The hume machine: can association networks do more than formal rules ?

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THE HUME MACHINE

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Abstract:

In this article, we push the cognitive and information-science consequences of the new sociology of science and technology as far as they will go. Since there is no coherence stronger than a circumstantial network condensed or summarized into forms, structures and microtheories; since the computer, once it has shed its anthropomorphic and epistemological projections, is already capable of dealing with significant association networks; and since there are no computer programs on the market for researchers in the social sciences who deal with a great number of heterogeneous textual sources, we propose to construct a machine capable of revitalizing Hume and Condillac's unfashionable philosophical program of associationism, by giving it the material base it hitherto lacked.

1 How can we give qualitative analyses in social science mechanical means for dealing with large bodies of heterogeneous data?

Despite contemporary progress in statistics, the social sciences are still too divided between quantitative and qualitative methods. To take a few examples, economics, electoral sociology, demography have at their disposition a number of mathematical tools and appropriate databases. The same cannot be said for anthropology, for numerous branches of history, for field studies in sociology . This difference of methods and tools is at once the cause and the consequence of several other divisions between macroscopic analyses and analyses of individual interactions; between explanations in terms of structure and explanations in terms of circumstances. Despite the presence of tools developed in part for sociologists, like factorial analysis, the progressive passage from global to local analyses never seems to get any easier.

This division is particularly deleterious for those who use the notion of network in order to account for multiplicity, heterogeneity and the variability of associations responsible for the solidity of a fact (Callon, Law, Rip, 1986; Latour 1987), a technical object (Hughes, 1983), a cultural feature (Hennion, 1981) or of an economic strategy (Callon, 1988). Such studies are not at ease either with quantitative methods - which do not follow the network faithfully enough - or with simple ethnographic descriptions (case studies) - which do not enable one to tie a given case study to any other. But at the same time, there is no way of charting a network by choosing a median solution and projecting it, by correspondence analysis for example, onto a common statistical space. So doing, one would lose the irreversible advance that constitutes the idea of networks: the possibility for the actors themselves to define their own reference frames as well as the metalanguages used within them[1].

We need to find a way of attenuating this distinction between quantitative and qualitative methods, while avoiding median solutions like correspondence analysis, so as to give the idea of the network the power to unify the social sciences in the way it should be able to.

In order to so do, we need to give qualitative workers a Computer Aided Sociology (CAS) tool that has the same degree of finesse as traditional qualitative studies but also has the same mobility, the same capacities of aggregation and synthesis as the quantitative methods employed by other social sciences. The limits to this tool are the same as those of any instrument from any scientific discipline. Firstly, it works from written documents or inscriptions and thus does not resolve the problem of how these documents are obtained. Secondly, it necessarily sheds some information in the act of re-representing the data. In the case of the social sciences, the tool that we give the specifications for below thus presupposes the prior transformation of the terrain into texts and the accumulation of enormous masses of documents, which the researcher risks getting drowned in. It does not claim to replace detailed analysis of a terrain or text. It only wants to provide a means for dealing with large numbers of documents.

The tool that we seek will begin by looking at texts, if possible full texts - whether these be archives, reports, open or closed interviews or finally field notes. In any case, instead of then wondering how to treat this enormous mass of data by applying methods of automatic reasoning or of artificial intelligence (AI) to the documentation obtained, we intend to follow the inverse strategy and use techniques for treating documents in order to help researchers to artificially produce intelligence about the terrain they are analyzing.

The advantage of this approach is that it constitutes a challenge at once for sociological theories themselves, for computer science and for cognitive science. In effect, the question can be posed in three ways:

- does the idea of networks enable us to deconstruct the set of forms and of vocabulary that the social sciences have used every which way up to the present?

- does it allow us to follow a class of problems with fluid definitions, something that computer science has not yet been able to deal with?

- is it possible to use the idea of networks to successfully reconstruct the logics that the concepts of forms and of structures only give us very partial access to?

These three questions can, we think, be tackled by taking them all on at the same time in the form of looking at a program written for a microcomputer.

We have given our project the code name of the <u>Hume-Condillac Machine</u>[2] in honor of the English (1711-1776) and French (1714-1760) philosophers whose research programs we are partly reviving using computers, which they evidently did not have access to. This project for Sociology Assisted by Computer is also a form of CAS (Computer Assisted by Sociology), of the sort sketched out by Hewitt (1985). We agree with him that models for developing cognitive science rooted in the mind or brain are less useful for constructing computer tools than those borrowed from organizations, society and networks.

In this paper, we draw certain logical, cognitive and information-science conclusions from work that has accumulated over the past ten years in the sociology of science and technology (Collins, 1985; Pinch 1986; Pickering, 1983; Hughes, 1983 and MacKenzie, 1981). What we have been able to show from studies of laboratories, theories, machines and technology is that their robustness, their solidity, their truth, their efficiency and their usefulness depend less on formal rules or on their own characteristics than on their local and historical <u>context</u> - this independently of the various ways that there are of defining that context.

2. The robustness of structured relations does not depend on qualities inherent to those relations but on the network of associations that form its context

The principle we started from in constructing the Hume machine is a <u>principle of calculability</u> different from that of Turing machines, but one which occupies the same strategical position for our project as his did for his project[3]. The reasoning is as follows:

- any form is a relationship of force;

- any relationship of force is a test;

- any test can be expressed as a list of modifications of a network;

- any network is resolvable into a list of associations of specific and contingent actants[4];

- this list is calculable.

Thus there is no <u>formal</u> concept used richer in information than that of a simple <u>list of specific and contingent actants</u>. There is a tendency to believe that we are better off with formal categories than with circumstantial facts, but forms are merely redundancies of force, that is to say of the number and distribution of associations.

The principle of calculability can, then, be summarized as follows. Any microtheory[5] can be deployed in a network of associations that is not itself a microtheory. To put it another way: any closed system is a local and circumstantial part of an open system. Following Hewitt, we take an open system to be a system that cannot in principle be completed or closed, and which therefore has to negotiate between conflicting decisions made by parts of the system that are independent of one another.

