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A new methodological approach for retracing the original version of an ancient text and its epistemological significance

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In this paper we shall develop a new methodology[1] to reconstruct a hypothetical original version of an ancient text, that Richard Swineshead wrote about mid-XIV century. This work is entitled "Opus Aureum Calculationum" and its author was an Oxonian "Calculator"; it includes the basic laws of fourteenth century Physics.

We will use eight witnesses in order to attain our aim, precisely this data set includes: two fourteenth-century manuscripts[2], three fifteenth-century manuscripts[3], three printed editions.[4]

It's sure enough that Richard Swineshead was the author of "Opus Aureum Calculationum",[5] even if some witnesses were emended by the transcribers,[6] so we can neglect the question about the author identity, but we must discuss how much the transcribers misrepresented the "Opus".

In our method, a basic element is the use of artificial neural networks, ANN, particularly we will use Auto Contractive Maps, ACM; it is a good instrument to cluster the witnesses.

Our method consists of two steps: first, we will cluster the witnesses by ACM according to their nearness; ANN are being used in philology, for example they were used to authenticate some Pessoa workers[7]; second, we'll try to reconstruct the original version of the "Opus".

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[1] We will use Auto Contractive Maps for retracing the original version of an ancient text.

[2] Swineshead Richard, *Opus aureum calculationum,* Cambridge, Gonville and Caius Library 499, ff. 165r-203v; Paris, French National Library, BN lat. 6558.

[3] Swineshead Richard, *Opus*, Rome, Vittorio Emanuele National Library 250; Rome, Angelica Library, 1963; Worcester, Worcester Cathedral Library, F35, ff. 3-124.

[4] Swineshead Richard, *Opus,* Sarnano, Comunal Library, Padova, 1477; Bologna, Archiginnasio Library, Pavia 1498; Bologna, Universitary Library, Venezia, 1520.

[5] Marshall Clagett, *The Science of Mechanics in the Middle Age*, Marison (Wisconsin), The University Wisconsin Press, 1959.

[6] "Subtilissimi Doctoris Anglici Suiset Calculationum Liber. Per Egregium Artium et Medicine Doctorem Magistrum Iohanem De Cipro diligentissime emendatus, foeliciter Explicit. DEO GRATIAS. PADUE." Padova, 1477, f. 85rb. "Subtilissimi doctoris anglici Suiseth calculationum liber: Per egregium artium et medicine doctorem magistrum Ioannem tollentinum veronensem diligentissime emendatis foeliciter explicit.", Pavia, 1498, f. 78rb; "Explicit Calculationum opus aureum magistri Raymundi Suiseth anglici viri in hac facultate eminentissimi atque acutissimi: nuper diligenti examine emendatum ab excellenti doctore domino Victore trinchavello veneto". Venezia, 1520, f. 68vb.

[7] Simone Celani, *Artificial adaptive systems for philological analysis: the Pessoa case,* in *ARCHEOSEMA Artificial Adaptive Systems for the Analysis of Complex Phenomena*, edited by Marco Ramazzotti, «*ARCHEOLOGIA E CALCOLATORI*», supplemento 6, 2014, Rome, All'insegna del Giglio, 2014, pp. 203-215.

In our case, we have eight witnesses of one single text, we need to adjust the strategy according to this circumstance.

From our witnesses, we have already generated eight files; each file contains three columns, these are composed by words, lemmas and parts of speech, respectively. The column of the lemmas will generate one table, by KNN algorithm,[8] that will implement an ACM. Eventually, we will normalise the original file by removing some parts of speech.

About this type of ANN, made up by three neural layers, with regard to its details, we refer to specific papers;[9] here we emphasize that, in some experiments, ACM produced better outcomes than other ANN.[10]

In our case, by ACM we should get a graph that allows a comparison between witnesses. For each graph we will evaluate the Hubness function[11], which gives the topological complexity[12] of a graph: higher H function entails more complex graphs; so, we'll gain witnesses clustering by nearness of the H functions.

By topology complexity of a graph, we mean the edges number and the type of these links. The H function gives a measure of this complexity. The graph that we gain by ACM has its topology, so we will calculate the H function in this way: we will build a pruning algorithm to analyse our graphs, it will give a pruning table, PT.

Let N be the nodes of the graph, M the needed number of cycles to disconnect the graph completely, P the pruning cycles for which the change from one cycle to the next is different from zero, S the summation of the degree for which this change is different from zero, A the number of edges, $\mu = N/A$, $\varphi = S/P$, then we can define the H function by:

$H = (\mu\varphi - 1)/A$, with $0<H<2$.

