Archeologia e Calcolatori
Supplemento 6, 2014, 15-52

# ANALYTICAL ARCHAEOLOGY AND ARTIFICIAL ADAPTIVE SYSTEMS

## 1. Back to the future. A tribute to the memory of D.L. Clarke (1937-1976)

In the late 1960s, David Leonard Clarke published *Analytical Archaeology*, a brilliant and unique synthesis that intended «to draw attention to specific areas and archaeological periods towards the General Theory that is the basis of modern archaeology» (Clarke 1968). At the same time, the Author introduced the first chapter of his main theoretical essay with a quote from Lewis Carroll's novel *Alice's Adventures in Wonderland*: «here … you must run as quickly as you can, if you want to stay in the same place». Since then a quick run has been carried out but, even though the archaeologies have been approaching new methods, tools and techniques, the heart of Clarke's reflection on drafting a new General Theory of the archaeological thought has slowly dissolved. It has been assimilated in the story-boards of studies and registered as an unresolved utopia, nonetheless interposed between the current scientific archaeology and the earlier or pre-paradigmatic archaeologies – as they have been named.

This Supplement to «Archeologia e Calcolatori» is the empirical consequence of theoretical approaches I advanced in *Archeologia e Semiotica*, since it derives from the desire to renew the empirical research on complex phenomena applying the new methods of Artificial Intelligence through the lens of Analytical Archaeology and collecting different and specific applicative case-studies (Ramazzotti 2010, 128-170). We do not know if this kind of intervention on the record's semiosphere, on the past interpreted and on the past to be interpreted, will contribute to the «loss of innocence» hoped for the future growth of the discipline by Clarke (1973), but we are convinced that the new research methods opened by Neurosciences and Artificial Intelligence will add an inner critical view-point on our present and future works.

*Analytical Archaeology* is perhaps the most representative, unfinished, document of the humanistic interest for data semantics, a grammar for the analytical reasoning and a syntax for its cognitive structures. A world-view is underlying it, but has not been performed or emphasised yet; the archaeological theory is strictly linked to the philosophy of science and becomes experiment. The first systemic natural and cultural mechanisms are now described without formulas, with the distance from the tool the humanist should maintain, without ignoring their logics. It would be pointless to read *Analytical Archaeology* without having first tried to imagine what contexts

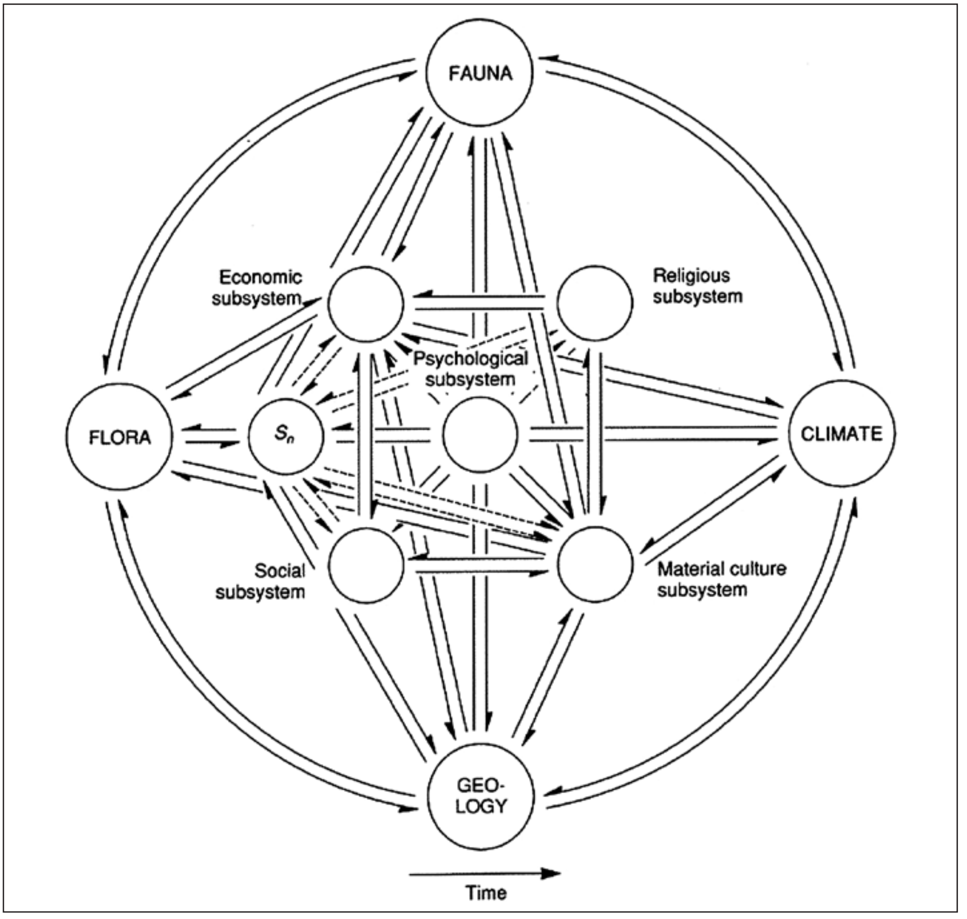



Fig. 1 – Culture as a system with subsystems. A static and schematic model of dynamic equilibrium between the subsystem network of a single socio-cultural system and its total environment system. The internal setting of subsystems within the general system constitutes cultural morphology, as opposed to the external setting of the system in its environment, comprising cultural ecology (Clarke 1968).

were behind the analysis of real world's segments through the processes, systems and models. Yet Clarke appears to have nearly revived this approach to the so-called complex phenomena, by attempting to qualify not only the form and matter of the record, but also the interconnected networks of "entities" able to simulate dynamic relations (Fig. 1).

In the UK, after Gordon Vere Childe (1892-1957), John Grahame Clark (1907-1995) argued, in an original way, its clarification in the concept of culture. Clark's major works are influenced by the theoretical commitment of the Australian archaeologist, although the Cambridge scholar sought not so much to act on the semantic level of the object, but rather on how Palaeoeconomy, with the contribution of natural sciences, would be able to recognise the subsistence techniques (Coles 2010). And it is this attention to the method's superstructure to be still intact in the *Analytical Archaeology*, because although Clarke was certainly addressed to collect the best techniques (statistical and mathematical) to analyse and classify the archaeological records in their spatio-temporal contexts, his work would probably never have been conceived if it were not firmly concentrated on the discipline's redefinition founded on the analysis of the data multi-factorial meanings (Ramazzotti 2010, 171-198).

In other words, what these considerations denote is the fact that this British Archaeology and its ideal-types, structures and models, by studying the archaeological data with the help of empirical languages, supported a deep knowledge of the record's semiosphere and of the relationship between structure and superstructure, but was also extremely involved in the evolution of the scientific-materialist thought, interpreted as a form of cognitive process, and adapted it to the questions posed by the philosophy of science. In this perspective the scientific-materialist thought seems to have answered these questions, about a decade in advance, with the criticism of the post-processualists, who were boasting of the primate of historicism in historiography, and of their idealistic methods. In fact, in the late 1970s, British archaeologists were also among the first to move from that epicentre to collaborate directly with French economic anthropology: so, while the early works of Ian Hodder insist on the non-linear relationship between structure and superstructure (Hodder 1982), those of Daniel Miller and Christopher Tilley, shortly after, are already focused on the concrete possibilities offered by the archaeological techniques to the reconstruction of the ideology of power through the study of material culture (Miller, Tilley 1984).

In addition, in conjunction with the external use of the materialist lexicon, other researches, such as Trigger's, focus on the Marxian evaluation of the impact of the social conditioning on the historical-cultural criticism (Trigger 1981b), and yet others tend to introduce the debate about objectivity and subjectivity in the historical analysis (Rowland 1984). In 1968 Clarke proudly defends the centrality of his own research position by repeating that: «archaeology is the archaeology, is the archaeology, is the archaeology», in the sense that – we would add – it transformed the grammars of the archaeological contexts in coding languages, summarised those languages in theoretical models, approached the model-system relationship in terms of logic (proposing a logic-based approach to the relationship between model and system), and inaugurated the thriving debate on the applicative use of inferential statistics. This archaeology does not minimise the complexity of such abstractions, but goes much more in depth in the conquest of the semantic significance – if this term can be adopted – of the document.

## 2. From System Theory to cognitive complexity

The attempt to increase the expressive potential of the record induced Clarke to treat it as a sign (*sema*), interpreted not as a unit in a system explaining only its historical and anthropological meanings, but rather as a node connected to a network of open cultural, technological and biological variables in continuous combination with each other. By comparing the supposed operational rules of organic systems and cultural systems centred on artefacts, *Analytical Archaeology* operates the brilliant conversion of the cultural complexity into a physical-biological complexity. This is the indelible legacy left by Clarke's early and greatest work, which also led to the desire for a radical transformation of the cognitive morphology of the discipline (Fig. 2).

However, by talking of this transformation of the discipline we should not simply mean an attempt to summarise the cultural complexity, since that would represent, and Clarke was aware of this, a somehow fruitless attempt. But we should rather highlight the fact that the models he created and classified always aimed at specifying every assessable segment of cultures, conventionally understood as Complex Systems. This measurability of relationships, mapped out with the pioneering aid of Cybernetics, was *de facto* the first and still unequalled attempt to offer an explanation for the operation regulating the interaction between the parts of a system, an explanation that would be able to make decisive use of the contribution of both mathematics and the nascent new mathematics.

Cybernetics, which Clarke explored as the direct expression of Systems Theory, offered him an appropriate language to consolidate the analogy between cultures and organism and, in the early 1960s, Cybernetics was essentially intended as the mechanical operation of interconnected parts; driven by an input, these interconnected parts would be able to report the whole procedure which caused the alteration of the *equilibria*, and the results observed would not be very dissimilar from those observable in the so-called cultural systems.

