Gilbert Simondon’s Genetic “Mecanology” and the understanding of laws of technical evolution

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Abstract
Since the 1930’s, several attempts have been made to develop a general theory of technical systems or objects and their evolution: in France, Jacques Lafitte, André Leroi-Gourhan, Bertrand Gille, Yves Deforge, and Gilbert Simondon are the main representatives of this trend. In this paper, we focus on the work of Simondon: his analysis of technical progress is based on the hypothesis that technology has its own laws and that customer demand has no paramount influence upon the evolution of technical systems. We first describe the process Simondon called “concretization” and compare it with the process of “idealization” as defined by Genrich Altshuller. We then explain how the progress of technical lineages can be characterized as following a specific rhythm of relaxation and how it thus obeys a “law” of evolution in the industrial context. Simondon’s theoretical approach, although similar to some aspects of methodologies of conception, emphasized a more accurate understanding of technical progress over possible operational applications. Simondon never intended to optimize the engineer’s tasks from an economic point of view and, in fact, his conception of technical progress can be considered as independent from the capitalistic trend of innovation. However, the philosophy of Simondon provides a better understanding of what is at stake theoretically in the modeling of laws of technical evolution.

Keywords: Invention, Laws of Technical Evolution, Log-periodic models, Mecanology, Relaxation, Simondon**.**

1. Introduction

Fifty years after its initial publication (1958), *Du mode d’existence des objets techniques* (1) is still a profound work of philosophy of technique and a source of inspiration for many engineers and researchers. Gilbert Simondon (1924-1989) elaborated his analysis alone, but it was rooted in an older French tradition of research. In 1932, Jacques Lafitte had proposed, in his book *Réflexions sur la science des machines* (2), to establish the theoretical foundation of 'la mécanologie' as an autonomous science. Among many others, the anthropologist André Leroi-Gourhan, the historian Bertrand Gille, and the technologist Yves Deforge have since tried to develop a general theory of technical systems and their evolution. Simondon’s main references were the work of Leroi-Gourhan on the evolution of prehistoric tools, the theorization of technical lineages by Lafitte, the analogies between technological, biological and political systems elaborated in Norbert Wiener’s cybernetic, and, on the philosophical side, the ontogenetic philosophy of Henri Bergson, Maurice Merleau-Ponty’s phenomenology, and Gaston Bachelard’s historical epistemology.

One may also compare his work with Genrich Altshuller’s contemporaneous theory (TRIZ). Altshuller’s theory of innovation and Simondon’s genetic approach are certainly the two theoretical contributions that are closest to engineers’ methodologies of conception**.** But, while TRIZ was developed with the explicit purpose of improving soviet engineering practices and industrial organization, Simondon's work eschewed such pragmatic intentions and intended rather to elaborate an ethical perspective on technological issues in order to reveal the cultural value of technical objects.

However, both Altshuller and Simondon presented the hypothesis that technical evolution obeys first and foremost the necessity of solving internal problems and that the user or the consumer's demand have no paramount influence upon this evolution. These similarities highlight the fact that, despite its foundation in philosophy, mecanology can converge with an applied methodology like TRIZ. Based on the hypothesis of an autonomous evolution of technical systems, genetic mecanology is still almost unknown to non-French scholars (3). Therefore it is useful to explain this original contribution to the understanding of technical systems.

With this goal in mind, we will first examine the process that Simondon called "concretization". The progress of technical lineages or the process of concretization is very similar to certain aspects of Davis Baird's analysis (4), especially in regard to the dynamism of "adaptation" and "emulation". According to Simondon, a "concrete" object is not simply a material one (as opposed to an abstract object such as a diagram). It is the final stage of a process of technical evolution, the state of a perfectly consistent functioning object. The concrete object is thus a real individual. Simondon knew that one can use another word for "concretiveness" (5)**,** so we can assume, for example, that Simondon's concretiveness in many respects stands for what is "ideality" in TRIZ (6).

Simondon thought that technical evolution shows phases of continuous progress (adaptation) alternating with other phases of saturation during which major improvement must emerge as a global reconfiguration of the structure (invention). These thresholds and ruptures of gradual evolution confer a typical rhythm to the historical evolution of technical lineages.

It is well known that the adaptation of a technical object can usually be described as a sigmoid process, although such a description is not so often justified by quantitative data (7). Nevertheless, we may ask whether there is a quantifiable law that can describe a sequence of successive sigmoid processes. It would mean that the rhythm of inventions inside a technical lineage can be predicted by a "law", just as some researchers currently propose to do with a log-periodic equation. But the mathematical modeling of this "law" remains somewhat ambiguous because many different concretization processes occur at different levels: according to Altshuller, the unequal development of the components determines the saturation of the adaptation of the technical system; Simondon also observes this operation with different objects in a much wider technological system; technological systems themselves change because of new scientific paradigms.

