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CONFERENCE PROGRAM

Monday, October 22

Special Session on Non-invasive systems and techniques for "on site" monitoring and diagnosis - PART I

Room: Aula Magna, Cassino University Campus
Chairs: *Emanuele Piuzzi, Sapienza, University of Rome, Italy*
Livio D'Alvia, Sapienza, University of Rome, Italy

Special Session on Artificial intelligence for measurements in cultural heritage - PART I

Room: B 2.07 Hall, Cassino University Campus
Chairs: *Francesco Colace, University of Salerno, Italy*
Mario Molinara, University of Cassino and Southern Lazio, Italy

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General Session PART I

Room: 1.09 Hall, Cassino University Campus

Chairs: *Maria Grazia D'Urso, University of Cassino and Southern Lazio, Italy*
Marco Laracca, University of Cassino and Southern Lazio, Italy

Tuesday, October 23

Special Session on Metrological approaches to the study of ancient and medieval written Heritage - PART I

Room: Aula Magna, Cassino University Campus
Chairs: *Gianluca Del Mastro, Università degli Studi di Napoli Federico II, Italy*

Special Session on Integrated Digital Survey Methodologies for the Knowledge and Enhancement of Architectural and Urban - PART I

Room: B 2.07 Hall, Cassino University Campus
Chairs: *Marco Giorgio Bevilacqua, University of Pisa, Italy*

Special Session on Artificial intelligence for measurements in cultural heritage - PART II

Room: 1.09 Hall, Cassino University Campus

Chairs: *Francesco Fontanella, University of Cassino and Southern Lazio, Italy*
Mario Molinara, University of Cassino and Southern Lazio, Italy

Special Session on Using multivariate analyses to interpret lithic variability: contributions and limitations

Room: Aula Magna, Cassino University Campus

Chairs: *Alice Leplongeon, Muséum national d'Histoire naturelle, France*
Elena A.A. Garcea, University of Cassino and Southern Latium, Italy

Special Session on Cultural Heritage: Measurement of Immeasurable Values - PART I

Room: B 2.07 Hall, Cassino University Campus

Chairs: *Magdalena Żmudzińska-Nowak, Silesian University of Technology, Poland*

Special Session on Geomatic Techniques for Integrated 3D Data Acquisition, Metric Validation and Management - PART I

Room: 1.09 Hall, Cassino University Campus
Chairs: *Gabriele Bitelli, Alma Mater Studiorum, University of Bologna, Italy*
Maria Grazia D'Urso, University of Cassino and Southern Lazio, Italy

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Special Session on Integrated Digital Survey Methodologies for the Knowledge and Enhancement of Architectural and Urban - PART II

Room: Aula Magna, Cassino University Campus
Chairs: *Marco Giorgio Bevilacqua, University of Pisa, Italy*

Special Session on Pondera Online: An international network for ancient and byzantine metrology

Room: B 2.07 Hall, Cassino University Campus
Chairs: *Charles Doyen, FNRS / UCLouvain, Belgium*
Maria Letizia Caldelli, Sapienza - Università di Roma, Italy

Special Session on Full Coverage Geophysical Prospection on Protohistoric and Roman Central Settlements in Italy

Room: 1.09 Hall, Cassino University Campus
Chairs: *Frank Vermeulen, Ghent University, Belgium*

Special Session on Non-invasive systems and techniques for "on site" monitoring and diagnosis - PART II

Room: 1.09 Hall, Cassino University Campus
Chairs: *Emanuele Piuzzi, Sapienza, University of Rome, Italy*
Livio D'Alvia, Sapienza, University of Rome, Italy

Wednesday, October 24

General Session - PART II

Room: Aula Magna, Cassino University Campus
Chairs: *Marilena Maniaci, University of Cassino and Southern Lazio, Italy*
Eugenio Polito, University of Cassino and Southern Lazio, Italy

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Special Session on Metrological approaches to the study of ancient and medieval written Heritage - PART II

Room: 1.09 Hall, Cassino University Campus
Chairs: *Lucio Del Corso, University of Cassino and Southern Lazio, Italy*

POSTER SESSION

Room: B 2.11 Hall, Cassino University Campus
Chairs: *Marco Laracca, University of Cassino and Southern Lazio, Italy*
Cristina Corsi, University of Cassino and Southern Lazio, Italy

