STANDARD TOOL FOR 3D DOCUMENTATION OF EXCAVATIONS

Laser Scanning and Archaeology

Terrestrial 3D laser scanning will become the future standard tool for high-resolution 3D documentation of archaeological excavations, but its capabilities are still underestimated by professional archaeologists and providers of scanners or scanning services. The new tool forces archaeologists to consider extension of archaeological stratigraphy theory. The author shows examples of the beneficial use of laser scanning and proposes an extended theory.

Excavation forms the main data retrieval process in field archaeÂology but is also destructive, based as is it upon salvaging in the reverse order of deposition or creation. Reconstruction of the site as it was is very important and requires 3D documentation. This has been mainly done using total-stations, GPS devices or photogrammetric methods. These are laborious; terrestrial 3D laser scanning (TLS) combined with digital imagery is more effective and provides the possibility of 3D-reconstruction.

Laser Scanner
TLS has been successfully applied in the documentation of historic buildings and archaeological features all over the world. Our own projects have proved the suitability of TLS for swiftly collecting reliable, high-resolution data. The scanners tested so far show high reliability and efficiency in topographic single-surface recording for everyday archaeological work and would save up to a hundred man-hours over a typical one-month excavation. The data gleaned might be used for archaeological documentation only, but also for creating virtual-reality models, restoration planning or virtual reconstruction and other products that could be fascinating for the general public. The Riegl LMS Z420i and Z390 proved perfect multipurpose scanners for most archaeological projects, reliable even under harsh conditions such as frequent changes in temperature, dust, mud, rain and storm. Transporting a Z420i to the top of the great pyramid of Khufu you might wish for a lighter scanner, but when the equipment faultlessly works for a full ten hours of data collection, even during a sand-storm, you appreciate its robustness. Not only the monument itself is of interest but also the surrounding topography, and capturing all of this requires a wide-range and long-distance scanner that is both compact and robust.

Harris Matrix
Any archaeological site shows stratification formed by one of two units: firstly deposits, and secondly surfaces of specifically human origin such as pits, ditches or wall-surfaces. Stratigraphic excavation aims at the unearthing these units of stratification and determining their sequential order of creation and deposition. Stratigraphic relations are based on topological observations of the units during excavation, and can also be derived from 3D-recordings. These also enable verification of the stratigraphic sequence, or Harris Matrix. This, the fundamental diagrammatic representation of time for an archaeological site, displays all uniquely numbered units of stratification in sequential diagram representing their succession over time and provides the relative calendar of a site that is the testing pattern for further analysis. However, complete 3D-recording of stratification is not yet the standard in archaeology, partly due to theoretical shortcomings. A deposit can only be documented in 3D by mapping its "hull", but because deposits are buried, access to the entire hull is limited. Using the stratigraphic excavation process only the top surface of a deposit is unearthed and can be mapped. So far, mapping of the bottom surface has been regarded as redundant or not considered at all. We suggest extending the stratigraphic theory of Harris as follows: unless the top and bottom surfaces of a deposit are defined and recorded the stratigraphic sequence cannot be fully compiled, nor can the true volume of the associated deposit be captured .

3D Single-surface
Harris identified the "interface", a surface in its own right, as an essential stratigraphic unit. Such specific surfaces have no related deposits and he therefore considerÂed them to be "interfacial", that is between two surfaces; in the absence of isolation and unique numbering of interface units a true stratigraphic sequence could not be compiled. In our proposal the interface is unique in that it combines top and bottom surfaces into a single stratigraphic unit, whereas the surfaces of deposits are separated into two units by the deposit itself. Thus all units can be represented in 3D-space by surfaces which have to be defined and recorded during excavation: stratigraphic recording should thereÂfore be based upon 3D-single-surface mapping. This forms the theoretical background for TLS application in archaeology.

GIS
Based on the above considerations we developed a digital 3D-documentation process that forms the basis for introducing TLS into archaeology. The standardised process is divided into subsequent steps to be repeated for each unit of stratification. Each unit is given a unique number and documented by its boundary polygon and its topography, enabling the capturing of surfaces in their entirety. The point-clouds of the units and their texture, derived from digital photographs, provide the primary data for mapping and analysis in a GIS. Import, terrain modelling and contouring of the surfaces are automated by the ArcView extension ArcDig. Further modules calculate volumes or generate sections along arbitrary lines for the purpose of better understanding complex stratification. All additional attributable data, such as descriptions of surfaces and deposits, and finds-database, are integrated into the GIS. The reconstruction of the site through time is achieved through relating in stratigraphic order all finds data to the stratigraphic sequence and display of topographical data. GIS permits the mapping of single surfaces or creation of composite maps based on single-surface data. The secondary data dealing with aspects such as location, material and date is stored in a spatial database where it can be combined with visualisations, analysed and counterchecked. One problem is automated extraction of the boundary polygon, marked by reflecting targets for clipping top and bottom surfaces in subsequent scans. This polygon can also be used for clipping orthophotos and export of triangulated mesh into GIS.

Future
We are working on a new Harris Matrix program incorporating a direct interface to the GIS-software. The matrix will be used for the creation of composite maps and 3D-reconstructions of phases and periods. Until the introduction of the Harris Matrix and GIS technology such reconstruction was often not possible.

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