The Plaited Structure of Time in Information Technology

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Abstract. The aim of this paper is to try to understand the structure of time in information technologies. Starting with historical arguments, it first shows that time is neither linear nor cyclic. This becomes clear if we consider that many technologies which were developed in the past and then gradually ignored have since enjoyed revivals. In a way, information technologies seem to have a life cycle. On the other hand, the time of information sciences and technologies is anything but cyclic, because information sciences and technologies introduce radically new devices that change our lives. One of the consequences of this strange structure of time is that, very often, long term predictions are more reliable than short term forecasts. This paper tries to explain the entangled structure of time in information sciences and technologies through a cybernetic model. It argues that the differences between information sciences and technologies and other technologies are due to their interactivity, whereby society intervenes in the design process.

1 Introduction

It is now a commonplace to talk about the acceleration of time and increasing world complexity. Everyone agrees that science and technology are producing ever more new results at an ever faster pace. It would thus seem to be becoming more and more difficult to make reliable predictions over a long period. However, in the field of IST — Information Science and Technology — things are not so simple and, surprising though this may be, the near future is more difficult to predict than the long-term future. We just need to look at the history of IST, which shows that short and medium-term predictions of, say, five to seven years have very often turned out to be wrong, while many long term forecasts have come true. For instance, let us take the example of the history of cybernetics, machine translation, artificial intelligence, expert systems, virtual realities, communication networks, minicomputers, microcomputers, the web, etc. We have regularly been wrong about the evolution and social consequences of these technologies. Meanwhile, many long-term predictions, 20, 30 or 40-year forecasts, say, have been correct. To be convinced, it is sufficient to read Alan Turing's forecasts in 1950 (cf. section 3.2), in his famous paper [12] about machine intelligence, or Jean-Francois Lyotard's 1979 book [2] relative to the status of knowledge in post-modern societies (cf. section 3.4) etc. The difficulty when trying to forecast imminent change comes simultaneously from the large number of different people taking part in the decision-making process and from the generalization of interaction that is typical of modern societies. Social interaction is becoming crucial in the development of advanced technologies — especially in the field of IST — and social practices play a more and more important role in the design process. The success of "user-centred design" (cf. [7]) in information technology is a sign of this trend. Since feedback is continuous and modifies predictions and expectations, production planning is becoming far more difficult and short term predictions are very risky. The structure of time is thus changing today and, as we shall see, is neither linear, nor cyclic, as was the case in the past. The aim of this paper is to try to understand this structure. To do so, it compares examples taken from the history of IST development with earlier predictions, and then suggests a cybernetic model in order to understand these changes to the time structure. In addition to this introduction, the paper is divided into four parts. The first shows how wrong past short-term predictions in the field of IST were; the second looks at medium and long-term predictions; the third provides an explanation of this phenomenon, and the fourth and last one proposes some conclusions about the new structure of time, which results from the broad dissemination of information and communication technologies.

2 Short term predictions

The history of data processing is marked by a long succession of errors of appreciation. The majority of short or medium-term forecasts were completely erroneous. To be convinced of this, it is enough to look at the major stepping stones in the development of data processing and, in particular, the software technologies. There are countless examples, of which a few are given below.

2.1 Cybernetics

At the beginning of the forties, cybernetics was enthusiastically embraced by many researchers who thought this offered radically new perspectives. The first automaton networks imagined by Warren McCulloch and Walter Pitts (cf. [3]), as well as the notions of feedback and of teleological machines introduced by Arturo Rosenblueth, Norbert Wienner and Julian Bigelow (cf. [10]), seemed to open up new horizons. According to many, a bridge between engineering sciences on the one hand and the brain or social simulation by means of information flows on the other, was in the process of being born. Many people thought they were now going to be able to establish the laws of complexity (cf. [6]) that govern biological phenomena, in particular the functioning of living organisms; physical phenomena, for example the spontaneous organization of atoms in crystals; political and social phenomena, which would make it possible to introduce laws of government based on strict foundations and, finally, neuron phenomena, which produce thought. The first attempts were quickly followed by disappointment. For example, Frank Rosenblatt's attempts to characterize an artificial retina (which was called the PERCEPTRON (cf. [9])) encountered many pitfalls, which were underlined at the end of the sixties by Marvin Minsky and Seymour Papert (cf. [5]). Later, at the beginning of the eighties, many paths of research which had been opened up by cybernetics, and which had seemed to lead to dead ends, were reopened. What we have here is an example of technological revival, as mentioned in the introduction. However, as we shall show in the following, this is far from being the only case.