The contemporary computational models that are still using analogue operators are divided into three types (French 2002):

1) Symbolic models: they refer to the paradigms of Artificial Intelligence and allow analogue codification of information to be examined by constructing more extended generic classes;
2) Connectionist models: they process relationships between differentiated objects and classes of objects, allowing the degrees of similarity to be measured;

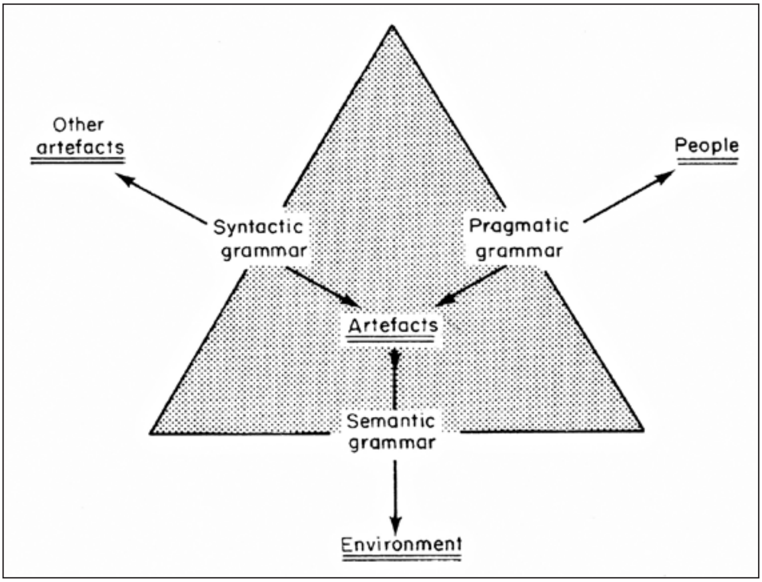



Fig. 2 – The three archaeological interactions grammars (Clarke 1979).

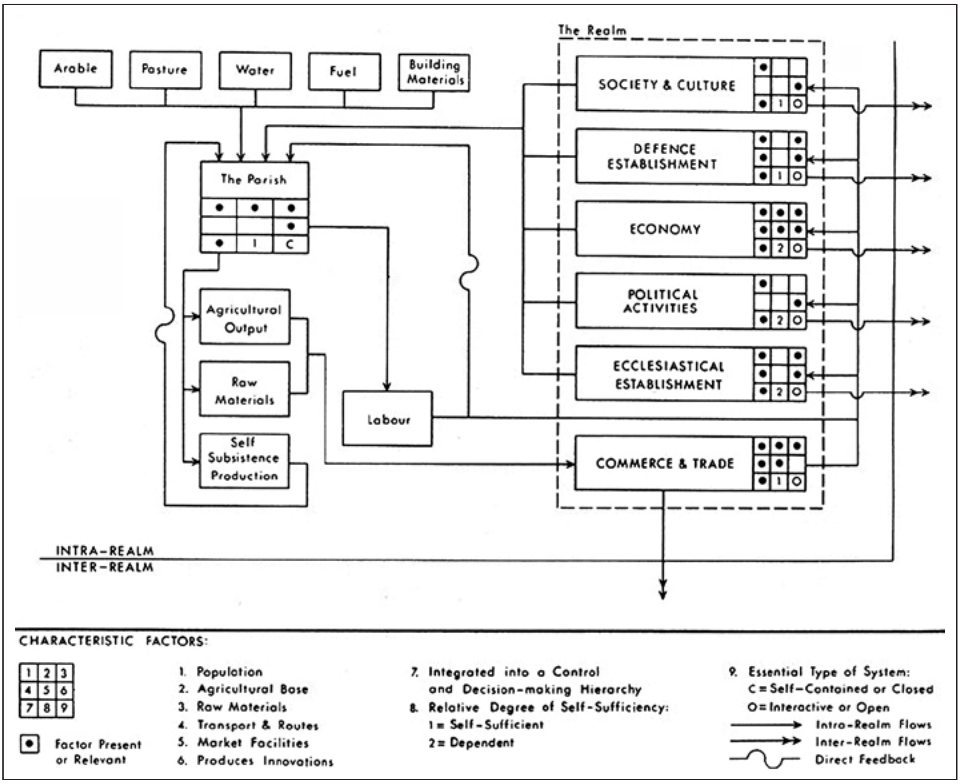



Fig. 3 – Code that formalizes the systemic operation of a Danish parish defining logical operating characteristics (Clarke 1979).

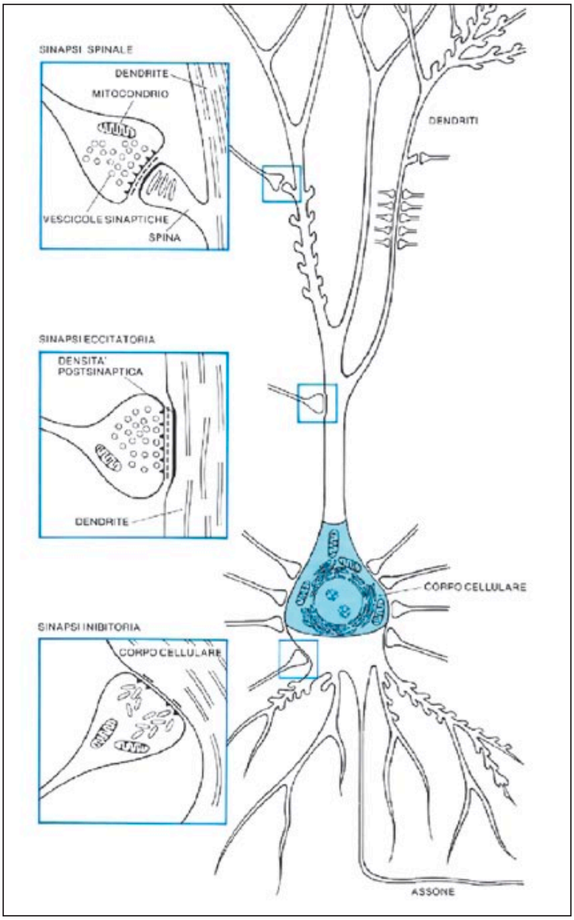
3) Hybrid models: they constitute architectures which integrate the functions of the first and second groups.

This mechanisation of the cultural complexity, as well as its transfer to the level of the mathematical discussion of the action performed by one or more factors on its entropy (Edelman 2004, 131), has then inspired almost half a century of experimental archaeology and has become a standard practice in the anthropological research, above all in the USA. Over time, nevertheless, the measurement of the difference between Cultural Systems and Mechanical Systems has been turned into the study of the cultural complexity through its reduction to groups of calculable parameters, and Clarke's central idea has been, in a certain sense, set aside (Fig. 3).

The insertion of the cultural variability in the more refined and contemporary Systems Theories and Expert Systems prevented from the search for other possible analogies that could have been involved to solve highly complex problems and, above all, radicalised a unique meaning of complexity itself, in other words its expression as external to man and independent of the human cognitive nature, as a product existing in and of itself and being the specific topic of the research (for these issues opened up by Computational Archaeology, see: Clarke 1962, 1968, 1972; Binford 1965; Gardin 1970; Level, Renfrew 1979; Bintliff 1997; Barceló 2008; Ramazzotti 2010, 171-198, 2012, 2013a, 2013b).

But at the end of the 1980s, numerous studies resurfaced in the attempt to understand complexity no longer as external to man and subject of our predominantly applicative research, but rather as a living expression of our constructive, mnemonic, perceptive capacities. In this sense, complexity was almost completely removed from the undisputed supremacy of external interpretation, able to be analysed through mechanical and linear systems, and became the subject of specific researches which aimed at recognising the man's cognitive development (that created it). The analogy between cultural complexity and the complexity of intelligence then gave birth to a new system of theoretical knowledge, methods and applications correlating archaeological research and Artificial Intelligence.

Those theories, methods and applications are already in use and identify a whole new world of archaeology, which is not a paradigm of it, as Cognitive Archaeology aims to be, but a (contemporary) way to undertake the same historical reconstruction (for the issues opened up by Cognitive Archaeology, see: Zubrow 1994; Doran 1996b; Gardin 1996b; Djindjian 2003; Zubrow 2003; Malafouris, Renfrew 2010; Ramazzotti 2010, 128-198, 2013a, 2013b). Indeed, while we certainly cannot debate the possibility to recreate intelligence artificially, it is equally evident that many models emulate and quite clearly come close to some segments of the cognitive process – memorisation, classification, orientation, reflection and perception (Fig. 4).

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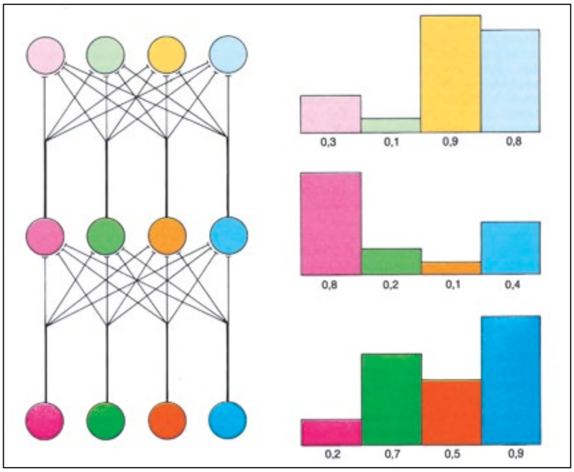


b

Fig. 4 – a) The synapses, which are based on a neuron in the brain, are excitatory or inhibitory depending on the neurotransmitter released (Storti Gajani 1982); b) Example of a three-layer ANNs in which input neurons (bottom left) elaborate a configuration of activations (bottom right) and transmit to one hidden layer (centre) on the basis of synaptic connections weighed. Hidden layer elements sum the inputs and produce a new configuration of activations (above) which is determined by the intensity of the connections between neurons (Churchland, Churchland 1982).

