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F. JAVIER MELERO · PEDRO CANO · JORGE REVELLES
EDITORS



FUSION OF CULTURES

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Fco. Javier Melero, Pedro Cano & Jorge Revelles (Editors)

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Contents

Invited Talks	1
• Out of Asia: A New Framework for Dating the Spread of Agriculture in Europe <i>Caitlin E. Buck</i>	3
• Gis Application to Archaeology: a critical view from a Spanish perspective <i>Javier Baena</i>	4
• Visualization of CH Models: Seeking for Just Visual Quality or Also Informative Content? <i>Roberto Scopigno</i>	5
Full Paper Extended Abstracts	7
➤ Recording, Interpretation and Evaluation of High Definition 3D Surface Data in Arts and Cultural Heritage, Archaeology and Anthropology	9
• 3D Reconstruction and Visualization of a Roman Theater <i>Chacón, R., Domínguez, V., Adán, A., Salamanca, S., Merchán, P.</i>	11
• An Improved Algorithm for Reconstructing Artifact Model from Multiple-Range Scans <i>Shui, W., Zhou, M., Wu, Z.</i>	15
• Underwater 3D shape reconstruction by fringe projection <i>Bianco, G., Bruno, F., Muzzupappa, M., Luchi, M.L.</i>	19
• Documenting and Monitoring Small Fractures on Michelangelo's David <i>Bathow, C., Breuckmann, B., Callieri, M., Corsini, M., Dellepiane, M., Dercks, U., Scopigno, R., Sigismondi, R.</i>	23
• Evaluation of Historical Coin 3D Models <i>Hödlmoser, M., Zambanini, S., Kampel, M., Schlapke, M.</i>	27
• Architectural Survey by Terrestrial Laserscanning – a new Method for efficient Plan Creation <i>Mechelke, K., Schnelle, M.</i>	31
• "FACE-R" 3D Database And Morphometrics For Facial Reconstruction <i>Kustár, Á., Forró, L., Kalina, I., Fazekas, F., Honti, Sz., Makra, Sz., Friess, M.</i>	35
• Evaluation of Acquisition and Post-Processing Pipeline for 3D Models of Ancient Statues <i>Hermon, S., Hadjicosti, M., Pilides, D., Ronzino, P., Pitzalis, D.</i>	39
• Cylinder Seals Revealed <i>Boon, P.J., de Vries-Melein, M.</i>	43
• 2D open-source editing techniques for 3D laser scans <i>Olsen, M.J., Ponto, K., Kimball, J., Seracini, M., Kuester, F.</i>	47



• Methodology and Technology for Rapid Three-Dimensional Scanning of In Situ Archaeological Materials in Remote Areas <i>Crane, E.R., Hassebrook, L.G., Begley, C.T., Lundly, W.F., Casey, C.J.</i>	51
• Arc3D and 3D Laser-Scanning. A comparison of two alternate technologies for 3D data acquisition <i>Hermon, S., Pilides, D., Amico, N., D'Andrea, A., Iannone, G., Chamberlain, M.</i>	55
➤ Databases	59
• MUD-Museernes UdgravningsData An Excavation database for the Danish Museums <i>Meinertz, C.</i>	61
• Spatial Data Infrastructures and Archaeological Excavation Data: SILEX, the SDI of the Neolithic Flint Mine of Casa Montero (Madrid, Spain) <i>Fraguas, A., Menchero, A., Uriarte, A., Vicent, J., Consuegra, S., Díaz-del-Río, P., Castañeda, N., Criado, C., Capdevila, E., Capote, M.</i>	63
• Spatial assessment of early human expansions using GIS and Database techniques: Examples from Southern Africa <i>Märker, M., Schmidt, P., Hochschild, V., Kanaeva, Z.</i>	67
• The hidden database <i>Lund, K.</i>	71
➤ Analytical GIS and Spatial Analysis	73
• Dynamic Models to Reconstruct Ancient Landscapes <i>Kormann, M., Lock, G.</i>	75
• In conspectu prope totius urbis: an application of different visual methods at the ager Tarraconensis landscape. <i>Fiz, I., Gorostidi, D., Prevosti, M., Lopez, J., Abela, J.</i>	79
• Integrative Distance Analysis: A Spatial Statistical Toolkit for Analyzing Complex Archaeological Datasets <i>Clark, T.N.</i>	83
• Spatial analysis of the Bronze Age sites of the region of Paphos in southwest Cyprus with the use of Geographical Information Systems <i>Agapiou, A., Iacovou, M., Sarris, A.</i>	87
• Observations of land use transformations during the Neolithic using exploratory spatial data analysis: contributions and limitations <i>Pillot, L., Saligny, L., Moreau, C.</i>	91
• Archaeological Evaluation of Ground Disturbance Activities for Planning and Development in Patras, Greece <i>Simoni, H.</i>	95
• Mashed up culture? interpretation, authenticity, technology and reinvention <i>Morel-EdnieBrown, F.A.</i>	99



