Archeologia e Calcolatori
22, 2011, 99-128

ARTIFICIAL NEURAL NETWORKS AND ANCIENT ARTEFACTS: JUSTIFICATIONS FOR A MULTIFORM INTEGRATED APPROACH USING PST AND AUTO-CM MODELS

1. Introduction

The use of cylinder seals in Mesopotamia developed along with urban civilization, and seems to be closely connected to the technology of the cuneiform written word (Schmandt-Besserat 1977, 1979a, b; Brandes 1979, 4-9; Collon 1987, 13-19; Boehmer 1999). According to the available data, cylinder seals and cuneiform signs (or proto-cuneiform and archaic pictographic signs) written in clay were born at the same time and the rise and decline in their use are parallel. At the end of the third millennium the so-called Third Dynasty of Ur (Ur III) ruled over a significant territory in Lower Mesopotamia.

According to what has been inferred from mainly epigraphic data, in that period the administrative organization of the region underwent a major transformation, based on an increasingly intense and widespread use of writing and sealing by the main branches of the state bureaucracy (Steinkeller 1977, 1987, 20-21; Winter 1987, 69-70; Porada 1980, 10; Waetzoldt 1991, 638). Written and sealed documents probably had become one of the fundamental means which guaranteed the inner cohesiveness in the Ur III state. The tendency towards the establishment of a centralized state, in fact, needed to be reconciled with the different strong local traditions of a number of peripheral provinces, which had a long history of independence and maintained local administrative traditions (Steinkeller 1987, 21; Sharlach 2004, 159-162).

The study of the iconography and administrative use of Ur III cylinder seals is thus inextricably linked to the cognitive and cultural history of Southern Mesopotamia, as well as the political and administrative phenomena of the area. The main purpose of this study is to obtain some useful evidence about administrative practices and languages by comparing the results obtained from two different studies. These are the result of the application of two different Artificial Neural Networks on Ur III artefacts: one regarding "presentation scenes" carved on seals, and the other concerning sealed administrative tablets (Di Ludovico 2005; in press a, b, c). Other studies on Mesopotamian glyptic products that deserve to be mentioned here have been carried out by a few other scholars in recent years, and employ different approaches and data processing models: Digard 1975; Kelly-Buccellati 1977; Rova 1994, 1995, 2000; Camiz, Rova 1996, 2001, 2003; Camiz, Rova, Tulli 1998, 2003.

2. Artificial Intelligence algorithms as a tool for the management of large databases

A relational database is a matrix where columns denote the circumstances in which the data were collected, and the rows record the occurrences corresponding to a given combination of circumstances. Circumstances are also known as variables, and occurrences are also said to be observations, or records. Although the elements of the matrix can be of any nature, in this study they are binary digits, where the digit "zero" denotes the absence or non-effectiveness of a variable and the digit "one", on the contrary, its presence or effectiveness.

It is important to state that, except in very simple cases, for humans it is very difficult to infer any sound conclusion from a binary digit matrix, even if it is small in size. This is the rationale for the use of statistical tools, such as Principal Components Analysis (PCA), and of Artificial Intelligence (AI) tools, like Pick and Squash Tracking (PST). AI offers a number of useful tools to allow scholars in various fields to dig out valuable information concealed within large DataBases (DBs). In general we may describe them as pertaining to three different levels of insight into the data:

– Basic level: mapping. The complex relations among those documents present as records in a DB, and among the variables describing them are graphically represented on a map. Pick and Squash Tracking (Buscema, Terzi 2006) is a valuable algorithm to obtain such a map.
– Structural level: structured mapping. This kind of mapping groups records by affinity and arranges the groups on a map. Each group is represented by a prototype. SOM algorithm (Kohonen 1997) is a valuable tool for creating such a map, and for identifying cluster prototypes.
– Deeper level: networking. The complex relations among documents are represented with a graph recording the most important connections. Auto-Contractive Maps (Buscema *et al.* 2008; examples of Auto-CM scientifically grounded applications are: Buscema *et al.* 1994; Buscema 1995; Buscema, Grossi 2007; Licastro *et al.* in press) provide the best way to do this.

The present work is part of a larger program for the interpretation of ancient artefacts, and is devoted to basic level mapping with a particular focus on the relative importance of variables. Further work will be dedicated to the other levels of interpretation. In the present work PST will be used as a tool. PST was devised by Buscema and Terzi, and its possibilities have been recently reviewed by Pieri (in press). In this article we are reporting on studies conducted both at the mapping level and at the networking level.

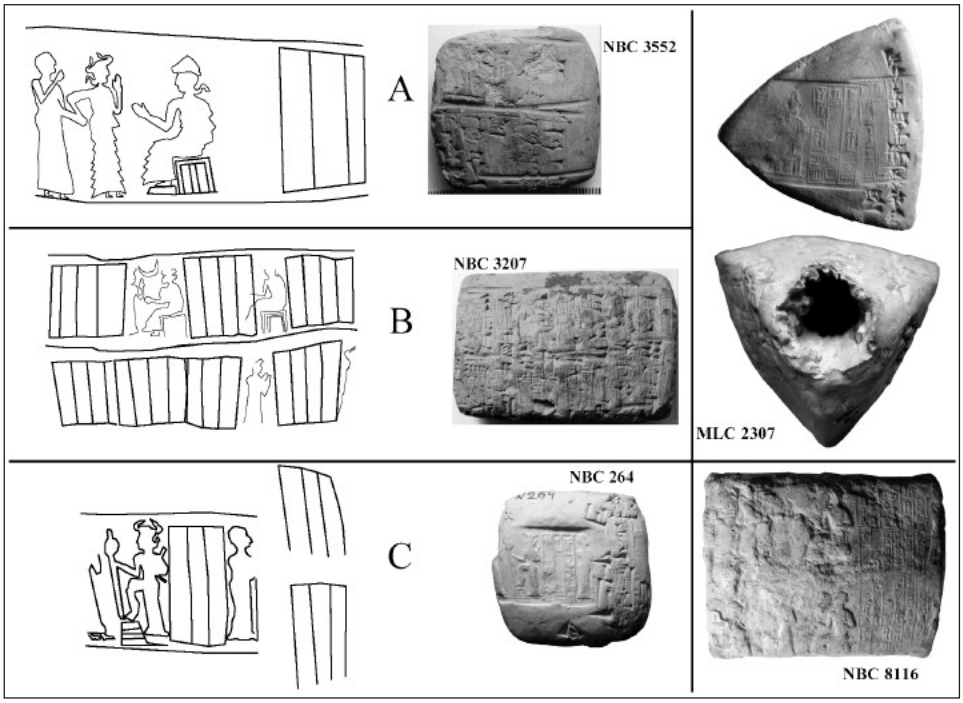


Fig. 1 – Examples of administrative documents and some of the relevant seal impressions (traced on the digital picture); on the right, a tetrahedral label and an envelope. All specimens come from Umma and date to the Ur III period.

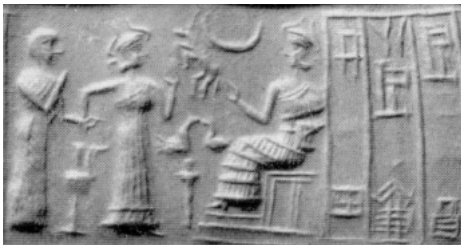
3. Tablet and seal DBs investigated in the present work

Two different DBs based on two *corpora* of administrative documents and cylinder seals dating to the Ur III period[1] have already been defined and elaborated. Administrative tablets are being investigated here almost exclusively for their physical features, and just a few of their very general data have been taken into consideration for the data mining process. Each one of the 314 tablets, envelopes, and labels has been codified into a string of 95 variables which describes its shape, dimensions, and the organization of the exploitation of its surfaces by the drafting of the document content and the sealing (Fig. 1). The whole *corpus* of administrative documents formalized in the data set is made up of Ur III sealed tablets, labels, and envelopes from Umma and currently stored at the Yale Babylonian Collection. Of these, 115

[1] It is very likely that not all cylinder seals were administrative tools in this period, and Mesopotamian cylinder seals did not only have an administrative or "bureaucratic" value (Cassin 1960; Porada 1993, 563; Winter 2001).

Collon 1982, n. 446 (BM 102510)

Collon 1982, n. 433 (BM 129505)



Buchanan 1966, n. 421 (Ashmolean 1952.27)

Moortgat 1940, n. 273 (Berlin, VA 3870)

Fig. 2 – Examples of "presentation scenes" depicted on Ur III cylinder seals.

date to the reign of Šulgi, 95 to that of Amar-Suen's, 83 to Šu-Suen, and 21 to Ibbi-Suen (see the chronological sequence of reigns below). Since the latter group is much smaller than the others, the documents dating to the reigns of Šu-Suen and Ibbi-Suen have been considered as a single group.

The cylinder seals were selected for their good state of preservation, and because they had representations referable to the group of "presentation scenes" (Di Ludovico 2005, 60-67). In fact, this research was based only on the scenes which are depicted on those seals, and not on their physical features as artefacts. The main purpose was to understand the deep ("hidden") logical relations existing between the iconographical elements which were used to compose the scenes. That is to say, the ultimate subject is the rationale of the use of the iconographic elements of the "presentation scenes"and their potential values as phonemes of a language built on icons (Fig. 2). The records of the data set refer to 354 seals, and their scenes have been segmented into 405 variables expressing the graphic features of the representations and their position in the field in relation to those of all the other elements depicted.