2.2 Machine Translation

At the beginning the fifties, considerable sums of money were invested in machine translation projects. Many people believed that computer resources, in particular storage capacity and their ability to handle character strings, would make it possible to build, quickly and cheaply, a machine able to automatically translate texts from one language to another, for instance texts written in Russian or French would automatically be transcribed in English. In support of this hypothesis, there was the possibility of designing dictionaries. Today, it seems obvious that it is not enough to have a dictionary in order to translate correctly; it is above all necessary to understand, which supposes a syntactical parsing followed by a semantic analysis and then a pragmatic analysis, many phases of which the engineers thought could be skipped. As a consequence, they were quickly disenchanted. However, these general considerations did not prevent the American government from engaging important sums of money in machine translation, and it also was the case of many European governments. It was only in 1966 that a report commanded by the American Senate [8] recognized the impasse at which the efforts of machine translation had arrived. As a result, the funding of all American laboratories working on machine translation quickly dried up and they were closed. However, this did not put an end to machine translation. In Europe, some laboratories continued to do research in this field and even today there are European research programmes, funded by the European Community, that support fundamental research on machine translation. Machine translation systems are even available to the general public on the Internet. The ambitions of machine translation have been reduced; it is no longer a question of translating all texts from one natural language to another, but of translating technical papers within a narrow field of knowledge, where there are no semantic ambiguities. The methods used now require knowledge of linguistics and semantics. Nevertheless, whatever the future of machine translation, the expectations and predictions of the early fifties now seem totally justified, even if they appeared to be completely wrong from the end of the sixties to the mid eighties.

2.3 Artificial Intelligence

From its very beginning, in 1956, artificial intelligence raised many hopes. It was imagined that a machine would be able to simulate almost all the cognitive capacities of intelligent beings (cf. [4][1]); for instance, that a computer would be able to perceive the outside world, to argue just like a human being, to play chess and to beat the best world players, to speak different languages and to understand everything. The very first research fed such expectations: a machine automatically proving most of the theorems of logic contained in Alfred Whitehead and Bertrand Russell's "Principia Mathematica" was built. These successes encouraged the pioneers of artificial intelligence to go further; they began to dream. So, Herbert Simon, future Nobel prizewinner for Economics and who also went on to receive the Turing awards, made resounding statements with his colleague Alan Newell (cf. [11]). According to them, 10 years hence (we were in 1958), if they were not excluded from international competitions, computers would no doubt become the world chess champions. Similarly, a computer would certainly be capable, again within 10 years, of composing music endowed with an unmistakable aesthetic value, of demonstrating totally original mathematical theorems, of imitating the psyche to the point that all psychological theories would have to be expressed by the means of computer programs, etc. It goes without saying that these predictions were soon proved wrong and, in 1965, a chess computer program was defeated by a 10-year-old child. Nevertheless, in 1997, that is to say less than 40 years on, a computer succeeded in challenging and beating the world champion chess player; computers are used a lot by musicians; computers play an important role in the activity of mathematicians to demonstrate new theorems; and psychologists also use many computer models. All of which goes to show that most of these announcements, even if they were proved wrong at the time, were not totally absurd. But the periods of time were not respected. Still in the field of artificial intelligence, many people got very excited at the beginning of eighties about what were called "expert systems". These are pieces of software which, unlike traditional computer programs, include specialized knowledge held by experts. Here, too, expectations were frustrated: the industrial development of expert systems or knowledge-based systems was much slower than what all specialists or forecasters had imagined. However, today, many industrial applications of these technologies can be found.

[1] The original text can also be found at $http://www-formal.stanford.edu/jmc/history/$