Transferred to the level of the necessary logical-mathematical identity, the "entities" of the cognitive complexity can be compared with nodes (neurons), and the relations (synapses) which regulate their inner dynamic functions (networks) are called connections (on the operation of Artificial Neural Networks, see: Minsky 1954; Minsky, Papert 1968; Amari, Arbib 1977; Grossberg 1982, 1988; Hopfield 1982; Anderson, Rosenfield 1988; Zeidenberg 1990; Kosko 1992; McCulloch, Pitts 1993; Arbib 1995; Kohonen 1995; Bishop 1995; Kasabov 1999; Szczpaniak 1999; Smolensky, Legendre 2006; Ehsani 2007; Nunes de Castro 2007; Buscema, Tastle 2013; Tastle 2013).

The terms imply another important "conversion", that of the biological-cognitive complexity of the world of intelligence into physical-cognitive complexity of the system of intelligence which, in this manner, enhances the processes of simulation and analysis by advanced computational models. Today, there is unceasing talk of Computer Semiotics as a discipline aiming at establishing the function of the logical operators of programming on the basis of structured and complex semantic units, but the semiotic analyses centred on redefining the analytical object are also one of the main trends in Computer Science and, in particular, in the sector interested in constructing nodes or cells composing many of the artificial models of the Artificial Adaptive Systems' class (Beckerman 1997; Miller, Page 2007; Ramazzotti 2012, 2013b), whether they are synthetic representations of the observed reality which must undergo interrogation processes (Expert Systems, Cellular Automata, Logical Networks) or the most advanced analytical tools for learning and modelling complex configurations (Artificial Neural Networks, Contractive Mapping, Genetic Algorithms).

Given these basic coordinates, it seems clear that simulating the behaviour (dynamic and complex) of the high variability of the cultural factors in networks thus conceived equals tracking down, selecting and recreating (separately) a wide variety of functions associating variables, a wide variety of inferences controlling their semantic structure and an equally wide variety of causes producing their transformation (Zubrow 2003; Bintliff 2005; Barceló 2008, 154-184; Renfrew 2008; Malafouris, Renfrew 2010).

This perception of functions, inferences and causes that generate and multiply the complex phenomena requires an archaeology interested in interpreting the past by debating the history itself of its different perceptions and, at the same time, attentive to the recognition of the cultures complexity by contrasting the classical and dualistic models, in order to display all its extraordinary variability and richness. In this specific sense, the application of Artificial Intelligence models to the archaeological problems has value: it recreates a possible world of other associations of meaning from the body of lacking sources and dispersed information, exhibits the nuances and complex interrelations and, furthermore, helps the researcher to codify other, unforeseen (or hidden) interrelations. In a certain sense, this is in itself a sort of metaphor illustrating the fact that the intelligence's complexity is related to culture's complexity.

## 3. Encoding cultural systems through the construction of a *lingua characterica*

The logical-formal description of the cognitive complexity is the subject of the latest epistemological debate in History, Archaeology and Anthropology, since cognitive complexity must be intended as one of the most important themes for the construction of a research method. Since the mid-1980s descriptions have been advanced using data coding techniques, intended as scientific tools for the construction of a *lingua characterica* capable of generating valid propositions and of overcoming the structural constraints of these artificial languages. It is almost natural that this intent is now bringing to the renewal of interest among those, especially historians and archaeologists, who founded their researches on deductive reasoning according to the Aristotelian and Kantian tradition, since the *lingua characterica* translation of the possible historical, archaeological and anthropological contexts – as Clarke already perceived – represents an attempt to recover the information exchange of every lost item (Clarke 1968, 485-486).

### 3.1 *The deductive inference*

Analyses and methods using the deductive inference tend «to *predict* the Result of a (true) Law through a Case» and to return that result (model) which represents a projection of the historical meaning ascribable to the data, in other words its prediction. Nevertheless, it has been noted that no automated reasoning programme can be universal, in the sense that it is necessary to decide for any set of inference rules and axioms, whether or not a given symbolic expression is a theorem of the theory in question and, if it is, supplying an effective deduction procedure (Pessa 1992, 83). Within the Humanities, the observations of the mathematical, statistical, economic and geographical relationships processed for a given body of data are represented with tables, matrices, histograms and dendrograms which perform the dual purpose of spatialising and structuring the values, the percentages, the trends and the intersections between a limited number of variables. These graphs are therefore models which summarise the repeated observation across multiple cases, as a result expressed through frequencies whose different variation and intensity always constitutes a degree of (cultural) intentionality. The cultural intentionality in a given production of artefacts indeed presupposes the concept of "type" as a principle, a finite planning entity, expressed by the intentional

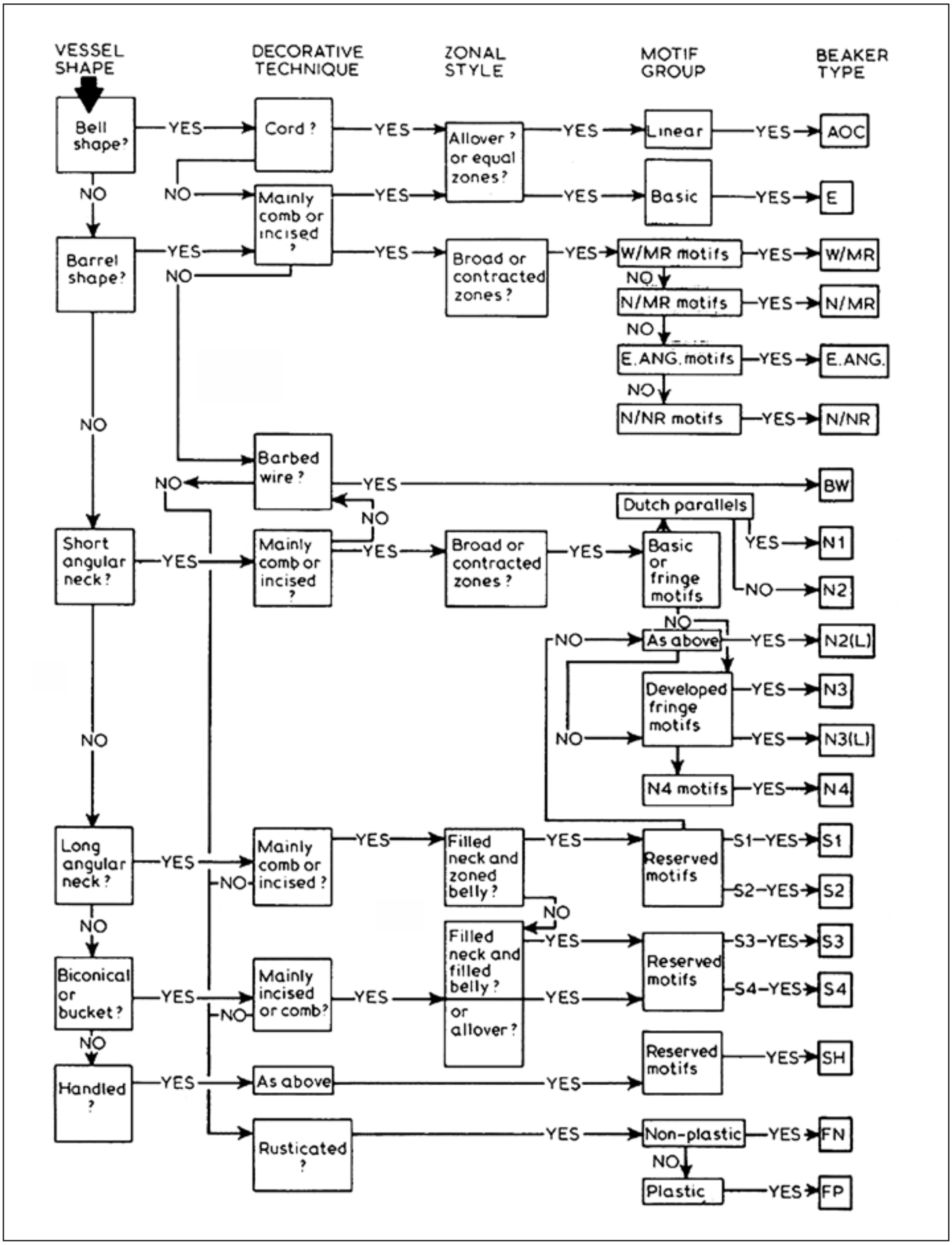


Fig. 5 – Combinatorial model developed by Clarke to classify and interpret the pottery beaker; the algorithm draws two different combinatorial routes that produce a high diversification of types (Clarke 1970).

correlation of different attributes. Each hidden organisation of the attributes defines the characteristics of a type, multiple types the characteristics of a class, and a class the "intentional" product of a culture (Fig. 5).

The analyses used first by *Analytical Archaeology*, and today by many other disciplines of the so-called Social Sciences, to classify attributes, types and classes of a given culture are nowadays, along with the greater variability of the observed systems, extremely varied and more sophisticated (Ramazzotti 2010, 88-126). The analysis of the metric frequencies of the attributes was conducted in this way to select trends, distributions and correlations in order to structure the artefacts, and the first histograms represented their formal characteristics in terms of modes and frequencies. In the same manner, the analysis of the nominal frequencies, performed through chi-square test of contingency tables, allowed the recognition of association matrices of two or more classes and the verification of whether a given decoration on the surface of a type of container was random or not.

The necessarily accelerating increase in the homogeneity of the classes and the presence of documents with strongly variable attributes (many of which shared by different artefacts, but none necessary or sufficient to distinguish or characterise them) was incorporated into the concept of "polythetic" groups, which is a key concept because it gave rise to specific research on the tools that are the most appropriate to highlight the *similarities* and *differences* which could structure composite and/or highly specialised production.