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Special Session on Non-Destructive Analytical Approaches applied to the Study of Ancient Stone Materials

Room: Aula Magna, Cassino University Campus
Chairs: *Giulio Lucarini, University of Cambridge, UK*
Andrea Manzo, University of Naples L'Orientale, Italy

Special Session on Archaeopalynology for the reconstruction of environmental and cultural landscapes

Room: B 2.07 Hall, Cassino University Campus
Chairs: *Assunta Florenzano, University of Modena and Reggio Emilia, Italy*
Sebastián Pérez-Díaz, Spanish National Research Council, CSIC, Spain

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General Session - PART III

Room: 1.09 Hall, Cassino University Campus
Chairs: *Assunta Pelliccio, University of Cassino and Southern Lazio, Italy*
Lucio Del Corso, University of Cassino and Southern Lazio, Italy

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Special Session on Dating and Provenance of Ancient Artifacts: Methods, Applications and Future Perspectives

Room: Aula Magna, Cassino University Campus
Chairs: *Enzo Ferrara, Istituto Nazionale di Ricerca Metrologica, Italy*
Lluís Casas, Universitat Autònoma de Barcelona, Spain

Special Session on Measuring in the past: ancient instruments

Room: B 2.07 Hall, Cassino University Campus
Chairs: *Margherita Bongiovanni, Politecnico di Torino, Italy*
Emma Angelini, Politecnico di Torino, Italy

Encoding and Simulating the Past. A Machine Learning Approach to the Archaeological Information

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***Abstract* — The encoding of the spatial-temporal archeological, historical and anthropological records can be considered an ideal-typical representation of the human reasoning and thus also an artificial membrane interposed between the researcher and the past. These membranes are here considered artificial networks and can undergo interrogation processes through the most advanced analytical tools for learning and modeling complex configurations. The aim of this paper is to synthesize recent advances in Artificial Intelligence and Computer Science and – at the same time – to support the connectionists and symbolic computational paradigms as a new epistemic frontier in the automatic annotation of tangible and intangible heritage as well in the contemporary theories and methods of the archeological thought.**

Keywords — *Analytical Archaeology, Artificial Intelligence, Computer Science, Computer Semiotic, Artificial Adaptive Systems, Biological Computing, Computational Modeling*

I. Introduction

The semiotic and logicist encoding of the spatial-temporal archeological, historical, geographical and anthropological records can be considered an ideal-typical representation of the contextual reality inspired by the human reasoning and thus also an artificial adaptive membrane interposed between the observer / researcher and the past (1).

Nowadays, these epistemic networks are semantic segmentations and can undergo interrogation processes through the most advanced analytical tools for learning and modeling complex data-set configurations. Encoding the epistemic contexts of the past and simulating the dynamic and complex behavior of the high variability of the natural and cultural factors in artificial membranes thus conceived equals tracking down, selecting, and separately recreating a wide variety of functions associating variables, a wide variety of inferences controlling their semantic structure, and an equally wide variety of causes producing their transformation (2).

In this specific sense, a machine learning approach to the quantity and to the quality of the archaeological information has value: it recreates a possible world of other associations of meaning from the body of lacking sources and dispersed information, exhibits the nuances and complex interrelations, and, furthermore, helps the researcher to codify other, unforeseen or even hidden interrelations.

II. Epistemology

Since the end of the 1980s, a matrix encoding of the different archaeological complex systems has been in the process of development for the purpose of tracking down, selecting, and recreating the functions, inferences, and rules that produced the economic, politic and aesthetic transformations of the ancient cultural *milieux* (3).

The artificial formal networks obtained by such structural and semantic matrix encoding were thus continously and massively described, analyzed, and simulated through symbolic and connectionist paradigms of the new Artificial Intelligence at Department of Classics and at Laboratory of Analytical Archaeology and Artificial Adaptive Systems (LAA&AAS) at Sapienza University, and at the Semeion Research Centre of Rome (4).

In fact, the 'connectionist paradigm' aims at massively parallel models that consist of many simple and uniform processing elements interconnected with extensive links (the artificial neural networks) and the 'symbolic paradigm' has been conceived as the development of models using symbol manipulation, and the computation in the models is based on explicit encoding that contain signs organized in some specific and semantic structures (5).