➤ New Technologies in Archaeological Museums	103
• Enhancing the experience	
<i>Baeza, U., Barrera, S.</i>	<i>105</i>
• Project Malmö 1692: a Didactic Resource in the Video Games World	
<i>Dell'Unto, N., Wallergård, M., Eriksson, J.</i>	<i>109</i>
• Digital Reconstruction and Immersive Exploration of the Entrance of the Ripoll Monastery	
<i>Besora, I., Brunet, P., Chica, A., Moyés, J.</i>	<i>111</i>
• Piloting Time-Tours: Experiences from the Development and Implementation of a Computer Based Exhibition in West Sweden	
<i>Stenborg, P., Tornberg, J., Ling, J., Söderström, M., Sevara, C., Thuvander, L.</i>	<i>115</i>
➤ Human evolution, a long trip without end: The application of data recovery, data management and computer analysis in Paleolithic sites	119
• Computer applications in the study of Paleolithic sites. Methodological approach to innovative methods and their use on earlier settlements	
<i>Sañudo, P., Fernández, J., Vaquero, M.</i>	<i>121</i>
• ArqueoUAB: A systematic archaeographic approach for the analysis of Palaeolithic sites	
<i>Mora, R., Martínez-Moreno, J., Torre, de la, I.</i>	<i>125</i>
• Neumark Nord 2/2: Spatial Analysis of an Eemian open-air Site	
<i>Klinkenberg, M.V.</i>	<i>129</i>
• Assessing Changes in Palaeo-Coastal Morphology Using 3D Surface Modelling.	
<i>Dresch, P.Z.</i>	<i>133</i>
➤ Refining Remote Sensing for archaeological environments : image processing techniques compared	137
• Remote Sensing Image Processing for Archaeology: Effectiveness, Issues, Prospects. A State of the Art.	
<i>Traviglia, A.</i>	<i>139</i>
• Investigation of the Urban-Suburban Center of Ancient Nikopolis (Greece) through the Employment of Geophysical Prospection Techniques	
<i>Sarris, A., Teichmann, M., Seferou, P., Kokinou, E.</i>	<i>143</i>
• Modelling the spatial distribution of Paleontological sites in the Makuyuni region, Tanzania	
<i>Märker, M., Bachofer, F., Quénehervé, G., Hertler, C., Saanane, C., Giemsch, L., Thiemeyer, H.</i>	<i>147</i>
• The potential of hyperspectral and multispectral imagery to augment archaeological cropmark detection: a comparative study.	
<i>Aqduş, S.A., Hanson, W.S., Drummond, J.</i>	<i>151</i>
➤ New Technologies in Archaeology Higher Education	155
• GIS as Geophysical Data Processor: Learning from the Ground Up	
<i>Kvamme, K.L.</i>	<i>157</i>