We will compare the H functions and the PT of the graphs, in order to obtain the similarity between witnesses; so, if we have close H functions and different PT, this similarity is weak; we can add to PT a column containing the variances of the nodes degree of the graphs, if the pruning tables are similar and these new columns are different, the similarity is soft, but if the PT and the column of the variances are similar, then we have a strong similarity. In this way we obtain a clustering of witnesses.

If the first step clustering witnesses isn't a novelty, the next stage is quite original.

When I transcribed the eight witnesses, I used a diplomatic notation to solve the abbreviations of the works written in these ancient texts, here we will use those diplomatic inedited transcriptions.

I think that sometimes the variables which make our witnesses different, may arise because of some cryptic abbreviations that can be solved in different ways.

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[8] Richard O. Duda, Peter E. Hart David G. Stork, *Pattern Classification*, New York, Wiley, 2001.

[9] Massimo Buscema and Pier Luigi Sacco, *Auto-Contractive Maps, the H Function and the Maximally Regular Graph (MRG): a new methodology for data mining* in *Auto Contractive Maps*, «Technical Paper» n. 32, Rome, Aracne, 2008, pp. 7-72.

[9] About Topological Complexity: Ronny Nauhm, *Topological Complexity of Graphs and their Spanning Trees,* Haifa (Israel), Department of Mathematics Science, Technion city, 1994.

[10] Simone Celani, *Artificial adaptive systems* cit.

[11] Massimo Buscema and Pier Luigi Sacco, *Auto-Contractive Maps* cit.

[12] About Topological Complexity: Ronny Nauhm, *Topological Complexity of Graphs and their Spanning Science*, Haifa, Israel, Department of Mathematics, Technion city, 1994.

We also suppose that in some witnesses, instead of the cryptic abbreviations, there are words with similar meaning, to which other witnesses give a possible explanation and some witnesses other interpretations.

In this case we must examine how the respective words are used in the witnesses in order to choose the more suitable interpretation.

We will proceed in this way. First, we will pick the lemmas connected to the words through which we may solve the cryptic abbreviations and those with similar meaning, from the lemma column of our files that are made up of three columns; we'll build a table from this selection in the same way of the previous step. Through this, we will implement an ACM that will give us the graphs which we'll study.

Through these graphs, we'll attain the H function and the PT, so we will be able to compare their similarity and their topological complexity. Moreover, we may repeat this procedure, by choosing similar contexts to the variant that we are studying in order to gain another way completing the previous step. If these ways give similar outcomes, we'll be sure enough of our decisions; than this point we will build a suitable algorithm.

We can apply the next steps to both procedures, even if the second method has the role of supervision. We can also substitute the word with a meaning similar to a possible interpretation of abbreviation, so we may study the degree of similarity between them.

After these steps, we will be able to cluster the graphs that we have attained through our Auto Contractive Maps, through this clustering we can recognise the closer witnesses and moreover we may plan a method to decide which variant we must choose; if a variant is the winner in the greatest part of the clusters, we will choose it as hypothetical section of the original text: if the majority is large, our hypothesis must credible enough, otherwise it must less trustworthy. If we haven't got a winner, we will search it in an entire set of witnesses; if we still haven't got a winner, then our method will fail and we will have to use usual philological methods, however we have got a clustering of our witnesses and it can be used in classical philological procedures too.

Now, we will apply this method to a case. In a point of some witnesses we find a cryptic abbreviation: "iux(ta) roξ"[13] or "iux(ta) rn^{e}ξ [14], which can be interpreted as "iuxta responsionem" or "iuxta remissionem". In the Cambridge manuscript we find "iuxta rnoξ"[15], Angelica proposes "iuxta rnsioξ"[16], but the Paris manuscript has "iux(ta) po(sition)eξ"[17]. Moreover, in the Padua edition, we read "iux^{a} remissione(m)" [18]; "responsionem" et "positionem" have similar meanings: we can translate "responsionem" as "response" or "reply", and "positionem" as "position" or "opinion", but "remissio" is the word connected to the reduction of a property, so "remissionem" is entirely disconnected from the other two words, therefore we can apply our method to this case.

Here, we have discussed a method that arises from the questions as to how we categorise the world and choose among different possibilities through our cognitive processes.

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[13] MS. Worcester, f. 3va.
[14] MS. Vittorio Emanuele, f. 1vb.
[15] MS. Gonville and Caius, f. 165va.
[16] MS. Angelica, f2rb; in two witnesses, Pavia and Venezia, we can solve the abbreviation as "iuxta positionem".
[17] MS. Paris, f. 1vb.
[18] Padova edition, f. 1vb.

