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The Islamic Revolution in Iran. Some Considerations on History as Complex System *

THE PROBLEM

According to a widely accepted opinion, complexity is the science of the 21st century. The countries that will master it will become the economic, cultural and political superpowers of the future. Complexity is a new way of tackling otherwise unresolvable problems with the traditional methods and tools so far known to us.

In this work, the relationship between this new scientific approach, in so far as it will bring about a potentially radical epistemological change, and some classic problems that have not yet been resolved to satisfaction (at least not altogether), will be looked at and demonstrated through historical and archaeological questions. There are essentially two aims to this study:

– to clarify how a theory of complexity (moreover, that is still to be constructed) enables one, at least in principle, to "scientifically" re–examine debates and topics that have always been assigned to the "humanistic" sphere: this misuse of language (pointed out by using quotation marks), is an attempt to achieve a crude association with a mentality, a way of thinking, that one may define "traditional" (with another language misuse).

– to show, with simple but realistic examples, the potential effectiveness of such an approach, using analytical tools that are still experimental although they have already been tested in significantly diverse and numerous contests. In this way, the use of the expression 'complex systems' acquires some provisional legitimacy as methodological experimentation.

A minor, but nonetheless important, consequence of this approach has been the rediscovery of the role that mathematics can play, given its more recent developments, in the formulation and solution of various aspects of many problems that are not related to the natural sciences. Economy (Haken 1981) and

* The authors have discussed together at lenght the problems raised in this article, and may be both considered responsible for all that has been written. However, Guido Lo Vecchio has especially dealt with the problems discussed in the first part of the text (pp. 1–11), and Ugo Bisteghi with those discussed in the second one (pp. 11–15).

more recently, psychology (Weidlich–Haag 1983; Farmer–Sidorowich 1988), have been the forerunners, even though they do not represent the most ideal terrain one would need to explore in order to understand the extent of this announced epistemological evolution: in fact, mathematics has had a passive role here, so that the formal outlines, in general, have been considered acritically, or worse, as expedients for justifying preconceived convictions with no real foundation on experimental evidences.

On the contrary, the correct way to deal with the problem would be to start by defining what a complex system is – a definition that could be derived from a series of scientifically tested facts. The formalization would be the last step to be taken in the process, and one may easily maintain that this goal is still far from being attained. In this essay, we will try to give examples of some of the most respected positions that have been taken on this question, which in their turn show how many difficulties have yet to be dealt with, given the amount of different and opposing points of view that there are on the matter.

The notion of a complex system refers to phenomena upon which many independent factors operate, in a great deal of possible ways.

It is easy to predict an almost complete failure for the reductionist approach to complexity (Waldrop 1992). Such an approach, which has always been successful in the "hard" sciences, has lead to the elaboration of ingeniously "approximate" theories for some of these phenomena (which were then attributed to complexity) before questioning the reductionist method suitability for the description and interpretation of such events. Merit must be given to those physicists and mathematicians who successfully elaborated cognitive methods from Galileo onwards, and first questioned the validity that these same methods could have when applied to the new reality of complex systems. It must be remembered that the separation of the two cultures allowed for the exclusion, in principle, of the possibility of taking "scientific" methods that in reality belonged to the "humanistic" sphere into consideration, and therefore ignored or overlooked those facts which could have led to the notion of complexity. In fact, the crisis exploded, if one could call it as such, when the "scientists" discovered the contagion right in their own homes (Monod 1970; Nicolis–Prigogine 1977; Haken 1982). If a little irony may be used, it must be said that until that moment, they (the humanists and scientists) who had never been apart, were only too happy to be so.

Nowadays, such a separation is becoming harder and harder to maintain, at least in terms of the main principles. Some phenomena which definitely belong to the "hard" sciences (for example, the climate) have very similar characteristics to those of certain biological, economic and even socio–political phenomena. The modern theory of chaos (Bergé–Pomeau–Vital 1984), which emerged out of and was developed within the field of physics and mathematics, is proving to be more and more interesting in its attempts to formulate theories on these systems: the theory of catastrophes (Thom 1980) even offers itself as a new epistemology upon which to base this relationship between the two cultures. All these considerations may seem vague and generic, infused with a naive optimism that could never survive a rigorous testing of their assumptions and procedures. We do not exclude such an outcome; one may only limit oneself to asserting the legitimacy of a similar research, in so far as it is undertaken with the use of irrefutably proven facts and evermore stringent analogies. At least the following "negative" conclusion is generally accepted: the traditional procedure of the natural sciences, that is experiment–test–analysis and data interpretation–construction of the model– elaboration of the theory, is proving to be more and more inadequate for research done on real systems, since it is evident that they are so complex. Do not misinterpret this conclusion: the above–described procedure which can be taken to be Galileo's method, has not lost its significance – it has simply become impractical. The most problematic part with insuperable difficulties may seem to be right at the beginning, in the phase when information are collected and put together, or during successive phases of the cognitive process, as inadequacy of mathematical tools, or as ambiguity of the procedures of falsification, or even simply as impossibility of identifying a sufficiently generalised theory. In fact, the most perfect chain may nevertheless break. The method adopted in this essay is to assume, as a guiding principle, the existing relationship between the sciences and the arts in order to try to identify partial explanations of the various phases of the aforementioned process. Particular emphasis is given to the identification of situations that, already at the research beginning, present problems in the transfer from information collecting to making a homogenous coherent data set, obtained through the use of unambiguous classifications, apt for the requirements of the analysis and interpretation. One may object that this has always been a problem as far as the humanistics are concerned (for example, history, archaeology, economics, etc.). The answer is: yes !