3.1 *Administrative documents DB, content and description of variables*

Various types of administrative documents are represented in the above mentioned DB. They are all sealed and bear inscriptions, and they are mostly

(rectangular) tablets, to a lesser degree labels (which very often have a tetrahedral shape), or envelopes wrapping unsealed tablets (Fig. 1). All of the documents cover a period of 44 years, starting from the 28th year of Shulgi's reign and ending in the 5th year of Ibbi-Suen. To place this period of the Ur III dynasty in context, here we list all the kings of the dynasty: Ur-Namma (ruled 18 years); Shulgi (ruled 48 years); Amar-Suen (ruled 9 years); Shu-Suen (ruled 9 years); Ibbi-Suen (ruled 25 years).

During the rule of Ibbi-Suen, documents from the provinces tend to become rarer as the reign gradually breaks up. Therefore, documents in the DB, all of which come from the important province of Umma, do not go beyond the 5th year of Ibbi-Suen's reign (see, for instance, the general diachronic frame in Lafont 1995).

Since the nature of the documents is composite, the 95 variables describing each record are grouped into several categories, as shown in Table 1.

3.2 *Presentation scenes DB, content and description of variables*

The DB is made of formalizations of Ur III "presentation scenes" carved on cylinder seals. These scenes show both human and divine characters: there is typically a receiver – either a regal person or a deity – and other figures, usually interpreted as an intercessor and a person being received (Di Ludovico 2005). In the Ur III period the total number of "presentation scene" characters varies, from a minimum of 2 to a maximum of 4 figures. Very often a cuneiform legend

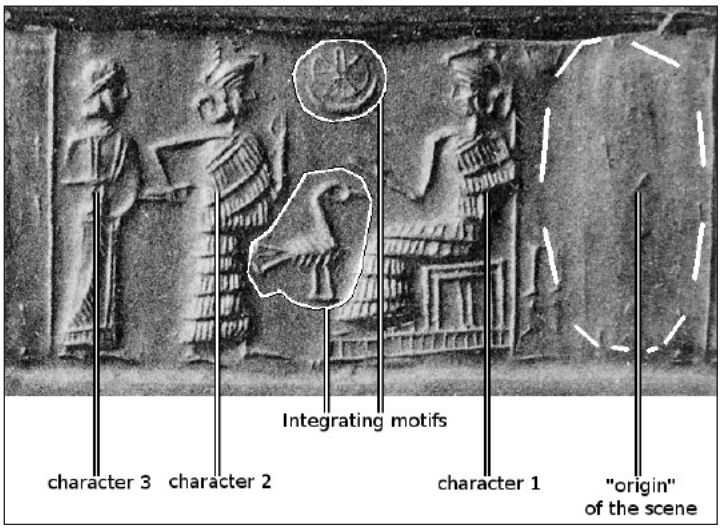


Fig. 3 – Reference points for the coding of a "presentation scene": receiver (character 1), integrating motifs, "origin" of the scene.

Progressive number of variables	Main features of the variables in the group	Examples of variables in the group
Variables related to the document		
1-5	Type of document	Tablet, label (and the relevant shape), envelope
6-8	Holes in the document	Hole in the tablet, hole in the label
9	Orientation of impression	The seal impression is parallel to the incised lines of the document's text
10	Not-written face	One face of the document does not bear any incised cuneiform sign
11-17	Size	Dimensions of the document and the relevant impression
18-20	Sequence of treatments on the faces of the documents	The document has been written after or before the impression of the seal; the surface is ruled (filled with incised parallel lines)
21-26	Date	Relative chronology of the tablet
Variables related to the seal scene		
27-32	Type of scene impressed by a seal	Presentation scene, Contest scene, orientation of the scene
33-36	Description of characters in the impressed scene	Number of characters in the scene, character N° 1 standing, small size character
37	Astral Symbol	A crescent in the upper part of the impression field
38-39	Secondary characters	Presence of "added" characters besides the main ones
40	Worked again scene	Presence of secondary carving intervention in the seal impression
41-43	Standard	A standard is shown in the scene
44-49	Attitude of the characters	The impression shows a king bearing a cup or a hand-in-hand couple of goddess and man
50-62	Type of impression	Kinds and number of rows of impressions on reverse, obverse, and presence of impressions on other sides of the tablet
Variables related to document text		
63-66	Written text	Number of lines of incised signs on each face of the document
67-73	Date position	Position of the date formula (usually on the reverse) in relation to the seal impression
74-78	Inscription of the seal impression	Shape of the impressed seal legend (among a set of recurring types)
79-83	Content of seal legend	Type of content of the impressed seal legend (among frequently used formulas)
84-95	Distribution of the written text on the sides of the document	Text on reverse, text on obverse, text on the left, text on the right, text uniformly distributed

Tab. 1 – Groups of variables in the tablet DB.

separates the first from the last character; otherwise, this separation may be achieved by the insertion of animals, trees, or objects. In this study, this part of the cylindrical surface has been dubbed the "origin" of the scene (Fig. 3), because the reading of the scene is conventionally established starting from there and going towards the other elements passing over the receiver (which is, in fact, the only character in "presentation scenes" that can be unambiguously recognized in every example: Di Ludovico 2005, 72-78).

Characters are distinguished by their positions within the scene; their posture, dress, hairstyle, headgear, and occasional attributes (such as jewels, cups, etc.). Each record in the DB describes the scene in a given seal using 405 variables. Almost all of them (about 95%) are related to the pure form of the scene, while the remaining 5% refers to the content of the seal legend. A short description of the groups of variables is reported in Table 2.

Progressive number of variables	Main features of the variables in the group	Examples of variables in the group
Variables related to the main characters		
1-3	N° of Characters	Total amount of the characters depicted in the scene.
4-11	N° of integrating motifs	Total amount of the integrating motifs depicted in the scene.
12	Inscription	The seal bears a legend.
13	Additional scene	An additional scene is carved besides the "presentation", into a different register.
14-25	Nature and gender of the characters	Characters can be male/female and divine/human.
26	Posture of the receiver	The receiver is sitting.
27-29	Orientation of characters	The receiver looks towards the left or right.[a]
30	Smaller size characters.	Second character is depicted in a smaller size than the others.
Variables for position of integrating motifs		
31-67	Genres and positions of integrating motifs	Positions in the vertical direction and genres of integrating motifs.
68-69	Traces of secondary carvings on the seal	Traces of secondary carvings on the seal (substitution or integration of elements).
70-94	Genres and positions of elements in the horizontal direction	Positions in the horizontal direction and genres of integrating motifs.
95-148	Specific integrating motifs	Specific integrating motifs depicted in the scene
Variables for characters appearance		
149-189	Posture of characters	Position of arms and legs of each character.
190-224	Dress	Dress of each character.
225-259	Headgear	Headgear of each character.
260-296	Objects and attributes of characters	Objects or attributes related to each character.
297-325	Hairstyle	Hairstyle of each character.
326-329	Beard	Some characters are bearded or not.
Variables for the seat and podium of the receiver		
330-352	Seat	Presence and kind of seat of the receiver.
353-363	Podium	Presence and kind of podium depicted.
Variables related to the legend		
364-378	Appearance of inscription	Shape of the inscribed legend.
379-405	Content of legend	Formulas which compose the legend.

[a] The directions referred to in the description of the scene are in this case always those that can be observed in the impression of the seal.

Tab. 2 – Groups of variables in the seals DB.

4. The processing of Ur III presentation scenes using Auto-Contractive Maps

Two separate investigations were carried out in 2008 using the Auto-Contractive Map algorithm. In both investigations (one regarding administrative documents and the other concerning "presentation scenes") the weighted connections established by the Auto-Contractive Map (or Auto-CM) were visualized in the form of the Minimum Spanning Tree (or MST) and the Maximally Regular Graph (or MRG).

Auto-CM establishes a matrix of connections between all of the DB records. The stronger the connection, the more similar the records. This simi-

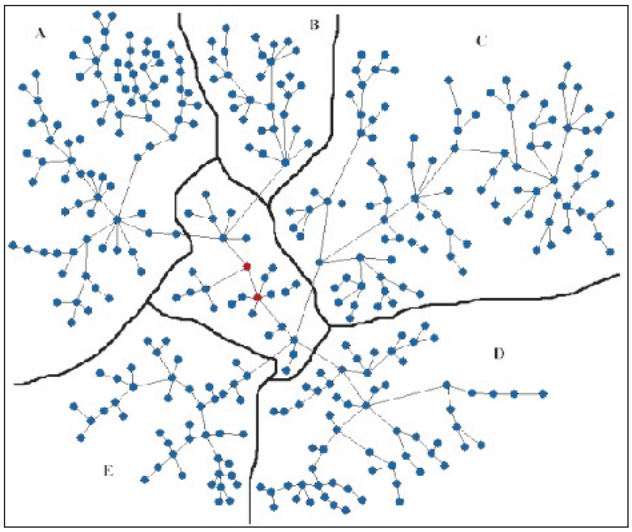


Fig. 4 – Minimum Spanning Tree showing the classification and relationships of "presentation scenes" after the Auto-CM processing (branches have been separated and named by the authors).

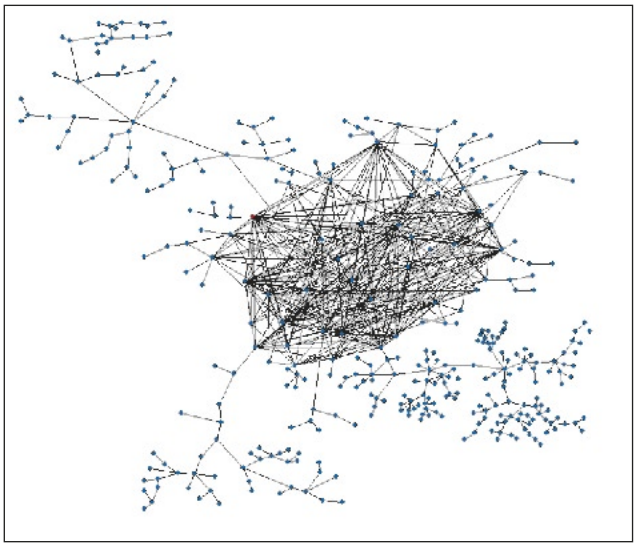


Fig. 5 – Maximally Regular Graph showing the classification and relationships of "presentation scenes" after the Auto-CM processing (the main cycles region is evident, about in the centre).