This postulate seems to be paradoxical. Logical forms, mathematical rules, sociological laws, structural stabilities and syntactical constructions do indeed seem much richer in content than mere association. P 'implies' Q, P 'is the cause of' Q, P 'possesses' Q, P 'is the father of' Q, P 'is complementary to' Q and P 'transforms' Q seem to be more robust determinations than the simple statement P 'is associated with' Q.

We postulate that these 'rich' terms have no other real content than that of summarizing, representing, gathering, condensing a network of 'poor' terms whose sole link is that of association. Structured forms are <u>synopses</u>, <u>clusters</u>, <u>digests</u>, <u>skeins</u> of associations. Their force, robustness, necessity and solidity cannot be deduced from their formal qualities, but from the <u>substance</u> of the network that they are capable of mobilizing. In other words, there is no formal notion that does not gain its substance from a (more or less pre-ordered) set of contingent circumstances[6]. In conclusion: in following the network of contingent circumstances we also gain access to the ultimate cause of the solidity of all structured forms.

Our postulate is only apparently reductionist. It is not a question of reducing the whole to its parts - as if we were saying that the human body is at root 'only' hydrogen plus carbon plus water. On the contrary, we want to show that the whole - the network of contingent circumstances - is superior to its parts - the skeins or structures that summarize its associations. The postulate is thus literally <u>irreductionist</u>. It deploys all forms in its network, and all power in its relationships of force[7].

It is clearly pointless to make such a statement about the origin of robustness if one uses it to <u>replace</u> procedures for the calculation of a microtheory within the very interior of the field of application of a microtheory. Why take the trouble of using networks of associations summarized by truth tables or by partial differential equations - even if this use is theoretically possible - when there are numerous tools in information science capable of treating these microtheories without the slightest difficulty? The postulate only becomes valuable if it is applied to a class of problems that microtheories cannot incorporate: that is to say to everything that is <u>between</u> microtheories, to Hewitt's <u>open system</u>. The Hume machine will always be <u>weaker</u> than microtheories taken on their own terms. It only comes into its own when compared to the performances of microtheories[8] not on their own terrain, <u>but on its complement</u>.

Microtheories form a more or less dense archipelago. The sea that links them is for the moment one that it is difficult and dangerous to navigate. Cognitive and computer scientists dream of covering over this sea by linking the set of microtheories. This, we now know, is an impossible dream[9] - or rather a nightmare (Winograd and Florès, 1986). Faced with this situation, there are, it seems, three possible solutions. The first consists of closing ranks, ignoring basic problems, lowering sights (but not sales!) and marching on, limiting computer prostheses to the simple cases of sets that are already well-defined and indeed predefined by metrology and by standardization procedures[10]. The second involves criticizing the weakness of computers by explaining why they will never be capable of dealing with ambiguous, polysemic, reflexive, hermeneutical problems, which necessitate a diffuse formalism and fluid sets[11]. The third is to postpone solving material problems for the present, and to write programmatic texts while waiting for computers or people to improve (Hewitt, **0000**). Each of these approaches has the effect of working from microtheories, and of postponing as long as possible a consideration of their margins and limits. We will see that, using a form/field reversal (Gestalt switch), it is possible to follow an inverse strategy and to work from open systems by treating microtheories as a special case, as a condensation.

******************Après le texte me semble trop différent, je n'ai pas poursuivi*********

3. Adapting what social sciences ask of computers to what they actually do

There is in effect a fourth path, one which does not rely on an extension of formalism, on the injection of Heidegger or Garfinkel into the chips, or on programmatic dreams featuring an Achilles who in fact never catches up with the tortoise. This is the path that we will take with the Hume-Condillac Machine. It involves adapting our philosophy, ontology and sociology as far as possible to what computers can do: statistics about the counting of marked occurrences. Instead of taking the royal road, which consists of making computers intelligent so that they are as skillful as the finest sociologists and most intricate hermeneuticians - a road which very soon becomes impossibly steep - we will take the service escalator. We accept the elementary stupidity of computers and we fashion a sociology, a logic and an ontology which work at their level of stupidity. Instead of being strong, we take the solution of weakness, hoping to turn this weakness into strength, since today's computers - and not those postulated for the year 2050 - can come to our aid right away. Whoever tries least goes furthest. We adopt this strategy of weakness, which was attempted without success by Hume and Condillac for explaining the human mind, for dealing with computers whose non-human mind is sufficiently dense to really resemble Condillac's statue or Hume's empty understanding.

Why should this new approach succeed when so many dreams of automata have failed? Precisely because the Hume machine does not dream, but takes the computer for what it is in itself, without imposing anthropomorphic projections and epistemological beliefs on it. The objection often made by hermeneuticians against the 'thoughts' of computers is that since it has no body nor project nor worries, the computer is not thrown-into-the-world, as Heidegger said humans were (Winograd and Florès, 1986). But this is point we are making - we are not talking about imitating humans. Amorphous silicon and electrons have their own way of being in the world. We have to work from them instead of vesting them with human properties so as to immediately deny that they have any.

What, then, is the minimal property that we should start by giving the Hume machine? Received opinion says that computers need a set of rules in order to calculate. Formalists claim that the computer is above all a generator of rules which are all reducible to an inference engine of the form IF ... THEN ... . This point is also accepted by hermeneutic critics, who go on to say that it is impossible to completely regulate language games (Collins, 1990) and consciousness. But this first supposition - viz that computers obey rules - is already an anthropomorphic projection. It involves attributing a particular view of formal human thought as elaborated by epistemologists to computers, with all the paradoxes that that entails.

Now the computer does not have any IFs or THENs - these are already functions within a predefined language. All it has is occurrences of addresses linked between themselves by an elementary association: address 1 'is the same as' or 'is different from' address 2. For its own part, in its own world, all the computer does is blindly deal with associations between contingent and specific addresses. In other words, it is already in itself an association network, in the sense defined above by our principle of calculability.

We can now understand that the only necessary point of departure is offered us by the computer itself. This is a network of associations between contingencies, having no other a priori characteristics than that they are different from one another, and that they can be addressed. Is the computer blind? Then so are we. Does the computer have no formal rules to start with? Neither do we. Does the computer not deal in abstractions? Neither do we. Does the computer just feel its way from trial to trial, from circumstance to circumstance? So do we, and we don't ask any more of it.