- **Multilayered Virtual Reality System for the Comparative Study of Measuring and Representation Methods of an Archaeological Site**
Lucet, G., Casas, A., Hernández, I. 161
- **Cooperative Learning in Archaeological Projects for Higher Education**
Schramm, T., Acevedo Pardo, C., Farjas Abadía, M. 165
- **Teaching 3d-documentation in situ - ruins - example from Turku Finland**
Uotila, K. 169
- **Taking the Long View: Putting Sustainability at the Heart of Data Creation 171**
 - **EDNA II, Taking the Electronic Archive for Dutch Archaeology to the Next Level**
Wansleben, M. 173
 - **Methodological keys for the acquisition and long-term use of photographic collections representing elements of Heritage**
Valle, J.M., Rodríguez, Á. 175
 - **Raising Standards: Creating Guides to Good Practice for the Archaeology Data Service and Digital Antiquity**
Niven, K. 179
 - **Towards the Development of a Sustainable National Record: a View from Scotland.**
McKeague, P. 183
 - **Sustaining Database Semantics**
Kintigh, K.W. 187
- **From New Generations of Web Services to Archaeological Knowledge 191**
 - **WikiBridge: a Semantic Wiki for Archaeological Applications**
Chevalier, P., Leclercq, E., Millereux, A., Sapin, C., Savonnet, M. 193
 - **Towards the Web Process: Urbanizing the Archaeological Information System**
Djindjian, F. 197
 - **ScotlandsPlaces: Accessing geo-spatially enabled archaeological and historical datasets**
Beamer, A., Gillick, M. 199
 - **A Web3D tool for online exploration of underwater sites**
Bruno, F., Bruno, S., Angilica, A., Muzzupappa, M., Drap, P. 203
 - **TOPOI2.0 – a Virtual Research Environment for Academics**
Lieberwirth, U. 207
 - **Challenges in the Archaeological ePublishing in the Context of the New Generations of Web Services**
Ștefan, D., Sirbu, V., Barnea, Al., Ștefan, M.M. 211
 - **OF WORK “WITH” IN WORK “TOGETHER WITH”. The Impact of the GIS in the French Institution of the Archaeology**
Costa, L. 215



• Knowledge Bases and Query Tools for a Better Cumulativity in the Field of Archaeology: The Arkeotek Project <i>Roux, V., Aussenac-Gilles, N.</i>	219
• Cochasquí, Ecuador: A Multi-faceted Approach <i>Baird, B., Okabe-Jawdat, E., Burbano, I.</i>	223
➤ Agent-Based Social Simulation in Archaeology	227
• Simulating social, economic and political decisions in a Hunter-gatherer group. The case of “Prehistoric” Patagonia. <i>Barceló, J.A., Del Castillo, F., Mameli, L., Quesada, F.J.M.</i>	229
• Late Bronze Age Mediterranean Urbanism and Depth Map Software: The Cases of Ugarit (Syria) and Enkomi (Cyprus). <i>Kontolaimos, P.</i>	233
• Norms in H-F-G societies. Grounds for agent-based social simulation. <i>De la Cruz, D., Estévez, J., Noriega, P., Pérez, M., Piqué, R., Sabater-Mir, J., Vila, A., Villatoro, D.</i>	237
• Potentiality, Prediction, and Perception: Using Caloric Landscapes to Reconstruct Cognitive Patterns of Subsistence and Social Behavior <i>Whitley, T.G.</i>	241
• Large-scale agent-based simulation in archaeology: an approach using High-performance computing <i>Rubio, X., Cela, J.M.</i>	245
➤ Semantic Infrastructures in Archaeology	249
• A Very Short Introduction to the Semantic Web <i>Isaksen, L., Earl, G., Martinez, K.</i>	251
• Methodology for CIDOC CRM Based Data Integration with Spatial Data <i>Hiebel, G., Hanke, K., Hayek, I.</i>	255
• ArchaeoKM: Managing Archaeological data through Archaeological Knowledge <i>Karmacharya, A., Cruz, C., Boochs, F., Marzani, F.</i>	259
• Semantic Technologies for Archaeology Resources: Results from the STAR project <i>Binding, C., May, K., Souza, R., Tudhope, D., Vlachidis, A.</i>	263
• Recent Developments in the ArcheoInf Project – Towards an Ontology of Archaeology <i>Lang, M., Türk, H.</i>	267
• A Framework for Transforming Archaeological Databases to Ontological Datasets <i>Hong Y., Solanki, M.</i>	271
• Accessing, Visualizing and Annotating Geographical Information in Archeology <i>Eckart, T., Förtsch, R., Kruse, S., Büchler, M.</i>	275
• Atom Feeds and Incremental Semantic Annotation of Archaeological Collections <i>Kansa, E.C., Elliott, T., Heath, S., Gillies, S.</i>	279
• Interoperate with whom? Archaeology, Formality and the Semantic Web <i>Isaksen, L., Earl, G., Martinez, K., Gibbins, N., Keay, S.</i>	283