2.4 Computer Networks

More generally, for anyone prepared to examine it closely, the history of data processing contains a surprising succession of forecasting errors. In the sixties, experts imagined that data processing would develop on a centralized model, with a huge mainframe computer to which everybody would be connected. For many engineers of that time, computing capacity should be viewed as water or electricity flow, with a central production source to irrigate a whole company, even a whole city or a whole state. As a consequence, places such as office blocks or universities which were built at that time were cabled so that everyone would have direct access to the computer resources from their own offices. By the end of the seventies, minicomputers had been developed, which meant that data processing could be decentralized, i.e. each department of a big company would have its own computer. In this context, connecting all the offices to a central computer network was no longer justified. All that was required was a local area network so that each department could access the appropriate local computer resources. A few years later, workstations appeared on the scene: these were very expensive personal computers that experts thought engineers could be equipped with. These personal computers were closely followed by microcomputers, in other words desktop computers, whose relatively low cost changed the game completely. Not only did all the engineers and administrators have a computer on their desks, but so did all the secretaries. As a consequence, it was necessary to set up networks to connect all the microcomputers. Note that these changes were not at all predictable and it took IBM, the largest office computer company, quite some time to be convinced of the place of microcomputers in offices. The first Personal Computer, i.e. the first IBM microcomputer, was only made and marketed in 1981, that is to say more than nine years after the first personal computers were designed and four years after the commercial success of Apple II. In this respect, the history of human-computer interfaces shows the hesitations before widespread use of the mouse and the adoption of the desk, files and trash can or waste bin metaphors. For a long time, the big computer firms considered that computing was only the business of specialists and no one even contemplated making computers accessible to the general public. Developed by Xerox Park as early as 1972, the first machines destined for non-specialists, in particular the Viola, the Dolphin and the Star, included a mouse and a high definition screen. However, they were not a commercial success, and it was the same thing with Lisa, the first machine developed in 1983 by Apple along the same lines. It was only in 1984, with the appearance of Macintosh, that these new human-computer interfaces conquered the world.

2.5 Internet and the Web

It is the same story for the telecommunication networks between computers. Remember that the first attempts at digital communication started at the end of the sixties. Development of the ARPANET network began at the beginning of the seventies in the United States, while at the same time similar projects were being developed in France, the Cyclades project, for example, or the Minitel, which relies on the use of the telephone network and which was operational at the beginning of the eighties. Many people spoke about on-line data processing. All the principles of networks were already there. And the coupling of computer networks and telephone networks, very much part of things today, already existed. Remember too, that the Web, which involves coupling hypertext technologies with a computer network, is a European invention made in Geneva by a European, on the site of the CERN. It is nevertheless in the United States that it first took off. Finally, closer to us, the craze for the Internet at the end of the nineties, and the speculative bubble which followed, also resulted from an error of judgment.

3 Long-term Predictions

In a word, a quick look at the recent history of IST — Information Sciences and Technologies — shows that short and medium-term predictions of, say, five to seven years have very often turned out to be wrong. According to a general principle which says that it is easier to predict that which is close than that which is far, the further away the future, the harder it is to guess what it will hold. Consequently, if the short or medium-term forecasts are incorrect, then the long-term forecasts will be all the more unreliable. But does this mean that it is no longer possible to make predictions in this domain? Reality seems to contradict these intuitions and we can see that many long-term forecasts, over periods of 20, 30 or 50 years, have in fact come true, as the following examples illustrate.

3.1 Moore's Law

Moore's Law stipulates that the speed of processors and their storage capacity double every 18 months. This empirical law was suggested in 1965 by Gordon Moore, co-founder of Intel (manufacturer of microprocessors) and was true for 40 years; the physical principles on which the design of current electronic circuits is based will certainly have to be revised if we wish to continue to make progress at the same pace beyond 2015 or 2020. The fact is that this law remains valid and should remain valid for at least the next 10 years. What we have here is a completely empirical law of prediction which is not based on any rigorous scientific foundation but which has nevertheless been confirmed by long-term experience.

3.2 Alan Turing's Imitation Game

In a famous paper [12] that he wrote in 1950, Alan Turing tried to clarify what it means for a machine "to think". According to him, thought and, more generally, intelligence have nothing to do either with physical appearance, or with voice texture, or even with facial expression. Nor do they have anything to do with consciousness. A machine can be described as an intelligent being if what we observe of its behaviour seems to emanate from an intelligent being. In order to make clear what exactly he understood by the intelligence of machines, Alan Turing imagined a subterfuge called the "imitation game". This is a game for three players: a man, we shall call him A; a woman, B, and an examiner, C, of either sex, it doesn't matter. A, B and C are in three separate rooms so that they cannot perceive each other's voices or physical appearance. In the first step, the examiner, C, has to ask A and B questions in order to distinguish the man from the woman, knowing that the man, A, imitates a woman. At this point there are no computers and no machines in the imitation game. What happens now if we replace the man who imitates the woman by a computer which imitates the man who imitates the woman? According to Alan Turing, a computer could be considered intelligent if it were able to deceive the examiner for as long as the man who imitates a woman. We won't go here into the relevance of this test of intelligence, which has been the subject of much comment, but will focus on what Alan Turing said. According to him, and remember that we were in 1950, we had 50 years to design a computer capable of deceiving an examiner in more than 70