This type of law is also ambiguous because the rhythm of invention is not the same thing, according to Simondon's view, as the actual economic trends of technological innovation: criteria of technical progress don't necessarily match the optimization constraints that affect engineers. Simondon's mecanology is above all a philosophical analysis and as such it is normative and irreducible to operational methods of conception, like TRIZ. Still, although they have different purposes, engineers' methods and genetic mecanology show deep similarities in their description of technical evolution and its hypothetical laws. We thus claim that a clear presentation of Simondon's work may provide a better understanding of the modeling of the evolution of technical systems in general, as well as provide interesting insights for engineers, even if they don't share the same purpose.

2. The progress of technical lineages: the analogy between processes of concretization and idealization.

Like Laffite before him (2), Simondon proposed the concept of *technical lineages* to understand the historical evolution of technical objects. A genuine mecanology contrasts with other studies of technique: the unity of a technical lineage must not be determined by the function and utilization of technical objects because such a criterion would regroup objects with very different structures and functioning. The unity of a lineage defined by utilization is not to be found in the nature of the technical objects themselves but in the functioning and perceptions of the consumers and users. For example, a steam engine, an electric engine, a gas engine, and a spring engine are not a single family and hence don’t belong to the same lineage: the spring engine is more like a cousin of the crossbow, unlike the other engines. Paul Dumouchel has well expressed the core of this genealogical method: “Technical objects have a reality which is independent of the user’s stance and which can be observed by studying their history and evolution” (3: 8). To establish a relationship between objects according to their internal functioning as opposed to their utilization is one of the main principles of genetic mecanology.

To talk about concretization outside of a technical lineage has no meaning. Of course, technical lineages are usually complex. Technical rationality can arise at the same time in many areas without connection and with local specificities. Simondon observed that the evolution of technical systems proceeds alternatively with ramifications and selections of the range of a lineage: technical evolution is sometimes proliferating and sometimes restrained. Hence it is subject to path dependence and may appear retrospectively linear.

Furthermore, the genetic method implies that one can identify the “origin” of each lineage. Simondon calls this first stage of evolution an “abstract object”, because, initially, the technical object is composed of independently functioning components: “In the old engine, each element gets involved at a precise stage of the cycle, then it is supposed to remain still and not interfere with the other elements; the pieces of the engine are like people who would work each at their turn but who would not know each other” (1: 21). Genetic mecanology also assumes that the evolution of technical systems is not meaningless, nor random; the transformations of the structures and functioning of the objects inside a lineage are determined by specific dynamics of self adaptation, self regulation and convergence of functions. Moreover, these transformations are recurrent: the technical object becomes a system of more and more synergic functions.

Just as Leroi-Gourhan showed in his study of prehistoric tools (8), Simondon’s genetic analysis of vacuum tubes and engines are validated by the fact that the immanent order of concretization is the same as that of the historically observed order. From the abstract object to the concrete object, the process is very similar to the growing of ideality. It is gratifying that these descriptions converge, though Altshuller and Simondon chose almost contradictory words: concrete and ideal.