• Metadating: dates as complex information <i>Johnson, I.</i>	287
➤ 3D Scanning Case Studies	291
• Virtual 3D Reconstruction of the East Pediment of the Temple of Zeus at Olympia <i>Patay-Horváth, A., Végvári, P.</i>	293
• 3-Dimensional Documentation of the Hadrian's Temple in Ephesus/Turkey <i>Quatember, U., Kalasek, R., Breuckmann, B., Bathow, Ch.</i>	297
• 3D Documentation in Architectural History: A case study of the 16th c. Church of Stavros tou Missirikou in Nicosia, Cyprus <i>Solomidou-Ieronymidou, M., D'Andrea, A., Bakirtzis, N., Iannone, G.</i>	301
• Combination of Different Surveying Methods for Archaeological Documentation: the Case Study of the Bronze Age Wooden Chest from Mitterberg <i>Hanke, K., Kovács, K., Moser, M.</i>	305
• Terrestrial Laser Scanning for the Documentation of Archaeological Objects and Sites on Easter Island <i>Kersten, Th., Lindstaedt, M., Mechelke, K., Vogt, B.</i>	309
• Reconstruction of Exhibits of the Egyptian Collection at the Ethnological Museum in Hamburg, Germany <i>Acevedo, C., Sternberg, H., Schramm, T., Wilhelm, J.</i>	313
• Digital mediation from discrete model to archaeological model: the Janus Arch <i>Ippolito, A., Borgogni, F., Pizzo, A.</i>	317
• Digital mediation from discrete model to archaeological model: the Monumental Complex of Merida <i>Senatore, L.J., Inglese, C., Pizzo, A.</i>	321
• The Hill of Agios Georgios, Nicosia: 3D analysis of an on-going archaeological excavation <i>Pilides, D., Hermon, S., Amico, N., Chamberlain, M., D'Andrea, A., Iannone, G., Ronzino, P.</i>	325
➤ Image Processing and Rendering	329
• Vectorizing Hand-Drawn Vessel Profiles with Active Contours <i>Hörr C., Kienel, E., Brunnett, G.</i>	331
• Detection of Archaeological Features in Geophysical Images Based on Enhancement of Curvilinear Patterns <i>Panagiotakis, C., Kokinou, E., Sarris, A.</i>	335
• Text Detection in Ancient Manuscripts using Orientation and Frequency-Signatures of the Texture <i>Garz, A., Sablatnig, R.</i>	339
• A new CBIR technology to help reassembling moorish ornamental carvings <i>Molina, F.J., Mora-Merchan, J.M., Barbancho, J., Leon, C.</i>	343
• Improved gamma ton tracing technique using height field profile tracing <i>Zhang, J.Y.</i>	347



➤ Analysis and Interpretation of Ancient Art	351
• The Digital Sculpture Project: Casting light on ancient sculpture with new 3D technologies <i>Koller, D., Frischer, B.</i>	353
• Interactive Visualization of the House of the Vettii and the House of the Tragic Poet in Pompeii <i>Cole, K., Fredrick, D., Merced, J., Newberry, R.</i>	357
• Mapping the senses: Perceptual and social aspects of Late Antique liturgy in San Vitale, Ravenna <i>Paliou, E., Knight, D.J.</i>	361
• Modeling Hypotheses in Pompeian Archaeology: The House of the Faun <i>Dobbins, J. J., Gruber, E.</i>	365
• A Formal Language for the Description of Historic Architectural Elements <i>González-Pérez, C., Blanco-Rotea, R., Mato-Fresán, C., Camiruaga-Osés, I.</i>	369
➤ Quantitative Methods in Archaeology	373
• Web based statistical data processing <i>Heinz, G., Mees, A.W.</i>	375
• Gappy Data Reconstruction and Applications in Archaeology <i>Stephan, R., Carlberg, K.</i>	379
• Information entropy for archaeological research <i>Laužikas, R.</i>	383
• Sexual Size Dimorphism: A Test of Methods <i>Jiménez-Arenas, J.M., Esquivel, J.A.</i>	385
➤ Archaeological Architecture: a challenging fusion of scientific cultures	389
• Archaeological Architecture: a challenging fusion of scientific cultures <i>Bianchini, C., Mateos Cruz, P.</i>	391
• Virtual Roman Leicester (VRL): An interactive Computer Model of a Romano-British City <i>Cawthorne, D., Watson, G., Hugill, A.</i>	395
• Democratization of 3D applications in Archaeology. A case of study: The Roman Dam of Muel (Zaragoza). <i>Angás, J., Uribe, P., Magallón, M.A.</i>	399
• The Figure of the Architect-Archaeologist. The Bauforschung, the Realization of the Model and the Anastylis of Ancient Architecture <i>De Mattia, D.</i>	403
➤ 3D Modelling and Virtual Reconstructions	407
• The Tower of Hercules: A walk through time and space <i>Noya, R., Otero, A., Goy, A., Flores, J.</i>	409