3.3 "2001, A Space Odyssey"

Although Stanley Kubrick's film was first screened in 1968, the script had been written some years earlier, in 1965. If we remove everything which refers to the myth of the all-powerful computer and if we look carefully at the various technologies which were shown there, the film is a pretty faithful reflection of the state of research in American laboratories at that time, i.e. in 1965. Now, 40 years on, we can see that many of these technologies, which were then at the cutting edge of research, are quite normal today, as the following examples show. The spaceship was piloted and regulated by a computer as are many planes, the space shuttle or rockets today. What seemed very innovative at that time is totally commonplace today. Another example, safety is ensured by comparing the results obtained by three computers: if two of them are in conflict with the third, then it is the third which is queried. This principle is used now to ensure the safety of complex systems and we even try, provided it is not too expensive, to get different teams to build several computer programs and activate them in parallel. Remember that in the film the spaceship computer was playing chess and systematically defeated all the adults, whereas at that time, that is to say in 1965, a 10-year-old child beat one of the first chess-playing computers. Since 1997, we all know that a computer is capable of defeating the world chess champion, and this more than once. Finally, the small androids inside the spaceship were able to speak, to understand what the astronauts were saying, and to talk with them. At that time, research on automatic speech recognition and on natural language processing was at a very basic level. Today, much progress has been made in this field. Now, machines are able to transcribe what we say and to improve their performance by automatically adapting their behaviour to our voice and to our vocabulary. Some people, such as philosophers Dan Sperber[2] or William Crossman [1], think that we are entering a society without writing where there will no longer be any need to write or to type. This means that following the example of the ancients, we shall just have to dictate to computers, which will take the place of the scribes in Antiquity. Let me just point out that, in many laboratories, android robots endowed with speech and vision, and similar in all respects to those of the "2001, A Space Odyssey" spaceship, are today commercially available. Studying science fiction films, if we go beyond the myths and examine what is being done in research laboratories, enables us to make totally satisfactory long-term predictions.

3.4 The Status of Knowledge in a Postmodern Society

At the end of the seventies, a French philosopher, Jean-Francois Lyotard, published a book entitled "The postmodern condition" [2] about the status of knowledge in post-modern societies. This book followed an inquiry ordered by the Canadian government on the long-term consequences of the development of on-line data processing. Without going into the detail of Jean-Francois Lyotard's analysis, let us just remember that the philosopher was examining the consequences of the development of information and communication technologies on the status of knowledge in modern societies. The question was how individuals would be able to read and interpret the knowledge recorded in immense data bases without going through the traditional well-established forms of mediation. More generally, Jean-Francois Lyotard was asking himself how social links would be affected and how the great narratives that legitimated knowledge in a totally decentralized society would be reconstituted. While the words of on-line data processing used at the time seem totally outdated, while the technologies to which Jean-Francois Lyotard referred, in particular the Minitel, are no longer in use, the questions that he asked are totally up to date; they are no longer projections as to the future but are burning issues today. In summary, whereas the first set of examples has shown that short-term forecasts are less and less reliable, the examples here suggest that long-term forecasts can often turn out to be more useful and correct. We are thus in a strange situation where the near future is more difficult to predict than the distant future. Let us now try to understand the origin of this apparent paradox.

4 The Interactive Society

4.1 User-centred Design

The first observation to be made is that the unpredictability of short-term change varies from one area of industrial and economic activity to the next. For instance, the development of electronic components seems relatively predictable in the short term but less predictable in the long term, thus obeying the classic law according to which the further ahead we are looking, the less precise the knowledge we have. So it is with the development of traditional industries, where technological progress does not directly involve social retroactivity. For example, in the production of electricity, in the nuclear, chemical or metal industries, it seems that predictions follow our common intuitions, i.e. the immediate future is more easily predicted than the distant future. Note, too, that it is neither the complexity, nor the profusion of results that makes prediction impossible. In many of the areas mentioned here, a good number of results are both practical and theoretical. And this is not in contradiction with short-term forecasts. If, on the other hand, we take the spheres of activity where the cognitive faculties of the users are involved, or the way in which people appropriate the technologies for themselves, then the classic laws do not apply. Let us take the example of the car industry. In purely technological terms, the development of new cars is dependent on technological progress in the field of both materials and engines. As such, new developments obey the traditional laws of progress and we can therefore predict them with the same degree of (un)certainty with which we predict developments in the domains of physics, materials, mechanical engineering industries or engines. However, in strategic terms, choices depend on social perceptions which are related, for example, to the ecological concerns of a society. At some point these remain totally unpredictable. In the particular case of the car industry, new developments depend mainly on exogenous factors which have nothing to do with technology but everything to do with the desire to limit the number of road accidents, for example, or with people's susceptibility to noise and to atmospheric pollution. Things are very similar in the field of information and communication technologies. This explains why human-machine interfaces, personal computers, personal digital assistants and telecommunication networks have developed in a very unpredictable way. More generally, this means that in a certain number of industries it is no longer enough to devise brilliant plans, as would have been the case with traditional industries at the beginning of the 20th century. Today, we are unable to foresee everything, we need to consider all potential users, and this cannot be done without their actual participation. We thus have to organise consultations and preliminary inquiries, in other words engage the users with the design process in what is known as "User-Centred Design" (cf. [7]). This results in a kind of solidarity between those involved in the first stages of the design, and the notion of users' clubs, which is very common in the field of computing, is a perfect answer. But there is also a practical aspect to this communication strategy: since the designers cannot control all the parameters which will lead to customer satisfaction, they ask for volunteers, who often feel they are part of the chosen few as they can test something for nothing. This is the only way for the designers to identify the weaknesses of the products that they have designed and to adapt them to satisfy the needs of the majority of users.