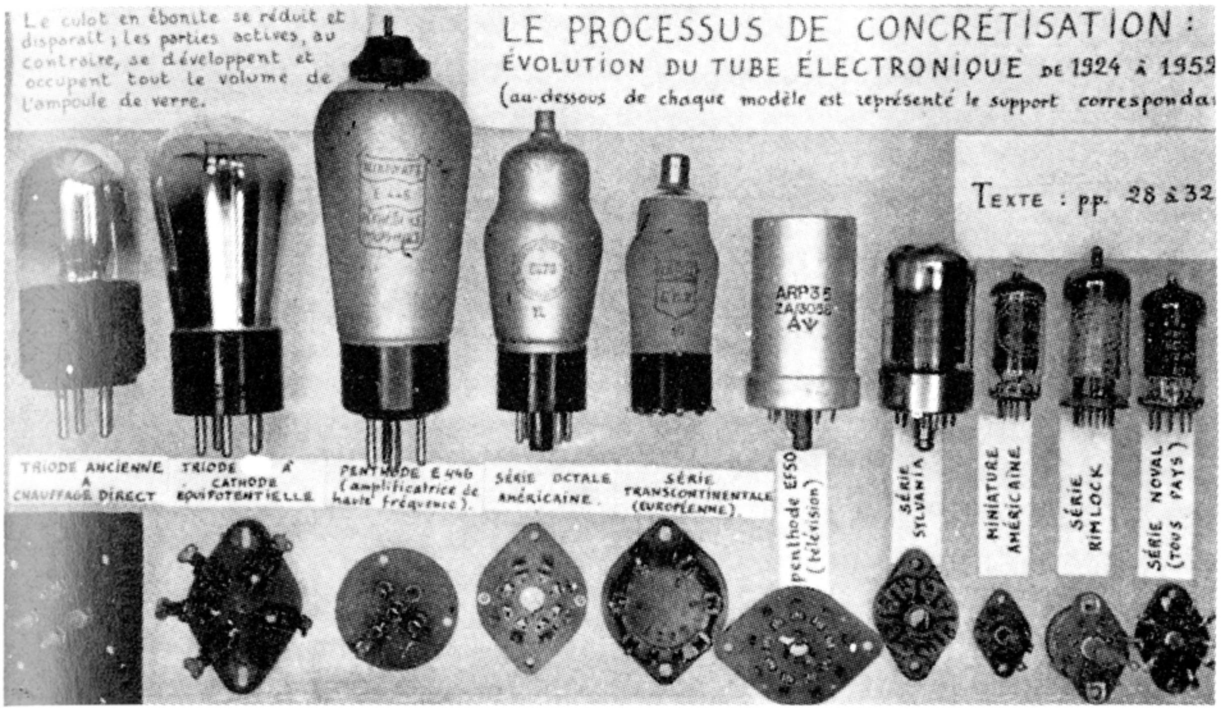

Figure 1: Printing plate 4 in MEOT (1). The concretization process: evolution of the electronic tube from 1924 to 1952. The ebonite base became smaller and smaller until it eventually vanished; the functional parts grew larger and larger and, at the end, fill the total volume of the glass light bulb. Functional convergences also imply the differentiation of functions. Specialization is accomplished synergy by synergy.

Another similarity is suggested by the fact that the abstract stage is, according to Simondon, an object where any energy exchange between the elements (which is not intended by the functioning) is considered as a defect: this is analogous to the TRIZ law of energy conductivity. From the abstract origin to the final concrete phase, the concretization process shows two types of progress: there is some minor progression, by gradual enhancement and adaptation of each technical element, function by function; and then come major improvements, inventions or reconfigurations of the structure, that do not represent compromise, but rather resolutions of incompatibilities between subsystems, so that they are integrated into the functioning of the entire system. Altshuller and Simondon also agree on the evaluation of the process of invention: real improvements in technical evolution do not result from a compromise between the contradictory effects or constraints caused by the functioning of subsystems but come from the outgoing of incompatibilities (or "contradictions" in the dialectical vocabulary of TRIZ). Major improvements must occur through a recombination of the subsystems in a way that they collaborate instead of opposing each other. Simondon uses the word "convergence" for this typical effect of major reinvention of an object in a lineage: "The technical problem is more that of a convergence of functions in a structural unity than of the search for a compromise between conflicting demands" (1:22). The evolution of a technical lineage leads to a totally unified technical individual.

Finally, TRIZ and genetic mecanology formulate the same hypothesis to account for the evolution of technical lineages: this is no blind or random process, nor is it subject to the caprice of external factors. Technical systems have, from the beginning, intrinsic potentialities of evolution and they can evolve only towards a limited number of final types: “If technical objects evolve towards a limited number of specific types, that is in virtue of an internal necessity and not on the strength of economical influences nor practical demands” (1: 24). Again we can quote Dumouchel who subtly notes: “Like spontaneous orders in economy, concretization is the result of human actions but not necessarily of human design or fantasy” (3: 12).

3. The criteria for the evaluation of technical progress (concretization).

The first manifestation of the concretiveness of an object is its individuality: a tool is a good tool if it is solid, a wheel or a simple machine must have a structural unity, and a more complex system is well constructed if its functioning is coherent. A machine can exist only if it is reliable, if its functioning is sustainable, that means first of all if it does not self-destruct: good functioning, coherence and stability are required in order to create a machine that will last. For example, the first diesel engine could not last because its conception could not prevent it from bursting: oil and air were mixing before the compression. The second diesel engine, on the other hand, was sustainable because the mixing occurs after the compression. A thin spraying of gas-oil sparks the ignition, because the air is simultaneously very hot. The different operations are thus well coordinated in order to ensure coherent functioning, in a synergistic way, while its “ancestor” was self-destructing.