- **Virtual Archaeology and Scientific Communication**
Gómez, J.L., Alonso, M.A. 413
- **Virtual Windows to the Past: Reconstructing the ‘Ceramics Workshop’ at Zominthos, Crete**
Papadopoulos, C., Sakellarakis, Y. 417
- **Illuminating Historical Architecture: The House of the Drinking Contest at Antioch**
Gruber, E., Dobbins, J. 421
- **The Church of the Charterhouse of Miraflores in Burgos: Virtual reconstruction of an artistic imaginary**
Bustillo, A., Martínez, L., Alaguero, M., Iglesias, L. S. 425
- **Issues in Least-Cost Analysis** 429
 - **Theory and Practice of Cost Functions**
Herzog, I. 431
 - **Cost-Distance Histograms and Their Use in the Study of Ancient Architecture**
Hacıgüzeller, P. 435
 - **On the road to nowhere? least-cost paths and the predictive modelling perspective**
Verhagen, P. 439
 - **Time geography, GIS and archaeology**
Mlekuž, D., Vermeulen, F. 443
 - **Least-Cost Kernel Density Estimation and Interpolation-Based Density Analysis Applied to Survey Data**
Herzog, I., Yépez, A. 447
- **Integrating and Comparing Technologies for Archaeological Applications** 451
 - **An Introduction to Computational Epigraphy – Methodology of using Computational Algorithms for deciphering Archeological Texts**
Rajendu, S. 453
 - **Finding the Language of Stereoscopic Technologies for Archaeological Sites and Artefacts**
Georgiou, R. 457
 - **Integrating 3D data acquisition techniques for comprehensive study of the ancient Hellenistic-Roman Theatre of Paphos, Cyprus**
Amico, N., Angelini, A., D'Andrea, A., Gabrielli, R., Iannone, G. 461
 - **Towards an integrated platform for urban planning rescue archaeology and public inclusion**
Hermon, S., Kaptan, I., Vassallo, V. 465
 - **Vector 3D Mapping and Visualization Techniques for Multi Story Structures in Montezuma Castle National Monument**
Trigoso, E., Holmlundl, J., Nicoli, J., Scott, R. 469
 - **Western Han Dynasty Mural Tombs: from the use of integrated technologies to the cybermap**
Di Giuseppantonio Di Franco, P., Galeazzi, F. 473



• Spatial data for large size archaeological projects – an example <i>Cramer, A., Heinz, G., Müller, H.</i>	477
• Methodologies and techniques for the reconstruction of ancient architectures <i>Vico, L., Vassallo, V.</i>	481
• Combining photogrammetric survey and 3D laser scanner of archaeological remains. First campaign in the Alberca Rota and Pozos Altos of the Cerro del Sol archaeological site at the Alhambra <i>García-Pulido, L.J., Torres, J.C., Sánchez, P., Pérez, M., Villafranca, M.M., Lamolda, F.</i>	485
• Towards the Collaborative Algorithmic Rendering Engine (CARE) Project <i>Mudge, M., Rusinkiewicz, S., Ashley, M., Schroer, C.</i>	489
➤ 3D Information Systems. Documenting the Past	493
• Discourse on the Use of a 3D Model as a Record of Excavation. <i>Avern, G.J.</i>	495
• A novel approach to 3D documentation and description of archaeological features <i>D'Andrea, A., Lorenzini, M., Milanese, M.</i>	499
• 12 years of archaeological data digital registry at the Santa Maria Cathedral of Vitoria-Gasteiz (1997-2009) <i>Koroso, I., Muñoz, O.</i>	503
• Model of sources: a proposal for the hierarchy, merging strategy and representation of the information sources in virtual models of historical buildings <i>Fernando de Fuetes, A., Valle, J.M., Rodriguez, A.</i>	507
• EIKowmGIS: A New Program for the Documentation of Archaeological Sites <i>Schuhmann, D., Le Tensorer, J.M.</i>	511
• Perspectives of a True 3D Visualisation and Measuring System in Archaeology <i>Stuber I., Szenthe G., Korom C., Varga Z., Szabó L., Eleki F., Eleki N.</i>	515
• Approaching 3D Digital Heritage Data from a Multitechnology, Lifecycle Perspective <i>Limp, W.F., Payne, A., Winters, S., Barnes, A., Cothren, J.</i>	519
• Integrated system for the study and management of the historical buildings <i>Parenti, R., Vecchi, A., Gilento, P.</i>	523
• 3DWS - 3D Web Service Project <i>Abate, D., Ciavarella, R., Frischer, B., Guarnieri, G., Furini, G., Migliori, S., S.Pierattini</i>	527
• VisArq. 1.0.: interactive archaeology and 3D data <i>Diarte, P., Sebastián, M., Guidazzoli, A., Delli Ponti, F., Diamanti, T.</i>	531
➤ GIS Application	535
• Geospatial Characterization of Archaeological Sites in La Serena Region (Badajoz) by Direct Methods (DGPS): Capturing and Analyzing Data. <i>Martínez, J.A., Uriarte, A., Mayoral, V., Pecharromán, J.L.</i>	537
• Getting Answers the Easy Way - Intrasis Explorer and Intrasis Analysis <i>Jansen, J.</i>	541