Nevertheless, the recognition of these qualities (analogies and differences) in the material culture follows the application of those methods in the psychological research, in order to recognise such functions of the cognitive process. In the first cumulative analyses, which were studying the growth of the level of technology in parallel with the evolutionary process, the percentages of artefact types were associated with the cranial capacities, in order to explain the presumed symmetry between the growth of the functional complexity of a given implement and the man's evolutionary growth, essentially understood as an adaptive growth, in other words a growth caused by the necessary acquisition of technological experiences (Leroi-Gourhan 1977).

In the same way, the methods of multivariate analysis, factor analysis, automatic classification and Principal Component Analysis intended to show the *structural* nature of variability present in the class, both to enable a future more precise comparative exploration and to draw its unique and irreducible associative root (e.g. Moscati 1984). This attempt to trace the origin of the class in order to redraw its relational structure was, on the other hand, equivalent to the first experiments which were performed in analytical psychology to outline the human ability to structure reality into similar and different (Sternberg 1985, 19-27), and indeed those very first studies using differential logic to understand intelligence gave rise to the hypothesis of applying techniques such as Correspondence Analysis in order to reduce the high level of variability of the recognised cultural traits into a limited and more controllable number of factors. The economic behaviour of a culture presupposes the principle of the archaeological site as an entity defined by a group of measurable geomorphological, stratigraphic and morphometric values. Accepting this principle, many territorial analyses applied statistical methods to document the existence of valid laws able to explain the different economic behaviours.

The first analyses of this type were performed to verify how the settlement structures, defined in graphical models of spatial structure, can be outlined in consistent logical networks, which would be transformed automatically by changes in the geometric measurement of their respective areas of influence, in their reciprocal linear distances, in the "weight" applied to the group of nearby settlements and, finally, in the relationships between distances and sizes of the centres present in a defined system.

These automatic changes, which evidently transform every organisation of the territory into a different settlement model, were then illustrated by the application of more complex rules which all aimed to define the structural characteristics of the transformations, considering them determined by the interaction of either two variables, i.e. the size occupied by the site in the hierarchy and its distance from the other nearby centres, or three variables, i.e. the size, distance, and influence on the region. Among the most appropriate tools to activate this process, the so-called Thiessen Polygons have had a strong impact since the early 1980s. The theory, originating with René Descartes and then mathematically developed in the 19th century by Johann Peter Gustav Lejeune Dirichlet and Georgij Feodos'evič Voronoj, provides for a grid of polygons to be drawn around the set of distributed points – each sides of the polygon is formed by the perpendicular line passing between the minimum distance of two points.

The calculation of the area of each polygon is understood to be indicative of the macroscopic differences in the distribution of the points in that space; in any case, since this grid does not take into account the high variability of factors of the three-dimensional space (e.g. geomorphological obstacles) and their temporal differentiation (e.g. the dynamics of attendance of the territory), the automatic use of the grid can produce questionable results. The measurement characteristics of the polygons have indeed recently been redefined, and a "weighting" system has been proposed, which is based on moving from the perpendicular to the distance between centres, therefore no longer passing between the midpoints, but fluctuating proportionally to the difference in size between sites. In the so-called X-Tent model, therefore, the calculation of the "weight" (in other words) influences every site on its surroundings.

The application of these models has become typical in research on a territorial scale, but they have also been used to simulate and compare landscapes of power on a much larger scale (Level, Renfrew 1979; Renfrew 1984). The automatic change in the transformation of a settlement structure did not, however, offer the chance to identify which ones of the functions activated in the structure were able to transform the settlement landscape. From this limit, a more ambitious attempt emerged to further summarise the recognised frames in order to ascertain which system of economic rules was the origin of the change. Once the syntax of the main relationships between the sites of a structure had been systematised in a theoretical list of associative constraints, could the exploration of the *rules* held to be at the base of the change began. Rules which – initially – were using the principles of urban economics, first of all that founded on the interpretation of the relationships between production and transport cost, then between production, cost and geometry of transportation.

The latter (which was a true geographical theory of optimisation in the early 1930s in Germany), the called Central Place Theory (CPT), is still widely applied in research into urban economics, economic geography and territorial archaeology. CPT presupposes that an organised distribution across a territory is based on at least two macro-categories of settlements – one composed of the most important in terms of size, population, availability of services, commercial structure, etc., and one composed of the less important ones. The second group of settlements will tend to arrange themselves around the first depending on the ease of access or administrative control, until they form a homogeneous hexagonal lattice. According to this economic theory devised by the German geographer Walter Christaller (1933), the centres' distribution in a given territory is regulated by "Principles", a logic by which optimising industrial production, reducing the difficulty of travel and transport and minimising production times and methods are inevitable. In this sense, CPT can be considered a deductive model founded on a series of postulates and axioms, and in this same sense it has been widely applied in the area of European and US territorial archaeology since the early 1970s (Johnson 1972; Clarke 1977).

The analysis of the economic relationships between settlement sites did not, in any case, have to be limited, or reduced to the presentation of those optimal operating rules that the systems would aim at obtaining and that would be lying beneath their diversity. The problem, encountered more than once, was the poor consideration of the geomorphological aspects of the territory, which *de facto* involve a constant deformation of the theoretical model (hexagonal lattice) into more or less rhomboidal or trapezoidal shapes, making highly questionable the causal explanation of the structural change. Moreover, as far back as 1972, Clarke's Gravity Model simulated the intensity of the economic relationship between multiple settlements by defining an expression directly proportional to the product of the activities performed and inversely proportional to the cost of transport, in order to reinterpret the meaning of the economic relationship in relation to the transport costs and the direct productivity variables, present in the classic CPT formulation, but subordinate to its rigid spatial geometry (Clarke 1972a, 7).

The limits of considering the complexity of the relationship behind the morphometric parameters of the sites and landscapes were soon perceived; indeed, the first ecological models can be understood as an attempt to shift the observation towards greater spatio-dimensional formalisation of the (theoretical) structure, which could support more refined analysis of the (adaptive) mechanisms originating the locational choices and the same socio-cultural transformations. As such, these mechanisms have later always been presented as highly complex and non-linear phenomena which can be simulated on an ethno-archaeological level, by comparing the spatial action of modifying, changing and structuring the landscape which is typical of the living cultures; on an anthropological level, by identifying osmotic and/or reciprocal relationships between groups, or in other words a spatiality that is no longer just diffusive and sequential, but able to alter the geometry itself of the occupation; on a social level, by predicting the settlement developments by applying distribution curves, e.g. normal, originally employed in the correction of geometric measurements; and finally, on a demographic level, by interpreting the influence of different conditions on the theoretical and regular growth trends.

The more culture is studied in biological terms, the less it is reduced to an automatic phenomenon, and the reasons for its specific spatial distribution are pursued with more sophisticated simulations which tie the occupational process to the action of specific algorithms (Foster 1989; Allen 1991, 1998; Chippindale 1992, 251-276). Moreover, some of the more recent researches, aiming to experiment with connectionist computational models, employ the formal and conceptual elements proper to Cellular Automata to simulate the dynamic complexity of the locational choices using bottom-up logic. The emphasis in these cases is not placed on the evolution of the settlement system but rather on the learning capacities of the automata; their ecology is wholly artificial, but the choice of their location does not just depend on the environmental input but rather on a complex relationship connecting sites, environment and experience.

We must remember, however, that the rules of transition driving the location choice and the organisation of the territory are a hotly debated topic; in isolated cases, indeed, on employing integration between Cellular Automata and Neural Networks, the use of predictive functions is preferred, such as the normal (or Gaussian) distribution curve which provides a prediction of the trend as the mean and standard deviation change, using the limit theorem to minimise systematic and/or accidental errors. In archaeology, it has been widely and indiscriminately used both as a tool for the correction of geometric and topographic measurements and as a support for the verification of theories about the economic and social behaviour of cultures (Rogers 1962; Renfrew 1984).

### 3.2 *The inductive inference*

The analyses and methods using the inductive inference tend «to *generate* Rules from the repeated observation of a Case», providing a formalisation (model) of the case which identifies and selects the rules and allows to postulate other rules. In experimental archaeology, these rules are stated as mathematical operations (equations, functions, algorithms) which offer reasonable theories on the causes which are behind the relationships between variables and which can generate other significant relationships. The fact that each cultural context leaves the traces of a series of actions produced by the ancient man on the territory, and that this evidence is the only *trail* left that allows us to recognise those same actions, has strongly supported, in the Humanities research, the adoption of the circumstantial paradigm, better known as the hypothetical-deductive method.

The analyses, procedures and models based on this euristic method always tended towards the formulation of a theory or a series of theories which could reveal (or *justify*) the events. Nevertheless, while the first models purported to formulate theories based on the comparative observation of the cases, or by comparing "the case" recovered with cases of living cultures, over time a method was refined which aimed to transform information into *evidence* and evidence into the apex of a network of semantic associations. This inference is particularly exploited today, when the intention is to present reasonable theories of the spatial and temporal data structure – in the first case, the models aim to supply a possible view of the physical causes of the materials distribution; in the second case, they generate a structural framework, generally phylogenetic, which observes the constraints imposed by the spatial structure.

The search for informative distribution rules therefore led to a long debate in spatial geography, territorial archaeology, ethno-geography and ethno-archaeology, but it currently seems to have been reduced to the suggestion to use models which are able to select which "physical" conditions are behind the formation of the deposits and which "theoretical" constraints are behind the adaptation. Today, informative distribution models can be understood as any process able to facilitate a widespread comprehension of the information, by indicating where it is significantly lacking in intensity and by predicting some of its structural typologies.

These models converge on the selection of transverse (physical and theoretical) rules which allude to the existence of a "natural" behaviour of the material culture and categorise those peculiar "adaptive" behaviours of the group (or groups) which use them. Despite the fact that over the years this commitment has produced enlightening hypotheses on the associations able to connect the structure of spatial data to the group adaptation, today there is a tendency to not overstate the "transversality" of the system but to examine rather the complex physical, mechanical and natural causes.