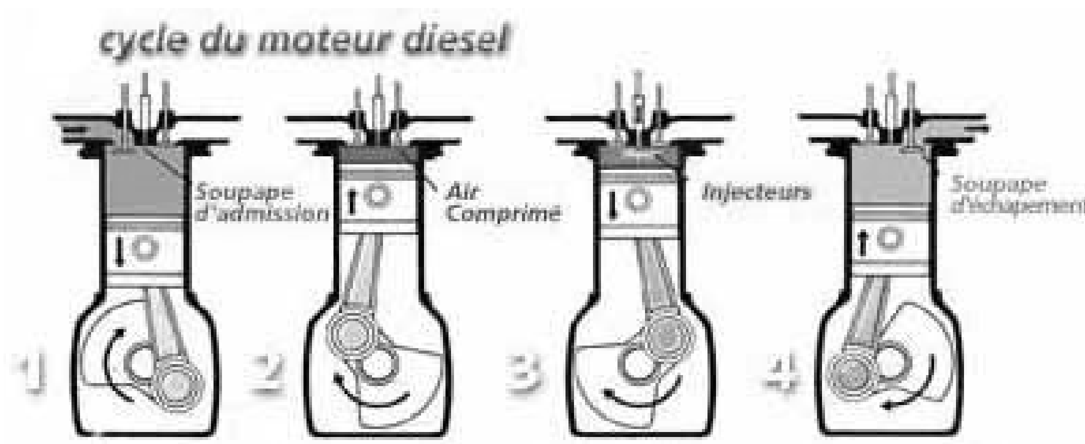

Figure 2: Cyclic functioning of diesel engine.

'Concretiveness' means therefore a perfect harmony in the technical object: the more constructive interferences there are between multifunctional elements, the more concrete the object is. Simondon’s favorite example is the fins of the cylinder in an air-cooled engine. The fins are obviously supposed to expand the surface of thermal exchange in order to evacuate more heat into the air, but they can also improve the solidity of the cylinder. This is clearly an example of synergic convergence of functions. The development of these convergences in a technical system is the most apparent outcome of concretization. When one structure of a technical object is replaced by another, there is progress only if the subsystems are more synergic. Moreover, concretization implies that the environment external to the functioning is more and more integrated into the global functioning: what is first outside the object, as background or“associated milieu”, becomes an internal environment inside the object. A concrete object often autonomously regulates its functioning. Simondon was very impressed by the turbine invented by the French engineer Jean Guimbal.