After some 30 years of such theoretical, computational and experimental broad spectrum advanced researches on different historical, archaeological and anthropological empirical contexts of the past, Artificial Intelligence connectionist and symbolic paradigms seem to maintain a distinct value in the recent history of the archaeological thought (6).

This distinct value is most evident in the Analytical and Spatial Archaeology, where the simulations through the most advanced technique for deep learning and data mining serve both as a new paradigm for computational modeling and as a new theoretical approach for the study natural and cultural complex systems.

The aim of this paper is to synthesize recent advances in the measurement and simulation of the archeological systemic complexity (here intended as historical, archaeological, linguistical and anthropological complexity) and – at the same time – to support the connectionists and symbolic paradigm of the Artificial Intelligence as a new epistemic frontier in the automatic annotation of tangible and intangible heritage as well in the contemporary history of the archeological thought.

III. Recent Advances in Artificial Intelligence: From Learnig the Complexity of the Past Through the System Ecology Stategy (SES)

Digital archiving allows the cataloguing of a mass of data coming from *records* (archaeological, anthropological, figurative and epigraphic) that have a multi-dimensional nature. Today in Computer Science we define the mass of this information Big Data. To question, analyze and integrate this vast and diversified context of information the Artificial Intelligence seems to be the only resource that can answer to the needed in this direction (7).

The Deep Learning system utilizes the Big Data into traditional Neural Networks based on the gradient descent method with many hidden levels. Each hidden layer can have different local activities (convolution, filter selection, invariant detection) to find the deep characteristics and features of the input models (8).

However, this procedure does not generate a true deep learning, but implements an effective and iterative pruning of the input from a single point of view, so to detect the deep abstract invariant elements of the different patterns.

These large networks do not extract from the data an abstract scheme that can be applied effectively to another completely different set of data (9).

METANET (Semeion ©)

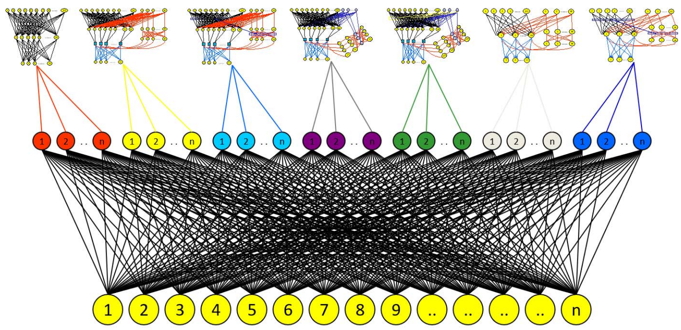

Fig. 1 An example of Ecological System: Metanet © Semeion

Therefore, we propose a new approach: the information coming from different sources must interact to be able of simulating complex scenario and find the rules that determine the spread / diffusion both of natural and cultural processes.

The new framework we propose works in a different way from what is called Deep Learning: it is an “ecological” system composed of different neural networks, evolutionary algorithms, dynamic associative memories, auto encoder, that work with different mathematics independently and simultaneously on the same data set or on different data sets that will be made to interact.

We have called this new artificial organism “Systems Ecology Strategy” (for short SES) (10).

SES observes the same phenomenon from different point of views (fig. 1): analyzes the dynamics and the rules that make it up or have generated and determined it; predicts its development or on the contrary retraces segments lost and / or inadequate, simulates scenarios; identifies the semantic network of relationships that connects it with other cultural and social phenomena and lastly can generates prototypes.

Every selected theme / aspect of a complex phenomenon can be thus analyzed because the points of views from which it is looked at are different, this theme / aspect can be artificially immersed in a context of relationships that define its domain of existence (11).

IV. A Machine Learning Approach to the Systemic Complexity of the Past: Unsupervised Learnings, Algorythmic Descriptions and Topological Centroids

Recent advances in Artificial Intelligence are revealing a completely new epistemic frontier also in the automatic annotation of tangible and intangible heritage as well in the contemporary history of the archeological thought.

