means selection in a more abstract way. Together with functionality, selectivity and selective regimes evolve. Systems increasing in their complexity evolve information processing. Thereby a functionality of constraining information propagation inside them might develop. When cohesion of a system is strong, information should be able to propagate through the entire system [11] uninfluenced by structural information of its elements. Since in systems where different sensitivities allow an adaptation to various different, potentially destabilizing inputs from the environment, cohesion is partially lost to differentiation of functions, there develops a need for functions organizing cohesion as well as for functions constraining the propagation of information. So in the end, in evolving systems, even the capacity to increase entropy inside the system can become functional and therefore be worth of being stored as internal information which can be activated to express it as a characteristic property when needed. There is no contradiction given an evolutionary view, because thus the succession of developments can be viewed in a larger context and the drive to entropy maximization as well as the drive to keep action stationary are both behind it, universally valid, but evolving their own context.

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