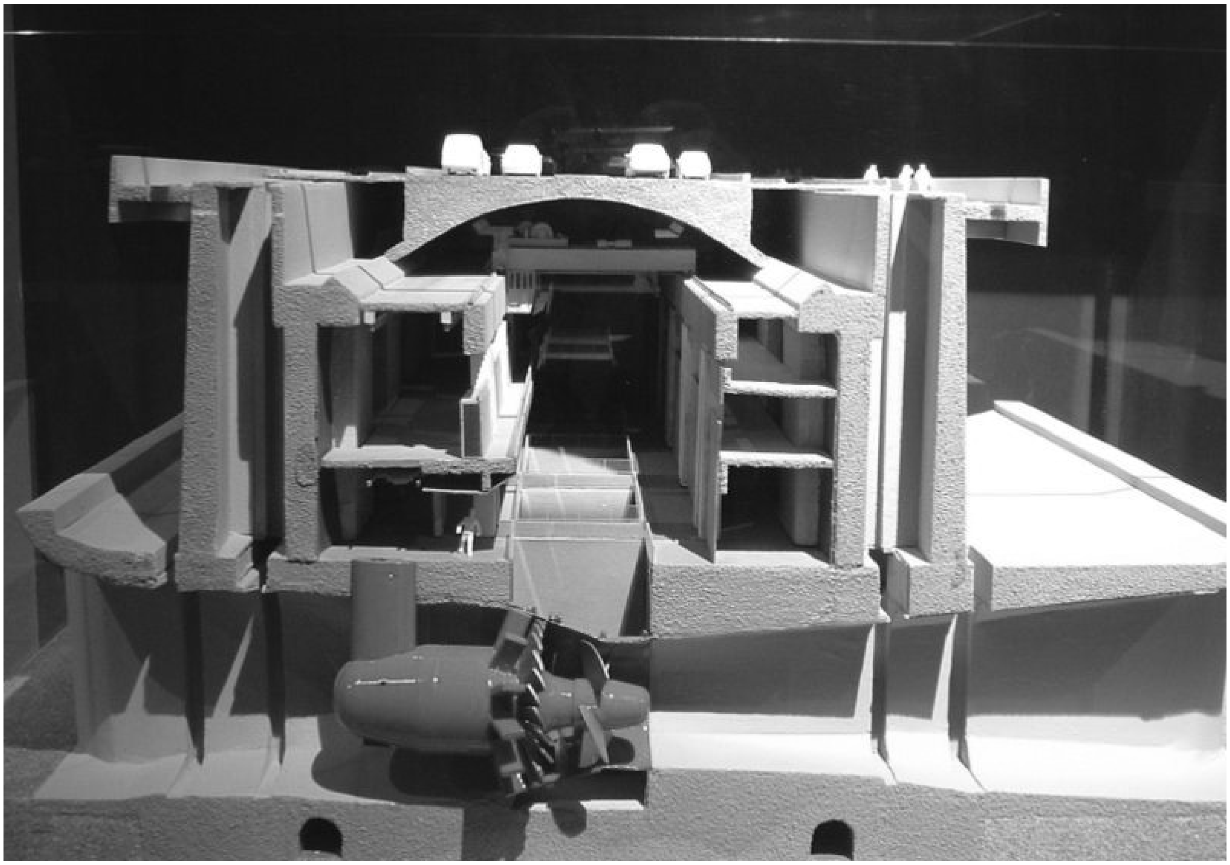

Figure 3 : Scale model of the Rance tidal power plant with its bulb turbine.

This "bulb turbine" was indeed a very clever invention: it is sustainable only because its environment was incorporated into its conception from the beginning. The idea was to fabricate an alternator which would be small enough to fit inside a watertight oil pan located just behind the turbine. To conceive such a small alternator, one has to consider cooling as resolved, otherwise the electric cables would be so tight that the high ohmic resistance would imply a huge thermal dissipation and therefore would lead to the self-destruction of the device through melting. By assuming that the alternator was able to be totally immersed in oil, which is commoved by its own rotation, Guimbal has solved this problem: the oil will bring the heat to the inner wall of the slum, which was itself immersed into the water pipe. The stronger the flow is, the more heat is produced, but more flow is also generated to clear up the heat. Guimbal solved the problem at the same time he formulated it. This example of auto-regulation reveals the strong influence that Wiener's work (9) and cybernetics in general exerted on Simondon's research. He extended the cybernetic notions of feed-back and of homeostasis to all machines, not only the information machine.

According to Simondon, the inventiveness of Guimbal is also revealed in the very elegant design of his invention: the space above the device is supposed to be empty, but an oil tank produces the overpressure inside the carter (so that no water can get inside). The very technical beauty is therefore invisible from outside: it can only be perceived by a technical analysis. It is not as if design were an independent activity employed to disguise the technical device after it is conceived. Simondon strongly criticizes this sort of superficial and cosmetic design that hides the real technical essence of an object. Evolution of the external appearance of an object, uncorrelated with an internal reconfiguration, is not part of the concretization process. The “historicity” of a technical object is defined by its stage of concretization. The external appearance and design are a sort of social and cultural “super-historicity” without any real technical meaning. Inventions are often first presented in the guise of older products in order not to disturb consumers. Some objects seem obsolete when they are only out of fashion, and others claim to be innovations when they are hiding archaic functioning with a flattering appearance. Simondon’s genetic mecanology uses only strictly internal criteria to evaluate the progress of technical lineages: “This notion of technical progress renders the evolution of technical objects independent from social demand and from the pressure it exerts upon the distribution and modification of such objects” (3: 14).

Thus Simondon describes concretization as an independent process marked by specific behavior: evolution proceeds level by level, from one systematic configuration to another, and gradual evolutions may appear during the stable periods at each level. Recurrent transformations between the levels give information about the “logic” of the progress and suggest that a law exists. This law of evolution of technical systems is not, like in Laffite’s work, the introduction of a natural law from physics into the new field of “mecanology”. As independent as they are, technical evolutions are not natural evolutions but artificial ones. So the law of technical evolution is the objectification of a regular rhythm from a human process: it is a tool for forecasting (prospective) not a rule for prediction.

4. Technical evolution during the industrial era: standardization and networks.

After the second industrial revolution, technical objects fabricated at our scale (*i.e.* at the individual level) are no longer the same organic totality they were when produced by handcrafted means and as a set of original parts. They are now just an assembling set: each element is produced in a series and can therefore be replaced by its equivalent. To function, an industrial assembly process must be composed of standardized pieces which are under the same constraints as those to which the whole formerly handcrafted object was subjected. Hence *standardization* expresses the process of concretization at the level of technical subsystems during the industrial phase. This subsystem is even more concrete than the object because it “exceeds by its power of adaptation and circulation the range of objects for domestic use: it fits into distribution and exchange channels that extend to the whole planet, it supplies networks at the scale of the world, and it can be employed in the building or the repairing of many different types of objects for domestic use” (10: 236).

