Modelling the Archaeologist's Thinking for the Automatic Classification of Uruk / Jamdat Nasr Seals Images

Sergio Camiz[1], Elena Rova[2] and Vanda Tulli[3]

[1]Università di Roma La Sapienza
[2]Università di Venezia Ca= Foscari
[3]Università di Milano Bicocca
sergio.camiz@uniroma1.it

1. Introduction

During a long-lasting study (Rova, 1994, 1995; Camiz and Rova, 1996, 2001, 2003; Camiz et al., 1998, 2003), we the present authors analysed a corpus of 1247 Near Eastern seals images of the Uruk / Jamdat Nasr period (II half of the IV millennium BC.) under the point of view of their iconographical content, and of its relations with the geographical origin and the context of discovery of the seals seal and of their impressions, as well as with their use to seal different kinds of objects. We believe that a comprehensive iconographical analysis of images needs to consider at least three levels of description:

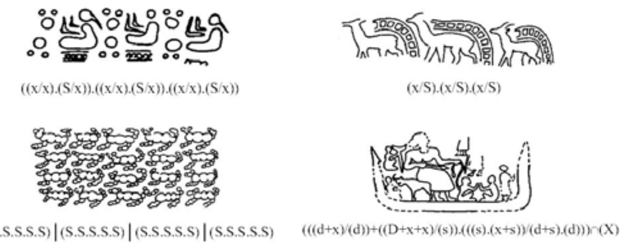

Fig. 1. Four different seal images with the corresponding symbolic sequences representing their syntax.

- the presence, or frequency, of single elements and their different positions, such as: different types of human beings, animals, objects; sitting, with open arms, etc;