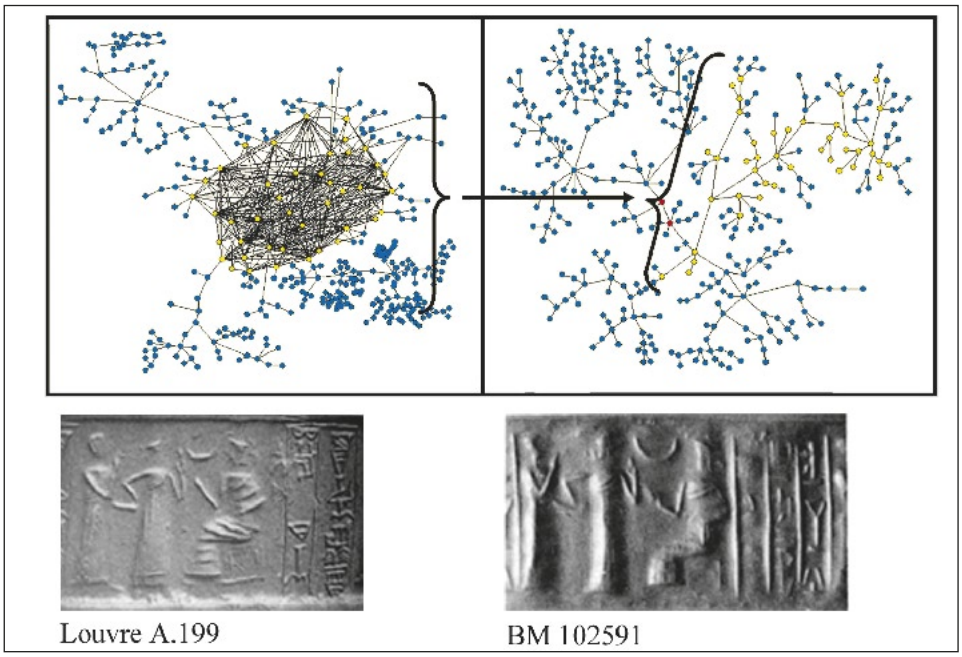


Fig. 6 – The main cycles region of the MRG and its relation with Branch C, with some examples of scenes belonging to this group.

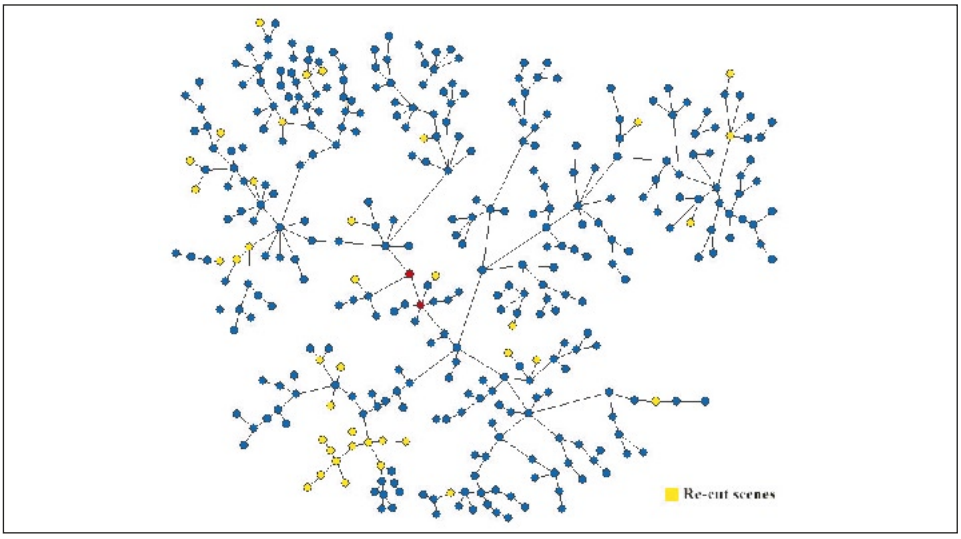


Fig. 7 – The position of reworked scenes in the MST.

larity follows criteria that emerge from the DB itself, and is not in any way conditioned by the operator.

As it is very difficult to use the matrix of connections alone to draw sound conclusions, further elaboration is necessary. For this task the connection matrix is converted into a distance matrix by the simple procedure of subtracting the connection from the value of the strongest connection. Thus, the stronger the connection, the shorter the distance.

From the distance matrix a graph is plotted which gives the minimum total distance (MST). The graph is in the shape of a tree and does not represent all connections, but by definition only those whose sum is minimum. This kind of graph does not contain any cycle. This is the way to represent connections among records in the DB only if they are among the strongest, and therefore the most important, in the DB.

Analogously, the MRG is built up from the distance matrix. In this case cycles are admitted if they maximize the regularity of the graph. The particular significance of the MST and MRG will be elucidated below by means of specific examples.

Auto-CM subdivided the "presentation scenes" *corpus* into five groups, corresponding to the five main branches of the MST, some of which had well defined sub-groups (Fig. 4). Auto-CM also subdivided the *corpus* in the same groups in MRG, but showing a central region of very tightly connected records (Fig. 5).

In the core region of the MRG – i.e., the region in which the connections and cycles are most densely concentrated – specimens belonging almost exclusively to one of the MST main branches were found to be concentrated. This may suggest that the scenes belonging to this group steadily express the basic features of the "presentation" concept. This does not imply, in general, iconographic elements or compositional arrangements or details which potentially could give the representations heavy connotational nuances. MST and MRG are compared to show the correspondence between the densely concentrated zone of connections in MRG and branch "C" of MST. Common records are highlighted in Fig. 6. In the same figure two typical examples of this type of scene are reported. The simple arrangement of the scenes, and the absence of integrating elements other than the moon sickle, should be noted.

In contrast to these types of "presentation scenes", the Auto-CM showed a particularly strong logical relationship between two groups: that of the so-called "royal presentations" and a specific kind of "presentation before male gods". This relationship was quite evident in the MST and strongly confirmed by the MRG (branches A and B in MST and the branches in the lower-right region of the MRG, just under the region of the main cycles).

Another evidently important clue given by the MST visualization lies in the seemingly uneven distribution of the "presentation scenes" which bear

signs of a secondary intervention. Indeed, they seem to concentrate particularly in branch "E". It appears that the Auto-CM distinguished different kinds of re-use of seals after being re-cut. In fact, some secondary worked seals bearing "presentation scenes" could have maintained an active administrative use, while a large number of those re-cut seals probably performed non-bureaucratic roles (Fig. 7). This picture concords with the fact that only in very rare circumstances original impressions of known cylinder seals are currently known (Hallo 2001), and that many re-cut cylinders we have were probably seals in a transitional stage of their bureaucratic existence (Waetzoldt 1995; Mayr 2001).

5. Auto-Contractive Maps used in the processing of features of Ur III presentation scenes and administrative documents

Both here and below the dual representation of a DB is used, i.e., the DB is seen as a collection of variables defined by the values corresponding to each record, instead of as a collection of records defined by the values corresponding to each variable, as has been discussed above. Both MST and MRG projections of the "presentation scenes" variable matrix confirm the picture that emerges from the scenes' matrix processing. This allows us to differentiate the semantic contribution of some characters and objects to the scene (complete results in Di Ludovico in press d). The relationship between "royal presentations" and "presentations before a god" is evidenced by the interaction of variables referable to their receivers, and the meaning of the presence of four characters in the scene seems to change, according to the graphs, depending on the gender of the receiver (Fig. 8). Both variables specifying a royal presentation and a presentation before a god are at the root of two important branches in both MST and MRG. The occurrence of one of the two entrains the occurrence of two different sets of variables that lie respectively on the branches that have the receiver type as a root.

Another seemingly important element in Ur III presentation scenes is the presence of the legend: though it is not part of the scene (since it is abstracted from the visual representation). Its absence changes the whole scene's general meaning. The legend in MST is very close to the root of the whole tree and from it a good half of the tree stems. In MRG the variable legend belongs to the central very connected nucleus of the graph. In the first case, this means that presentation scenes are classified in two different types: those with a legend and those without a legend, each with a different set of variables preferably used in connection with legend or in its absence. The basic formula of the legend is the seal owner's name, but also the mention of the owner's status and his patronymic are of great significance.

Among the integrating motifs, the astral symbol (moon sickle or sun-disc with the moon sickle) – usually placed in the upper part of the field, before

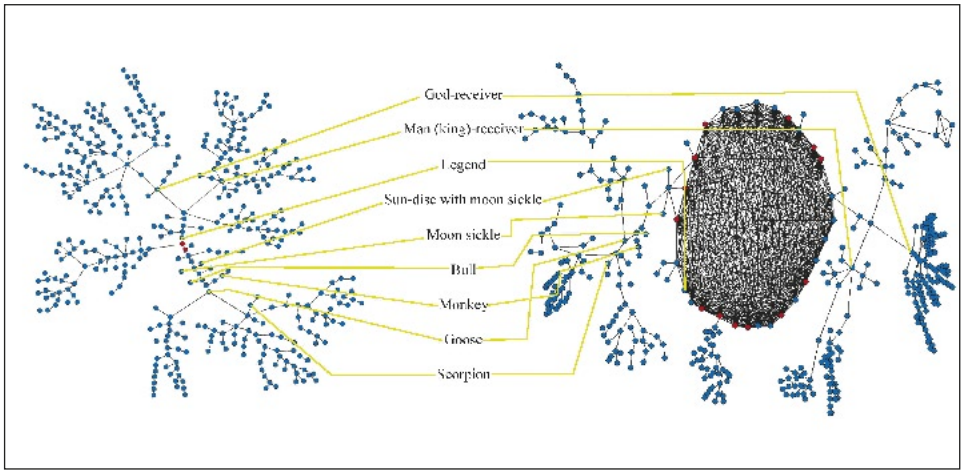


Fig. 8 – Location of some variables in the relevant MST and MRG.