The paradox of discussions about the possibilities of computers is that they are leant qualities that they do not have - formalism, the epistemological dream of humans (Slezak, 1989) - whereas they are denied hermeneutic capacities that they already have! Indeed, in its own terms the computer is already an open system in Hewitt's sense[12]. It respects contingencies and specificities much more than humans who try to program it believe. We then give up on ever being able to get out of it what it is already capable of providing if only we abandon our epistemological fantasies!

This conception of what computers do for themselves is clearly the <u>result</u> of applying back our argument about the origin of structured forms, since it is this argument that enables us to unravel epistemological fantasies. But this result is in turn what will allow us to use the computer right away to prove our argument about the network origin of said forms. The Hume machine is an associationist machine and is only that. It does not come with any logical category, any syntactic form, any structure. It is, dare we say, blindly empiricist. What we hope to gain from our strategy is to find, instead of the chaos that might be expected, all the emergent properties that are worthy of our attention - and which will enable us to circulate between microtheories[13].

4. The only inference engine that the Hume-Condillac Machine needs is a calculation of co-occurrences; in the scale model of the machine this is a Leximappe™ network

In order for the Machine to remain an open system, we will suppose that it has at the outset no information at all about the nature of the data it is dealing with. The only information that can be fed in is of a general nature, relating to the way in which its perceptions are to be memorized, associated and aggregated[14]. The different objects present in its memory are always represented by labels. This is an indispensable condition for the treatment of the data. The only logic needed to govern these labels is that of identity: two perceptions are either the same or they are different.

Working from a flux of data present in the form of label without properties (at least before any learning is done), how can the internal state of the Machine sufficiently structure itself to be able to offer interpretations which <u>sufficiently resemble</u> those of the sociologist, logician or historian who want to use it to help them deal with their research data?

The fact of being able to perceive labels without any other treatment is clearly not enough to reconstruct microtheories. The least that we can then ask is to be able to count the occurrence of these labels, then to record statistical associations between labels by counting their co-occurrences - as Hume or Condillac's statue did. No structure, no microtheory, should come into the machine that it has not obtained by its analysis of co-occurrences.

But won't it be said that it is the absurdity of just such an associationist project that, waking Kant from his 'dogmatic sleep', proved the necessity of synthetic a priori judgements? Why should we be able to succeed where Hume and Condillac failed? The fact is that they tried to pass directly from the recording of associations to formal structures. They forget to mention an essential link: the network. And they did not know about computers, which alone can accumulate enough contingent circumstances to substitute number for the formal force of rules[15]. It is the network that will allow the Machine to serve its <u>apprenticeship</u> by transforming any set of contingent circumstances into a point, which will then serve for the reconstitution of the network. A network of co-occurrences that is only constructed with ANDs and ORs is very poor compared to microtheories, but it has an advantage over all of them that largely overcomes this imbalance: it is a formidable means of travel and of displacement.

In order to prove that it is possible to obtain from networks of co-occurrences what it was believed could only be achieved with formal rules, we have to provide a scale-model of the Hume-Condillac machine. Indeed, since we refuse programmatic discourse, we should already be able to realize in the model certain of the capacities of the Machine, since only its size and not its principle will distinguish the current Machine from any future one[16].

In order to construct this model, we are going to take the least favorable conditions. That is to say, we will take a micro-computer treating full texts reduced to keywords, and we are going to establish a network using co-word analysis (Leximappe™). If under these extreme conditions we are able to prove that this simple network of associations already enables us to bring out even a limited number of structures believed till then to be defined by formal elements, then we will have proved that any real Hume machine treating a greater number of texts will be able to realize our goal[17]

The model that we have made in our Center works as follows. It first of all records occurrences of keywords in the machine's addresses. These keywords have no other characteristics other than that of having an address. It draws up a list of all the occurrences of a word - for the machine, this list is made up of a string of 0s and 1s. Next it performs its calculation, which is a comparison of co-occurrences. It classifies the associations it finds in order of degree of co-occurrence (maximum 1, minimum 0).

From the range of possible measures, we chose the following coefficient of equivalence E:

$$\boxed{E = \frac{Cij^2}{Ci*Cj}}.$$

where C is the occurrence of keywords i and j.

This coefficient has the advantage of not rendering links dependant on the total number of occurrences (a high degree of co-occurrence between infrequent words are classified with high degrees of co-occurrence between common words, and are not lost sight of [Courtial, 0000; Michelet, 1988]). The result is then projected in the form of relationships between words. These relationships have no other content that that of being 'tensors' that register the relative degree of co-occurrence. Any extension of the corpus (whatever type of corpus it may be) will produce a (possibly null) modification of the value of the 'tensors'. It is this modification, which results from a trial of strength, that is the sole and unique point of departure in this rough prototype of the Hume-Condillac machine for any interpretation of the nature, essence and form of actors and of the nature, essence and robustness of structures linking those actors. The recording of the variation of associations as a function of these trials is its only reality principle.

Our model of the Hume-Condillac machine starts from this level of self-imposed poverty and empirical blindness. Nothing in its constitution - except for the indexing of keywords and the choice of the coefficient of equivalence E, which for our purposes is only justified by the contingent existence of the Leximappe™ tools - is in disaccord with the real functioning of Boolean logic nor with the material functioning of electrons in transistors.

On the contrary, the 'higher-level' language of co-occurrences, the machine language and the material that constitutes the machine operate - or think, or speak - in exactly the same way.

What can we learn from such a primitive network of co-occurrences and such a contingent treatment of associated keywords? Nothing, say the formalists - and their fraternal enemies the hermeneuticians (Collins, 1990). Everything, we say. Or at least everything of interest to us in looking at large bodies of qualitative documents, which have remained opaque to the costliest and most sophisticated treatments.