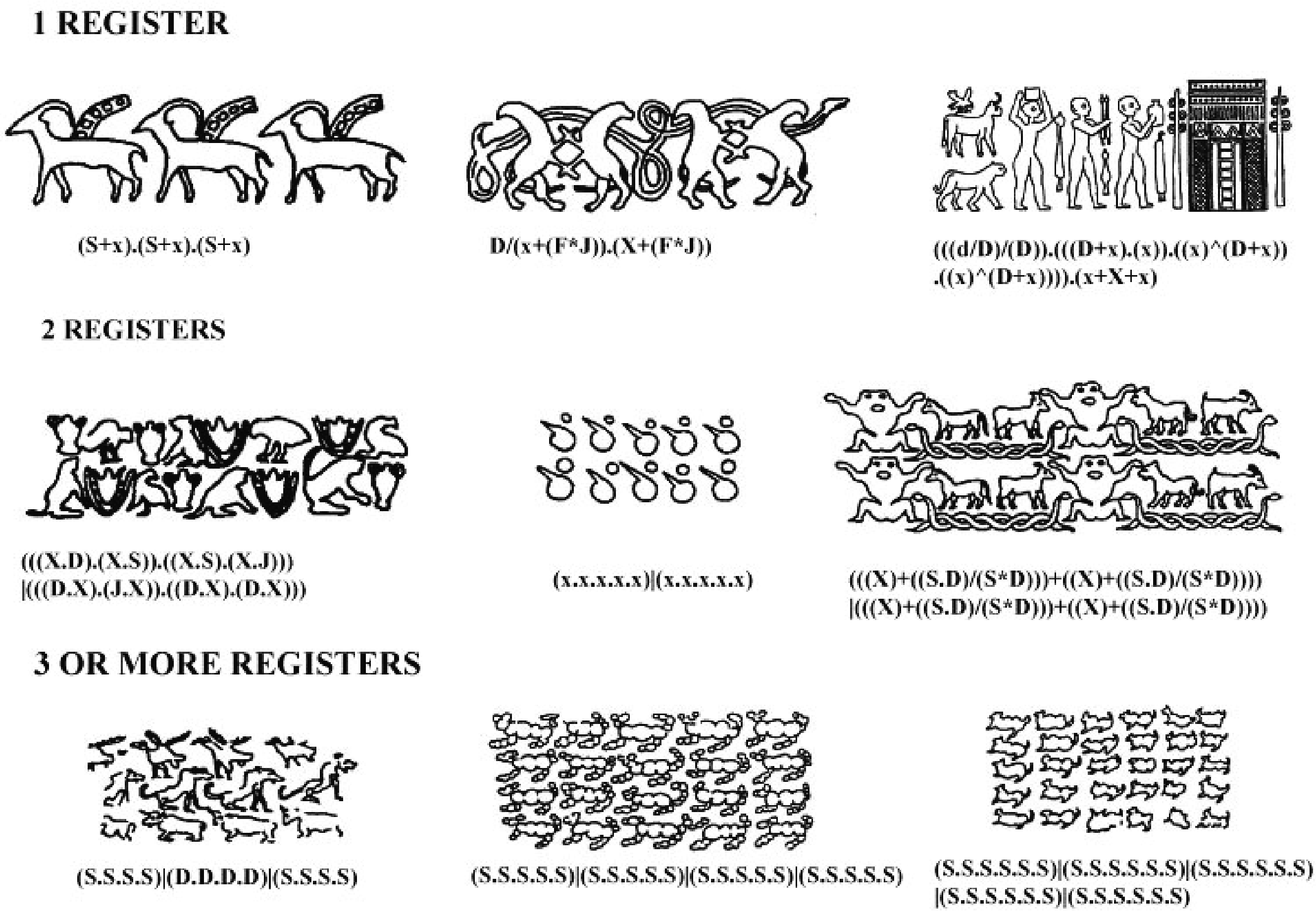

Fig. 2. Seals with images on one, two, or more registers.

- the presence of small sub-patterns, such as: woman with open arms sitting left on a bench: or king-priest passing right with asymmetric arms with bow and arrow: which can be repeated several times on the same image, or appear identical on different images;
- the overall syntactic image structure, such as image on four registers, each one composed of five identical (repeated) elements:or image composed of two repeated subpatterns, each one composed of two sub-subpatterns, the first one consisting of a small central element surrounded by two larger elements, the second one consisting of three superimposed elements:

For this reason, we implemented three different coding systems, able to describe these three levels, and we checked their ability in revealing similarities and differences between images through exploratory factor analyses, chosen in agreement with the kind of data used in each step:

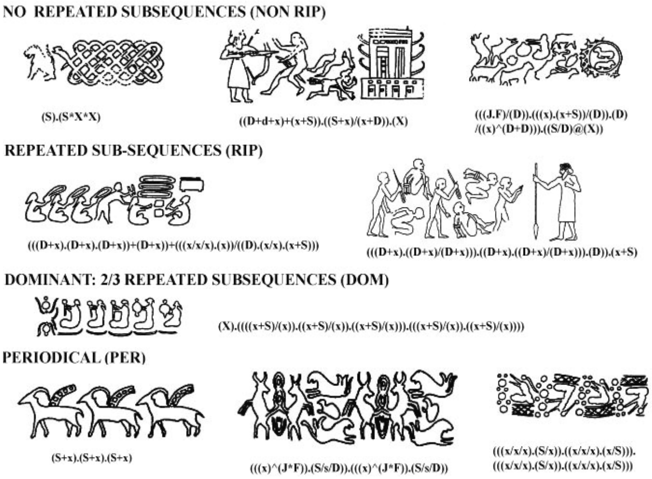

Fig. 3. Seals with or without repeated subsequences.

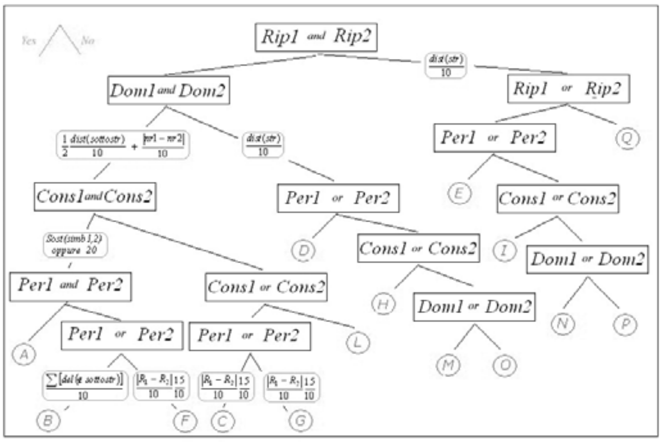

Fig. 4. The decision tree for the repeated sequences in the images.