In the micro-space, on the other hand, the search for spatial articulation rules has, over the last decade, made use of generative models able to outline (or assimilate) the occupation and, in particular, the construction of intra-site architectural spaces, direct and inverse, in which "nuclear" elements are added or removed by following certain constraints (or rules). These constraints (or rules) differ depending on the case, but they all aim to express the complexity of a class of spatialised attributes as if they were generated by a resolutely oriented relational process; either progressive or inverse, these relationships always replicate a linear evolutionary trend.

Given their simple behavioural mechanism, generative models find widespread use in archaeological and geographical research and have been used in the past both as tools for the automation of archaeological hypotheses at a given level of complexity (Doran 1972), and as technical tools which identify the steps of each specific evolution or regression of the typologies (Chippindale 1992); on rare occasions, in any case, the interpretation in studies thus designed comes from a shared linearity of the process for investigating the action of variables on logotechnics. It is nevertheless interesting to observe the growth of the applicative research integrating Geographic Information Systems and ANNs (Black 1995; Openshaw, Openshaw 1997; Fischer, Reismann 2002; Zubrow 2003; Ramazzotti 2013c).

The network of semantic associations drawn from the physical relationships of the geological stratigraphy is also behind those models aiming to select the most suitable rules for the relative temporal placement of the document (Fig. 6). On the other hand, the position of the document in its stratigraphic level is the best evidence for defining it in terms of relative chronology. It is evident if only we observe the many experiments which are performed today, both to formalise the stratigraphic logic and to use IT techniques to refine the procedures for referencing the elements located in the archaeological deposits. Therefore, the desire to save all the evidences from the destructive mechanics of the archaeological excavation also favoured complementary analysis to the usual ones, which could provide integrated management of the position of the document in space and time and, in this manner, feed the chain of hypotheses and deductions that are necessary to perform any historical interpretation.

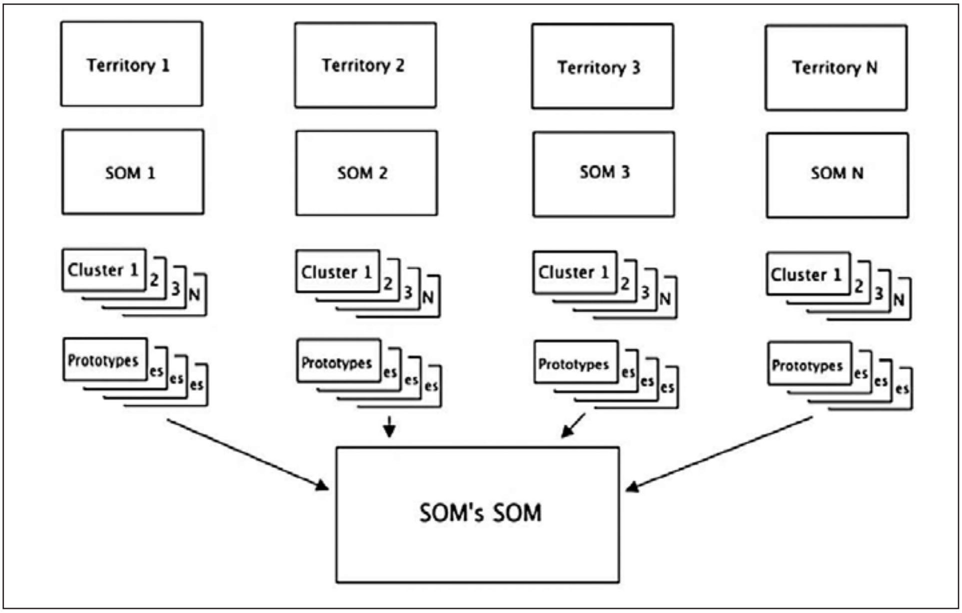


Fig. 6 – Blocks diagram of SOM's SOM procedure. The huge amount of spatial data generated by software GIS development, the increasing number of geographic computer applications available, the computerization of a large amount of information sources, and the availability of digital maps have increased the opportunity and need for the utilization of methods for spatial classification, for both research and applied purposes. Artificial Neural Networks (ANNs) can be used to develop a classification procedure which blends traditional statistical methods with a machine learning approach, allowing the system to iterate over a collection of datasets until patterns can be learned and realized (Londei 2013).

The highly variable nature of the features present in some classes of artefacts poses the problem of inserting them into a classification, able to subclassify into other classes relevant in the relative spatial and temporal placement of the artefacts themselves. For these reasons, the first "combinatorial models" were implemented; through the formalisation of the observation into decomposition rules, founded initially on the presence/absence relationship, these models would offer a structured description of the spatial-temporal object through calculation algorithms. But although this decomposition could have been sufficient for a reasoned deconstruction and reclassification of the highly specialised artefacts, it would not have added anything new to their relationship with other variables of their original archaeological context.

This possibility was offered to experimental research precisely when it was decided to manage the contextual issues in an integrated manner through a more general theory, which allowed the comprehension of the action applied by a variable on the system of connections, connecting it to further important characteristics of the context, these variables being similar to those of a constructed mechanical system or to those of a known natural one. Therefore, three paths were available to recognise the functions fulfilled by each given archaeological and/or geographical variable in a specific context, systematically structured following the analytical approach: to interpret the entire mechanism as if it was a theoretical and always functioning machine, with known relationships between the various elements; to suppose that each cultural and/or natural system has a biological life characterised by complex moments of growth, withdrawal and collapse; and to find the natural probability of the connections between the various elements of the system.

The first path would offer an optimal and theoretical presentation of the syntax regulating the various parts of the system. A presentation by which the same variability of the aspects of a context, in order for it to be able to function mechanically, would be defined *a priori* (Systems Theory); in the second path, the system of variables of a given context would be superimposed on the functional cycles of the biological systems and therefore undergo their same growth rules up to the point of collapse (Catastrophe Theory); in the third, the probability of the associations between variables of the cultural system would be codified, and their behaviour simulated with probabilistic network, this is the case of, for example, the Bayesian networks (Gardin 1987; Clarke 1994; Bintliff 1997; Ramazzotti 2010, 171-198).

The contemporary archaeological research does not limit itself demonstrating the principles of complexity in cultural, economic and social systems, slowly starting, since the early 1960s, to work together with radically different disciplines, for instance Cybernetics, which, by their own theoretical admission, live and develop for analysis of and experimentation on the rules of complexity (Ashby 1964; Hall 1989; Gehlen 2003, 46; Rogers, McClelland 2004). This approach to other fields prompted the construction of a wide range of models which select the causes of complexity in systems and, therefore, attempt to represent their origins. It should be noted that the working together of Archaeology and *Κυβερνητική* (Cybernetics) was neither sudden nor revolutionary (nor even linked to the advent of the American New Archaeology); it was rather the first, enlightening attempt to compare archaeological contexts with dynamic systems which promoted the inevitable intersection of the two different disciplines.

As in mechanical systems, the relationship between variables of a given context could therefore be described not only in recognisable geometric forms then redefined into theoretical maps causing a distinctive activity, but also in maps from which those Rules able to transform their internal connections and their organisation could be selected – feedback, attractor, and dynamic equilibrium, which had already been studied by “Mechanical Intelligence” even before Cybernetics. This would, on the one hand clarify the limit of automatic operation of the systems and, on the other, lead towards the replacement of the mechanical (and linear) nature of the relationships with the physical-biological (non-linear) one (nature) of the connections.

The feedback rule has been selected, reviewed and discussed in many models aiming to represent the complex formation of the State; the recognition of attractors in many models aiming to recognise the homoeostasis of social and economic organisation in a chronologically and spatially localised state, and, moreover, the dynamic equilibria in many others which emphasised the anomalies of a given territorial structure (Waldrop 1993; Page 2010). Models which perform analogical inference, «which *form* Hypotheses based on the comparison between Cases», are founded on, amongst others, analogies or similitudes, through which the intention is to grasp the logic of a particular phenomenon in relation to the better known operation or directly observable. In this sense, working them out requires a "symbolic capacity", in other words the ability to grasp the whole from the allusive evidence of the part (Gehlen 1983, 207-208).

### 3.3 *The analogy and abductive inference*

The models which use analogies have dealt with the relationship between the physical scattering of the materials in their contexts and the operation of the cultural systems which had produced them; the relationship between the behavioural variables of the cultural systems and the formal variables of the major economic theories; the relationship between the perceptions of the objects and their environment and those of the operation of memory and perception. The models which establish a comparison between Culture and Environment aim to present the transformation of cultural phenomena as being dependant on physical and biological laws which can be checked scientifically; but while most of this processing reaches the environmental determinism – a term which, indeed, highlights how a group of natural causes can condition the structural change of the same social organisations – the confidence that these transformations could instead relate to the human action on the resources is owed to the Department of Prehistory at Cambridge, known as Palaeoeconomy (Higgs 1975).