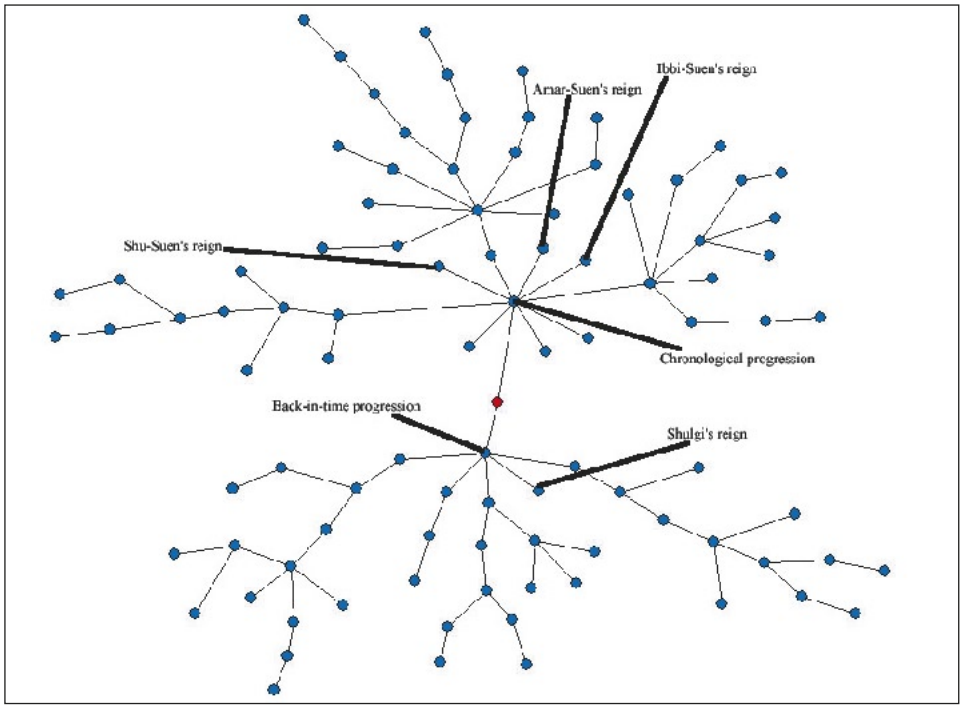


Fig. 9 – MST of the administrative documents features matrix; the centroid vertex corresponds to the variable expressing the dimensions of the seal impressions.

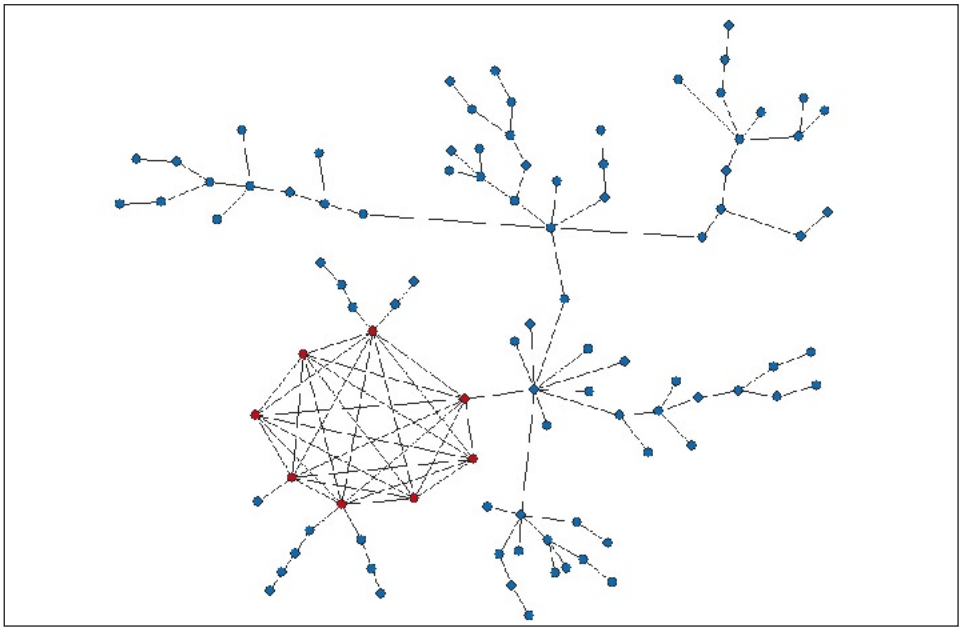


Fig. 10 – MRG of the administrative documents' features matrix.

the receiver – is the one which most evidently brings a semantic contribution to the scene. Quite important also is the contribution given by the goose and, though less evident, those of other animals. For example the monkey (placed between the receiver and the second character, in the middle part of the field), the scorpion (the location of which is often the same as the monkey), and the (comparatively rare) bull.

The processing effected by the Auto-CM of Umma administrative documents data set has led to the separation of these documents' features into two main groups, marking a clear-cut organizational change between the end of Šulgi's reign and the beginning of that of Amar-Suena (Fig. 9). The results suggest that the dimensions and uses of seals played a central role in the structuring of the physical organization of administrative documents in the central reigns of the Ur III Dynasty. It seems that the bulk and physical appearance of cylinder seals had a strong cognitive feedback effect on the way scribes drafted documents, looked at tablets and labels, and organized the distribution of signs on their surfaces. The MST visualization of Auto-CM processing on the documents' data set seems indirectly to confirm what appeared in the processing of the "presentation scenes": in general, scenes showing presentations before goddesses could have been expressions of the

basic formal logics of the "presentation scene", while being considered, from a bureaucratic point of view, increasingly less able to carry the semantic potency of the "presentation" in its "administrative" effectiveness. Their administrative involvement seems to be, in fact, increasingly marginal in the Umma provincial administration, especially after the reign of Šulgi. What is not implied at all is that the carving of these scenes was outdated[2].

In the MRG the most dense set of cycles and edges connects the variables which express the basic traits of the administrative document (Fig. 10): a) the homogeneous distribution of cuneiform signs on the obverse; b) the double series of sealings… c) …showing the seal legend on the obverse; d) only one series of sealings on the reverse; e) the use of seals with legends that mention the patronymic and f) the professional status of the owner; g) the document is a tablet; h) the document has been drafted before being sealed (according to the criteria adopted by Hattori 2001, 98). This result will be confirmed later by analyzing variables with another AI tool.

6. PST main features

PST views the DB as a multi-dimensional space, where the data are represented as a collection of points. A given DB has two possible spatial representations:

– In the first case each variable is an axis of the reference system, and the actual values assumed by the variables state the position of each record in space. This is called variable space and shows records as points.
– In the second case each record is an axis of the reference system and the particular value that a certain variable takes in each record is the collection of coordinates, which state the position of the variable in space. This is called record (or observation) space and shows variables as points.

PST squeezes each space into a two-dimensional map, minimizing distortion of the original relative position of points in the multi-dimensional space. Such a simple representation of data is obtained at a certain price: PST does not give the coordinates referred to by the position of a point on the map. They are simply undetermined by the PST, and therefore unavailable to the user as part of the result. However, the absolute lack of information on the nature of PST coordinates can be overcome by using the specific semantics of the DB to single out specific directions within the map, which can then be assigned a meaning.

[2] Similar observations have been expressed by Fischer 1997, 152. Fischer thinks that the scenes with a god-receiver, but whose legend mentions a goddess, had been produced in series, already inscribed, and then finished and provided with the "new" receiver. Authors of this article do not agree with such an interpretation: there is no evidence that scenes were carved after the legend: it seems rather the contrary (Moortgat-Correns 1968, 257, n. 56; von der Osten 1934, n. 172 and n. 186; Collon 1982, n. 463 and n. 432).

7. The tablet DB, description and interpretation of PST results

A comprehensive PST processing may give an answer to the important question concerning the different degrees of significance these variables may have for the study and understanding of the administrative documents and the process of their drafting. In Fig. 11 a PST map of the variables is shown. The unit of measurement on the two coordinate axes is the same as the distance among the variables. A variable in the record space is represented by a string of 314 "zeros" and "ones", and the distance between two variables is simply the number of locations along the string where the two strings differ. By definition a string of 314 "zeros" and a string of 314 "ones" differ by 314, thus the maximum distance possible for a couple of variables. Of course the minimum distance is nil for two equal strings. So in the map of Fig. 11 two variables represented by two close points have a small distance between one another, in fact PST is conceived to save the distance between variables as much as possible. So, referring to the variables "tavoletta" (tablet) and "siglato_prima" (document sealed before being drafted) the distance is of the order of the maximum; this means that their behaviour is opposite. On the contrary, the variables referred to "labels" are placed in the mass of almost superimposed variables not far from "siglato_prima".