When we cluster a set of objects, our procedures are similar to those that we have planned through Auto Contractive Maps which, maybe, give more precise outcomes. We can analyse different contexts and spheres, which are completely different from philology, to confront human and artificial performances: for example, we can study sports that came from Gaelic Football. In the XIX century, in England this ancient sport[19] generated Football[20] and Rugby Union,[21] while in Australia, it developed as Australian Football[22]. Football generated Indoor Football and Beach Soccer, while Rugby developed into Rugby League[23], American Football, Rugby Sevens[24] Touch Rugby[25] and other similar variants.[26] We may cluster these sports in this way: a cluster with Football, Indoor Football and Beach Soccer, another cluster with Rugby. Rugby league, American Football, Touch Rugby and other similar sports, but we can't put Gaelic Football and Australian Football with certainty in either one or in the other cluster; it can be an interesting experiment accomplishing their clustering through Auto Contractive Maps or other Artificial Neural Networks[27]. It is a playful example, but we can apply our protocol to more important contexts; for example, to Medicine: if before a debauched illness, some parts of the body were infected and we have got the medical records of a specific case, this can give us some information about the evolution of this condition, so we should know what cells originated from the deterioration. It's a similar example to philological cryptic abbreviations. Here, through our method, we might try to retrace the original conditions. We can experiment our method in another setting. INGV has got a catalogue of Italian earthquakes that goes back to the Roman empire. We can study the evolution of the events in relation to a fault and try to know how this was before a seismic sequence. Maybe this study can be useful to predict earthquake.

Some dynamic systems that haven't depicted by deterministic physical laws, in my opinion, can be studied by Artificial Instruments as the Artificial Neural Networks. It's the case of our examples.

Sometimes, human mind develops plans of actions by studying phenomena that are impossible to describe through exact mathematic formulas, but that can be examined through Artificial procedures which follow human behaviour.

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[19] The first official document of this sport dates back to 1670, but this sport is more ancient, even if its rules were codified in 1887.

[20] The first rules of Football were written in 1848 in England, but its ancestors go back to ancient Greece in the IV century.

[21] In Rugby Union each team is assembled by 15 players.

[22] The first match was played between Melbourne Grammar and Scotch College in 1958.

[23] In Rugby League each team is assembled by 13 players. Rugby Union and Rugby League have different rule.
Rugby League has some affinity with American Football.

[24] In Rugby Sevens there are seven players in each team, this sport is similar to Union Rugby, even if some rules are different enough.

[25] Touch Football (Touch Rugby) is a version of Rugby League and arose in 1926 in Australia. Each Team is assembled by six players. There are a lot of variants of Touch Football: Tag Rugby, Touch Rugby Union, etc.

[26] In my opinion, we can't consider Underwater Rugby a sport that arises from Gaelic Football.

[27] I think that is very hard applying our method to determine the original rules of this ancient sport which arose from Florentine football of the XIV century, however we could use it to achieve the purpose. For example, a question arises about the original form of the Gaelic Football ball. We know that first of 1862, the ball had an air chamber of pork skin, therefore it was very hard to attain a perfectly spherical ball. This is an interesting example that has analogies with our philological example where we have a cryptic abbreviation, here this is replaced by the original form of the ball.

I think these phenomena hide structures with some similar parts, here we have shown examples where an ambiguity, regardless of its physical or human origin, influences the dynamical evolution of a system in a similar way: a cryptic abbreviation entails different interpretations, a fault generates a seismic sequence of earthquakes with different magnitudes, etc. But what do we mean by "analogy"? Moreover, when the human mind interacts with the world, does it catch analogies through it can answer to some questions?

Charles Sanders Pierce emphasized three types of inference: induction, deduction and abduction. [28] He presents this example: "The beans in this sack are white", "These beans are from this sack", then "These beans are white", this is a deduction, the first statement is the rule, the second one is the case, the third one is the result, in the induction we see case and result entailing the rule, while in the abduction, rule and result imply the case. He said that only scientific abduction allows statements to be physical laws. His conclusion isn't a simple explanation of the premises, but it entails a risk, an interpretation of the result. In this interpretation we connect the result to the rule through an intuitive act which doesn't catch any semantic link among them, but we understand an idea that, in a way, could hypothetically connect them.

In the XI century Avicenna[29] considered three types of inferences: the syllogism, the induction and the reasoning by analogy. About the syllogism he says: "The syllogism is a discourse composed of statements. If the propositions which the syllogism involves are admitted, this by itself necessarily leads to another statement"[30], in other words here he is setting a deduction. About induction, the Arabic philosopher says: "Induction is a judgment about a universal, inasmuch as it is found in its many particulars"[31], it coincides with our concept of induction. About analogy, he asserts: "Analogy is an attempt to judge a thing by a judgement already made about a similar thing. It is a judgment about a particular thing, made by virtue of a similar one which the former agree by a common idea…What insures the analogy is that the common idea is the cause or sign for the judgment about what is called "fundamental".[32]

In my opinion, this definition of analogy is very similar to way in which Peirce defines "abduction". This thing called "fundamental" doesn't necessarily link two or more objects that can be physically different, but it entails an intuition involving a certain risk in our conclusions, as Peirce says. The question is whether we can recognize an analogy in our examples.