- A classical coding based on presence/absence of elements and/or characters.
  In this case we used Multiple Correspondence Analysis (Lebart et al., 1995; Rova, 1994; Camiz and Rova, 2001).
- A formalised language, able to describe images without any ambiguities or redundancies. In this way, a formalised text is associated to each image. This fully describes both the elements composing the image, their attitudes and attributes, and the relations among elements. In this language, the terms are not declined nor conjugated, so that the correspondence among elements, attitudes, and relations and the terms describing them is biunivocal. We took into account the fact that each image was composed by sub-images via both repeated segments and quasi-segments, sequences of terms corresponding to such sub-patterns. For this case we used Textual Correspondence Analysis (Lebart and Salem, 1994; Camiz and Rova, 2001).
- A symbolic code was developed to describe the image skeleton, that is its syntactical structure, based on the relations among both elements and sub-patterns, regardless of the nature of the former (Table 1; Camiz et al., 1998, 2003).

The coding results in a hierarchical sequence of symbols, where couples of parentheses enclose the set of symbols corresponding to a subpattern (Figure 1). For this coding, we had to develop a distance among sequences, able to take into account the differences between the whole image structures and those between the single subpatterns composing them. Once created a distance matrix among sequences, we used the Principal Coordinates Analysis (Gower, 1966) in the same way of the other factor analyses.

In all cases, a hierarchical classification of images (Gordon, 1999) was obtained, considering the first few factors which seemed important for the description of the images and for their characterisation.

In this paper, we focus on the third coding and on a new proposal for the computation of the distances among the sequences. In the past, we developed a bottom-up technique that, theoretically, should solve all the problems concerning the computation of distances among hierarchical sequences (Camiz et al., 1998, 2003). Instead, in practice, the experimentation showed that the method was too sensitive to the alignment of the sequences, in particular as far as concerned the sequences with more than one register were concerned. For this reason, we developed a program able to roughly simulate the archaeologist's reasoning when dealing with the problem of dividing, in successive steps, the images corpus into different image groups.

2. The Distance Among Sequences

In order to define a distance among the sequences corresponding to the seal images, in Camiz et al. (1998) a method was proposed, based on weights and factorisation. We briefly remind here its their main features:

2.1 Weighing Symbols

The distance between two sequences (Levenshtein, 1966) is based on symbols insertion, deletion, or substitution: each operation has a specific weight, decided by the archaeologist, observing three conditions:

- all weights should be positive;
- hey must be coherent: thus insertion and deletion of the same symbol should have the same weight, the main elements should weight more than the secondary ones, both

insertion and deletion of substructures weight more than those of e simple symbols, etc.;
- the weights should be univocal: if different structures may be described in different ways or the transformation of one sequence into another may be done in different ways, the weights should be determined independently from the different ways.

2.2 Factorisation of Sequences

Subsequences enclosed in parentheses are subpatterns. Thus, a new representative symbol is introduced for them, together with its corresponding weights. In order to estimate such weights, all possible combinations of insertion, deletion, and substitution necessary to transform a sequence into the other are considered, as weighed edges of an oriented graph. The weight of the minimum weight paths is thus the weight of the substitution of a sequence with the other.

The operation is repeated for all subpatterns up to the whole image pattern, giving a distance between the two images.

The method for studying symbolic sequences described so far does not consider, however, some elements of similarity between images. In particular:

- a common structure (or common substructures) as far as the differences among elements (main, secondary, orientation, etc.) are ignored, has no weight;
- the presence of common subpatterns is ignored. Thus, for instance, the difference between images on one register and images on two or more registers, is not given enough importance (Figure 2). In the same way, periodical images (that is images composed of repeated sub-patterns) do not stand out as a separate group. For this reason, a more complex algorithm had to be developed, more close to the actual archaeologist's chain of decisions, when evaluating similarities between different images. Actually, the basic technique, namely the weighting and the factorisation, remains the same, but the procedure takes into account other aspects that are suitably weighted suitably, in order to emphasize the importance of the common structure.