In Fig. 11 other variables are labelled so that they can be recognized. It would be expected that the two variables "A-O" and "O-A" should lie at opposite parts of the map, because they both locate the document in time, but one in the reverse order of the other (where "O-A" is the back-in-time order). The fact that they are quite close to each other on the map means a weak representation of time sequence. Also other time variables ("A-O_Sh", "A-O_As", "A-O_Shs", "A-O_Is", each related to a particular reign) are almost grouped together and their effect does not result much differentiated.

However, Pieri devised a method to separate the more important variables from the less important ones (Pieri in press). A variable is retained if it satisfies two conditions:

– it is far from the map centre (the square purple mark on the map);
– its distance from the centre is more than a high percentage of the number of "ones" in the variable.

The rationale for this method is that the distance of a variable from the centre of the map depends on two reasons. The first is trivial: the larger the number of "ones" in the variable is, the further the variable is from the centre. The second is due to the interaction with the other variables: the stronger the interaction, the further the variable. Variables are retained if the second effect is comparatively stronger than the first.

By applying this method only 24 variables out of 95 "survive". They are listed in Table 3 and are the most significant ones in describing administrative

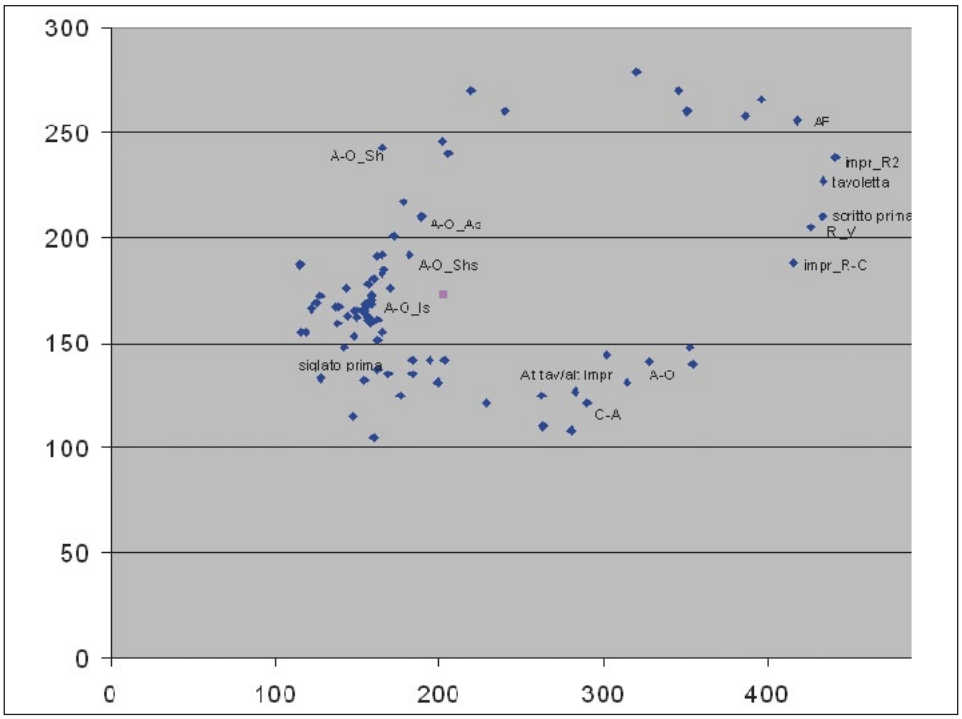


Fig. 11 – PST map of variables in the record space of tablet DB.

N°	Variable Name	Variable description
1	Tavoletta	The document is a tablet
2	Scritto_Prima	The document was written before sealing
3	A-O_Sh	Document's chronology within the reign of Šulgi
4	S_Pres_R	The scene of the impressed seal is a "royal presentation"
5	4Pers	The scene of the impressed seal shows 4 characters
6	Sc_rilav	The impressed seal was reworked
7	Re_coppa_con	The king in the impressed seal scene bears a triangular shaped cup
8	Pres_isol	The person presented to the king is physically isolated from other characters
9	Impr_R-A	The seal impression on the tablet obverse shows the scene and the legend without paying a particular attention to the legend
10	Impr_R-C	The seal impression on the tablet obverse pays a particular attention to the legend
11	Impr_A1	The tablet reverse bears one row of seal impressions
12	Impr_R2	The tablet obverse bears two rows of seal impressions
13	IMPR_FacceMIN	Tablet bearing seal impression also on faces different from reverse and obverse
14	Iscrl3	Impressed seal legend is made of two framed lines
15	Iscrc1c2	Impressed seal legend is made of two parallel rows of lines
16	AB	Impressed seal legend contains the name and the profession of the owner
17	AE	Impressed seal legend contains the name and the patronymic of the owner
18	J	Impressed seal legend contains the "his servant" formula
19	NORZ	Impressed seal legend contains royal official epithets and/or other epithets of the same kinds
20	R_DS	Incised signs on the obverse distributed on the right side
21	R_SN	Incised signs on the obverse distributed on the left side
22	R_CT	Incised signs on the obverse distributed on the central part
23	R_V	Incised signs on the obverse uniformly distributed
24	Shs+Is	The document's chronology falls either in the reign of Shu-Sin or of Ibbi-Sin

Tab. 3 – The tablet DB at reduced variables.

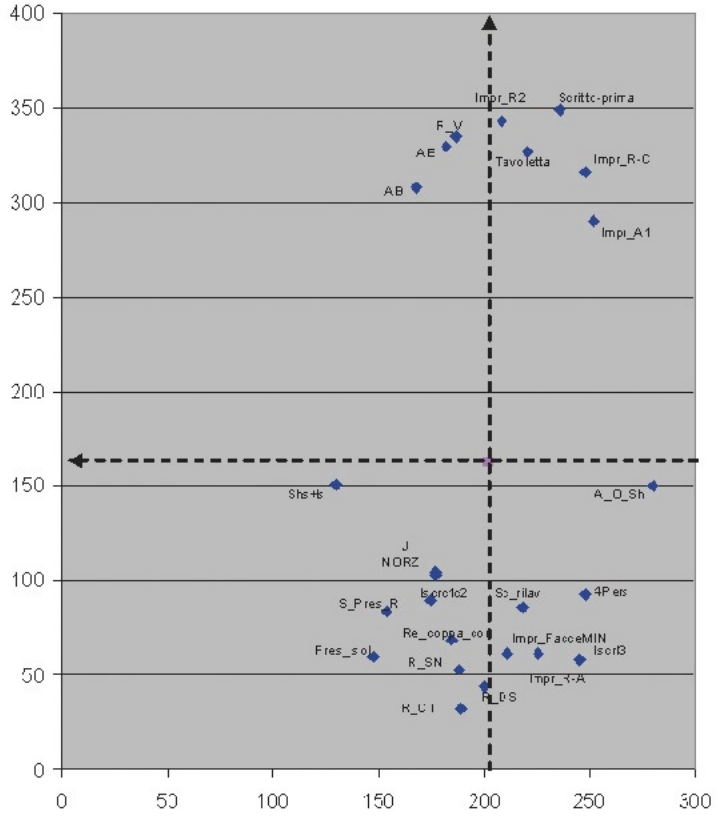


Fig. 12 – PST map of 24 variables in the record space of tablet DB.

documents. We can note that no variable related to the size of the document is present, while all variables but one are retained, and variables related to the content of the seal scene and the position of the impression both in relation to the tablet sides and to the legend are also retained. Two variables connected with time are retained, one related to the reign of Shulgi, at the beginning of the 44 year time span, and the other including both reigns of Shu-Suen and Ibbi-Suen, at the end of this time period.

On the map of Fig. 12, besides the points representing the variables, two axes are drawn: the horizontal one indicates the direction of time going from the reign of Šulgi ("A_O_Sh") to the reign of Shu-Suen and Ibbi-Suen, from the beginning to the end of the historical period covered by the tablet DB. The other axis goes from the bottom to the top, from the least essential

variables to the most essential ones. In fact, the variables on the map gather in two well-identified clusters: the top one with 8 variables (highlighted in Table 3) and the bottom one with 16 variables.

The main feature of the top cluster variables is that they have a high number of "ones", more than 250. On the contrary, the main feature of the bottom cluster variables is a low number of "ones", less than 80. All of these variables are significant in classifying administrative documents, but those in the top cluster recur in more than 80% of the documents, while the others are less frequent and recur in less than 25% of the documents. So PST, besides supplying the most significant variables, separates those which differentiate documents by their *absence* (top cluster) from those which differentiate by their *presence* (bottom cluster).

It is for this reason that we call the top cluster "essential variables", the bottom cluster "non-essential variables" and the axis connecting the two clusters from bottom to top "essentiality axis". The essentiality concept must not be confused with the significance concept: all the variables in Table 2 are significant, but they interact with the other variables in a different way. To clarify this concept we propose this analogy: in a house the heating system for the winter is essential, while the cooling system for the summer is not. Thus we mention houses that have a cooling system, and not those having a heating system; the contrary would be trivial.

We note here that the 8 variables identified as essential by PST are the same variables represented in Fig. 10 in the tightly connected nucleus, which have been given the same meaning by Auto-CM elaboration. Each variable is characterized by two coordinates on the map of Fig. 11, the measure of its historical time and the measure of its essentiality. The most essential is "Scritto_prima" (text written before sealing) and the least essential is "R_CT" text in the obverse in the central part of the field.

The most "ancient" variables are "Impr_A1" (the impression of the seal on the tablet reverse in a single row) and "4Pers" (the seal scene has 4 characters). The most recent is "Pres_isol" (the person presented to the king in the seal impression has no physical contact with other people). This correlation between time and figurative and compositional patterns in administrative glyptic iconography might be a clue suggesting some paths followed by the Ur III Umma administration in the transformation and defining of the symbolization of bureaucratic roles from scenes with many characters, to simpler scenes with the owner of the seal presenting himself.