What is new is that now the same problem is beginning to emerge in cases related to the natural sciences, the "hard" sciences. Having already quoted the climate as an example, a more specific case that may seem to belong to the field of physics may be taken: that of the measurement of pollution levels in brief periods in critical situations (such as the explosion of a factory chemical products or of a nuclear reactor). An example, incidentally, that is of very concrete interest to us. Evidence shows that numerous teams operating in the field (measurement of pollution levels) have reached conclusions of considerable discrepancy ranging from zero to the threshold of risk: these teams had the top world specialists working in them.

The explanation for this discrepancy is the following: the measured quantities were, in reality, ambiguously defined and so the information in this limit case could not be transformed into reliable data. In the successive section, we will indicate the instruments and methods with which an attempt to confront these preliminary difficulties in the cognitive process may be made, difficulties that are unknown or at least more easily overcome in the traditional laboratory experimentation. In such a case, the problem is how to imagine or put into practice the appropriate apparatus: an aim which is not easy or always possible to reach, and with obstacles that are qualitatively different from those of the collection of information in experiences outside the laboratory. Here, the monitoring – when made possible – is not even able to filter the "indicators" efficiently enough and so render all the information useless. A totally different approach has to be taken where the analytical analysis and model–making processes are concerned, although it is just as necessary to revise old methods. Nowadays, it is generally accepted that in the formulation of a model or even of a more general theory, the part played by "human invention" is not easily controllable. The only sensible proof that is possible and may be accepted, is that which is derived from a rigorous deductive logic (mathematics, for example, may use axioms that are foreign to common sense, but in order to draw conclusions impose an absolute methodological severity). This situation has been recognised, although with some difficulty and certain reservations sustained by various schools of thought, and is exemplified in Einstein's famous opinion that valid scientific theories are simple and *beautiful*, where the improbable use of an aesthetic category is introduced with surreptitious irony. The concrete result of such a choice, very positive in our opinion, has been the greater freedom of epistemological research, once it is established that such research is necessary.

This freedom of research, however, must not exclude in our opinion definitions, assumptions and concepts of the traditional epistemology. A research method that may be slower but certainly more sound, and above all more "communicative" to the scientific community, is one that, without denying the existence of it from the beginning, selects a starting point from within sound thought systems by looking for it in "the darkest corners". This has been the strategy so far taken by the principal scholars of complexity. What is anomalous about this fact, if one can call it thus, is that these scholars are essentially physicists and mathematicians, with some biologists and some (very few) humanists. It would be counterproductive to emphasize this factor right from the start: the object of this research is to reconstruct the cognitive process. Since our jugment must be given only according to the final results, in this introductory presentation we will analize the relationship between phenomenal reality and models, without worrying too much about its explicitly physico–mathematical connotations.

This topic may be introduced by expressing a simple and shared opinion: experimental observations are based upon the measurement of various quantities, that is to say, upon the association between specific successions of numbers and given successions of events. These quantities are operatively defined, i.e. they are defined according to the same succession of operations carried out in order to determine the number which represents the measure.

These operations are not always well defined, and upon careful examination, may reveal that they do not fulfill the necessary requirements in order to be considered a mathematically precise notion. A physicist would not be interested in these aspects: he would consider a certain quantity well defined when the empirical procedure involved in the measuring of it is clear. The measurement procedure would be considered clear when all the observers obtain the same results when measuring the same quantity. It is important to stress that this is an empirical criterion and one which is eternally subject to being revised.

Measurements that are now considered by physicists as clearly defined, in the future could well be different, with a poorer degree of definition. A physicist, therefore, from the observations that he makes on the world, obtains a series of numbers which correspond to specific operations considered to have been objectively defined. In order to arrange these numbers into a coherent pattern, often (although not always), a physicist utilizes models, that is, he makes an association between the measurements taken and well defined mathematical structures, and then tries to establish a (small) number of mathematical relations between these structures. This logically leads to further deductions, which reinterpreted through the use of a model (in the inverse sense), can then serve to predict the relations between empirical measurements which have not yet been examined. The same faith in the existence of sound models led scholars of the 17th century to state that philosophy is written in this huge book that is always open before our eyes (I mean the universe), but can only be understood if first the language and the letters it was written in, are learnt. It is written in a mathematical language, and the letters are triangles, circles, and other geometric figures, instruments without which it would be humanly impossible to understand a word; without these it would really become like a futile merry–go–round in a dark labyrinth. A mathematical model is considered to be satisfactory if it does give contradictory results when put into practice. If this happens, however, a physicist would eliminate it as an "incorrect" model, even though its mathematical construction would remain valid as a witness to the imperfect representation of the nature.

In strict sense, all models are incorrect: at most there are models that have not been proved to be incorrect. Moreover, often when a scientist analyses the mathematical properties of a model which proves to be "incorrect", at the same time he finds useful tools to formulate an improved model (which is the true aim of the research).

Therefore, it is clear that the relationship between physical reality and mathematics is established by what we have called a "model". It seems impossible, however, to give a precise mathematical definition of a model which is in itself empirical. One may only understand its real meaning by taking into consideration some concrete examples.

If another scientist were to take the place of the physicist, the considerations proposed would remain correct. Galileo talks of mathematics and of geometric figures: in our analysis, mathematics and geometric figures will probably be much more complicated than the traditional ones, and have perhaps not yet been known or understood – but the whole history of science shows that these new formulations could not make sense without them.