For the founder Clark, indeed, the comparison between the physical-biological laws which control the characterisation of the environment and the cultural-economic laws which govern the social structures would lend itself to the construction of an integrated and global transformation model in which they would all interact; the discipline would therefore be responsible for the job of reorganising them in other different theories (local and contextual) of the individual processes (Fig. 7). This model which, starting from a common base of principles, would allow hypothetical theories of the individual

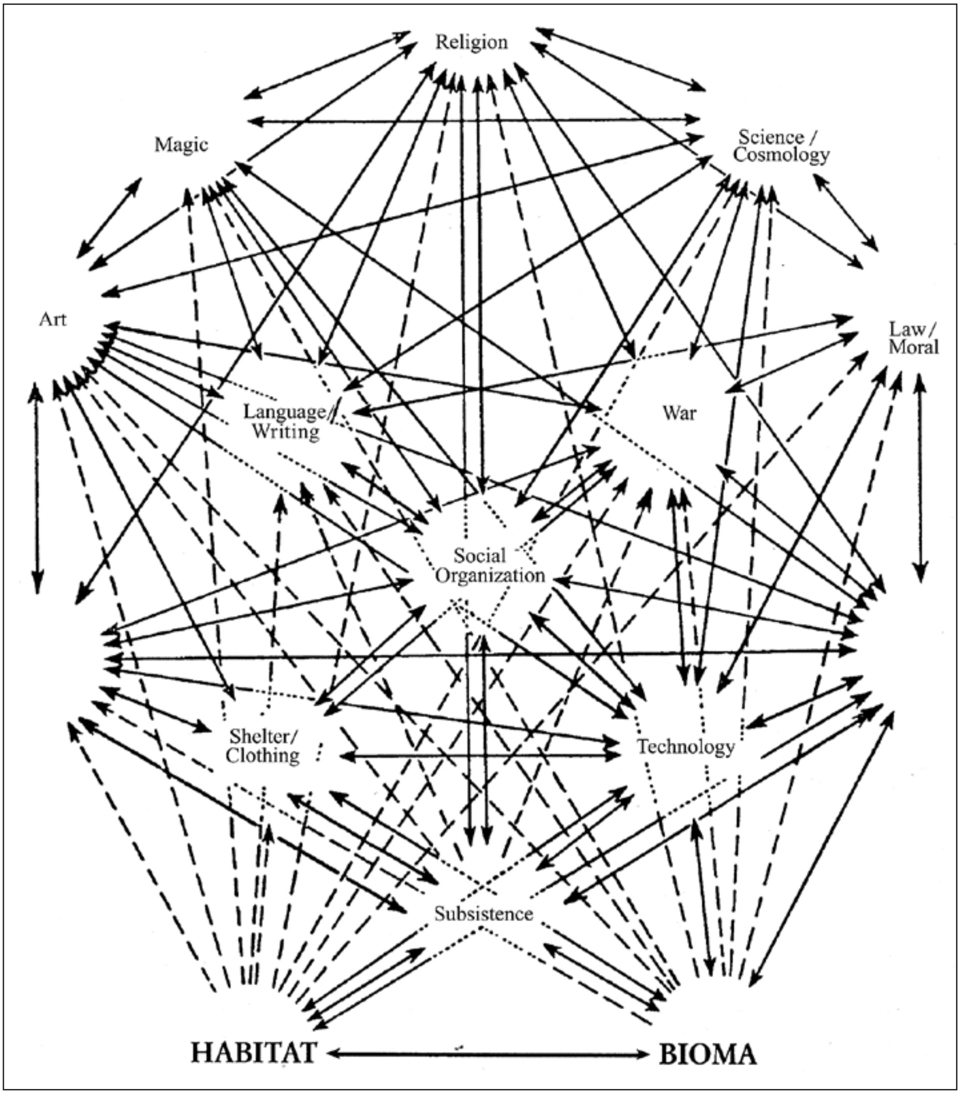


Fig. 7 – Diagram of interactions between Habitat and Biome. In the interpretation of the British archaeologist both ends of arrows imply dynamic and reciprocal relations. This is one of the earliest and most notorious attempts to deal with socio-cultural organizations as integrated and parallel to those present in the environment (Clark 1992).

economic developments to be established, would be represented in a spatialised and structured system in which social organisation would occupy the centre of a network of connections (direct and inverse), with most variables depending on it or which could simply characterise it; a system nevertheless constrained at its base by the reciprocal relationship between Habitat and Biome (Clarke 1999).

The model generated by keen comparison between physical-biological laws of natural transformation and cultural-economic laws of social transformation, and spatialised as a complete system tied to interdependent relationships would therefore offer a precise and general theory of the economic and cultural operation regulated by systemic principles of structural equilibrium, or of homoeostasis, as explicitly stated by the Australian archaeologist (Clark 1992, 162). As we have observed, the analogy between Culture and Environment, decoded by Clark into a systemic model, had a very large following in archaeological research aimed at reconstructing economic processes, but it was also relevant for introducing the concrete possibility of also comparing the principles regulating cultural transformation with those controlling natural transformation. This analogy could be conventionally defined as being second level, and its analytical potential was noticed rather early by D.L. Clarke.

Analyses and methods which follow abductive inference generate theories on these cases from the possible results and offer all those representations (models) which outline a theory of the cultural, social, political, economic and cognitive function, looking for their foundations outside the perimeter of strictly archaeological analyses, methods and techniques. These theories can be displayed as "closed systems" tied to a precise logical structure, or as "open systems" characterised by a dynamic combination of connections, but in both cases they express a global and integrated interpretation of processes, events and facts; they exhibit the set of relationships that these three "elements" of the story have with the world of the present and the past; they change their morphological structure in relationship to the quantitative and qualitative growth of the documentation.

From the results obtained in the biological area through the study of the rules of operation of the selective process (Edelman 1987, 1988, 1989), some archaeological research is starting to update the classical body of tools of linear and multi-linear neo-evolutionist theories and to head resolutely to set up a new semantics of cultural function. The attempt to deconstruct the functional complexity of the archaeological documentation is indeed encouraging some experiments on "generative grammar" which can be related to it, which is understood as the codes of a given spatial and temporal structure, necessarily constrained and therefore subject to the same rules of the selection process ingrained in the theory of evolutionary biology.

Other, even more specific, studies examine the processes of cultural diffusion, aggregation and classification through the models of coevolution, thus identifying how they fulfil themselves by the interaction between genetic evolution of species and the effect of human action in influencing the exploitation of resources.

Going beyond the limits of analysing archaeological cultures as concrete expressions of their documents and the transformation processes with the mechanical logic of human action on the environment, or conversely of the conditioning the environment might have on it, the possibility also stands out to define cultural diversity on a genetic basis, to interpret its slow transformations by making an equivalence between the concept of "population" and that of "culture" and that of a spatial circumscription for it which is not just geographical, ethnic or linguistic. This diversity, which has many different contours and nuances only apparently recognised on ethno-linguistic foundations, necessarily subject to the possible manipulation of old and new ideologies, foreshadows a map of the ancient human genome, predominantly useful for medicine, but also sufficient to make the spatio-temporal relationships which have always been focused, in one way or in another, on the critical distance taken in relationship with some more complex principles of equivalence, such as the classic one between "culture and typology".

The results obtained concerning the social complexity of the mechanisms which regulate cultural relationships did not only produce a reduction of the classical application of Systems Theory to archaeology, but also, at the same time, a trend of the discipline developed which, by updating that same theory with the aid of the new mathematics, aims to define some characters which predate cultural complexity itself and which, in the same way, can be examined again in light of that renewed theory. As already highlighted, beginning in the 1980s the attempt was made to dissolve the intrinsic rigidity of the regulatory mechanisms of the Systems by replacing the linear Input-Output function with some rules of anthropological relationships, considered more flexible in documenting the structural transformation of cultures (Peer-Polity-Interaction), or by clarifying the natural and biological direction followed by each system (Catastrophe Theory). But since the early 1990s, that "critical" path aiming to detail these limits and, therefore, to identify the mathematical rules which predict the ancient functional use of the objects has been undertaken (Rough Set Theory).

Some studies examine the dynamic oscillations of the processes of territorial organisation, employing models which organise themselves and which, as other cases present in nature show, tend to reach a stationary state of *equilibrium*, beyond which they transform themselves. Other simulative studies trace the problem of location choices, traditionally dealt with through the principles of urban economics (agglomeration, accessibility, interaction and hierarchy), back to the multiplicity of choices and the constraints determining this.

The self-organisation of highly complex structures and the multifactorial nature of the choices influencing the territorial form of the systems are all recent phenomena which inevitably act to construct a new semantics of cultural transformation. Indeed, these phenomena require to overcome the obstacle of an interpretation which reads the purely "human" construction of ever-more complex systems to understand the cultural transformation and advance the illusion (or the ambition) of paying more attention to those phenomena, present in nature, which do not require external inputs to act dynamically and transform themselves. In the same manner, they require to cross the limit of the "mechanical" construction of organisational complexity, in which an Instruction (or a few fundamental relationships) would be sufficient to transform the system in order to observe, classify, formalise and organise other rationalities of the locational choices.

Some of the most recent archaeological studies have been inspired by the continuous results obtained by contemporary Semiotics, Semantics and Logic in shaping, deconstructing and reconstructing the world of meanings of structures, signs and symbols, as well as their internal constraints and the rules governing their perception and communication, to further theorise other information analysis procedures, propose other forms of their communication and generate other theories of their combination.

These are also expressed in models, more structured than the ones we have already dealt with, because those are summarised within them. As far as the data analysis is concerned, as we have seen, Clarke, with the definition and elaboration of polythetic entities, had already supplied categories for learning, translating and transferring technical experience, seeing them in the grammar of the first semantic-perceptive models which were still, in the late 1970s, largely structuralist. This first step towards a logic of the sign transmission – which has been improperly excluded from the critical historiography – is today, indeed, right at the roots of that search for techniques and models suitable for transforming the documentary archaeological situation into structures, codes and messages, both written and visual, which can, in a certain sense, distinguish it.

Jean-Claude Gardin's constant attempts to prepare the logic of archaeological theoretical-inferential reasoning are, indeed, operations destined to yield an anatomy of the perceptive mechanisms which are behind historical knowledge and its inevitable reworking (Moscati 2013). This anatomy of the human historical reasoning wishes to display all the strength of the subject, the arbitrariness and the conditioning of meaning and, for this reason, has always offered itself to elaboration and simulation (Gardin 1970, 1980, 1987, 1989, 1996a, 1996b). Labelled as a speculative and sometimes ineffective attempt, this trend has, on the contrary, painted a picture of archaeology as logical-scientific research, always open to enquiry, aiming to build a "metalanguage" which expresses its most profound nature.

As far as the modalities of scientific communication are concerned, on the other hand, many archaeologists draw inspiration from the semiotic communication theories to design and exhibit other forms of research. Thus, for example, Colin Renfrew attempts to overcome the purely descriptive and analytical obstacles of investigation, in order to relate the complexity of the archaeological reasoning through the transmission of aesthetic experiences which organise new suggestive and effectual descriptions of the discipline, without, however, denying its internal order, its syntax, the organisation of work and the costs which, he presumes, are useless, boring and uninteresting details for the public as they are for specialists.