Time and essentiality, as two concepts classifying variables, can also be exported to the documents. For instance, a record has an associated value for essentiality, which is calculated as follows: each variable taking the value "one" in the record adds its essentiality value to the record, a variable taking the value "zero" in the record does not add anything. The final sum of all of

the contributions is attributed to the record as its essentiality value. A time value is similarly attributed.

This transfer of concepts from variables to records requires some caution: in itself a record cannot be more essential than any other. A high essentiality value for a record means only that it is characterized by mainly essential variables.

On the contrary, the concept of time is strictly tied in with records: documents usually show the date of their drafting at the end of the text. However, the concept time conveyed by the variables is something different from historical time. Concept time is a sort of indirect integrated measurement of old/recent characteristics contained in a record.

In conclusion, we may say: PST maps can be oriented by choosing appropriate macro-variables *after* plotting the map, without having any predetermined reference frame. Such maps allow us to answer the question of whether the variables all have equal importance. The example of the tablets DB shows that PST maps may be used to simplify the DB itself, by strongly reducing the number of variables, and by reducing the number of records, referring only to the most representative collection.

8. The Ur III presentation scenes DB: description and discussion of PST results

A PST map of variables gives an answer to the question of how many variables are really necessary to describe a "presentation scene". Only 96 variables "survive" the application of the procedure (i.e. are significant). The significant variables are not evenly distributed among the various groups of Table 3. They concentrate mainly on those related to:

– main characters (36.7% of the group are significant);
– posture variables, position of arms and legs (36.6% of the group are significant);
– character dress (50% of the group are significant);
– specific features of the robe (24% of the group are significant);
– headgear of characters (14.3% of the group are significant);
– attributes of characters (10.8% of the group are significant);
– hairstyle and beard (12.1% of the group are significant);
– seat and podium (20% of the group are significant);
– legend variables (40% of the group are significant).

In summary, we can say that the most significant elements of a seal with a "presentation scene" are the legend and three characters. The presence of a fourth character and additional elements such as animals, astral symbols, plants and similar seems, on the contrary, not to be significant, with only a few exceptions.

9. How PST variable significance may help in deciphering the communication flux needed to work a seal

In the language of PST a variable is significant when strongly interacting with other variables. However, as the production of a seal is a human activity, a significant variable should describe some important aspects of the scene from the point of view of those involved in the production process. More clearly, significance should correlate with intentional behaviour in deciding the features of the scene. In fact, features intentionally given to a scene are consistent with each other, since they are the expression of the same will. Therefore the variables representing those features must result as being correlated to each other, and in opposition with other variables representing different intentional choices of features: this is no less than the description of a strong interaction among variables, or, by definition, PST "significance".

There were at least two persons involved in the process of producing a seal in the Ur III period: the seal owner and the craftsman physically carving the seal. It is very likely that other persons were involved in the process; sometimes, some of them may have been explicitly recalled by significant variables describing the legend content; others may have been involved by virtue of their office. All of these persons may have had a decisional role in determining the presentation scene. It is difficult to identify them, so we will treat them as a single figurative "mind": the "decision maker", distinguished from the craftsman. At first sight communication between the decision maker and the craftsman appears to be difficult.

The amount of information is not so large (405 bits each corresponding to the 405 variables, according to our interpretation) in terms of bits (binary units), but in terms of natural language, the description of the information content of a scene requires some effort.

In addition, the unintentional component of the iconic language production process which underlies each "presentation scene" must be considered. We assume here that such a component, as well as the intentional one, is largely structured in the form of language. In this perspective, a meaningful part of the "decision maker" (or "decision making process") is based on some specific social and political approaches to the shared symbolic heritage of the late third millennium in Southern Mesopotamia.

9.1 *Hypotheses on the decision-making process*

An analysis of a PST variable map may shed light on the grey area between the decision maker's instructions and the craftsman's practice, because we assume that traces of the ultimate aims of the decision maker can be found in the variable significance. In light of this assumption we make the following observations:

a) The scenes with 3 characters are significant, scenes with either 2 or 4 characters are not. The will of the decision maker is more frequently directed towards this kind of scene (88.7% of the DB records). As high frequency is not enough to make a variable significant, there must also be a strong interaction with other variables, in other words a consistent expression of will related to other variables. In the case of 2 and 4 characters in a scene there is not such a strong connection.
b) The variable related to the receiver looking to the left is both frequent (96.9%) and significant.
c) The variable related to the receiver seated on a throne is both frequent (94.1%) and significant. Less significant may be the variables concerning the kind of seat and podium the receiver is seated on: or, rather, the place where the receiver sits may only be an important part of the message conveyed by the seal in special cases.
d) The gender analysis shows that the basic scene is composed by two female figures (one of them, the receiver) and a male figure. The lack of significance of the variables describing this basic (and more frequent) scene means that there was no need to specify it. The scenes which are differentiated from the "basic" ones (as for the gender) have – on the contrary – a larger number of significant variables. In Table 4 frequency and significance of the gender variables are reported. It is easy to note that significance always accompanies the lower frequency.

We notice here the traces of a communication by exception[3]. In this case the craftsman does not decide anything about the scene: he either obeys some (exceptional) instructions or he applies well consolidated standards. Since this method saves a lot of communication effort, it was probably adopted in other cases.

e) The legend is a feature of the scene at the same level of importance as the characters. Many variables referring to its position in the scene, its appearance and its content are both frequent and significant. It appears that the most significant content of the legend is not directly referred to the seal owner, but to his/her relations to the social and political environment.
f) To confirm the close bond between the significance of a variable and intentionality, the variable describing reworking of the seal is significant, even if it is not frequent.
g) The vertical and horizontal position of integrating elements is never significant: the craftsman had a certain freedom in placing them. Their presence might not convey any special meaning beyond a generic one.

[3] Communication by exception is a way to simplify communication between two subjects who know each other and have entered into an agreement not to explicitly communicate what is obvious. In other words what is not said is by default completed by the receiver and only what is a real novelty is explicitly communicated.

Character	Frequency	Significance
First Character		
Female	209 (60.6%)	no
Male	145 (39.4%)	yes
Second Character		
Female	309 (87.3%)	no
Male	45 (12.7%)	yes
Third Character		
Female	45 (12.7%)	yes
Male	292 (82.5%)*	no

Tab. 4 – Gender of the characters (scenes with only two characters are not included).

h) There is one exception to the above: the significance of an animal between receiver and presenter, especially if it is a single bird. The presence of an animal should convey a specific message and therefore would probably have been required by the decision maker.
i) Besides the bird, the crescent is the only significant additional element, irrespective of its position.

10. Analysis of twin variables

Posture, dress, headgear, hairstyle, beard and objects are described by many variables and a consistent number of them are significant, especially when connected to the receiver. In more detail, fringed and flounced robes are significant, while pleated robes never are. Other small details are also not significant. Only a few headgear variables are significant. Arms and legs seem to refer to a code which conveys some message to the viewer of the scene, since many variables connected to their position are significant.

Beard and a tuft on the neck of the receiver are significant, as is a bald head for the second character, and a double curl for the third figure. In all cases these characteristics are significant, but not frequent. Also some jewels and other objects connected to the characters are significant. Bracelets and collars are significant items, as is a cup in the hand of the receiver. The pairs of variables referring to the same feature attributed to the receiver and to the second figure look like twin variables. Comparing them gives us a better understanding of their roles in the decision making process. To analyse this data four parameters are employed: the distance on the map between the two members of the couple, the frequency of the feature for both, and its significance. When the distance is short, this means that the two twin variables behave in the same way.

The first 7 couples of Table 5 show a very short distance (9.4 or less). They not only are non-significant in the sense of PST elaboration, but also have very low frequency. No indication of their role in the communication system can be drawn, because the short distance is a direct consequence of the low frequency.

Four couples of variables are highlighted: they have a short distance, if compared to their high frequency. This means that these features were attributed very frequently to both characters, without the need of a specific will of the decision maker. The last three couples are related to cases where the initiative was probably not strictly predetermined by the decision maker, but it was customary to attach the feature to only one of the characters, and therefore the distance is long. In summary: in the case of a non-significant feature it was frequently attached to both characters, without the strict influence of the decision maker.

Table 6 shows 8 features that are significant for the receiver and mainly shown by him/her. At the same time, the frequency for the second figure is comparatively low, but for two cases (fringes on the dress and four couples of horns in the headgear). All the distances of this group are quite large, showing the intentionality for the receiver and a certain freedom on the part of the craftsman.

Table 7 shows 3 features which are significant for the second figure. All of the distances of this group are quite large, showing intentionality for the second figure, and a certain freedom on the part of the craftsman in attributing the same feature to the receiver. A flounced dress is very frequent but not significant for the receiver and can be recognized as a feature added by the craftsman, while to give the same feature to the second figure would have required an explicit order from the decision maker.

In Table 8 four cases of twin variables are reported, all of them significant. Here the decision maker not only prescribes a long dress for the characters, but also requires that it be present for both at the same time.

The case of the position of the arm in the rear is the opposite: it is prescribed frequently for the receiver, but rarely for the second figure. The other two cases are somehow intermediate between the two previous ones and may be commented on in the same way.

The analysis of the variables gives us an idea of the decision making and communication process which led to the realization of a cylinder seal. Decisions on the appearance of the scene seem to have been taken (as one would expect), at a fairly high level, leaving only a limited autonomy to the will of the craftsman. In general, the freedom left to the craftsman seems to be a way of reducing the amount of information to be passed "top-down", and therefore facilitates communication.

11. Conclusive remarks. Administrative documents, "presentations" and ANN Maps

The results obtained by the experimental use of different Artificial Neural Network tools on both *corpora* led to important basic observations that can be considered sound, though both data sets need to be enlarged and further investigated in order to refine the research.