The Tools. Some examples of advanced methodologies

To talk of tools in order to consider the problem of complexity is naive and pretentious at the same time. Hopefully the reader will concede this 'poetic licence' to the authors: it would not be easy to define the combination of mathematics, logic and computer science in any other way – these days, poetic licence is taken (or so one says) in the desperate attempt to understand such a "complex" subject.

Interactive Data Base

The methodological approach we want to take starts from the following observation: complex systems cannot be easily defined in terms of the logical and procedural rules of the laboratoty experience, i.e. the measurement of quantities in a repeteable phenomenon, for many different reasons (Garey–Johnson 1979).

In the first place, the phenomena which we are considering take place outside the laboratory without any chance of repeatibility: well–known examples are historical, economical and climatic events. It is easy to imagine why the gathering of informations is problematic. Information and not data: the first problem to consider is, in fact, how to transform the gathered information into sound and meaningful data. Computer science and statistics are the most important tools in the preliminary process of interpreting observed phenomena, investigated according to a class scheme, and, in a more general perspective (that is still far from being understood), of combining such interpretations into a theory of complexity. A more thorough research of the technical aspects of this process will not be looked into in this work. Moreover, it is not an exaggeration to say that the existing scientific and technical literature on the subject is immense; therefore it would be senseless to give bibliographical references other than those quoted below in the *Applications*. We will limit ourselves to making a description of the typical methods adopted for such research. One could start with the formulation of an interactive data–bank pertinent to the investigated phenomena. This data–bank offers the possibility to organize the collected information into a structural relationship, which would then enable the elaboration of statistics at different levels of complexity. These are the following:

– elementary statistics, which enable one to analyse absolute frequencies and to make simple correlations;

– multiple statistics, which enable one to make statistical analyses of more than one variable (examined simultaneously) in relation to several objects;

– cluster analysis, which enables one to select data according to a predefined model, in order to make groups composed of similar elements;

– other methods like factor analysis, discriminant analysis and multi-dimensional scaling analysis all tend to reduce multidimensional problems into more "visible" and essential terms in the same way that cluster analysis does.

The hinging factor which leads to the elaboration and analysis of data (with a cautious use of terms here, since the processes we are describing may be resorted to through trial and error), is the method of scientific visualization and what are called 'expert systems'. Two characteristics of scientific visualization (which is connected to the notion of virtual reality, fig. 1) are important to emphasize: the simulation power provided by the instrument to the researcher, and its (excessive) arbitrariness which is only limited by a grid of "sound" facts available to the scientist. This kind of method would hardly be accepted by traditional scholars. They would insist upon a clearly defined threshold to the certainties and unambiguities for research results. In fact, the use of these analytical tools that are so powerful and yet also ambiguous, may only be justified by taking one further methodological step – that of the use of expert systems which work according to criteria where the Aristotelian logic of the third exclusive turns out to be softened or changed. This is essential in order to understand how much methodology has changed, and also in order to recognize the ambiguity as an intrinsic element of the representation of complex phenomena. In the next section, this topic will be looked at in greater detail.

Fuzzy Logic

In the traditional set theory, an object either belongs or does not belong to a whole. Fuzzy sets, however, from a certain point of view, violate the Aristotelian rule of the third exclusive: an element only belongs partially to a fuzzy set and may belong to more than one set. The degrees of fuzziness cannot be identified with percentages of probability and this is a tricky point which has led to some confusion amongst critics. Probability measures the possibility of something either happening or not happening. Fuzziness measures to what degree something actually happens. The statement that "There are thirty chances over one hundred that it will be cool", tells us what is the probability of there being cool weather; but 'This morning seems to be only 30% cool', means that it seems to be quite cool and yet, at the same time, is pleasantly warm. The only limit is that the belonging degrees of an object to complementary groups have to make a unit sum.

Fuzzy logic, which enables the formulation and regulation of fuzzy sets, is based upon rules that may be expressed with the formula 'if...then': these rules transform an input into an output, both being presented in the form of fuzzy sets. In order to construct a fuzzy whole, one may start from a complex of fuzzy rules given by the expert in question; the degree to which the input and output belong to diverse fuzzy sets may be defined by using a series of mathematical curves: these curves may then help in the establishing of the relation between the sets. For example, the rule 'If the air seems cool, then regulate the engine according to a lower speed' – here the input (the temperature) should be put on the axis of a graph and the output (the engine speed) should be put on a second axis. The "sum" of these fuzzy sets forms a fuzzy patch: this is the area where all the mathematical associations established by the formula between input and output are represented. Fig. 2 gives an example of fuzzy logic application to this problem: it is shown that the use of fuzzy sets may lead to the formulation of precise instructions. The conditioner measures the temperature of the air and then determines the adequate engine speed according to fuzzy rules.