Thus mecanology must change its level of analysis to apply its method to industrial concretization: the technical characteristics of the object are no longer at their own scale but, from then on, at the levels of their components and network. At the individual level, the object is subject to a design that is adapted to the consumer’s taste: “This is the most important positive characteristic of industrial production. The alienation of super-historicity takes place only at the human scale and focuses at this level, while the micro-level of the components, the real technical elements, and the macro-level of distribution and exchange networks, are exempt from it” (10: 236). Somehow, industrial production, by standardizing and developing huge networks, frees technique from the bounds of the object’s dimension at the same time that it reveals the non-coincidence of the technical essence of an object and it’s utility.

Simondon calls this process a “phase différentiation” of “technicity” towards inferior and superior technological levels, whereas concretization works at other scales. The non-equivalent evolution of the elements must have an influence on the evolution of technical individuals. The concretization of the components leads, for example, to the miniaturization of objects: “Therefore, the magneto-electric engines are now a lot smaller than they were in Gramme’s time, because the magnets are considerably reduced” (1: 65). However, miniaturization is not the same process as concretization, but rather one of its results: miniaturization represents progress from the user’s point of view but not necessarily from a technical point of view if a reconfiguration is not accomplished at the same time. Nevertheless, the link between miniaturization and concretization may be precisely the point that must be studied in detail if we want to understand what a law of technical evolution would be according to Simondon.

The uneven development of the component’s functions causes the saturation of the progress of a technical system. But Simondon also analysed this phenomenon at another level: the global technological network is subject to saturation when the improvements of objects’ concretization are exhausted. Therefore, studying at this level allows us to find a specific rhythm and its law of relaxation. The standardization of components creates an historical solidarity between all the technical realities: historicity. How can we understand and, perhaps, forecast this historicity? There is not only synchronic solidarity between technical devices but also diachronic rhythm, a very specific duration of a technique all along the succession inside a lineage “that determines by its law of serrated evolution the significant periods of the life of a technique” (1: 67).

5. The law of relaxation as law of technological evolution: a log-periodic equation?

Evolution’s law of the technical system is a “law of relaxation”, which, according to Simondon, is without any equivalent in the natural (physical or biological) world. Technique has a specific and original rhythm of relaxation: “Such a rhythm of relaxation has no equivalent anywhere else; neither the human world, nor the geographic world can produce such an oscillation with successive crises and emergence of new structures” (1:67). These new structures are not only the reconfigurations inside of technical lineages but also the results of bifurcations and substitution between lineages. When a real technological revolution occurs, a technical lineage may be transformed, but it may also be abandoned and replaced by new ones with different functioning processes.

Following his research on the concretization of electronic tubes, Simondon also studied transistors and the amplification process (11). His other philosophical works employ “modulation” as a main concept. So we can be sure that he observed very closely the technical evolution that led to microchips. Nevertheless it is not a single lineage. From the electronic tube to semi-conductors, and then from the transistor to microchips, technical evolution has only a functional unity. Hence it is not a simple concretization process but a “substitution after saturation” as Smaïl Aït-el-Hadj describes it (12).