The new procedure acts as follows:

- as a first step, seals on one register are set apart from those with two, three or more registers;
- secondly, sequences are examined and characterised according to the pattern of repeated sequences (Figure 3):
  1 presence of repeated sub-sequences (RIP);
  2 dominant (2/3) presence of repeated sub-sequences (DOM);
  3 dominant presence of repeated consecutive sub-sequences (CONS);
  4 the sequence is composed only by one repeated sub-sequence (periodical, PER);
  5 periodicity of the spatial relations (PERSP);
  this step has the structure of the decision tree represented in Figure 4;
- then, the elements contained in the sequences of symbols are compared, according to the rules described in 2.1 and 2.2;
- finally, the sequence skeletons, as defined only by parentheses and spatial relations (that is, the left columns of Table 1), are compared.

	Elements		Relations
D	Main element right oriented	.	adjacent to (and)
S	Main element left oriented	+	joined with, touching, attribute
X	Main element not oriented	*	intertwined with
F	Main element doubly oriented, main right/	/	on
J	Main element doubly oriented, main left	??	on / under and by
d	Secondary element right oriented	*I*	into
s	Secondary element left oriented	??	above
x	Secondary element not oriented		*Subpattern*
f	Secondary element doubly oriented, main right	(	beginning
j	Secondary element doubly oriented,main left	)	end

Table 1. The codes used for the description of the imagef syntactical structure.

To each of these operations special weights are given, according to the importance decided by the archaeologist. Thus, the distance between each two strings of symbols is given by the total of the weights accumulated during the whole comparison process.

3. First Results

A test to evaluate the ability of this method to effectively characterise the seal images according to their syntactical structure has been carried out. We used for this the same 100 seals used by Camiz and Rova (2001, 2003) and Camiz et al. (1998, 2003) and we applied the Principal Coordinates Analysis (PCoA; Gower, 1966), in order to check which features of the images appear as significant on the first, most important axes. In fact, PCoA, as the other exploratory analyses based on the eigenanalysis, returns a geometrical representation of the units (in our case, the seals) in several dimensions. Since the returned dimensions are given in decreasing order of importance, one can evaluate the importance of the different features, according to their appearance on the different axes of the graphical scatter

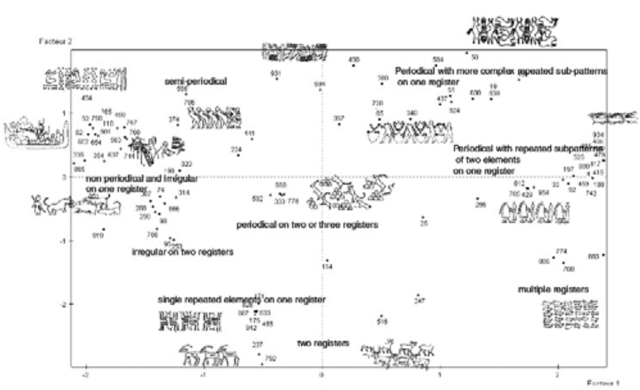

Fig. 6. The scatter of seals images on the plane spanned by the first two axes of PCoA on the distance matrix given by the newly proposed weighing procedure.

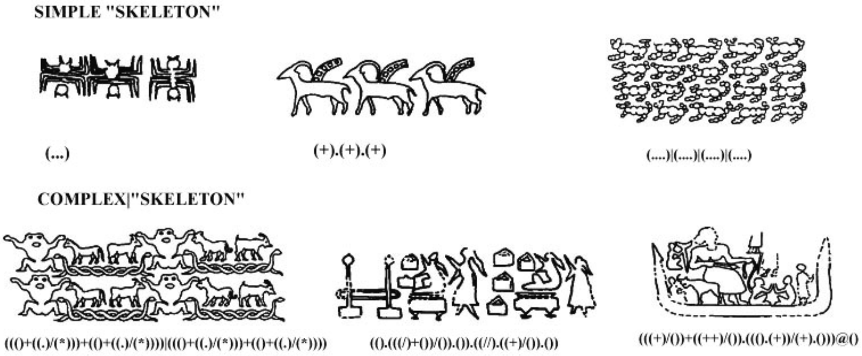

Fig. 5. The skeletons of some images of the seals.

diagrams. Here, we comment briefly the results of one of the first experimentation, using the same basic weights used in the previous works.