Almost all products available these days are based upon subjective rules provided by experts, who then engage in the long process of refining them, a job which is not always met with success. Nowadays, expert systems are used in order to render the process automatic. This is a methodology which has become very common; it enables one to use codified knowledge by simulating the logical–deductive reasoning of an expert and recording the successes and failures for the improving the code (one may speak here, although with caution, of a trial and error method). A very powerful system class is that of the neural networks, a set of *neurons and synapses*: this terminology is taken from the well–known structure and mechanisms of the brain and nervous system. The neural network acts like a computer establishing relations between output and input. A single neuron sums up all the signals coming from other neurons and then gives its own response in digital form. The signals spread down the synapses which, by means of its own numerical code, attribute different weights to the sign flow emitted by the neurons. When the input data activate the neurons in the network, the synaptic values may change slightly. A neural network "learns" when the values of its own synapses change. Networks can help to formulate the rules for a fuzzy system as if they were synapses, and they tend to conserve the changes that improve its functioning, while ignoring the others. The evaluation of improvement is obviously given by the increase in the relative frequency of success in relation to an objective which has stayed the same. It is evident that such techniques are useful only if powerful processors and adequate software are at disposal. A final point to remember here is one which is related somehow to the problem of adequate software. Fuzzy logic is susceptible like any other data processing model to a difficulty which can made unmanageable all problems: the number of fuzzy rules increase esponentially with the increase in the system's variables. Therefore, a compromise between the management of the system (big patches of rules) and the precision of the choices (inversely proportional to the dimension of the same patches) has to be found (Kosko 1991; Fadini 1979).

Dynamic Systems

In order to complete this analysis, it would be necessary to propose a formalized theory of complexity. This is the present frontier yet to be reached on the subject. In fact, there are no doubts as to the fundamental role played by data processing and statistics in the transformation of untidy and ambiguous information into homogeneous and coherent data. The proposals for methodological approaches regarding the second question are the same as those already described, that is they are to be based upon fuzzy logic. Empirical models of linking between variables provide the system with a control structure to refine its own criteria of choice (expert systems). The problem of identifiying a formal scheme for a (future) theory of complexity is of another kind. Research methods on the subject may be divided into two classes. The first methodological approach does not take traditional epistemology and the tools related to it into consideration at all, without offering at the same time (at least until now) a convincingly constructive alternative. The second approach which we will make brief mention of, departs from a traditionally piloted scheme – the theory of dynamic systems

– integrated with the notions of fractal set, deterministic chaos and order–disorder transition, all of which have emerged out of the restricted dominion of specialized mathematical research (see for instance Mandelbrot 1975; Woodcock–Davis 1982; Haken 1983). In order to discuss this topic, even if only in elementary terms, it will be necessary to look at some notions and basic definitions regarding dynamic systems.

Dynamic systems are systems that evolve over time according to certain parameters, which we will call control factors. Examples of dynamic systems are: astronomic systems, mechanical systems (cars, machine tools, etc.), thermodynamic systems which change according to temperature and pressure variations, price systems which regulate their equilibrium on the price change of important products (such as petrol) . Dynamic systems may be described (represented) in terms of dynamic variables, quantitative functions of time. The global representation of dynamic systems may be found in an abstract multidimensional space, the phase space. A coordinate of this space is associated with each dynamic variable. Certain characteristics of dynamic systems render them particularly interesting as "candidates" for providing one with a formal theory of complexity. The subdivision into *conservative* and *dissipative* dynamic systems is one of the characteristics which has been most studied, and is indicative of some of the problems which one has to face when dealing with complexity.

At a certain degree of approximation one may describe conservative systems as closed structures, that do not conduct exchanges with elements outside of the system; whereas dissipative systems may be seen as open structures where there is an exchange with elements from the outside. What do they exchange? In analytical mechanics, one talks of energy, in statistical mechanics of energy and particles; in our analysis, we can leave this question without an immediate answer. In fact, what is most interesting to us, at least in this preliminary phase, is the effect that the exchange (or non–exchange) may have for both kinds of system: chaos and stability, or both at different moments of the evolution of each system. Such an analogy is superficial even though not without some significance (for the most part still to be understood, and the same applies for the mathematical analysis of dynamic systems). In fact, by attempting a more in–depth study of stability, being an essential behavioural characteristic of the system, one discovers that stability may be observed in both kinds of system, but in very different forms. By making a simple qualitative analysis of these two forms of stability, one realises the extent of the difficulties encountered right from the start, even when using an elementary approach to a formalized theory of complexity.

Stability, in dissipative systems, particularly manifests itself as being asymptotic (that is, it reaches a state of equilibrium that is definitive and unchangeable), or by self–organization, which is a well–known phenomenon in scientific experimentation, although not been satisfactorily interpreted until now. Quite famous scholars, such as Prigogine, Haken and others, have proposed *ad hoc* theories for the interpretation of the phenomenon of self–organization, using the conceptual tools of thermodynamics and statistical mechanics. The direction which contemporary research is taking, concentrates more upon a better understanding of the change from chaos to a state of self–organization, which may be visually recognised for its geometrical, structurally regular characteristics; the so–called method of *Pattern Recognition* (Haken 1979; Sprandel 1972) deals with this aspect of the phenomenon. A crucial point in the theory of complexity is to understand how generalised this behaviour is (the transition from disorder to order and vice versa), and whether it manifests itself only in the case of dissipative dynamic systems. The theory of catastrophes, which analyses the behaviour of conservative systems by applying the notion of *structural stability*, seems to suggest a different and certainly better articulated answer. In the section dedicated to the *Applications*, there is an example of this (see also Bisteghi – Lo Vecchio 1993). The fundamental concept for understanding it is, in fact, the structural stability in a dynamic system, which may be characterized as follows: the time evolution of structurally stable systems remains qualitatively unchanged under the action of small perturbations; the same behaviour occurs for a system evolution depending on other parameters. It must be remembered that structurally stable dynamic systems are not generic. This means, from an operative point of view, that a preliminary analysis of the system is necessary in order to presume that it is structurally stable. Once this presumption has been made, the theory of catastrophes states the existence of a function of control parameters and dynamic variables with this following fundamental property: the zero points of this function represent the system equilibrium states, which are just the interesting situations for our analysis. There are also dynamic variables whose zero points represent the system's existing state, which is what interests us: that is, it presents a state of equilibrium. Fig. 3 shows a very interesting application of the catastrophe theory. On the basis of the available data, we traced a plausible outline for the situation under examination, that of the modernization of Iran and the consequent fall of the Shah's power. As in all applications of the theory of catastrophes, the kind of catastrophe presumed for the description of the discontinuity analysed may be simple or complex depending on the available data. In fact, such a degree of arbitrariness in the choice of basic characteristics of the abstract spaces in which the studied phenomenon may be represented is of great concern to physicists and mathematicians. On more than one occasion, they have strongly criticized the general outline of the theory, as the theoretical physicist, Bruno Vitale, did in the introduction of the Italian edition (1982) of the *Catastrophe Theory* by Woodcock and Davis (1979). However, there is a scientific theorem that drastically reduces the arbitrariness of the analysis while guaranteeing, at the same time, the possibility for a quantitative comparison of "similar and close" situations. This theorem (Marmo–Vitale 1977) states the following: in every system governed by a potential and whose behaviour is determined by not more than four different control parameters, only seven kinds of qualitatively different discontinuities are possible.