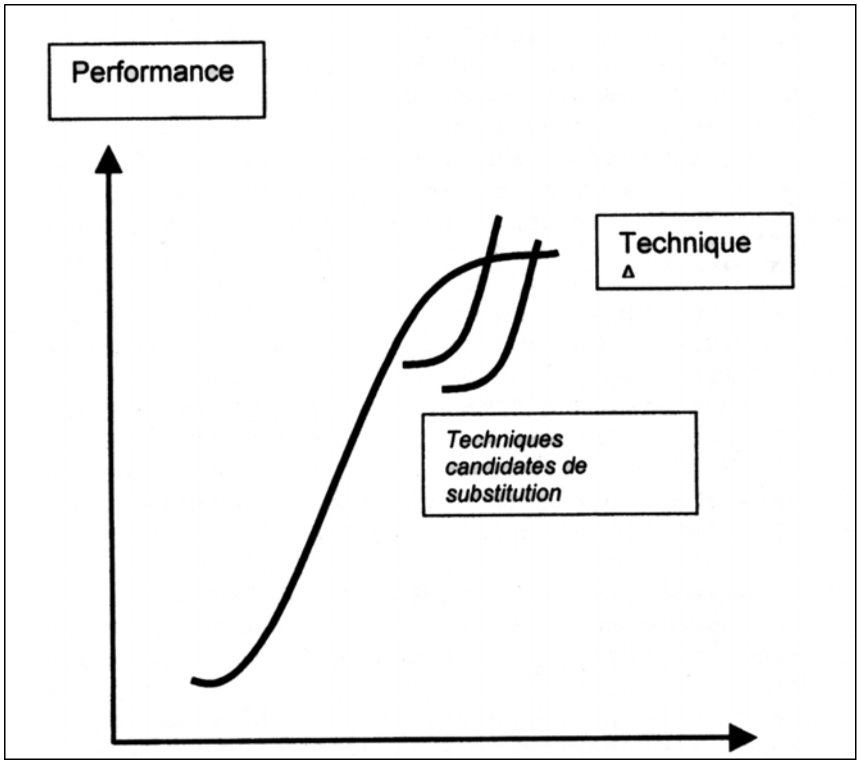

Figure 4: Technological substitution after the saturation of a technical lineage (12: 148).

As it creates new structures in a proliferating ramification, the relaxation of technological evolution can be set apart from all other laws of evolution by Simondon. It is to be noticed that, according to Simondon, the difference between the natural and the technological world is not exactly the same as that between a natural and an artificial object: technicity can be found in some organic tools (like crab claws) but it is found foremost in organized matter; artificiality is quite different, because it means that an artificial object needs a specific and artificial environment to live or function: hothouse flowers are artificial, and so are machines that cannot function anywhere. Concretization can lead to hypertely but in general the more concrete a machine the better it adapts to every environment (because it has integrated its own “milieu associé”) and so, in fact, it’s more natural than artificial! However, concretization itself is an artificial process because it occurs only in a technological system. Some relaxation processes do exist in the natural world, like certain geysers for example, but such processes are functioning as a periodic cycle: in the end they come back to their initial state, they do not create any new structures. But recent research (13, 14) shows that these differences are not particularly relevant: many physical as well as biological morphogenetic processes have been identified which show exactly the same recurrent crises and creation of new structures. Does this mean that there are no longer any differences between the law of evolution of a technical system and natural laws? Probably not. On the one hand, there is still a difference of nature between artificial and natural systems ; on the other hand, it appears that we now have a new way to model this sort of evolution: *log-periodic equations*.

These models have been invented precisely to describe processes that show alternative phases of gradual progress and crisis culminating in a global change. Therefore, they correspond qualitatively to the natural processes of relaxation which are analogous to the succession of the sigmoid curves in the evolution of technological systems.

These log-periodic laws are already used for modeling many different processes, such as the aftershocks of earthquakes or stock market crashes (13). This sort of equation has also been proposed for modeling the morphogenesis of astronomical structures, the evolution of biological species or the long cycle of economic development (14), the evolution of particle accelerators (from the first cyclotron to the proton collider LHC) and even the chronologic evolution of jazz! (15).

After he studied earthquakes, Didier Sornette was the first to determine the range of this sort of equation, afterwards becoming a respected economist. He defined log-periodical laws as a modification of classical power laws with a complex dimension. The basic equation describes a self-similar fractal ramification. For a temporal evolution (like a genealogical lineage), it predicts the time interval between two evolutional crises:

$$(1)\ (T_n - T_c) = (T^0 - T_c) \square g^{-n}$$

T_c is a critical time (for example, the concrete stage for a technical lineage) and the end of the evolution predicted by the theory. This limit can be reached only after a series of events T_n (successive crisis: saturation and then invention or substitution). There is a constant ratio g between two successive events (T_{n+1} / T_n) and T^0 is also a constant that can be calculated for each type of lineage. So the equation (1) means that there is a self-similarity with a factor g when one compares the series of time intervals in a logarithmic scale: log (T_n-T_c). One may thus model an accelerating evolution as well as a decelerating one. This sort of "law" is a probabilistic one and it predicts only the rhythm of major transformations, not their nature. The only prediction about what will happen is then provided by the supposed recurrence of these events. We are therefore invited to interpret TRIZ and Simondon's analysis as qualitative laws that complete this quantitative law of relaxation.

This sort of anticipation works only during the crisis within a technical lineage. During a technological revolution, the substitution of one technical lineage by another is the result of a selection between many new structures and functioning possibilities. So, even if the concepts of "laws" and "lineage" suggest a linear evolution and a predetermined process, it is a retrospective illusion: there is path dependence in the technical evolution that hides the other possibilities. One may invent in the future a new structure that is in fact the resurgence of a previously abandoned process of concretization.