5. The simple network of unstructured co-occurrences enables us to produce structuring differentiations

Those who are not used to looking at heterogeneous networks and who prefer the solid shelter of microtheories always imagine that putting things into network terms signifies going from order to chaos. However, a network is not undifferentiated, it is not "the night wherein all cows are equally grey", to use Hegel's expression. Chaos would mean that all associations were equally probable. That is to say that in the model any one keyword would have exactly the same chance of being associated with any one term as with any other. Now a record of keywords is, in contrast to this hypothetical chaos, in fact highly differentiated. It is not the case that any given keyword is associated with any other. There are preferences, asymmetries, power relationships. In brief, there is order. It is simply that since these differences do not appear in terms of structure or category but as a trajectory of associations, they do not appear right away. However, it is sufficient to get used to the idea of their being there to discern the minimum order with which the Hume machine will learn to organize its world - and thus help human researchers organize their own.

We will show that even at the current state of the machine, the use of network analysis already enables us to obtain effects of meaning that are much richer than those which others strive at great cost to impose on machines.

a) "No machine can ever recognize hermeneutical finesses, such as synonymy." On the contrary. Nothing is easier for a network of co-occurrences - even the model of the Hume machine can already do it.

How will we make the machine understand that two distinct terms admit a single referent? The first solution that comes to mind is to enter a dictionary of synonyms into the machine. This would enable it to automatically substitute one term for the other. In fact, this solution poses many more problems than it resolves, since linguists have shown that there is never any pure synonymy, and that it is necessary to take the words' use context into account in order to decide the substitution of one term for another.

Now the very interest of a network of co-occurrences resides precisely in the fact that there is no other definition of an actant than a contextual one - that is to say in terms of the set of actants it is associated with. Thus by working from a network of associations, we can in principle recover synonyms - at whatever degree of purity or impurity - without having to enter a dictionary into the computer. This quite clearly leads us to modify the definition of synonymy along the way, as always with the Hume machine, from a substantialist to an 'existentialist' one. Two words are synonymous in the context formed by a given body of texts if they give rise to the same association profile. However, it is clear that with rare exceptions two words never have exactly the same profile. There are no pure synonyms. The small differences that have to be eliminated at great cost in the dictionary approach and by categories are all maintained in the approach by networks of co-occurrences. The richness of language is in its use context. Thus, paradoxically, a management in terms of association networks retains more richness than a classification by definition.

In the current model, we analyze the first Leximappe™ network using a second program called Vector™, which compares not the keywords but their association profiles[18]. Thus we can recognize synonyms by the simple fact that two terms which have neighboring association profiles are put side by side on the Vector™ map. If one is superposed on the other, then they are pure synonyms.

This approach even enables us to treat the implicit and the hidden or absent referent. Suppose that the set under consideration is made up of interviews with people who are talking about a thing which for some hidden reason they never actually mention explicitly. In our Center, for example, everyone interrogated uses the word 'Mac', the researcher may not know what a 'Mac' is. Looking at its association profile, the researcher will be able to reconstitute the semantic field of the hidden word 'microcomputer', even if the word itself does not figure in any of the interviews. It the association profile is markedly different from the hidden word that the researcher believed it proper to substitute, then the burden of proof is on the researcher. Does s/he have the right to impute this hidden referent to interviewees, even though co-occurrence analysis does not justify the inference? Is a "Mac" the same thing as a 'microcomputer' or is it really something quite different? Here again, the retention of use contexts in the Machine enables us to retain the 'existentialist' richness that 'essentialist' questions always impoverish - for us in the Center a Mac is not <u>a</u> computer but <u>the</u> computer! A lot would be lost if this nuance were ignored ... .

From the example of synonymy, we can see the strategy of the Hume machine. Instead of invoking a weighty formalism that tries to store up thousands of particular dictionary rules in an effort to reduce ambiguities, we offer a disorderly accumulation of a body of whatever size and the rediscovery of fine nuances through a simple mapping of semantic fields. On the one side there are hundreds of rules that in the long run do not enable us to take the different uses of words into account, and on the other there are no rules, but there is the contextual richness of use.

b) "The definition of <u>categories</u> necessarily depends on human intervention. In themselves raw data are scattered all over the place." On the contrary. The Hume machine finds it particularly easy to generate categories automatically. Even our model can already do this.

It is said that when we look at form compared to context, we find ourselves faced with 'empirical' data void of all significance, dispersed. The role of the researcher is seen to be that of 'putting things into order', imposing definitions, examining special cases. This strange duty does not exist when one is faced with a network - but then neither does empirical dispersion. When the form is nothing more than a condensation of the context it is no longer necessary to follow Kant and impose categories on a hint of a stimulus. There are no brute facts, there are only researchers who brutalize their data. All you have to do is to ask the context itself to <u>designate</u> its own categories, by bringing out regroupings implicit in the network. The naming of the category can itself be made entirely automatically by a process of genuinely democratic <u>elections</u> - bottom-up, not top-down!

Thus we can see the advantages to be gained from automating our procedures. In our own relativist or post-Garfinkel world, it has become impossible to define a category from above. We have to let the actants work out their own dimensions, liaisons and relative weight. But the task of triangulation also seems to be enormous. Once there are more than a few actants, how can we do enough 'by hand' to respect the multiplicity of categories and of definitions of actants? It is only this <u>practical</u> difficulty that has made people reject the relativist consequences of all network theories. In the absence of material means for letting the facts organize themselves in their own way, researchers believe that they are forced to continue imposing their own metalanguage.

Our CANDIDE™ model, using Vector™, can already largely do this. Take a set of keywords whose co-occurrence has been calculated. We obtain a network of points and of tensors. This network enables us to detect <u>clusters</u>, that is to say sets of points that have similar association profiles (Callon, Law and Rip, 1986; Michelet, 1988). Is there one macro-term that can summarize the cluster better than any other? The Machine holds elections, and designates the word or words whose association profile is closest to that of the cluster as a whole. This word, generally a composite one, henceforth serves to designate the whole of the network - looked at from a certain point of view. This 'nomination' is entirely revokable and reversible. The chosen keyword is not a substance, it is simply the representative or the network node that will enable us during other treatments of the data to gain access to the category and through it to the network that alone gives it meaning. It is not, as used to be the case, the category alone which gives meaning to a scattered collection of data. On the contrary, it is the network alone which gives meaning to the category. And since the election is dependant on the point of view taken, one can always within a given network untangle the initial categories and tangle up the data into alternative ones for some other purpose.