Through the researcher's direct experience, it may be shown that with four control parameters, it is possible to investigate a wide variety of phenomena that are more than sufficient at this stage of the analysis of complexity. This brief

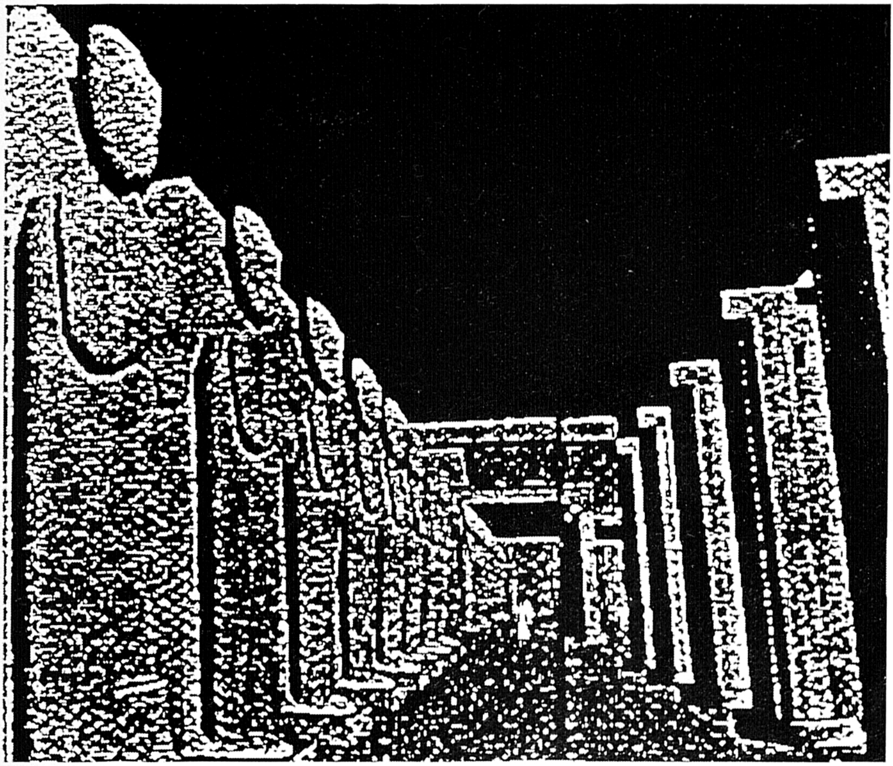

Fig. 1 – The temple of Amon in Karnak (electronic simulation by J.C. Golvin).

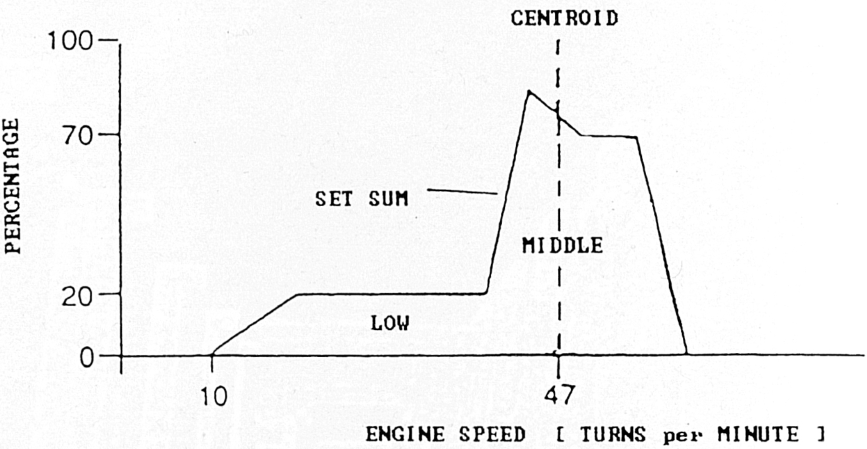

Fig. 2 – Correlation diagram between fuzzy sets: a temperature of 20° C. 20% "cool" and 70% "right", activates two rules which bring the engine speed to that determined by the centroid, obtained by the "sun" of the two engine output curves:
"low" speed < > "cool" temperature;
"intermediate" speed < > "right" temperature.