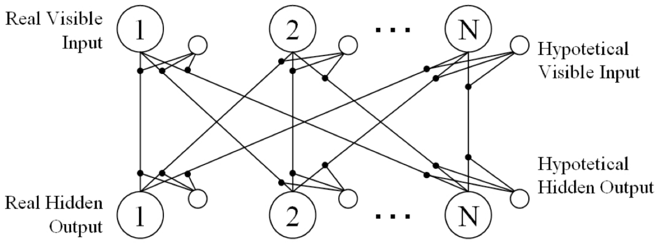

Fig. 2: Dynamic Associative Memory New Recirculation ANN © Semeion

In particular, the study of the natural and cultural complexity of the past through Analytical Archaeology, Computer Semiotics and Artificial Adaptive Systems is now declined to program and to shape a specific "Systems Ecology Strategy" for modelling and simulating the higher complexity of sign's systems coming from the Past.

Is now important to delineate the recent history of this theoretical and methodological approach, following the passages between the first unsupervised learnings of complex configurations and the modern biological computing of the cultural systems.

The spatial organization of the Mesopotamian Urban Revolution Landscape (MURL) in central-southern Babylonia has been the first archeological, historical and anthropological context to introduce a machine learning approach based on different types of Artificial Neural Networks for the multifactorial analysis of the first world Urbanism.

The Recirculation Artificial Neural Networks (fig. 2) were first applied to typological subdivision of the Fourth and Third Millennium BC southern Mesopotamian pottery considered as Constraint Satisfaction (CS) problem, in which the recognition of a class or a type must satisfy a number of constraints.

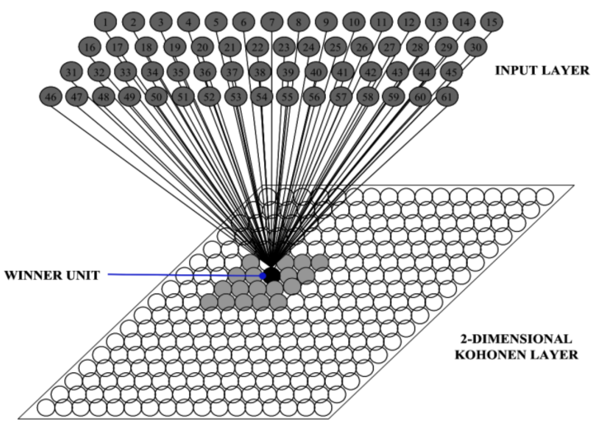

Fig. 3: Unsupervised ANN for natural clustering Self-Organizing Map

The unsupervised algorithms (fig. 2), such Self-Organizing Map (SOM) were contextually applied to classify and to delineate the Fourth and Third millennium BC human mobility trends in central-southern Babylonia, depending on a multifactorial, fuzzy and unforeseen correlations between many different variables (12).

A turning point in the planning of a machine learning approach to the archeological complexity has been the possibility for searching unforeseen and fuzzy connections in Big Data coming from direct and indirect encoding of archeological records.

A procedure based on Auto-CM and MST algorithms has been first tested in the Settlement Archaeology to investigate the possible spatial location of one of the most relevant cemetery of the ancient near east, the Royal Mausoleums recorded in the Royal Archives of Ebla – Tell Mardikh in northern Syria and dated back to the second half of the Third Millennium BC (13).

Auto-CM is one of the most powerful algorithms for searching for unknown or hidden connections in Big Data is called the Auto-Contractive Map (Auto-CM) (14). This powerful algorithm is able to encode the many to many relationships of similarity and to synthesize them within a matrix *N* x *N* of weights, where *N* is the number of variables (or records) among which we want to investigate relationships and connections.

The peculiarity of this unsupervised artificial neural network is that the final output will be zero while all knowledge will be combined in a highly non-linear way and stored in a matrix *N* x *N* in which each cell *ij* denotes how much variable *i* and variable *j* are similar to each other, also considering the interactions had with all other *N*-2 variables.

Since reading an *N* x *N* matrix is not very easy, especially when you have a very high N number of relationships to "measure", new techniques have been designed to make them visible and self-explanatory.

It is possible to visualize the most important relations in terms of strength through a two-dimensional graph that represents on a plane the *N* variables in the form of points.

A pair of points (Pi, Pj), i.e. a pair of variables, is connected by a link *l* only if the value of their connection, determined by the weight found by Auto-CM, respects certain constraints. Filters of this kind are the Minimum Spanning Tree and the Maximally Regular Graph (15).