However, we claim that log-periodic laws should be included among the theoretical tools of genetic mecanology as well as those of TRIZ. They can be used for many types of empirical studies and even for forecasting. The physicist Laurent Nottale is one of the researchers that use these equations. He has recently (17) proposed to apply them to the alternative phases of gradual progress and saturation of technological evolution by identifying major events as technological ruptures caused by scientific revolutions (16). For him "technological innovation is not a random process. Moreover, it is certainly not disconnected from the great changes of paradigms occurring in fundamental physics. Fundamental theories and knowledge are indeed the ground and basis for the development of innovations" (17: 2). This approach holds much promise although many theoretical problems remain. First, Altshuller, Simondon and Nottale seem to share the same ambition of modeling technical evolution and propose analogous tools to do it. We may nevertheless ask whether they are really studying the same object as those engineers and designers who want to anticipate technological innovation.

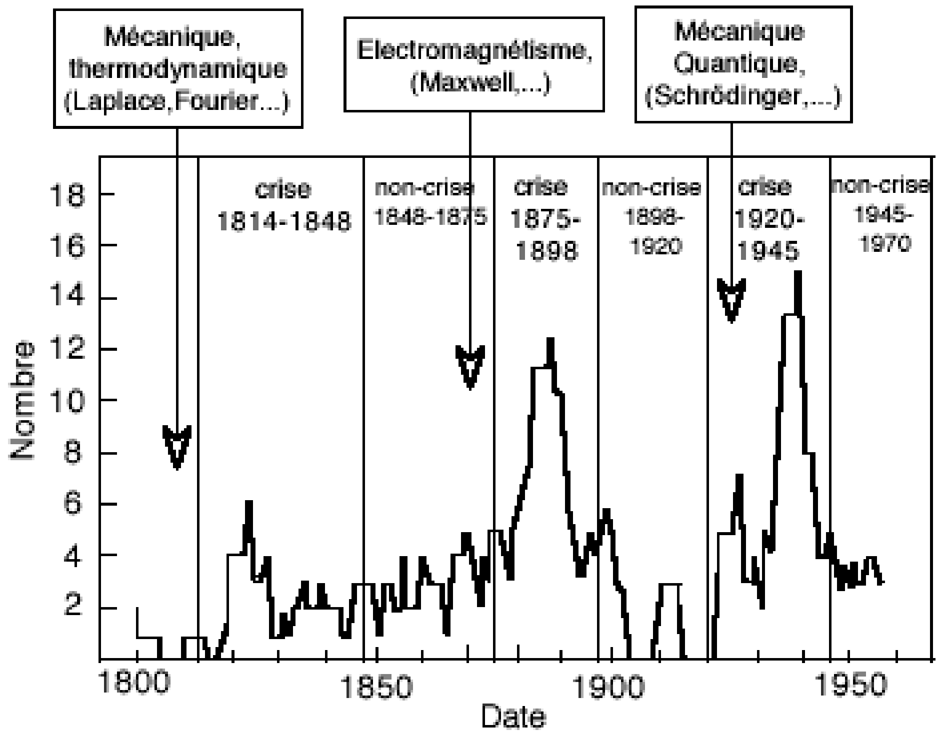

Figure 5: Chronological correspondence between scientific revolutions, long economic cycles and the alternative rhythm of technological progress and stagnation phases between 1800 and 1960 (17: 2).

6. Conclusion

The work of Nottale seems to confirm some of the hypotheses of genetic mecanology, especially the possibility of modeling a law of the evolution of technical systems and the importance of saturation phases. But the inventions (technical reconfigurations) that can be predicted are not the same events as innovations (modifications in order to increase the value). Altshuller developed his theory in a non-capitalistic environment; Simondon explicitly described concretization as a process disconnected from economic factors (which can only disturb the process); Nottale has connected the scientific, technological and economic processes, but he still gives priority to technology over economy.

Is this what engineers and designers are looking for? Or is the methodology of conception concerned more with understanding the capitalistic dynamic? Against any naive hope of predicting the creation of new technologies, it must be reminded that concretization is not the same process as what we observe today in technological innovation and the search for the greatest economic productivity.

For instance, Simondon sometimes gave very surprising definitions of progress: during an interview with the technologist Jean Le Moyne, in 1968, he defends the idea that, in some respects, a thermal machine is superior to an electric machine because it can work without being connected to a network. What a strange point of view! Simondon then recalls that, at the end of World War II, steam engines were very useful to the French resistance. So, we must conclude with a dilemma: Simondon’s work offers a law of evolution of *pure* technique; but what most of people are eager to understand, from an operational point of view, is precisely not so pure.

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