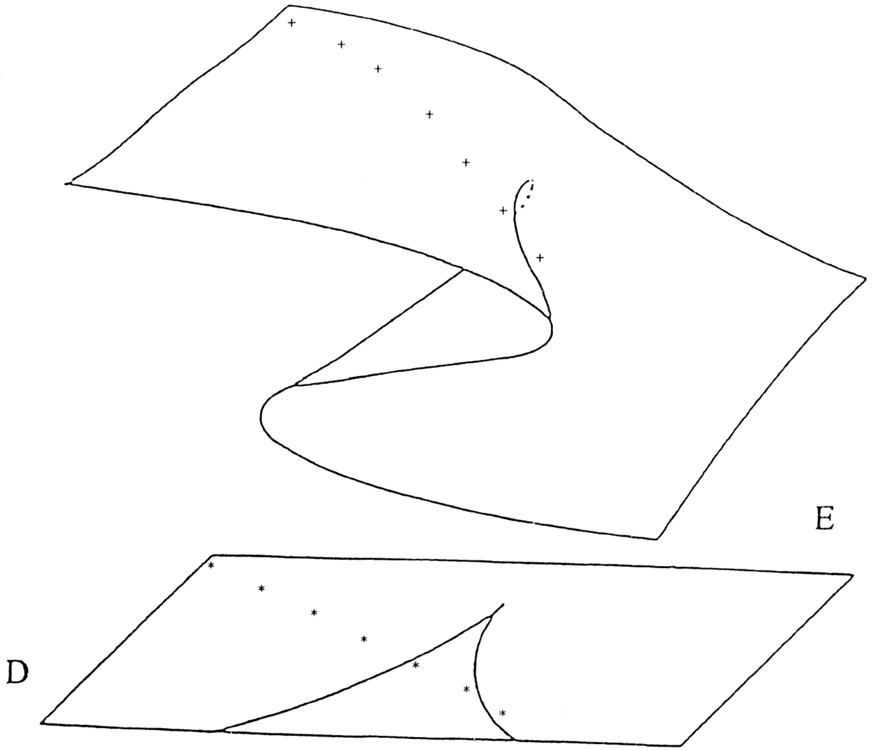

Fig. 3 – E economic control factor.
D demographic control factor.
+ Iran country *trajectory* in a 3-D representation on the zero potential surface (equilibrium point surface).
* Iran country *trajectory* projection on the E–D control plane.

mention of the various ways in which the theory of dynamic systems may be applied in these studies, indicates the extent of the difficulties involved when establishing a clear and accepted basis from which to construct a formalization strategy. On the other hand, as already explained in the introduction, the interest in this subject emerged not only out of scientific research. Economists and political analysts, in particular, firmly believe that they will be able to obtain sound tools for brief and medium term predictions (obviously according to the time scale which most interests them) from a convincing theory of complexity. In fact, it is no coincidence that stability as a factor in the study of dynamic systems has received so much interest and attention. This may lead to some distortions, such as those to be found in the attempts made to apply the theory of catastrophes to concrete situations (Zeeman 1977). This is nothing new, though, in the history of science. The relationship between the objectives of those in power and of those who conduct scientific research is by now a reoccuring theme in historical analysis and has become very popular amongst scholars of modern (and not only modern) history.

Applications. The Example of Iran

The example chosen to illustrate our considerations on complexity is that of Islam, with particular reference to the recent history of Iran (its modernization, the fall of the Shah, the emergence of the integralists). No answers will be given here, at least not in the technical sense of the term; what is analysed is rather the plausibility of the conceptual tools used, with strong emphasis given to the consistency of the framework.

Analysis Outline of the Chronology of the Modernization of Islam

The modernization of Iran presents itself within the general context of the modernization of all of Islam, with its particular characteristics as are to be found in the modernization of every Islamic country.

The first of these differences and characteristics to be examined is the chronology. The transformations that came about in Islamic societies are different, because of the particular period in which they occurred, and next because of the ways in which they took place. The very fact that these changes were brought about at different times, led to the different ways in which they took place, and to the different consequences they had on each society and, in general, on the historical evolution of Islam. In the first place, the different moments in which these changes came about, brought Islamic societies into conflict with the European societies they had contact with. If one hypothetically imagines that (we will see, however, that this was not so) these events had the same causes and developments, the very fact that they came into conflict with European societies at different times means that the consequences were inevitably different. Moreover, the diffusion and penetration of the ideas of a renewal of Islam within the Islamic world came about at different moments and to varying degrees from society to society. It is this problem of how to compare the chronological developments that must be brought into focus (Badie 1990).

This approach, which may seem to be neutral, provides us with a framework of the differential traits which, even if considered only for this aspect, could help to indicate how Islamic societies would evolve in a far–off time.

In other words chronology can indicate by itself the limits within which Islamic society can change and conform to the challenges made first by the European powers and then by the modern industrialized world. In order to make an 'evolution diagram', it is necessary to represent the evolution of Islamic societies and the moment of the impact of European powers by using two kinds of schematic descriptions commonly applied by historians in these cases.

The first one examines the inner developments of European societies and the moment in which they started to extend their power to other societies and in particular to the Islamic world. This is an approach which is often used by European historians to describe the impact that European societies had on the Islamic world. We will refer to the beginning of European colonial policy for our analysis as many historians do, and we will focus upon the policies adopted by Great Britain and France and less importantly upon those adopted by Germany and Italy. It is important to establish when the power in question initiated its penetration into the Islamic world, and to show the economical, strategic and cultural aims, as well as those of prestige, that it intended to obtain and the means by which it achieved them. Right from the start, it is possible to obtain substantial differences between the policies adopted by England and France, the two most important countries to consider. This approach is very well–known, and has been the basis for the historical analysis of recent Islam for a long time.