This procedure allows us to have at that same time, in the same Machine, the hitherto contradictory advantages of nominalism and of categories. Indeed it is possible, in our model, to re-aggregate the data using macro-terms by obtaining clusters of clusters - up to any desired level of granularity. But since any category keeps a memory of its own engendering through a series of elections based on a particular and contingent list of associations, it is always possible to retrace one's steps and to rediscover any particular use context. It is this zoom and backtracking effect, so particular to modern network theories, that is the principal advantage of the Hume-Condillac Machine, since it is what enables us to deal with large masses of heterogeneous data without splitting them up into micro and macro levels, into case studies and general theories, or into raw data and interpretations.

c) "There is no automatic treatment of written language that we can use to feed into the Hume machine from above." Yes there is. Provided we look at semantics rather than syntax. The model already does this to a degree.

It will be pointed out that vast bodies of texts are needed in order to get at a word's semantic field, or to get self-designated categories, . Now since there is no practical way of dealing with complete texts (Lebart and Salem, 1989), it would appear that the Hume machine has merely displaced the problem from logic to linguistics. By claiming that language - here texts and other written documents - can restore the context (whose logic is only a condensation of the network), we are still faced with the problem of dealing with language. Now we accept that the structure of language is infinitely more complex than the structure of formal logic. But precisely because of this complexity, it is tied to the network of associations and the irreduction that we have already created for the actants. These are so much the more valuable for those actants among us which are words.

It is possible to reduce syntax to semantics in the same way that we have reduced formal structures to particular instances of which they summarize the association. And to reduce semantics to the list of trials each word-actant is submitted to. Quite clearly this irreduction would be absurd if it involved going up against the richness of the language used in the interior of the many microtheories that make up linguistics. It is not a matter of re-establishing rules about the agreement of participles from a calculation of co-occurrences. Nor is it a question of re-discovering the relationship between volume and pressure in gases using a Leximappe™ network. The work of cognitivists like Thagard (1988) or Slezak (1989) notwithstanding, this is not our aim. The aim of the Hume machine is to travel between microtheories. It does not need any heavy equipment, but on the contrary it needs just the bare minimum to enable it to produce meaningful statements about sets of texts in the absence of any microtheory. Like all explorers who have to carry the most food in the least space, it wants to be able to do with a language concentrate.

Now one of the most radical ways of 'concentrating' language is to keep only substantives, and to consider all syntactical forms (verbs in particular) as configurations of word networks. In the phrase "the cats eat the mouse", we only take away with us the co-occurrence of cats and mice, and we ask the machine to restore the verb "to eat", if necessary, by recognizing the non co-occurrence of "cats" and "mice"! This procedure is not too efficient for the verb "to eat", which belongs to microtheories, but is much more useful for exploring configurations of networks for which there are no verbs in the language, or for which existing verbs - to be able to, to cause, to want, to occupy, to hold (whether they are taken sociologically or logically) - do not suffice.

This simplification becomes crucial when it is complemented by the irreduction of substantives themselves. In effect, what we said above about categories also applies to words. The model of the Hume machine treats all common words as proper nouns - extreme nominalism. But then all proper nouns are macro-terms elected by the network itself - reversal of nominalism by the network. There is no definition of any word richer than the co-definition obtained by looking at the use context of all words associated with it[19]. In most social sciences we need to operate in terms of networks, since the multiplicity of points of view, of informants, of transformations can entail that a given name cannot be assigned to a particular person or institution. The 'same' person can be successively designated in interviews by initials, 'Mr Smith', 'John', 'the representative of the authorities' or by 'industrialist'. If the isotopy of this actor is in question - if the different words do not have the same association profile - then there is nothing forcing the researcher to consider that nevertheless there is a single essence having different manifestations[20]. We are simply dealing with a 'variable geometry' actor. If we wish to stabilize this actor, then we must work just as hard to maintain this isotopy as we would for any other actant[21].

Here, as elsewhere, researchers do not have to decide. Nor do they expect the Hume machine to decide for them. On the contrary, they want it to help them maintain a state of variation, of opening, of a possible recomposition of the association network. Here again we can clearly see the abyss that separates our strategy from that of AI experts. We do not delegate the most rule-driven and formal parts of our actions and the surest of our knowledge to the Machine while reserving fine-grained interpretation and ambiguous cases for ourselves. On the contrary, we use the Machine to keep the system open as long as possible, by keeping for ourselves the tasks of putting things into categories and of locally closing microtheories. It is the computer that enables us to retain a 'natural' form of intelligence, and ourselves who continue to produce 'artificial' - that is to say, closed - forms. While AI's delegations hardly help us at all except in managing existing microtheories from the inside, the new mixture between the Hume machine and the researcher promises to be more useful between microtheories.

In the currently available model, this 'concentration' of the language for an exploration not bounded by microtheories is done by transforming a full text into as many keywords[22] as desired. The task of indexing is aided by an adaptation of the Lexinet™ procedure (Chartron, 1987).

6. How can the Hume machine serve its apprenticeship?

In the preceding section, we showed that the network of co-occurrences forming the first layer of a Hume machine and the greater part of our model does not dissolve into chaos, and enables us to keep open a great number of characteristics of the context. The network is much richer and much more differentiated than all 'higher' terms, which in fact have no other content than that they summarize or condense the network.

Let us note at this point that any model of the Hume machine, however primitive and of whatever early version is already a valuable tool for our declared aim: to help researchers in the social sciences to mobilize masses of heterogeneous data in the form of full texts. Even a machine that could merely let us range over a set of categorizations and synonyms in a mass of interviews is already extremely useful.

However, in the preceding section it was the humans who did the work of simplification, of expressing in terms of microtheories. They only asked the machine to produce reversible categories and to keep the system open. The machine is an extreme empiricist; the researchers are the microtheorists. Now there are two ways that we can present the advantages of the Hume machine. The first is that it is effective because it enables researchers to keep their microtheories reversible. This is the cut-rate version. The second is that it is effective because it itself can produce microtheories. This is the upmarket version, and it is this version that enables the Hume machine to compete on their own grounds with the 'scientific discovery' programs reviewed by Thagard (1988). Like Condillac's statue, it has to be able to learn to recognize network configurations for itself. We want to progress from a primitive model to advanced ones. In order to do so, the machine must not simply keep the association network open, but must also contribute to closing it. This becomes essential once the number of databases increases. It must be able to serve its apprenticeship and initiate a new dialogue between researcher and machine, whereby it can test its interpretations of the state of the network. It should be able to locally propose microtheories, or at least to propose to the human a progressive passage from the unfolded, irreduced network to a condensed microtheory and vice versa. This progressive and reversible passage is the essential feature of the upmarket version of the Hume machine. However, this time we do not have any working model ... .