4.2 The Law of the Second Newcomer

To show just how important user satisfaction is, there is even a law known as the "second newcomer law", which stipulates that on the very advanced technology market the second newcomer possesses a major strategic advantage if he can learn from the failures of his predecessors. Many examples can be given in support of this law. The success of Macintosh in 1984, and the spread of microcomputers with a graphic interface and mouse which followed, had been preceded by numerous unsuccessful attempts which, even though all the ingredients to make the fortune of these machines were there, didn't take off. More recently, some may remember the "Newton", the particularly innovative machine invented by Apple. This computer, with no keyboard but with a touch-sensitive screen and a stylet, prefigured today's pocket computers (which are usually called "palm" computers), UMPC — Ultra Mobile PC — and PC tablets. Although the "Newton", with its graphic interface and automatic handwriting

[2] The Sperber paper in favour of this thesis can be found at $http://www.text-e.org/conf/index.cfm?ConfText_ID=12$

recognition, anticipated a whole new generation of machines, it was unsuccessful. Many more illustrations of this law could be given. The point here is that the traditional principle according to which precursors adopt a dominating and dominant place on markets is proving wrong in the field of information and communication technologies. For example, in the field of electronics a huge number of patents have been taken out, which makes it impossible today for anyone to get into the market if he does not already possess a large amount of technological knowledge, because the cost of purchasing all these licenses would be prohibitive. The strategic advantage should thus go, as in traditional industries, to the pioneers who, with their know-how and their intelligence, knew how to be the first ones there. Now, curiously, in the most modern industries where design requires a kind of mutual participation of all, it would seem that the pioneers have a handicap, and it is the second newcomers who defeat the first. The recent history of the development of search engines is a very good illustration of this principle: many financiers decided to invest very early on in the first companies to propose search engines, because they believed they would dominate the market, alone. It is doubtlessly this fear which fed the speculative bubble around the development of the Internet. If we now look closely at the development of these technologies, we see that these fears were ungrounded, on the contrary. To prove my point, we just have to see when some of the most well-known search engines appeared: Incite 1993, Lycos 1994, Yahoo 1994, Altavista 1995, Hotbot 1996, Google 1998, etc. It would seem that the latecomers had the edge over the first newcomers.

4.3 Retroactivity

As soon as we consider this interactive model of design and industrial development, we can no longer think in terms of authoritarian orders simply being transmitted by expert panels with an established and recognized competence. We have to consider all interactions of all possible users during the design and manufacturing processes. To summarize the state of things today, let us consider the comments of a large computer manufacturer who, about twenty years ago, asserted that those who refused to learn the language of technology would be left behind, abandoned at the roadside of modernity. Against this traditional view of progress being imposed on the whole of society, another view would recognise the mutual dependence between designer and user. This is illustrated perfectly by the answer of another computer manufacturer, who said that the manufacturer who does not know how to propose tools which are adapted to the needs and abilities of the users runs the risk of being left by the wayside of economic development and of going bankrupt. Let us now suppose that, in order to understand the causes of the above-mentioned paradox, we try to model progress and development. To do so, we must not take one promoter — the chief engineer — in isolation, nor an interdependent group of people acting jointly — the producers —, but a set of people — including different producers and consumers — interacting with each other, with different competencies and different goals. It follows that the laws of change no longer obey the rules of classical causality, where the effect occurs as a consequence of the cause. Here, it is necessary to consider all possible feedback, which requires using the dynamic system theory where short-term behaviours may be chaotic whereas long-term changes converge. In a word, it is easy to explain this strange above-mentioned phenomenon whereby short-term predictions are more unreliable than long-term ones, through dynamic system theory. Even if there is no pretension of producing a science or a theory of scientific progress, it is at least possible to propose a model which explains the erratic character of predictions.