• GIS Applications in Developing Models of Rock Art Protection in the Valencian Community <i>Hernández, M.S., García, G., Barciela, V., Molina, F.J.</i>	543
• Excavation in Grumentum-South-Italy: GIS and Photogrammetry; application of 2D and 3D <i>Thaler, H.</i>	547
• The management of archaeological information at the site of Vascos (Navalmoralejo, Toledo); Approach, data integration and representation in an intra- and intersite model <i>Sánchez, I., Varela, A., Bru, M.A., Iniesto, M.J., Izquierdo, R., de Juan, J., Carballo, P.</i>	551
➤ Open Source in Archaeology	555
• Free and Open Source Software in archaeological research processes: an application to the study of African Red Slip Ware in Northern Italy <i>Costa, S.</i>	557
• Aramus Excavations and Field School. Experiences in Using, Developing, Teaching and Sharing Free/Libre and Open Source Software <i>Bezzi, A., Bezzi, L., Gietl, R., Heinsch, S., Kuntner, W., Naponiello, G.</i>	561
• Open Source Software in Archaeology: beyond passive users <i>Costa, S., Bianconi, L., Pesce, G.L.A.</i>	565
• An Experiment of Integrated Technologies in Digital Archaeology: Creation of New Pipelines to Increase the Perception of Archaeological Data <i>Dell'Unto, N., Wallergård, M., Lindgren, S., Dellepiane, M., Eriksson, J., Petersson, B., Paardekooper, R.P.</i>	569
➤ 3D Databases	571
• Reconstruction 3D Model of Chinese Ancient Buildings Basing on Components Database <i>Ru, W., Mingquan, Z., Yuhua, X., Xuesong, W.</i>	573
• A procedural approach to the modelling of urban historical contexts <i>Pescarin, S., Pietroni, E., Ferdani, D.</i>	577
• WILD-GOAT. Towards a virtual “Corpus Vasorum” of wild-goat style vessels of museum collections <i>Damnjanovic, U., Hermon, S., Coulie, A.</i>	579
• 3D Shape Matching and Retrieval for Archaeological Analysis <i>Jiménez, D., Ruíz, S.</i>	583
Short Paper Abstracts	587
Poster Abstracts	699
Authors Index	733



Remote Sensing Image Processing for Archaeology: Effectiveness, Issues, Prospects. A State of the Art.

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1. Introduction

Since the introduction of multispectral and hyperspectral remotely sensed data in archaeological investigation, the significance and the implications of the image processing activity have been clear to archaeologists employing remote sensing in their research activity.

Image processing, by improving the quality or the contrast of the image or transforming it in a new set of images where relevant information can be more easily detected, often produces results far more useful than the ones that visual analysis of the original, raw data guarantee, providing an enhanced visualization of the studied landscapes and promoting the recognition of not yet identified ephemeral archaeological marks.

In the past 20 years a consistent part of the projects involving the use of multispectral and hyperspectral data have included image processing as part of their routines activities in preparatory steps before under-taking visual analysis and interpretation.

The extensive use of a vast range of techniques, however, does not translate yet into a coherent methodological strategy for the application of this important set of practices to particular archaeological situations and environments and their application is often left more to attempts than being planned and targeted. Consequently, despite the high potential offered by the enhancement and transformation of digital images, the adopted approach subsides often to a series of well-established, routine techniques that often do not consider fully the characteristics of a territory or the peculiarities of each portion of it.