More structured, on the other hand, is the network model proposed by Hodder, for whom a horizontal circulation of archaeological information, established from a non-hierarchical, co-operative and collaborative work set-up would combine perfectly both the workable metaphor of IT networks, which are able, with many nodes and no centre, to transfer the complexity of information, its frequency and its relativity, like a metalanguage, and the literary metaphor of archaeology as narration, able to exhibit both the plurality and the same antimony as well as evaluations concerning the given object, as a never unique nor conclusive book written about.

### 3.4 *The connectionist inference*

But above all, the results obtained, together, in the disciplines of Semantics, Semiotics, Logic and Neurobiology, gave rise to different theories of the so-called "cognitive function" which were gathered first by Analytical Psychology and, only later, by Experimental Psychology. The contact between Archaeology and Cybernetics, already identified by Clarke as central in order to let archaeology abandon its aura of innocence, is not therefore a purely generational fact, but the product of a *wonderful* intuition, through which the English archaeologist intended to reconnect the abyss which had taken form, essentially due to the effect of the historical-cultural approach, between the Humanities and the Sciences, and in this way to offer a new category of meaning to the same definition of archaeology as "human science" (and it is not by chance that today we group it with the Social Sciences).

In the late 1960s, as we have seen, Cybernetics was, in any case, simply understood as an extension of Systems Theory and Artificial Intelligence, then nascent, effectively representing the pioneering technological illusion of reducing the function of the logic of knowledge to a formalism which could be managed with that theory. Nevertheless, while initial research in Experimental Philosophy used guinea pigs as if they were automatic machines and applied multifactorial analysis to trace the differentiability of intelligence, in the 1950s Neuroscience began to disown the paradigm of a brain regulated only by the modularity of electrical impulses (Oliverio 2004, 22-23).

The division of the observed world into classes and forms (*Gestalt*) then began to be gathered into more complex models which attempted to integrate the awareness that some perceptive functions were not simply calculable, predicted or predictable actions or functions with the necessary linearity of automatisation in "naturalising" the cognitive function (innervating the experience in the elaborative process of the synapses between neurons). But the Artificial Intelligence inspired, instead, by "theoretical" Neuroscience research and by "practical" Neurobiology research, in other words inspired by the interpretation of the cognitive function as a certainly more complex expression of a relation between the physical and irreducible elements of the brain, appeared only in the early 1990s.

Today, its foundations and origins are still discussed, but it is at least unanimously recognised that its advancements in recreating some segments of knowledge trace back to that area of the Neurobiology of memory which, having risen in radical opposition to the more ancient and traditional behaviourist school, was then defined as "connectionism". Connectionism is understood as a theory born inside neurobiological research on natural intelligence and the reproduction of an artificial intelligence; according to it, the brain is not just ascribable to a system of rules and symbols, but it is composed of the operation of simple and non-intelligent elements known as "neurons", whose connections (synapses) express properties of coherence (Fig. 8).

The connectionist approach represents, in this sense, a reaction to the "behaviourist" and "representationalist" theories which did not tackle the study of Artificial Intelligence based on the dynamic and connective relationship between the neurons, but interprets the logic of its operation in the mechanical Input-Output flow (Fodor 1975; Minsky 1986; McClelland, Rumelhart 1986, 1-20; Ackley 1987; Fodor, Pylyshyn 1988; Feldman, Ballard 1989; Ackley, Littman 1992; Fodor 1999; Marcus 2001; Clark, Eliasmith 2002; McClelland *et al.* 2010). In international archaeology, it was chiefly Jim Doran's research which supported the applicability of this logic for studying social systems; of particular importance was the insertion of Multiple Agents System Theory (MAS) and Distributed Artificial Intelligence Theory (DAI) as the foundations for building dynamic socio-cultural models (Doran 1970, 1996a, 1997).

In particular, the second theory (DAI) aimed to conceptualise the structure of artificial scenarios to combine the representations of the individual cognitions of every agent and verify the qualitative characteristics of the birth of social hierarchies in the French Palaeolithic communities (Doran, Palmer 1995, 103-125). Since today any analysis of the principles regulating memory, learning and classification (that is to say the fundamentals of all Theoreti-

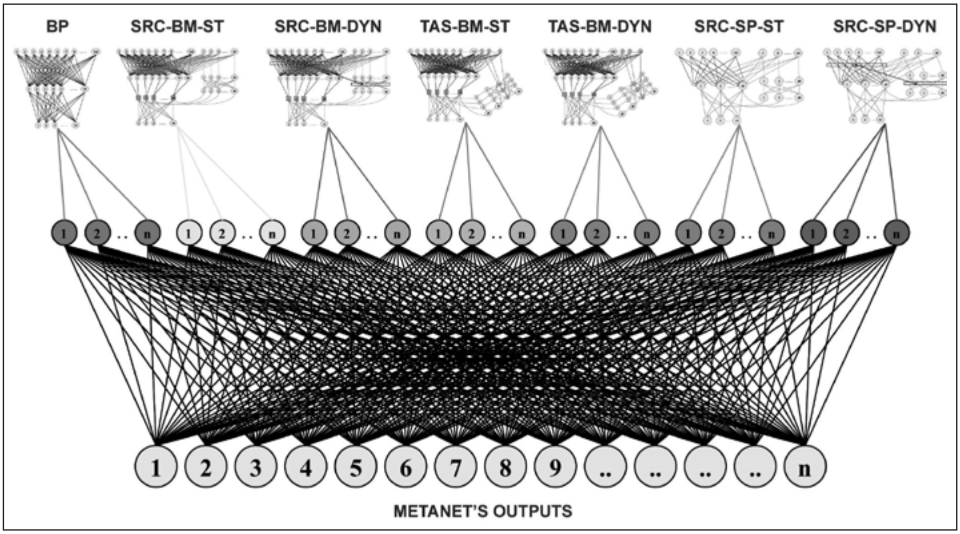


Fig. 8 – Metanet Topology. Between 1994 and 2008 Semeion researchers conceived and developed a series of Meta-Classifiers based on some common traits and called them "Meta-Nets." All Meta-Nets have typically similar neural network architecture; certain input nodes are the whole outputs of all composing classifiers, and certain output nodes are the output classes of the classification problem (Buscema, Tastle, Terzi 2013).

cal and Experimental Archaeology) depends on this border. Back in the late 1990s a series of studies was proposed, in the archaeological field, which had already perceived the epistemological relevance of the connectionist models (Ramazzotti 1997, 1999a, 1999b).

## 4. Encoding cognitive complexity through the Artificial Adaptive Systems

Currently, less than a decade after these studies, we can already distinguish at least two different directions: the first aims to explore the high level of complexity of the archaeological processes, structures and systems, supporting the semantic instrumental value of the Artificial Intelligence in rewriting a General Theory of Archaeology; the second, instead, shows and emphasises all the statistical instrumental potential of the same models which are in reality replacing the more traditional mathematics of classification.

### 4.1 *Systemic complexity and Artificial Neural Networks*

Most researches relating to both directions make use of the principles according to which every cultural expression is the reflection of conceptual and cognitive human processing (in the real, or not random sense), and the human conceptual and cognitive expression can be reproduced through the construction and simulation of systemic and mathematical rules (in empirical, not dogmatic terms). Even though they leave open the whole problem of how non-calculable factors (such as emotivity) can alter any state of equilibrium, the first Networks, which are physical architectures of the complex relationships between the irreducible elements of the brain, historically represent the point of reference of the two analogies – they are inspired by the biological model of knowledge (hence neural) and represent, in a structured manner, some of their aspects (or segments), which can be empirically checked, through a great variety of techniques and models (hence artificial).

In the psychological-cognitive area it has by now been demonstrated that the organisation of reality by each individual does not just depend on the action of the environment on their formation, or (*vice versa*) only on the action of their choices on the environment, but that rationality is understood as functions of experience. Among these functions of experience, neuroscience studies memory, first in its evolutionary dynamic, then as a biological model and finally as the dependent nature of genetics. Observed as a biological model, memory is a product of the nervous circuits subjected to an experience, and in the area of dynamic mathematics it can be simulated in regulated (or self-regulated) systems. Associative Memories are, in effect, among the first processing mechanisms which learn by taking rules from complex systems and, as such, they demonstrate to be capable of finding possible solutions to non-linear problems.

An archaeologist studying the complexity of archaeological processes through these models investigates the relational dynamics between the classified variables of a given context in the same way as a psychobiologist studying the complexity of the perceptive-analytical process of an individual (or a group of individuals), and a neurobiologist exploring it on an empirical level. Rather than calibrate suitable and expert tools which repeat the relationship between variables like the one present in connected parts of a machine, the archaeologist will therefore aim to trace the possible, nuanced and non-linear rules of their operation and will never obtain a single result, but rather analytical surfaces (hypersurfaces) which will lend themselves (with humble, controllable repeatability) to historical-archaeological interpretation. In the psycho-cognitive field it is well-known that the perception and organisation of reality by an individual increases and changes in relation to the quantitative and qualitative growth of the information and messages they exchange and receive.

Phenomena such as orientation, which in psychobiology are also considered adaptive phenomena (i.e. depending on learning and memory), can be simplified into highly complex and structured systems which change dynamically in relation with the increase of the information. Some experiments performed with Cellular Automata demonstrate how these can identify the rules which connect different groups of data and organise their adaption, by transforming them in relation to that given quantitative and qualitative (but nevertheless dynamic) growth or regression of the information (or the constraints).

Their first applications to archaeological spatiality are therefore to be understood as simulations destined to explore, recognise, classify and typify the different spatial forms that a behaviour assumes in relation to the increase and decrease of the information (instructions) received by it or subtracted from it, and in this sense it is today guiding the application of neural models to the topology analysis of the forms of dynamic adaptation (Buscema, Breda *et al.* 2013; Buscema, Sacco *et al.* 2013; Buscema, Tastle, Terzi 2013).