The manoeuvre is in principle fairly simple. In the same way that the machine is easily capable of assembling clusters and designating categories, we could ask it to recognize configurations of associations and to designate these configurations by a term (Pomian, 1989). It would obtain its - syntactical - metalanguage by extraction of the form of relationships exactly as it obtains its - semantic - metalanguage by clustering relationships. If it is admitted that the form 'to be an obligatory passage point' is recognizable in networks, then it is easy to add the term 'obligatory passage point'. If such an addition is made systematically, then the distribution of occurrences of the form synthesized by the Machine will be the same as that of the word qualifying that situation. Now such a distribution can in fact easily be detected in a statistical network. We can by repetition therefore teach the machine a certain vocabulary, which is fed to it in terms of the synthetic forms that the words are synonymous with. It learns how to say: "A is an 'obligatory passage point' for B". Learning to speak by statistical accumulation may seem a long way round, but such apprenticeship is only necessary at the beginning - although in principle it remains always reversible, always able to be unfolded into its original network. It suffices that certain words be synonymous with "network modifications induced by other words" for them to serve to directly produce such modifications in other instances. In other words, the Machine learns after a certain stage to pick up its vocabulary directly in terms of definitions that it provides itself, and no longer through repetition and slow apprenticeship. For the Hume machine, the passage from synthetic a posteriori judgments to synthetic a prior judgments has to be made progressively. It will construct its a priori judgments, in thoroughly unKantian fashion, by accretion.

Let us, for example, take a logical concept with a rich history in philosophy, like that of implication. In modern logic, implication can be summarized by the following statement: "It is impossible to have simultaneously the presence of A, the presence of the rule 'A implies B', and the absence of B". What can be done with the logical form of implication within the microtheory of formal logic? It enables us to treat the validity of a statement automatically, by just looking at its form - by drawing up its truth table[23]. Whoever has A, and the rule "A implies B" and the definition of implication can re-engender B at will. They can, therefore, do without B. It is this formidable economy of thought and its ability to treat data automatically that explains the force of such microtheories - and the power they hold to fascinate people. Even any expert system can be considered as an accumulation of a large number of such *modus ponens*.

Of course the virtues of implication cease as soon as one approaches the limits of microtheories. The deduction of B from A and the rule 'A implies B' will be carried out or will not as a function of the context of action, of the intention of the system. 'A' is no more than a logically sufficient condition, in practice it is not sufficient. Other things are needed: a context, aims to achieve[24]. It is here that the network of co-occurrences regains the advantages that it seemed to have lost when we were immersed in microtheory. In network language, implication involves the recognition of the form of co-occurrence of A and B by way of its inclusion coefficient[25]. It is thus perfectly possible to ask the machine to replace the cluster A-B with coefficient 1 by the single term A, and to qualify the link that has been defined up to the present solely in terms of associations by an implication 'rule'. Whoever can do the most - hold together the statistical network - can do the least - incorporate the formal microtheory of implication. But the big advantage to retaining the whole network is that one can always return from the qualified rule to the qualifying network. If the addition of new data diminishes the association coefficient - now there are Bs without As - then nothing is modified in the analysis of the network, since it is progressive and reversible. On the contrary, logical analysis would not know where to go: the consequence is not correct, there are exceptions that one doesn't know how to deal with[26].

The Hume machine should be able to use the classical terms of the various microtheories. However, it seeks less to compete with them than to decide between them. It takes traditional categorizations 'with a grain of salt', checking each time to see what is worth keeping for an interpretation in terms of networks. For example, implication in its logical form is not necessarily usable. It is only useful for clearing up very well stabilized sections of the network - since A implies B, we just need to write A. But we should be wary of it as soon as we want to take the context of the deduction into account. It is the interaction between the researcher and the Machine that will enable one to choose a useful metalanguage and to then reinject it - always reversibly - into the Machine.

The Hume machine project is a means of selecting from the language that we have inherited from the old fields of logic, cognitive science, sociology and politics in order to extract word-networks that enable us to simultaneously grasp the form and the context which gives meaning to it[27]. In practice, the interesting metalanguage will be idiosyncratic, adapted much more to the topography of networks than to terminologies that long use has deposited in the epistemological beliefs of microtheories. This is the case, for example, for a concept like that of translation (Callon, 1989). The word 'translation' is a word in the Machine's metalanguage. It indicates the number of points that separates two given points. It is then possible, by comparing the association profile of these points, to decide if they are intermediaries or mediators (Hennion, 1981). Intermediary points will have similar association profiles. This entails that even if there are many points between A and B, none of the intermediaries can much disturb the association. They are, if you like, faithful allies.

On the other hand, if the points have differing association profiles and if you nevertheless need to pass through them, then you are dealing with mediators - unfaithful, dangerous, interested allies, who can profoundly disturb the network's layout. The extent and degree of risk attached to the translation is thus clearly tied to a consideration of the number of points and to their quality as mediator or intermediary.

Another concept from the Machine's metalanguage is that of the black box (Latour, 1987; Callon, 1988; Michelet, 1988). The reproach always made against network analyses is that they consider points and relations, without being able to recompose entities - or surfaces and territories, to use the language of cartographic projections. Thus it is claimed that the network is a good means of travelling and of zooming, but that it is incapable of reconstituting 'essences'. Now the concept of the black box enables us to give associations boundaries and limits. If for actor A - an actor internal or external to the network - all the points in cluster B are synonymous, then one can trace a boundary around cluster B, which will be considered as a single black box, however many points it is composed of. For example, for the user a MacIntosh microcomputer is such a closed black box. Viewed from whatever perspective, there is always only one visible computer, which counts as one. Clearly this does not hold for the repairperson who looks into the box. A slight modification in perspective ends up dissociating what appeared to be a single entity into thousands of components. This notion is essential for structuring the network. It is what makes the composition of essences depend at once on the perspective taken and the trial. It is what will enable the Hume machine to capitalize both on existences - networks - and essences - black boxes.