The present paper will cover the use of both the most commonly adopted image processing methods

and the ones that, although not frequent, have produced relevant outcomes, and it will try to analyse the strength of the different techniques, the bias and issues encountered in their implementation, the ambits and the physical environments in which they can be better used and exploited.

2. Defining a work strategy

It is unquestionable -and long accepted- that it is impossible to define a priori what type of image processing will provide the best results for archaeological research. It is also well recognized and quite obvious that the results that have been reached in a specific landscape context are peculiar to that ambit only and to such a determinate spatio-temporal situation and that different outcomes could be achieved applying similar processes to other areas (even similar ones).

Nevertheless this does not prevent researchers from planning accurately a strategy for implementing the best and most suitable image processing techniques that apply to specific factors like, for example but not limited to, type of environment (crop land, bush land, bare soil, sandy soil etc), morphologic characteristics of the landscape, specific goals of the research (e.g. identification of quarries by searching for the concentration of a rock type) etc.

Thus, for example, in a territory that is mainly devoted to agriculture a large application of Vegetation Indices (VI) should be necessarily planned, but these should be selected on the basis of the defining characteristics of the fields, which are often not homogeneous: next to fields where the crops are dense and thick, where DVI or NDVI can work effectively, there could be fields less productive with a different, looser plant density, where the reflectance of the soil introduces a significant bias on the overall pixel reflectance. Consequently, in those situations it

be-comes necessary to apply Vegetation Indices that take this factor into consideration (e.g. SAVI or MSAVI2).

Like the density of crops and vegetation, it is necessary to tackle beforehand many other aspects of the target landscapes, like the morphological, ecological, seasonal ones or even particular situations related, for example, to the presence of shades on imagery: all these conditions in fact can alter significantly the spectral content of the pixels.

Consequently the recognition of a targeted set of procedures should become the gateway of a remote sensing analysis rather than applying the same image processing as standard practise on vast territories with no real connection with the investigated landscape.

It is sometime hard to judge, based on the current literature devoted to the topic, the level of improvement of the features visibility given by image processing. This is mainly related to the fact that we mostly tend to speak about our successful research, forgetting that even information on the failure of a technique or of an approach can be really valuable in the advance of the archaeological application of the discipline. Thus, in perusing the by now vast bibliography on the subject, one gains often the impression that all the applied image processing techniques multiply exponentially the capacity of features identification, but this is not always reflected in the exponential growth of number of identified and recorded features.

That the application of image processing techniques is always successful is not possible or credible. There is doubtless a bias introduced by the fact that most of the articles on the subject (frequently restrained to a short number of pages allowed by Proceedings) deal more with technical aspects illustrated by few examples than with overall statistics on the number of detected features, so the real impact of image processing is simply not described. Nonetheless, a lack of quantification of the obtained results makes it hard to judge in the right perspective the adequacy of an application, its effectiveness and the level of improvement it can guarantee if compared to the raw data or other similar procedures.

3. Image processing: a brief resume of common and less common techniques

Among the most common procedures adopted in archaeological remote sensing Vegetation Indices, Classifications, Ratios, Principal Component Analysis (PCA) and Tasseled cap Transformation (TCT) are to be included. These methods of processing have been adopted since the 80's (or in few sporadic cases even before) and exerted to different types of remotely sensed data, including

Landsat, ARIES, ASTER and more recently Quickbird and Ikonos, among the most common.

3.1. Assessing vegetation quality: Vegetation Indices

Vegetation Indices find wide application in the archaeological research, since studies about the quality of the vegetation, monitoring deviations in its vigour, can enable the detection of subterranean archaeological deposits that promote or, on the contrary, reduce the development of the vegetation.

The largest part of the archaeological researches involving the use of VIs has entailed primarily the use of the Normalized Vegetation Index (NDVI) (CHALLIS, HOWARD 2006, ESTRADA-BELLI, KOCH 2007, LASAPONARA, MASINI 2006), especially when using hyperspectral data (EMMOLO et al. 2004, MEROLA et al. 2005).