Avicenna says that analogy is a fundamental idea that connects different objects. In our case, the fundamental common idea is a cryptic initial condition that changes the dynamic evolution of a system in an irregular way. How can we use an Artificial Neural Network in order to measure the distance among these systems? This measure could give us an information about their structural nearness. We might act in this way: first we'll perform a clustering of these different systems with our protocol, then we'll determine how much the sets of clusters are similar, if they are similar enough then we can confront H functions, Pruning Tables and other characteristics that appear in graphs, among the clusters of different systems. In this way, we reach two aims.

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[28] Charles Sanders Pierce, *Deduction, Induction and Hypothesis*, in «*Popular Science Monthly*», vol. 13, New York, Popular Science Pub. Co, 1878, pp. 470-482.

[29] His true name is Ibn Sina.

[30] Ibn Sina, *Remarks and Admonition. Part one: Logic*, translated by Shams Constant Inati, «*Medieval Sources in Translation*», vol. 28, Toronto, Pontificial Institute of Medieval Study, 1984, p. 130.

[31] Ibn Sina, *Remarks and Admonition,* p. 129.

[32] Ibn Sina, *Remarks and Admonition,* pp. 129-130.

First, we gain knowledge about the structure of physically different systems; secondly, we could think of an architecture of an ANN that is able to recognise similar structures of different dynamical systems and operate on them.

Here we have emphasised a deep structure of dynamical systems that overlooks their nature. What connects these system is a fundamental common idea that can be grasped, but this is a risky move that can give place to wrong interpretation, it is like the human mind formulates scientific laws. In my opinion, the Catastrophe Theory, CT, emphasises deep connections among dynamical systems. About abduction, we have spoken of a lack of semantic connections among its premises, but we should speak of a lack of superficial semantic links, in fact the links relative to the premises of abduction overlook the nature of a system, they emphasize a deep semantic structure, if CT is a mathematical way that allows to catch it, we could try in order to reach the same aim by Artificial Instruments.

Chomsky[33] theorised his transformational grammars to emphasize the deep structure of the syntax, Greimas[34] highlighted a deep structure composed of agents[35] and relationships among agents that characterize the narrative, while here we overlook the nature of objects. In my opinion, in order to explain this, we can examine Rene Thom's Language Theory that is presented in some chapters of his *"Modèles mathématiques de la morphogénèse"*.[36] We'll try to explain this CT application [37] in an easier way, Thom states that the basis of our language is the interaction between Mind and Reality which implies a mechanism of catastrophe, that is a transition from a hypersurface to another hypersurface of structurally stable points of equilibrium. According to Thom, this is a basic mechanism for our essential syntactic forms. For example, in the statement "Eva eats the apple[38]" a catastrophe of capture is depicted, where the Subject-Agent, Eva, survives to it. [39] We could to explain it in this manner: the syntax Subject-Verb-Object implies a catastrophe of capture or ejection and this is the deep sense of the sentence and what the interaction Mind-Reality catches in first place; so we could say that the Sense entails the Syntax.[40] In other words, the Mind through interaction with Reality, first of the nature of phenomena, recognises a catastrophe where there is a discontinuous transition from set of structurally stable points to another set of structurally stable points and this generates a change of our inner states and the Syntax of Language depicts it. In my opinion, we can state that catastrophes of same kind are those analogies which were defined by Avicenna.

The question is whether this Theory can help us in order to design an Artificial Neural Network that is able to depict this interaction Mind-Reality which goes beyond the nature of Phenomena, and whether it's possible to reach an artificial method that allows to represent an important part of human judgements.

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[33] Noam Chomsky, *Le Strutture della Sintassi*, Roma-Bari, Laterza, 1970.

[34] Algirdas Julien Greimas, *Del Senso 2. Narrativa, Modalità, Passioni*, Sonzogno (MI), Bompiani, 1998.

[35] In Italian: "attanti".

[36] Renè Thom, *Modelli Matematici della Morfogenesi*, Torino, Einaudi, 1980, chapters X-XVI.

[37] Petitot applies the CT to the Greimas theory: Jean Petitot-Cocorda, *Morfogenesi del Senso. Per uno schematismo della struttura.* Sonzogno (MI), Bompiani, 1990.

[38] Renè Thom, *Modelli Matematici* cit., chapter X.

[39] According to Thom, in French, each statement Subject-Verb-Object entails a mechanism of capture or ejection.

[40] Thom doesn't claim a deterministic position, he gives a great importance to the different cultures which can give rise to different semiotic contexts.