In this case, the first three axes of PCoA summarized over half of the total dispersion of the images, so that attention could be limited for the moment to these three dimension, with particular care to the scatter graphics of the first two axes (Figure 6). In this one, the first (horizontal) axis outlines the difference among periodic images on the right side and non-periodic on the left; the second (vertical) axis outlines the difference among images with only one register (above) and with two or more (below). As a matter of facts, this distinction seems even more clear on the third axis, not represented here. Based on this scatter, the following groups of seals can be distinguished: the irregular and non-periodical on one register on the extreme left, above and to the centre; the same on several registers, a little below; then, on the higher side of the plane, from left to right:, semi-periodical seals on one register, periodical seals on one register composed by complex sub-patterns, made of composed by three or more elements; periodical seals on one register composed by simple two-elements subpatterns, on the right. The periodical seals on two or more registers are close to the origin. Finally, , on the bottom, there are the seals with only one register with the repetition of a single element, to the on the left; those on two registers near to the centre those on two registers, while and those on multiple registers are on the right.

4. Conclusions

Compared with the results of the procedure proposed by Camiz et al. (1998, 2003), the idea of modelling the archaeologist's reasoning seems to give better results, since the distinction among the different image patterns of the image is better outlined. Nevertheless, the weighting system should be improved, albeit in the previous essays the procedure resulted enough robust in respect to the weights variation.

In respect to the previous experimentations, in this study the importance of the archaeologist's thinking is much higher, since with the textual coding it his/her role was limited to the coding, whereas in the bottom-up procedure only the weighting system was his/her responsibility. Now, it is the entire procedure that is modelled models on his/her thinking. Of course, this reflects witnesses the complexity of the proposed problem.

Considering the different coding used so far, we think that an integrated approach could be forecasted for the future. In fact, we proceeded according to several levels of abstraction (the elements, the sub-patterns, the syntax, and the skeleton) so that one can consider the utility to code the seals via a textual coding that could be easily, perhaps automatically, be transformed into the different coding required for the other treatments. In this way, the relations among the different elements or the subpatterns composing the images and the syntax could be better investigated.

References

Camiz, S. and Rova, E., 1996. Metodi di analisi per lo studio di un gruppo di sigigilli cilindrici vicino-orientali e di altre immagini strutturate, III Convegno Internazionale di Archeologia e Informatica, *Archeologia e Calcolatori* 7, 647–659.

Camiz, S. and Rova, E., 2001. Exploratory Analyses of Structured Images: a Test on Different Coding Procedures and Analysis Methods, *Archeologia e Calcolatori* 12, 7–46.

Camiz, S. and Rova, E., 2003. Quantitative Study of Images in Archaeology: I. Textual Coding. In Schader, M., Gaul, W., Vichi, M. (eds), *Between Data Science and Applied Data Analysis*. Berlin, Springer, 624–632.

Camiz, S., Rova, E. and Tulli, V., 1998. Exploratory Analysis of Images Engraved on Ancient Near-Eastern Seals based on a Distance among Strings. *Statistica* 58(4), 669–689.

Camiz, S., Rova, E. and Tulli, V., 2003. Quantitative Study of Images in Archaeology: II. Symbolic Coding. In Schader, M., Gaul, W., Vichi, M. (eds), *Between Data Science and Applied Data Analysis*. Berlin, Springer, 633–641.

Gower, J. C., 1966. Some Distance Properties of Latent Root and Vector Methods used in Multivariate Analysis. *Biometrika* 53, 325–338.

Lebart, L., Morineau, A. and Piron, M., 1995. *Statistique exploratoire multidimensionnelle*. Paris, Dunod.

Lebart, L. and Salem, A., 1994. *Statistique textuelle*. Paris, Dunod.

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

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.