Such use, however, appears in certain cases to be more dictated by conventions than from the conviction that it represents the most appropriate process in the given circumstances, based, for example, on the particular environmental and morphological characteristics of the target site. In spite of its common adoption over every type of environmental conditions, other VIs (namely RVI, DVI, MSAVI2, to cite some) have demonstrated better results for archaeological purposes (MEROLA et al. 2006, TRAVIGLIA 2005). In those cases the vegetation coverage type, the density of the canopy or other more complex factors have been preliminarily taken in consideration when selecting them as the most appropriate processes to evaluate the biomass of a certain area. Such factors in fact can strongly affect the results of the process itself.

This process selection activity tailored to the landscape cannot always ensure by default successful results (TRAVIGLIA 2005) but can support avoiding inevitably incorrect outcomes delivered by mistaken assumptions.

3.2. Classifications

Another largely applied image processing technique is classification, in the forms of supervised and unsupervised. Since the beginning of the image processing activity related to archaeology, researchers have tried to automatically extract meaningful information from the imagery by correlating spectral content with distinctive archaeological features through the clustering of sets of pixel with similar spectral characteristics (one of the first examples dates back to the 70's. HAMLIN 1977).

Classification devoted to recognise a specific spectral response characterising archaeological features, however, seems to fail to fulfill completely the expectations and to deliver invalid and

questionable results in archaeological applications, (BECK 2007, TRAVIGLIA 2006), largely less rewarding than the successful results for other classes of materials in different disciplines (geology, for example). Where classification can instead support effectively the archaeological research is in locating environmental settings with similar characteristics, e.g. types of soil or other environmental variables, whose presence can be correlated to archaeological sites (CUSTER et al. 1986).

3.3. Principal Component Analysis

Principal Component Analysis is another highly implemented image processing techniques (ALTAWHEEL 2005, ESTRADA-BELLI et al. 2007, GIARDINO, HALEY 2006, to mention a few). This is due to the fact that the application of the PCA to archaeological study can be of great utility since it may provide in many cases supplementary information compared to the original bands and allows a better discrimination of different surfaces that become more distinguishable in visual analysis.

Despite the recognizable advantages obtainable applying the PCA, it is rarely stressed that many details that are visible analysing singularly the original bands cannot always be recognized in the PCs -single components or composites- because they are covered by the overlaying information from other bands. Consequently in specific cases, e.g. when dealing with hyperspectral data, improved outcomes in terms of detectable features can be achieved through the computation of spectral subsets, referred as SPCs (Selective Principal Components): these are obtained through a PCA computed for groups of bands, detected by a single spectrometer of the sensor or belonging the same spectral region (MEROLA 2005, TRAVIGLIA 2005).

3.4. Tasselled cap Transformation

Quite considerable potential has been shown by the recourse to the Tasselled Cap Transformation. The TCT is a linear transformation of bands that defines a new coordinate system in terms of which the soil line and the spectral region of vegetation are more clearly represented. After performing TCT, the majority of information is contained in few components or "features", directly related to physical scene characteristics. Brightness axis is associated with changes in the soil background reflectance. Another "feature", the Greenness, is closely orthogonal to brightness and is a contrast between NIR and visible bands: this means that it is correlated with variations in the vigour of green vegetation and related to the amount present in the scene. The Wetness axis provides information about the level of humidity of the soil.

The implications of the use of the Tasselled Cap in archaeological research appear clear: contributing in identify humid areas, ancient riverbeds, artificial and natural canalisations etc. this transformation concurs to reproduce the hydro-morphologic conditions of the ancient landscape (BRIVIO, et al. 2000, RICHASON, HRITZ 2007, WILLIAMSON et al. 2002).

3.5. Even more processes...

Filters and Stretches are common methods to highlight and enhance tonal variations between neighbouring pixels and have found vast application over a variety of spectral data. Edge enhancement filters have been lately quite efficiently used (DE LAET 2007, LEUCCI et al. 2002) in several projects.

Among others of the first types of processing adopted (MARCOLONGO, MASCELLARI 1977, MORAIN 1981) band ratios are still used a lot (CARLA 1998, SEVER 1998, PAVLIDIS et al 2002) although their strength is somehow outmoded by more refine procedures.

The list of other image processing techniques includes more methods (IHS transform, Brovery and Fourier transformations, data fusion etc), bringing the total amount to several tens of applied techniques. This fact is sufficient to understand that due to the high number of possible applicable methods some sort of pre-selection must be applied in advance. The choice can be affected by several factors embedded with the research program and has to be driven by landscape characteristics and the goals of the project.

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