One of the innovations brought about by the use of the Auto-CM algorithm is the possibility of querying the network through the Spin Algorithm. The Spin Net algorithm was programmed to exploit Auto-CM's ability to understand the deep structure of the world of which the learned data is a part.

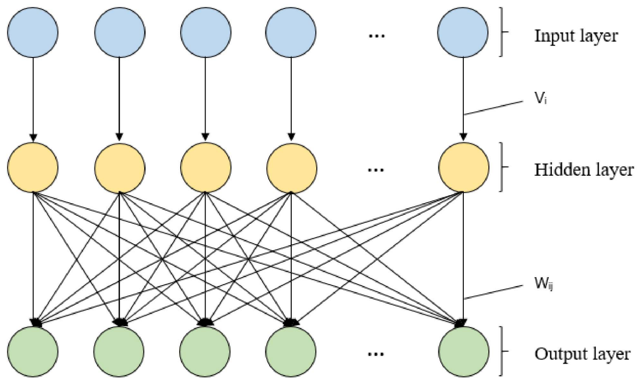

Fig. 4: Auto-CM © Semeion

Spin Net belongs to that category of algorithms called "associative memories" and is able, once an incomplete record is proposed as input, to reconstruct it exploiting the knowledge embedded in the weights (16).

The output of Spin Net is therefore constituted by an N-variables vector whose values, iteration after iteration, stabilize following a continuous dialogue and interaction among themselves based on the weights determined by Auto-CM. The potentialities of spin net in the artificial intelligence filed are decidedly relevant.

On the one hand, once a damaged record or one with missing values is input, the network will be able to converge towards the most probable correct values. Otherwise, activating only some of the variables will have the effect of a real questioning: "What would happen if ...?" and the system will simulate the most plausible scenario.

The recent advances in the programming of a more sophisticated machine learning approach has been supported by powerful algorithms specifically designed to analyze the dynamic morphology of a processes, and has been first experimented to simulate the spatial origin and the topology of the central Babylonia settlement systems during the Vth, IVth and IIIrd millennium BCE in the region between Eridu and Nippur in southern Iraq (17).

If there is an interest in the evolution of a phenomenon or a process, it is possible to use sophisticated algorithms designed to analyze the diffusion of space/time processes through an innovative model called topological approach based on the Topological Weighted Centroid (TWC) theory (18).

The TWC is a complex evolutionary algorithm that, starting from a dataset consisting of at least the spatial coordinates of events, tries to reconstruct the points and relevant areas related to the starting distribution.

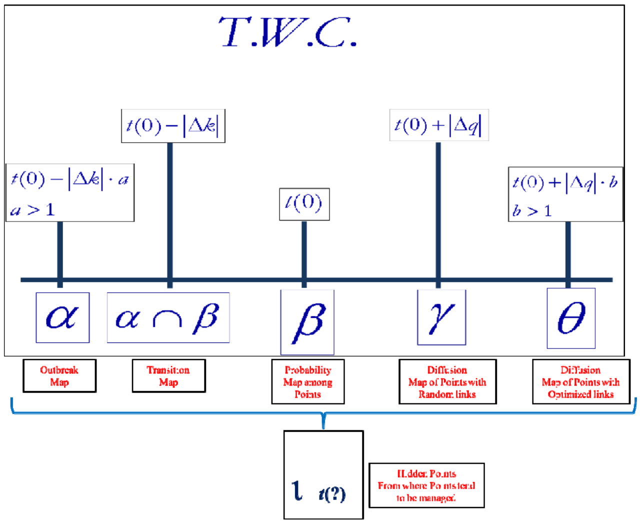

Fig. 5: TWC © Semeion

The basic intuition behind the topological approach is that every distribution of point in space has an implicit semantics, provided the following conditions are met: 1) Each point of the distribution represents a discrete occurrence of the same process; 2) The distribution of points is statistically representative of the process to be analyzed; Once again, the objective of this innovative technique is to extract Implicit information, hidden in the relations among the data-points.

The salient points related to the distribution that the TWC technique can determine are of two different natures. The Alpha point, which corresponds to spatial estimate of the hidden (outbreak) point, where the process under study originated. Iota points, instead, are the vantage points from where the distribution of points becomes most intelligible.