4.4 A Cybernetic Model

For the sake of clarity, let us take the following example. Suppose we have two technologies, T_1 and T_2, and the knowledge required to design each of the two technologies T_i is made up of two knowledge sources K_i^t and K_i^u. The first, i.e. K_i^t, is just technological and can be acquired either by a single initial investment or, progressively, by repeated investments corresponding to a percentage of the profits. The second source, K_i^u, corresponds to user feedback. It may be empty in the initial state, but not necessarily. It is then possible to express the investment flows between the users, the technologies and the different knowledge sources. Such a very simple dynamic network makes it possible to study different systems of technological innovation. In the first case, user feedback does not play a key role in user satisfaction and therefore in the amount purchased. The determining factor is the technological knowledge. It then appears that the technology T_i which takes advantage of the highest knowledge source K_i^t will provide more user satisfaction and therefore will become dominant. This is especially the case when the two technologies T_1 and T_2 are alternatives, i.e. when users can choose between the two. With time, new knowledge sources K_i^t may appear, which could generate new dominant technologies. In technical terms, the attractors may change if the number of knowledge sources given to a non dominant technology increases. However, this comes at a cost and if the new knowledge sources mean buying the previous one, this will prevent any newcomer from coming on the market. Let us now consider the case where user feedback is required to design a technology T_1. If the initial user feedback is too low, i.e. if K_1^u is almost empty, the design may be wrong, which causes a failure, even if the technological knowledge sources of T_1, i.e. K_i^t, are satisfactory. In the case of two competing technologies, T_1 and T_2, one technology, T_1, for instance, which came first, may turn out to have made bad design choices, while the second can take advantage of the user feedback concerning the first one. The final point is that feedback delay can cause instabilities in the system. Whatever the case, all possible situations and scenarios can be simulated using automata networks, which will show different behaviours corresponding to different systems of technological development, depending on the nature and cost of knowledge required. The first implementation has been carried out using multi-agent architecture, on a NetLogo platform[3]. It shows the different behaviours that have been mentioned here.

5 Plaited Time

By way of conclusion, let us now consider the new structure of time as a result of taking such interactions into consideration. In one way, the time of progress is linear and runs without ever going back on itself, as if it were an arrow flying forward, pursuing its course without knowing if and when this will end. This linear time of perpetually renewed modernity is in opposition to traditional cyclic time, in which the future is never other than a return to the past, which means that time is eminently predictable since nothing really new can happen. In the present case, it seems obvious that time cannot be conceived of as being cyclic, because technological and industrial developments impose endless renewal: nothing is today as it was yesterday. The contemporary imperative, which orders us to be modern, is proof of the singular novelty of modernity. As a consequence, the present cannot be considered as the return to a former present. Does this mean

[3] NetLogo is a free multi-agent modelling environment that is available at http://ccl.northwestern.edu/netlogo/

that current time must be seen as being strictly linear? It is undoubtedly a time of progress, which accumulates results and which thus every day opens up new perspectives. In this respect, we could indeed be tempted to see it as being linear. Nevertheless, reducing time to a straight line would be misleading. After all, as we have just seen in this paper, present time surprises us, its progress sometimes takes on a chaotic look. It goes back to the past. Paths which had been trodden in the course of investigation, then abandoned, reappear and are successful. Some strands of change are divided and subdivided to such an extent that the thread of time seems to be forked and twisted rather than simply linear. But in spite of these twists and forks, the long-term predictions are relatively stable since, quite often, those that came too soon are rejected for a while, before returning to the front of the stage. The structure of time is therefore not really ordered like shelf space is, but is somewhat tangled. In other words, at any given point several alternatives can be envisaged, some of which exercise the most brilliant minds, while others seem to be in retreat, hidden from the general public. Then, from time to time, what seemed hidden reappears and what has gradually been emerging into view disappears. Time is thus a tangled hank, a plait of hair, its strands scattering and even moving out of sight before reappearing under a new light, then hiding anew. It is in this sense that we can speak about the time of contemporary modernity as plaited time.

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