### 4.2 *Artificial Adaptive Systems and archaeological thought*

The archaeologist studying the complexity of the archaeological processes through such models therefore intends to investigate the forms of the adaptation in the same way as a psychologist would investigate the perceptive-analytical reasons driving the organisation of a space (individual and collective), and a psychobiologist the physiological models which are at the origin of orientation; therefore, rather than building closed memorisation systems, which gather all possible information in a given context, this archaeologist would design systems which are as open as possible in order to receive the natural growth of information.

Since this open system would not only become another data typology, but would also become processable with other Artificial Intelligence models, its historical-archaeological interpretation would inevitably be subject to continuous updates, to the necessary extent. In the field of experimental and cognitive psychology, an individual's process of classifying reality occurs by effect of his capacity owing to the experience he acquired in operating summaries and generalisations; as such, the organisation of forms into categories of meaning is considered a complex phenomenon which provides for mnemonic and learning skills.

The Artificial Neural Networks which have been trained to trace those rules which structure a given complex system can also perform corrected generalisations on the system, redefining the system itself into other relational classes. Their first applications in the seriation of archaeological data – a classification which necessarily increases in complexity in relation to the increase in information – are therefore also to be understood as attempts to apply a given individual's adaptive skill and experience to organising the reality surrounding him. In the area of experimental and cognitive psychology, the predictive abilities of an individual depend on the dynamic behaviour and structure of the variables he has at his disposal to take on the solution to a given problem; this behaviour, therefore, focuses on a response which transforms the input information into highly structured surfaces, representing the form and substance of the observed reality.

The Artificial Neural Networks that are trained to trace the nuanced rules of a given complex system can construct a surface geometry of their learning, which changes in relationship to the qualitative and quantitative characteristics of the other stimuli received (Buscema, Breda *et al.* 2013). The ANNs trained to define the rules of a given complex system therefore offer a possible generalisation which lends itself, at a later date, to being interrogated using prototypical questions in order to delineate a given object of investigation in quantum terms, both by modifying the number and intensity of the inputs (simple interrogation) and by adding other possible (complex) ones, and observing how that representation (surface) changes its structure with each response. Their first applications to predictive archaeological problems are, therefore, to be understood as attempts to apply the diagnostic abilities of an individual to transform what he observes into a possible prediction of its function.

The archaeologist who simulates the dynamic behaviour of a Complex System through these Artificial Intelligence models intends to explore the configuration of the data (which has been learned) as an analytical surface, in a similar way to that of a psychologist investigating the perceptive-analytical processes of the predictive potential of an individual. Therefore, rather than describing the purely systemic complexity of a given context, the archaeologyst would aim to work on how that context was learned in order to interrogate it in a diversified manner and to trace every possible combination of it, thus providing a wide cross-section of historical-archaeological predictions of its state.

When *Analytical Archaeology* appeared on the scene of international archaeology, as it had happened to other essential scientific essays of the archaeological research, the English-speaking academic world, British and American, broke decisively in the evaluations (Chapman 1979). While for some scholars that work, that in the great archaeologist's expectations would have provided a central body to the theory of archaeological knowledge, became a kind of *simulacrum*, a new method of investigation, and, more generally, any proposal for other experiments, for others it would have remained just an unnecessary (and unacceptable) mystical brushstroke.

The first Italian translation of the *Analytical Archaeology* (Clarke 1998) speaks more than any other consideration on how this work – recognised as a prophecy – was perceived in Italy; in fact, there are no less than thirty years running between 1968, the year of its establishment, and 1998. Thirty long years of this century that was already leaving behind the historical-cultural orientation of the Italian archaeology, immobile to the generational change. We may then ask about the profound reasons of this delay, not to exhibit an opposition to the Normative Archaeology, a redundant and sometimes rhetorical critic of the American archaeology (always renewed), but only in order to understand those reasons and reopen that debate (Guidi 1998).

While Clarke was writing his theory, in 1968, in Italy the most distinguished representatives of critical thought, archaeological and anthropological historians were debating, in the prestigious scientific journal «Dialoghi di Archeologia», on the economic nature of cultures and on their specific political dimensions, aesthetic and symbolic (Ramazzotti 2010, 50-87). Far away from those premises that had been maturing into a unique and unmatched polyphony of historical, artistic approaches, renewing the same aesthetic and critical thinking as materialistic science, the debate on the morphology of the discipline and its ambition to become a General Theory was discussed by the Classical Archaeology and remained lively until the Gordian knot of the so-called "bi-front" archaeological thought was solved.

Today, after forty-five years, the adoption as well as the purchase of this volume are still singular. Arduous and written with a purely scientific vocabulary, *Analytical Archaeology* does not lend itself to be neither manual nor wise, even the intelligent editorial choice to frame it in a valuable series that aims in the first place to convey an image of archaeology as research and analysis; but archaeology as research and analysis for the broad public is still the symptom of a hazard, while the audience of specialists is often so sectarian, and in fact, hardly supports such a generality of the theme, such breadth and openness of discussion on empirical methods.

To remember the troubled history of the UK edition does not represent, for this essay, a nonsense: the balance of that reasoning; the accuracy of syntax; the ambition of an entire generation that grew up in that world so much projected into the future as attentive to dialogue with the past and with the tradition; the preconditions for a grammar of archaeology as the frontier not only of a General Theory, but of a Theory of Knowledge; the mention of the archaeological report of signs as communication are all elements that have inspired this work because they remind us that it is not possible to rebuild anything without a solid theoretical vision, without looking around, without being contaminated, without trying every possible solution.

The study of complex archaeological systems which can make use of the philosophy of Artificial Intelligence is, ultimately, a research project which evaluates the historical meaning of the relationships between archaeological documents as an essentially human construction which repeats, in this, a *strong* position of Analytical Archaeology, but updates it on the basis of the progress made by Cognitive Science, Neuroscience and Cybernetics in simulating the principles which regulate memory, orientation, classification and interpretation of reality. It is important to highlight that these models, unlike others, must make use of a precise encoding of the documents and take on an important role in the research only when the results which they produce become the hyper-surface to continue, update, refine or open the analysis itself.

Some considerations, after this brief, subjective and critical introduction to the history and use of the models in archaeology, are necessary before concluding this epistemological introduction to the volume. On one hand, these models, as the reader will have understood, almost always introduce new problems, even only for the fact that they are subject to constant re-examination. In this sense they irremediably prevent the closure of the research. On the other hand, even though today those research theories seem to be the most used in experimental and applicative studies, they should not be considered as forming a new paradigm since, like others, they respond to specific questions posed by the past.

If this was the case, if they really did represent a paradigm, we would indeed have to assume that those questions have been diversifying, developing and becoming more complex when, on the contrary, they always fit into the human categories of enquiry. What is changing, however, and decidedly, is the man's relationship with the technique which is now transforming natural reality from the inside, moving it onto a first artificial, then virtual plane, where everything, within the (desirable) limits imposed by ethics, is apparently possible. Our action on this new world is a field still to be explored on the historical, anthropological and archaeological level, but, by observing our models, we seem to perceive already at least the formation of different research areas into communication. The deductive models are headed towards a check or an anticipation of the possible context and they show today the desire, known to the discipline since its remote foundation, to orient themselves in the world which is created and replicated.

They spread out from underlying convictions, as old as the postulates and their axioms, they communicate a certainty that the referent can grasp in all their lucidity and rationality. The inductive models which continue to produce rules from observation arrange themselves (given their specific nature) in a more chaotic manner; they do not have those certainties, but they always live in the experiment, communicating the state of a new discipline, or one always in the course of renewal. Those which inflect analogy, on the other hand, resist and grow in this reality codified in signs and symbols precisely because they require "symbolic capacity". When it would seem that the *hiatus* which every analogy entails might fade away, here the metaphor, the similitude, the allusion appears.

In the *Time of Technique* it is even too predictable that the last perceptible limit is still that of the relationship (metaphorical, nuanced or allusive) between "mind and machine". Besides, in this age, it is almost instinctive to replicate the function of knowledge, to retrieve its origin and to rebuild a backstory for it. The models which, on the other hand, have searched for a place in the discipline by drawing their inspiration from other distant disciplines and at the same time from the theories which emerged and tried to explain cognitive function, would, in the *Time of Technique*, be absorbed by the recreation, even though minimal or "impossible", of intelligences, first the "ancient" and then the "new" Artificial Intelligence.

The other theory they would be inspired by is *reason as a tool* and, in the *Time of Technique*, this becomes the condition for interpreting and communicating the man's historical, archaeological and anthropological complexity.

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ABSTRACT

The study of complex archaeological systems with the support of the philosophy of Artificial Intelligence is a research project that evaluates the historical meaning of the relationships between archaeological documents, intended as an essentially human construction, reaffirming, in this way, the importance of Analytical Archaeology, and updating it on the basis of the progress made by Cognitive Science, Neuroscience and Cybernetics through the simulation of the principles regulating memory, orientation, classification and interpretation of reality. It is important to highlight that these models, unlike others, require a precise encoding of the documents and acquire an important role in the research only when the results they produce become the hyper-surface to continue, update, refine or open the analysis itself. In the *Time of Techniques* it is still too predictable that the last perceptible limit is still that of the relationship (metaphorical, nuanced or allusive) between "mind and machine". Besides, in this age, it is almost instinctive to replicate the function of knowledge, to retrieve its origin and to postulate a backstory for it. On the other hand, the models seeking a place in this discipline, by drawing their inspiration both from other dissimilar disciplines and from the theories that try to explain the cognitive function, would be absorbed by the recreation, even though minimal or impossible, of intelligences, first the Cybernetic and then the Artificial Intelligence. The other model they would be inspired by is reason as a tool and this becomes, today, the condition for interpreting and communicating the historical, archaeological and anthropological complexity of the human being.