7. Conclusion: an aid to narrative

We have pushed the cognitive and information science consequences of the new sociology of science and technology as far as they will go. Since there is no coherence stronger than a circumstantial network condensed or summarized into forms, structures and microtheories; since the computer, once it has shed its anthropomorphic and epistemological projections, is already capable of dealing with significant association networks; and since there are no computer programs on the market for researchers in the social sciences who deal with a great number of heterogeneous textual sources, we have proposed constructing a machine capable of revitalizing Hume and Condillac's unfashionable philosophical program of associationism, by giving it the material base it hitherto lacked.

We can now see the direction taken by researchers interacting with more and more elaborate versions of our Hume machine. What is happening is that we are getting closer and closer to the techniques of narrative - an essential tool for historians, ethnologists, field sociologists and naturalists - and to the description of association networks made up of a jumble of heterogeneous databases. In this fusion of qualitative literary qualities and the power of quantitative treatment we expect a renewal of methods and explanations in the humanities. There is no more powerful explanation than the analysis of the contingent circumstances of association networks, but for the moment the only way of obtaining this form of meaning is through a narrative limited to narrow terrains. Up until now, the only remedy to this limitation was to go over to statistical tables and to quantitative analyses. This was at the price of a rupture with the fine tissue of networks and circumstances - whence the interminable debate between field sociology and the sociology of structures, between history and sociology, between economic history and economic theory, between arts and sciences. The Hume machine opens an alternative route. It is quali-quantitative. Since it is not based on any particular innovation in material or in programming, it can immediately begin to guide the construction of models, each of which will at once be of use to researchers in the humanities.

This workstation is a contribution to the debate that is taking shape between the cognitive sciences and the new sociology of science. But instead of a sterile opposition of psychology and sociology (Slezak's [1989] solution), we propose to select from <u>within</u> each field those schools of thought that give rise to fruitful associations. Instead of restraining the context so as to enable the mind of the scientist or the computer to make discoveries limited to microtheories in complete isolation, we propose on the contrary to choose each time the school of thought which enables us to follow the context in the most continuous and complete fashion. Just as Bloor and Collins' program - asymmetric, since it has a different treatment of society and nature - is badly adapted to the mentalist cognitive sciences as defined by Slezak and to Thagard's computer prostheses, so does the symmetrical program that we propose in the name of network theory seem well suited to the cognitive sciences as defined by the connectionists (Rumelhart and McClelland, 1988; Hutchins, 0000) and to Hewitt's (1985) computer prostheses. All the debates about the construction of society, science and psychology that Slezak hoped to end continue within cognitive science, within programming languages, within the sociology of science and technology. And probably within computers themselves.

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Notes:

This work would not have seen the light of day without Michel Callon's previous work on the economy of networks and without Bill Turner's enthusiasm and active support.

[1] The great limitation of factorial analyses (Benzecri, 1973) is that they dump the data they obtain through questionnaires into a homogeneous space and project them onto axes. So doing, they impose a necessarily arbitrary unification based on their own measures onto the actors' own analyses. ******INsérer****** In order to be in tune with the new relativist sociology, we need to develop methods which are closer to pre-classical perspective, wherein each part of the surface of the painting has its own projection rule. Any method adapted to the ethnomethodological revolution (Garfinkel, 1973) has to leave the data as many dimensions as there are points. There are two classes of philosophies of measure in the social sciences: the one works in terms of categories and the other in terms of linking and networks. The former makes all marginal or uncertain cases, willingly or not, adhere to the category defined by the mean. By contrast, the other does not establish any link which is not made 'in the flesh' by the actor him or herself, by means of a linkage made between two terms by way of as many intermediaries as are necessary. This article works within this latter tradition.

[2] The Hume Machine, or Condillac's Statue represent the associationist program, which we hope will thus be awakened from its 'dogmatic sleep'. It goes without saying that we are displacing the psychogenesis conjured by these two authors from people onto machines. What they say about humanity is not very likely, but what Hume's vision of the formation of human understanding or Condillac's design for his statue should apply just as well to the computers described below.

[3] For the present, we can summarize the analogy as follows: the two principles of calculability replace higher, structured cognitive capacities by a determined and systematic management of stupidity. They are strategies of weakness. The Hume machine is determinist but is not refutable - since refutability can only occur within a microtheory.

[4] *****insérer la footnote de la lettre**

[5] We borrow the term 'microtheory' from Hewitt. He uses it to describe a set of formal rules in a closed system (the theory of relativity, calculation of Sales Tax, stock management programs). Clearly, this definition presupposes that there are no macro-theories. There are only local theories, whether these be theories of relativity, cosmology or

accounting rules. Thus the question is one of knowing if we can extend microtheories in order to help them survive in an 'open system', or if we need to profoundly modify the very way in which one microtheory is extended to reach another.

6 The concept of 'contingency', like that of 'circumstances', is modified by this postulate, since neither remains confined to the residual role generally allotted them. This form/field inversion is a kind of Gestalt switch. The same holds for ideas of 'part' and 'whole'.

7 An important corollary for our project is that it opens any formal result that has been obtained by a science into <u>prose</u> or into a <u>story</u>. Narrative techniques and historical accounts are closer to the network than their formal synopsis. This is why it is equally crucial to work out a mechanical means for treating masses of texts and narratives.

8 It would be just as absurd to try to make the Hume machine work <u>within</u> a given microtheory as to ask modern astronomers to make their calculations by hand. But this very image is a case in point. It shows to what extent the development of computers has allowed us to demystify microtheories - whence their current name of <u>microthe</u>ories. There is a <u>delegation</u> of the act of calculation to blind automata. This is captured by the concept of 'algorithm'. Formal procedures are economical and mechanical, they are operative and operational. They no longer have the intellectual aura which made us look for the form or structure 'beyond' 'simple' empirical and contingent data. This materialization and banalization of operations once considered to be spiritual or at least mental is probably the most significant cultural effect of computers.