Common features of receiver and second figure	Distance on the map	Frequency receiver	Frequency second figure	Significance
Front forearm extended horizontally	0	1	2	none
Flat headgear	0	1	1	none
Dragon heads emerging from the shoulders of the character	1	2	1	none
Three couples of horns on the headgear	2.8	8	9	none
Weapons appearing behind the shoulders of the character	3.2	2	1	none
Gender: female	8.9	1	7	none
"Striped Headgear"	9.4	3	6	none
Dress with a thick hem	9.2	11	17	none
Ellipsoidal element in the headgear	11.7	99	105	none
One couple of horns in the headgear	35.1	206	223	none
Goddess	112.8	208	302	none
Plain dress	37.4	21	25	none
Pleated dress	160.6	11	159	none
Bent forearm with the hand close to the face	257.4	3	261	none

Tab. 5 – Low degree of significance twin variables.

Common Feature of receiver and second figure	Distance on the map	Frequency receiver	Frequency second figure	Significance
Necklace	38.2	37	9	only receiver
Bracelet	45.4	30	16	only receiver
Fringed robe	94.5	45	58	only receiver
Skull-cap	61.4	66	5	only receiver
Four couples of horns on the headgear	112.3	55	59	only receiver
Beard	122.3	120	2	only receiver
Front forearm extended towards each other	322.4	348	50	only receiver
Left-oriented	344.3	343	6	only receiver

Tab. 6 – Twin variables which are significant only for the receiver.

Common Feature of receiver and second figure	Distance on the map	Frequency receiver	Frequency Second figure	Significance
Double bracelet	22.1	6	20	only second figure
Front forearm extended along the body	42.6	1	41	only second figure
Flounced dress	363.5	276	112	only second figure

Tab. 7 – Significant variables for the second figure.

Common Feature of receiver and second figure	Distance on the map	Frequency receiver	Frequency second figure	Significance
Long robe	15.7	298	302	both
Men	40.2	70	45	both
Multiple necklace	63	31	75	both
Rear arm of the character extended along the body	392	350	45	both

Tab. 8 – Significant twin variables.

In the light of what has emerged from previous studies, and from this research, Ur III "presentation scenes" were conceived and realized on the basis of the model of the presentation of three characters before a goddess. The most typical and frequent features of the compositional scheme show the female divine receiver facing the goddess who stands hand in hand with a shaven man all of which have a central position in the Auto-CM graphs, but they also always have quite a low degree of significance (Table 4). It would be very interesting to find a "genealogical" relationship between this basic scheme and the Akkadian specimens of "presentation scenes" in glyptic. Indeed, a purely formal relationship could be found from a simple investigation, based on more or less traditional procedures (an attempt that has been made in Di Ludovico 2005), but a logical and deeper relationship requires a wide range analysis and a complex investigation.

The figurative elements that may give the scene a strong semantic contribution are in many cases features belonging to the Ur III iconographic tradition, though some subjects can be referred to older iconic themes. As one might assume, the body language of all the characters, and especially that of their arms, is a fundamental trait of the scene, and gives the representation its enunciative unity. The posture variation of some characters seems, however, to imply a change in the general message of the scene more than others. The posture of the standing shaven man and the male (human or divine) receiver are the elements that usually have this kind of influence on the scene. The presence of a fourth character in the scene has different meanings, according to the graphs presented here, depending on the kind of scene into which it is inserted.

In Ur III glyptic, "presentation scenes" composed of four characters are usually based on the composition of the sitting receiver and the hand in hand pair of standing goddess and man. A fourth figure is usually placed between this pair and the "origin" of the scene. In all but one specimen this fourth figure is a standing goddess; the semantic role played by this goddess definitely seems to be different in presentations before male figures, if compared to presentations before goddesses.

Integrating motifs depicted in the scenes are sometimes connected with reworking operations, especially if they are four or more. As one could expect, integrating motifs do not all have the same role in the constitution of the general message of the scene: the astral symbol placed in the upper part of the field, before the receiver, is a fundamental part of the scene, since its presence or absence deeply affects the semantic set up of the representation. Also some animal integrating motifs show a noteworthy semantic importance in the scene, especially the goose (possible religious symbolisms related to the goose have been discussed in Battini 2006). The scorpion may have some importance in the definition of the scene's message, but it seems to be quite enigmatic: in the Auto-CM processing it appears as a borderline motif, while

in the PST variable examination it seems to have had limited significance. This is probably due to a double life of this symbol in Ur III glyptic. Nevertheless, the Auto-CM graphs give a clear indication of a non-negligible role of this symbol in "presentation scenes".

Other integrating motifs besides the scorpion, that are already attested to in Akkadian glyptic (for example, the different kinds of trees and vegetables) actually tend not to be very frequent, and to have a low degree of significance in Ur III "presentation scenes". Finally, it is very interesting to notice that some infrequent integrating motifs, like the bull and the monkey (this motif is probably very late), bear a significant contribution to the message of the scene, but do not deserve an important position in the diagrams revealing the semantic weight of elements in the "presentations". Perhaps this seemingly contradictory picture is based on the relative rarity of these motifs in the database, and on their weak thematic relationship with the very structure of the "presentation scene".

The research on Umma administrative documents has also given unambiguous results, both with the Auto-CM and with the PST processing. The inner structure of the Ur III Umma administrative record appears to have been increasingly influenced by the physicality of cylinder seals used by the officers, and always conceptually referred to the form of the tablet. In general, the use of the tablets' surfaces, both for drafting and sealing, was quite strictly systematized from the end of Šulgi's reign: this could mean that data of this kind are concrete clues of the so-called reforms of Šulgi in the state bureaucracies (Steinkeller 1987, 20-21; Waetzoldt 1991, 638; Sallaberger 1999, 146-156, 234-237).

Finally, it is very important to notice that results of all of the methods applied in this research to both data sets converge at the same outline of the history of Ur III "presentation" glyptic. On the one hand, in fact, in both investigations the same features (or "variables") were recognized as "basic" both by Auto-CM (see the MRG representations of results) and PST. On the other hand, the only variable describing the scene's receiver selected by PST is that related to the royal figure (Fig. 12, "S_Pres_R"). In the map it is not considered to be very significant, but if this information and that coming from the relevant MST are combined, the confirmation emerges that the so-called "royal presentation" was a sub-genre of a large category of subjects.

Alessandro Di Ludovico
Department of European, American and Intercultural Studies
Sapienza University of Rome

Giovanni Pieri
SEMEION
Research Centre of Sciences of Communication
Rome

Acknowledgements

The work published here was conducted with the fundamental help of the following computer algorithms: MST v 5.2 (M. Buscema, Semeion 2008); PST v 9.1 (M. Buscema, Semeion 2009); Trees Visualizer v. 3 (G. Massini, Semeion 2007). Both authors of this article are greatly honoured to have had the chance to cooperate with the Semeion Research Centre of Sciences of Communication, the contribution of which to this project has been – and remains – vital and fundamental. All models and software products used for this research were planned and developed by the researchers of Semeion. The authors also wish to express their gratitude to Prof. Dr. B. Foster (Yale Babylonian Collection), Dr. U. Kasten (Yale Babylonian Collection) and Prof. Dr. M. Sigrist (École Biblique, Jerusalem) for their kindness, helpfulness and friendship. This article is entirely the result by a joint effort by its two authors, and cannot be considered as a composition of separately written parts. Only for academic purposes, we may mention here that: Di Ludovico is the author of Introduction and paragraphs 3, 4, 5, 9; Pieri is the author of paragraphs 2, 6, 7, 8, 9.1; both are authors of paragraphs 3.1, 3.2, 10, 11. A special thank is due to Agnes Crawford for revising English.

REFERENCES

Battini L. 2006, *La déesse aux oies: une représentation de la fertilité?*, «Revue d'Assyriologie et d'Archéologie orientale», 100, 57-70.

Boehmer R.M. 1999, *Uruk. Früheste Siegelabrollungen*, Ausgrabungen in Uruk-Warka. Endberichte 24, Mainz am Rhein, Philipp von Zabern Verlag.

Brandes M.A. 1979, *Siegelabrollungen aus den archaischen Bauschichten in Uruk-Warka*, Wiesbaden, Franz Steiner Verlag.

Buchanan B. 1966, *Catalogue of the Ancient Near Eastern Seals in the Ashmolean Museum I, Cylinder Seals*, Oxford, Clarendon.

Buscema M. 1995, *Self-reflexive networks. Theory, topology, applications*, «Quality & Quantity», 29, 339-403.

Buscema M., Didoné G., Pandin M. 1994, *Reti neurali auto riflessive, teoria, metodi, applicazioni e confronti*, Quaderni di Ricerca, 1, Roma, Armando.

Buscema M., Grossi E. 2007, *A novel adapting mapping method for emergent properties discovery in data bases: experience in medical field*, in Y. Nakamori, Z. Wang, J. Gu, T. Ma (eds.), *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics (The Hague 2007)*, Montreal, IEEE Omnipress, 3457-3463.

Buscema M., Petritoli R., Pieri G., Sacco P. 2008, *Auto Contractive Maps*, Technical Paper, 32, Rome, Semeion-Aracne.

Buscema M., Terzi S. 2006, *PST: A new evolutionary approach to topographic mapping*, «WSEAS Transactions on Information Science and Applications», 9, 1704-1710.

Camiz S., Rova E. 1996, *Metodi di analisi per lo studio di un gruppo di sigilli cilindrici vicino-orientali e di altre immagini strutturate*, «Archeologia e Calcolatori», 7, 647-659.