The second approach examines the internal evolution of each Islamic country – of their conditions at the moment when European expansion began, of the level of stability and efficiency of their governments. All this is analysed independently from the relations that the Islamic world had with Europe, only their internal dynamics being considered. When the expansion of the European powers began, the level of civilization reached by Islamic societies was not generally inferior to the most evolved of European societies. We know this from the records of many travellers in Persia, India and China: generally speaking, the admiration they expressed for the great works of these empires was genuine; there is no sense of superiority in the observations made on their institutions and the capability of their governements to rule well. On the contrary, throughout the 17th century the myth of Imperial China and of the Great Sophi was used as an example to Europe of the greatness of state power, and it was this, together with the founding myth of exoticism, which permeated European culture. The magnificence of those countries blinded the European observers to the problems and weaknesses of their state formations, which were soon to bring about their decadence and ruin. The observations made by European travellers show, however, that there was not a great difference in the effectiveness of state power between European and Islamic states at this time: in certain areas, the Europeans were definitely at an advantage, but generally speaking, these differences could be overcome. Actually, the disintegration of the Islamic states had already begun, and because of the conflict with European powers, that which could have been a temporary crisis of any complex society was destined to become more final. Since the start of the crisis, the European invasion of each Islamic state had diverse effects, not so much for the different ways in which they were invaded, but more because of the existing internal situations of each state at the moment when they were invaded. Two parallel processes examined from within and in some way linear, came into contact with one other at different moments and produced diverse effects.

Analysis Outline of the Fall of the Pahlavi Monarchy in Iran: a Historical Approach.

Our initial proposition was that history is comparable, that it is a series of comparable events. At the basis of this idea is the whole of storiography starting from Vico, which scholars maintain enables one to trace permanent structures of ciclically reoccurring situations within the history of a people. Lévi Strauss' work may be mentioned here in passing as an example of a structuralist approach to anthropology; but it is more pertinent to recall the pursuit of our past proposed by some scholars of ancient history (Nissen 1990), that is, the passage from history to protohistory to prehistory. The decreasing number of written sources and, finally, their absence, means that firstly models for ancient economy, and next of ancient society are to be founded with increasing frequency upon the archaeological evidence or even – more daringly – upon anthropological analysis, which compares the similarities in contemporary and prehistoric situations. Then there is historiography which analyses history as the history of civilizations and, within it, traces a certain number of cultures that are comparable: the most significant and famous example is that of Toynbee (1967). He not only outlines a definite number of cultural models, but also compares their institutions by identifying common elements with different contexts and uses. A recent example of this approach, in our opinion, is the model of Indian society described by Louis Dumont (1991), in which the same elements of hierarchy of caste are recognized in India as well as in other Arian societies, only that in India they manifest themselves in another way and the power is held and exercised according to a different scale. It is important to emphasize this fact as a starting point for the analysis of the question from within the discipline: this is an approach which in principle does not give great importance to the definition of a major cause for historical events. What is fundamental is to take into consideration all elements without being limited by external factors: such an approach is appropriate for the creation of models of comparison to which the methods and techniques of the "hard" sciences may be applied.

In our opinion, it is fundamental to insist upon this approach from within (based upon considerations on historical methods), to keep away and, if possible, to avoid the risk of imposing on a discipline methods belonging to another discipline: this imposition inevitably leads to a useless exercise of parallel tautologies (such as when the language of literary criticism is applied to music criticism, or to figurative criticism and vice versa, etc). This is all the more important if our intention is, as in this case, to apply scientific methods to a humanistic subject or more exactly, mathematical methods to history. Therefore, one must find a historical formulation that is compatible with a mathematical model and one which may be used to represent historical facts without changing their significance. In our opinion, a promising start is the consideration of a cyclical concept (even if from an oblique angle) or the search for types, cultures and models in historical developments. This approach does not betray traditional historical methods and, at the same time, takes into consideration the methods employed by the social sciences in historical analysis without giving particular priority to any one of them. In other words, history that is seen as a juxtaposition and interaction of cultures, elements and subelements, may be defined with the use of static and dynamic models created through the comparison of similar and compatible factors. If one is able to define a certain number of static and dynamic situations by comparing homogeneous data, this method may be very useful. The problem then is how to rationally select facts which may be considered together and used to create mathematical representations for models. One may ask whether our definition of the Islamic system may be obtained through the use of categories ("variables") specifically related to the nature of the problem, such as secular and religious power, popular consensus and other similar factors, without falling into the trap of pointless tautologies and ambiguities. This experiment was attempted in the theory of catastrophes for the fall of the Pahlavi dynasty in Iran by using two general parameters, one being demographic and the other being economical (Bisteghi–Lo Vecchio 1993).

We would like to propose here two other parameters that will be similarly useful: those of secular and religious power, to be quantitatively defined through the application of fuzzy logic. We assumed the following to be the measurable elements of what we defined as secular power: the "quantitative" institutions of schools, banks, administrative offices etc. introduced by the reform of Reza Khan in Pahlavi Iran. These institutions deliberately imposed by the Shah were previously nonexistent. Other easily quantitative factors which we ignored were roads, railways and telephone lines, because these would have been difficult to confront with the religious institutions, that is, the mosques, Koran schools and bazars.