9 The aporia which Gödel arrived at - that 'any formal system sufficiently rich to include arithmetic contains undecidable propositions' - and which was so mortifying to formalists is merely a consequence of the project of expanding microtheories to the set of open systems. The associationism proposed here does not lead to the same contradictions. The Hume machine is not bound by the incompleteness theorem. It produces interpretations in the form of networks of possibilities and not in the form of a microtheory. Thus it is neither complete nor indeterminist. Far from being contradictory, it can be applied to the very theory of open systems, without taking refuge in a metalanguage which would close them. The theory is therefore reflexive, and conforms to the principle of irony (Woolgar, 1988).

10 It is in effect always possible to sufficiently stabilize the exterior of a tool for calculating in such a way as to make its calculations 'apply' to the exterior. This apparent adequation should, however, be seen rather as an <u>extension</u> of the network of validity of the microtheory in question (Latour, 1987).

11 **Insérer la footnote******

12 Hewitt wants to develop a microtheory of open systems, which is a contradiction in terms. Whence his lists of specifications. Since this contradiction comes down to his wanting to open a machine that is in fact already open, the machine does not do what he wants. Whence his programmatic texts which always refer the realization of his dreams of openness to a later generation of machines machines than at present. Now the open system is by definition a network and not a microtheory. And since the computer is already a network, what Hewitt is looking for in the distant future is already right in front of his eyes, without his noticing it. Of course, we also need a microtheory - the one that we used above to define the principles of calculability and of irreduction. But we only need one of them.

13 Our procedure is linked to the ideas used in the field of neural nets and by connectionists. Neural nets very elegantly resolve certain difficulties in calculation and in

form recognition by short-circuiting traditional stepwise programming. However, they presuppose the existence of highly structured forms either at the outset or in their output. Even if they offer certain advantages for programming the Hume Machine, they have no way of resolving the basic problem of its architecture: there are no structured forms to start with.

[14] If one takes formalism to mean 'metalanguage', then it is clear that we ourselves have a metalanguage for describing the Hume Machine and for interacting with it. However, it is not formal in the strong sense of the word. An inspection of its inherent properties will never enable one, by itself, to judge its correctness. Thus there are metalanguages which designate simple trajectories through the context and stronger metalanguages (microtheories) which aim to substitute themselves for the context or to do without it.

[15] They committed two other errors, which current sociology of science protects us from. The first was to want to replace microtheories by working from their own terrain - epistemology - whilst there was no reason fro them to conserve them and anyway they are inapplicable outside of their range of validity. The second is that they vested the universality and robustness of microtheories in the human mind, whilst they are summaries of practices, techniques, organizations and collective tools. They do not have anything particularly 'cognitive' about them. The human mind is only a metaphor.

[16] This model already prefigures the workstation that we want to make of the Hume Machine in the future. It is in current use as a tool in network analysis (in the particular fields of science policy, sociology of science and the economy of networks). It works in a Hypercard™ environment on a MacIntosh, using a tool for the indexing of key-words and a Leximappe™ program. It is already capable of treating large bodies of heterogeneous written documents. See the account of the CANDIDE™ workstation by Teil (1990).

[17] The Leximappe™ program detects the occurrence of A, and that it co-occurs with B, C and Z. The Vector™ program analyses this first list, and looks at which words Y, N, etc also have B, C and Z as 'associates'. The interest of such a profile is that it does not depend on the form of the network, but on the contingent nature of the key words that are in fact linked to such and such another word.

[18] The 'vocabulary' of automatic analysis developed by working from large databases using slow programs has already proved interesting. Take for example 'negation' (Courtial and Pomian, 1987), judgements about 'central research, dense research, peripheral research' etc (Callon, Courtial, Lavergne, 1989), the answer 'question well put, question badly formulated, peripheral question' (Pomian, 1989) and 'A and B are in competition' (Teil) etc.

[19] This formulation is simply a transcription into network language of Saussure's definition in terms of structure. Its only advantage is precisely that it allows us to do away with the notion of structure - a notion that is too far-fetched for the Hume Machine, and in any case not accessible by the model.

[20] The Hume Machine does not make any assumptions about essences. it considers that all the co-occurrences of a single word are simply homonyms that are then considered in the analysis of the network to see if they are synonyms or not.

[21] For the practical means of following this geometry, see Latour, Mauguin and Teil, forthcoming.

[22] The question of composite words is resolved, as are other questions of synonymy, by a comparison of association profiles. If the single terms 'battery' and 'fuel' have in addition to their own particular semantic domains a common intersection with exactly the same terms, the machine then automatically proposes to designate this intersection by a

composite word. In the course of these operations, the composite word becomes a single term 'fuel battery', with its own semantic field.

[23] Column 5 of the truth table corresponds to the combinations 1011: if p is true, then q cannot be false, but if p is false then q can either be false or true. It can be read "then necessarily" or "implies".

[24] As can be seen, the accusation of 'behaviorism' that has been levelled against the sociology of science (Slezak, 1989) is particularly absurd. On the contrary, the new sociology of science is characterized by a proliferation of actors, of intentions, of wills and of aims.

[25] Logical necessity is simply the number 1 assigned to the coefficient E, which defines the relationships between words in the Leximappe™ model. "If A then B" is equivalent statistically to the phrase "A and B have a coefficient E equal to 1", but it can also be translated by other possibly equally pertinent statements. Here again, the exact formulation - or the formula - counts less than the contingent network that holds the formulation and gives it meaning.

[26] We can see the advantage of the network even in a pons asinorum like the syllogism: "All men are mortal. Socrates is a man. Therefore Socrates is mortal". If we asked the Machine to verify this proposition statistically, it would not come up with any absurd solutions. On the contrary, it would notice that there are 5 thousand million exceptions to this rule; that these 5 thousand million are perhaps more numerous than all previous deaths. It would be obliged to come up with other major premisses: "Men are not mortal enough"; "Many men are not dead" etc.!

[27] The 'moratorium' proposed by Latour (1987) on cognitive explanations applies equally - this has been somewhat overlooked - to sociological explanations. If 'cognitive' explanations interrupt the continuity of the network analysis, they should not be used; and the same thing applies to explanations in terms of micro- or macro-society. No vocabulary which presents us from following the networks themselves is good.