Camiz S., Rova E. 2001, *Exploratory analyses of structured images: A test on different coding procedures and analysis methods*, «Archeologia e Calcolatori», 12, 7-45.

Camiz S., Rova E. 2003, *Quantitative study of images in archaeology: I. Textual coding*, in M. Schader, W. Gaul, M. Vichi (eds.), *Between Data Science and Applied Data Analysis*, Berlin, Springer, 624-632.

Camiz S., Rova E., Tulli V. 1998, *Exploratory analysis of images engraved on ancient Near-Eastern seals based on a distance among strings*, «Statistica», 58, 670-689.

Camiz S., Rova E., Tulli V. 2003, *Quantitative study of images in archaeology: II. Symbolic coding*, in M. Schader, W. Gaul, M. Vichi (eds.), *Between Data Science and Applied Data Analysis*, Berlin, Springer, 633-641.

Cassin E. 1960, *Le sceau: un fait de civilisation dans la Mésopotamie ancienne*, «Annales. Economies Sociétés Civilisations», 4, 742-751.

Collon D. 1982, *Catalogue of the Western Asiatic Seals in the British Museum. Cylinder Seals II. Akkadian, Post Akkadian, Ur III Periods*, London, British Museum Publications.

Collon D. 1987, *First Impressions. Cylinder Seals in the Ancient Near East*, London, British Museum Publications.

Digard F. (ed.) 1975, *Répertoire analytique des cylindres orientaux*, Paris, Centre National de la Recherche Scientifique.

Di Ludovico A. 2005, *Scene-in-frammenti: una proposta di analisi delle "scene di presentazione" dei sigilli a cilindro mesopotamici orientata all'elaborazione statistica ed informatica dei dati*, in A. Di Ludovico, D. Nadali (eds.), *Studi in onore di Paolo Matthiae presentati in occasione del suo sessantacinquesimo compleanno*, «Contributi e Materiali di Archeologia Orientale», X, Special Issue, Roma, Università "La Sapienza", 57-95.

Di Ludovico A. in press a, *La glittica della fine del Terzo Millennio come strumento di controllo e di consolidamento del potere in Mesopotamia*, in R. Dolce (ed.), *Quale Oriente? Omaggio a un Maestro. Studi di Arte e di Archeologia del Vicino Oriente in memoria di A. Moortgat a trenta anni dalla sua scomparsa*, Palermo, Flaccovio.

Di Ludovico A. in press b, *Experimental approaches to glyptic art using Artificial Neural Networks. An investigation into the Ur III iconological context*, in *On the Road to Reconstructing the Past. Proceedings of the 36th Annual Conference on Computer Applications and Quantitative Methods in Archaeology (Budapest 2008)*, Budapest, Archaeolingua.

Di Ludovico A. in press c, *The uses of the cylinder seal as clues of mental structuring processes inside Ur III state machinery*, in *Proceedings of the LIV Rencontre Assyriologique Internationale (Würzburg 2008)*.

Di Ludovico A. in press d, *Microsolutions to miniproblems? Approaches to ancient artefacts by the means of Artificial Neural Networks*, «Archeologia Cognitiva», 0.

Fischer C. 1997, *Siegelabrollungen im British Museum auf Ur-III-Zeitlichen Texten aus der Provinz Lagaš*, «Baghdader Mitteilungen», 28, 97-183.

Gibson McG., Biggs R.D. (eds.), *The Organization of Power. Aspects of Bureaucracy in the Ancient Near East*, Studies in Ancient Oriental Civilization, 46, Chicago, The Oriental Institute of the University of Chicago.

Hallo W.W. 2001, *Seals and seal impressions*, in Hallo, Winter 2001, 239-254.

Hallo W.W., Winter I.J. (eds.), *Proceedings of the XLVe Rencontre Assyriologique Internationale. Part II: Yale University: Seals and Seal Impressions*, Bethesda, CDL Press.

Hattori A. 2001, *Sealing practices in Ur III Nippur*, in Hallo, Winter 2001, 71-99.

Kelly-Buccellati M. 1977, *Towards the use of quantitative analysis in Mesopotamian sphragistics*, «Mesopotamia. Rivista di Archeologia, Epigrafia e Storia Orientale Antica», 12, 41-52.

Kohonen T. 1997, *Self-Organizing Maps*, New York, Springer.

Lafont B. 1995, *La chute des rois d'Ur et la fin des archives dans les grands centres administratifs de leur empire*, «Revue d'Assyriologie et d'Archéologie orientale», 89, 3-13.

Licastro F., Porcellini E., Chiappelli M., Forti P., Buscema M., Ravaglia G., Grossi E. in press, *Multivariable network associated with cognitive decline and dementia*, «Neurobiology of Aging», 29.

Mayr R.H. 2001, *Intermittent recarving of seals in the Neo-Sumerian period*, in Hallo, Winter 2001, 49-58.

Moortgat A. 1940, *Vorderasiatische Rollsiegel: Ein Beitrag zur Geschichte der Steinschneidekunst*, Berlin, Gebrüder Mann.

Moortgat-Correns U. 1968, *Die ehemalige Rollsiegel-Sammlung Erwin Oppenländer*, «Baghdader Mitteilungen», 4, 233-289.

VON DER OSTEN H.H. 1934, *Ancient Oriental Seals in the Collection of Mr. Edward T. Newell*, Oriental Institute Publications, 22, Chicago, The Oriental Institute of the University of Chicago.

PIERI G. in press, *Some interpretation tips for PST maps*, «Archeologia Cognitiva», 0.

PORADA E. 1980, *Introduction*, in E. PORADA (ed.), *Ancient Art in Seals*, Princeton, Princeton University Press, 3-30.

PORADA E. 1993, *Why Cylinder Seals? Engraved Cylindrical Seal Stones of the Ancient Near East, Fourth to First Millennium B.C.*, «Art Bulletin», 75, 563-582.

ROVA E. 1994, *Ricerche sui sigilli a cilindro vicino-orientali del periodo di Uruk/Jemdet Nasr*, Orientis Antiqui Collectio, 20, Roma, Istituto per l'Oriente "C. Nallino".

ROVA E. 1995, *Metodi di codifica e analisi per lo studio di immagini strutturate: un'applicazione ai sigilli cilindrici del periodo di Uruk/Jemdet Nasr*, «Archeologia e Calcolatori», 6, 7-34.

ROVA E. 2000, *Automatic classification of archaeological materials: Possibilities and limits. An example (Uruk/Jamdat Nasr cylinder seals from greater Mesopotamia)*, in E. ROVA (ed.), *Patavina Orientalia Selecta*, History of the Ancient Near East, Monographs, 4, Padova, S.A.R.G.O.N., 1-20.

SALLABERGER W. 1999, *Ur III-Zeit*, Orbis Biblicus et Orientalis 160/3, Freiburg, Universitätsverlag Freiburg, 121-336.

SCHMANDT-BESSERAT D. 1977, *An Archaic Recording System and the Origin of Writing*, Monographic Journals of the Near East. Syro-Mesopotamian Studies, 1/2, Malibu, Undena Publications.

SCHMANDT-BESSERAT D. 1979a, *An archaic recording system in the Uruk-Jemdet Nasr period*, «American Journal of Archaeology», 83, 19-48.

SCHMANDT-BESSERAT D. 1979b, *On the origins of writing*, in D. SCHMANDT-BESSERAT (ed.), *Early Technologies*, Malibu, Undena Publications, 41-45.

SHARLACH T.M. 2004, *Provincial Taxation and the Ur III State*, Cuneiform Monographs, 26, Leiden-Boston, Brill-Styx.

STEINKELLER P. 1977, *Seal practice in the Ur III period*, in McG. GIBSON, R.D. BIGGS (eds.), *Seals and Sealings in the Ancient Near East*, Bibliotheca Mesopotamica, 6, Malibu, Undena Publications, 41-53.

STEINKELLER P. 1987, *The administrative and economic organization of the Ur III state: The core and the periphery*, in GIBSON, BIGGS 1987, 19-41.

WAETZOLDT H. 1991, *Review* to GIBSON, BIGGS 1987, «Journal of the American Oriental Society», 111, 637-641.

WAETZOLDT H. 1995, *Änderung von Siegellegenden als Reflex der 'großen Politik'*, in U. FINKBEINER, H. HAUPTMANN (eds.), *Beiträge zur Kulturgeschichte Vorderasiens. Festschrift für Rainer Michael Boehmer*, Mainz am Rhein, Philipp von Zabern, 659-663.

WINTER I.J. 1987, *Legitimation of authority through image and legend: Seals belonging to officials in the administrative bureaucracy of the Ur III state*, in GIBSON, BIGGS 1987, 69-116.

WINTER I.J. 2001, *Introduction: Glyptic, history, and historiography*, in HALLO, WINTER 2001, 1-14.

ABSTRACT

The integration of different approaches based on Artificial Neural Networks models has here been adopted to draw the guidelines of a map of a Mesopotamian administrative system. Two data sets concerning two different classes of findings have been contemporarily investigated using different models and procedures: a *corpus* of glyptic presentation scenes and

a group of administrative tablets from the archives of Umma. Both *corpora* are witnesses to the inner logics of late third millennium Mesopotamian state administration, and the investigations into them gave interesting contributions to the development of sound hypotheses for a general outline of the Ur III state bureaucratic culture. In fact, the results, obtained through different methodologies, show a large number of points of convergence, and the same features were recognized as "basic" both by Auto-CM and PST. In summary, through research on heterogeneous documents related to Ur III administrative communication, such as the relics of visual languages and traces of writing and sealing procedures, this work demonstrates how proper data mining techniques can partly reveal the very cultural background of some ancient centralized organizations and stimulate the development of new ways of considering the use and perception of those products.