All these equally objective facts, although difficult to place in one category, may be represented on an x and y scale, x being for the category of secular power and y being for the category of religious power. For example, bazar individuals and their capital may participate in the creation of a modern economy and finance, as modern individuals and institutions may share and practise an Islamic vision of the modernization of society. This is in fact what happened (Taheri 1989).

The problem of ambiguity of the notion of "measurement" for the "variables", from which an unacceptable degree of vagueness is derived in the process of model formulation, may be confronted with the use of fuzzy logic. As previously illustrated, this enables one to measure phenomena that are 'out of focus' such as the belonging of an individual to a secular or religious institution. To give an elementary example, one may establish a quantitative relation between the number of "fuzzy" mullahs and the religious power, that is, one may "measure" the extent of religious power and other similar "variables" at a certain time; in the same way, one may establish a quantitative relation between "fuzzy" entrepreneurs, teachers and secular power, thus repeating the model formulation already calculated for the economic and demographic variables (fig. 3).

In this way, like the economic and demographic curves considered for the countries examined by Bisteghi–Lo Vecchio (1993), which only in the case of Iran led to a "catastrophe", the analysis of the relation between secular and religious power, only in the case of Iran will probably lead to a similar definition of a "catastrophic crisis". This is therefore another element of the descriptive capacity offered by the model. What we are dealing with at the moment is really hypothetical, because, as we explained, the rules of fuzzy logic cannot be determined a priori. Another even more subtle ambiguity is created in this way, given the relationship between the observer of the historical phenomenon, who in this case has to establish the rules of identification, and the phenomenon itself. The historian becomes subjectively involved in the events he observes, and the elements under examination determine the very events with which they interact. This relationship, which is experienced to varying degrees of awareness according to each different situation, may have a negative influence on the objectivity of the representation, as it would depend upon who the observer is – and in our case, he is a historian.

There are many analogies between this situation and the well–known problem faced by physicists studying quantum mechanics. During the measurement process there is a significant interaction between the measurement itself and the quantities measured, particularly in the atomic and subatomic processes. Until now, no satisfactory solution has been found for this problem of ambiguity which is expressed by the principle of uncertainty. To conclude, one may say that nowadays many physicists propose good arguments for doubting the interpretative capability of quantum mechanics as far as systems of many degrees of freedom and, in general, complex systems are concerned. One could 'negatively' justify the use of "hard" science methods in the historical field, given that subjectivity is no longer only a characteristic of the humanistic subjects, but also of the sciences, and therefore cannot be the only reason for doubting a historian's scientific soundness.

References

Badie, B. (1990) *I due stati,* Genova (or. edn. *Les deux états*, 1986. Paris).

Bergé, P. , Pomeau Y. and Vidal C. (1984) *L'ordre dans le chaos.* Paris.

Bisteghi, U. and Lo Vecchio, G. (1993) La modellizzazione dei sistemi storico–politici: il caso esemplare dell'Islam, *Annali dell'Istituto Universitario Orientale.* 53, pp. 255–265. Napoli.

Dumont , L. (1991) *Homo hierarchicus*, Milano (or. edn. *Homo hierarchicus. Le système de castes et ses implications*, 1966. Paris).

Fadini, A. (1979) *Introduzione alla teoria degli insiemi sfocati*. Napoli.

Farmer, J.D. and Sidorowich, J.J. (1988) *Evolution, Learning and Cognition*. Singapore.

Garey, M.R. and Johnson, D.S. (1979) *Computers and Intractability*, Oxford.

Haken, H. (1979) *Pattern Formation by Dynamic System and Pattern Recognition*. New York.

Haken, H. (1981) *Erfolgsgeheimnisse der Natur*. Stuttgart.

Haken, H. (1982) *Evolution of Order and Chaos*. New York.

Haken, H. (1983) *Advanced Synergetics*. New York.

Kosko, B. (1991) *Neural Networks and Fuzzy Systems*. New York.

Mandelbrot, B. (1977) *Fractals: Form, Chance and Dimension*. San Francisco.

Marmo, G. and Vitale B. (1977) La teoria delle catastrofi, in *Sapere*, 80, n. 804, Milano.

Monod, J. (1970) *Il caso e la necessità*, Milano (or. edn. *Hazard et Nécessité*, 1970. Paris).

Nicolis, G. and Prigogine, I. (1977) *Self–Organization in Non–Equilibrium Systems*. New York.

Nissen, H. J. (1990) *Protostoria del Vicino Oriente*, Bari (or.edn. *Grundzüge einer Geschichte der Frühzeit des Vorderen Orients*, 1983. Darmstadt).

Sprandel, R. (1972) *Mentalitäten und Systeme, Neue Zugänge zur mittelalterlichen Geschichte*, Stuttgart.

Taheri, A. (1989) *Lo spirito di Allah*. Firenze.

Thom, R. (1980) *Stabilità strutturale e morfogenesi*. Torino (or. edn. *Structural Stability and Morphogenes*, 1975. Reading).

Toynbee, A.J. (1967) *Il mondo ellenico*, Torino (or. edn. *Hellenism, The History of Civilization*, 1959. London).

Waldrop, M.M. (1992) *Complexity. The Emerging Science at the Edge of Order and Chaos*. Santa Fe.

Weidlich, W. and Haag G. (1983) *Quantitative Sociology*. Springer Series Synergetics, 14. New York.

Woodcock, A. and Davis, M. (1982) *La teoria delle catastrofi*. Milano (or. edn. *Catastrophe Theory*, 1979. New York).

Zeeman, E.C. (1977) *Catastrophe Theory. Selected Papers 1972–77*. Reading.