While the Alpha point, by its nature, lies within the convex hull of the distribution and is unique (19), Iota points can be more than one and generally fall outside the smallest convex containing the points. It is possible to determine the activation strength of each of the iota points and display it via heat map to determine the respective areas of influence (Iota map). The determination of these points is very complex and sophisticated, for complete mathematical details see the publication cited.

In addition to determining points of interest, the TWC algorithm is able to generate heat maps to predict the possible development of distribution in the past (TWC alpha map), present (TWC beta map) and future (TWC Gamma and TWC theta maps). The algorithm is also able to draw directly on the map the possible nonlinear trajectories that have allowed communication between the points of the distribution (Gamma and Theta paths).

If the dataset containing the event locations is also equipped with other attributes (e.g. extra information about the events), it is possible to make the TWC system interact with Auto-CM by creating an additional space semantization. Although the two systems are completely different and designed to analyze different aspects can be used to increase the points of view, and therefore the knowledge, on the same problem, a biodiversity of information extractors (20).

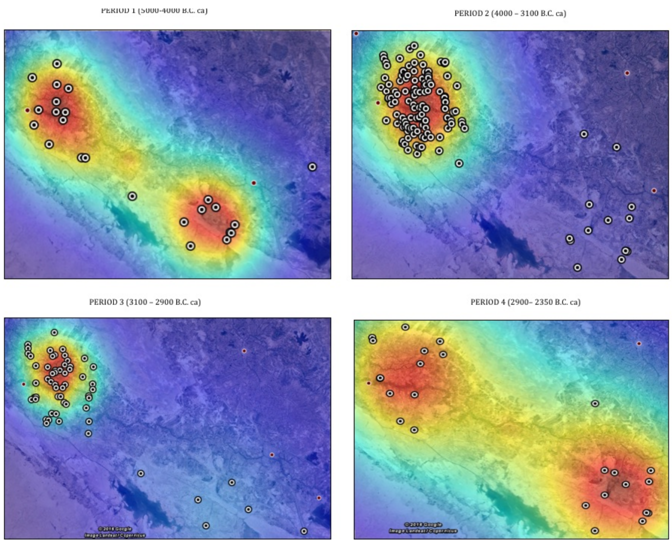

Fig. 6: TWC topological analysis of the first urbanism process in central-southern Mesopotamia © Semeion / LAA&SAA

The last frontier of our machine learning approach is to formalize an "ecological system" that addresses complex classification problems by analyzing them from multiple points of view and implementing different mathematics finds its realization with the algorithms grouped under the name of "MetaNets" (23).

In fact, MetaNets are unsupervised meta-classifiers: they classify the records of the problem on the basis of the attributions that have already been carried out by other classification algorithms usually called "component classifiers". They are neural networks that take in input all the output nodes of all the component classifiers and produce in output their own choice.

All the MetaNets have the same architecture but different equations to determine the output. Using different MetaNets on different component classifiers with the same dataset multiplies the point of view through which analyze the problem, letting each element say its opinion, as in a parliament. Because of their equations, MetaNets do not know the architecture of the component networks but base their response on the relative outputs and, therefore, also on the errors.

In this way, it is possible to use together extremely different models and let MetaNets, independently, give them more or less credibility. The weights, in fact, take into account the plausibility and the implausibility of each classification, considering excitatory and inhibitory credibility of each composing classifier. Furthermore, it is possible, by means of an evolutionary algorithm called GenD (21) to determine the subset of base classifiers that produce the best result.

One of the prerogatives of the MetaNets is not to consider, as one would expect, only the best of the component classifiers but also some of the weakest that, perhaps, implement different mathematics and make mistakes of different nature. This methodology has been applied with excellent results in several fields (22).

ACKNOWLEDGMENT

We are grateful to La Sapienza University of Rome who made new computational researches on ancient Near Eastern urbanisms and urbanizations possible, awarding the interdisciplinary project Analytical Archaeology for the Southern Mesopotamian Urbanism (AASMU) in 2014. We thank all the colleagues working at Analytical Archaeology and Artificial Adaptive Systems Laboratory (LAA&AAS) at La Sapienza Department of Classics for a very thorough and thoughtful review, which improved the analytical, experimental and applied archaeological research significantly.

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