VIRTUAL RECONSTRUCTION OF THE VINČA-BELO BRDO SITE

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The complex task of bridging the gap between photogrammetry or TLS/ALS-captured data and its visualization has many aspects, each of them heavily affecting the final output. This becomes even more apparent when dealing with information acquired on large scale surveys – which in practice can be described as individual projects covering areas of more than few tens of hectares; whilst data can always be displayed in a static form – a 2D rendering in a specialized GIS/supplementary software, or an output formed in quasi-3D format (2.5D), this does not quite satisfy the needs of the reconstruction and visualization of environments/landscapes of the past.

In this kind of situations, a decision can be made to turn to 3D modelling software that is able to cope with our input data, whatever the origin of the data. For the reconstruction of the Neolithic site of Vinča, Serbia, our sources included a combination of photogrammetry record and the open-access spatial data, such as SRTM (1 arcsecond) terrain models, freely available from the USGS repository. The core photogrammetric model consists of little less than 1000 photos of the area of 1 km^2. The additional area provided by SRTM extended a few kilometres down the Danube and was used as a means of closing the scene; the nearby Ritopek hill and the Vinča hill together form an open valley that marks the boundaries of the reconstruction.

It is important to note that the laser/photogrammetry scanned surfaces and reconstructed areas for the use in virtualization are not the only possible sources. A number of data sources can be and have been used for past landscape visualization – e.g. the tools like geophysical prospection with ERT (electric resistivity tomography), auger drilling, reflection seismology (Fitch et al. 2007), GPR (Watters 2009)– as long as they allow to single out properties of a horizon that is of interest to the researcher. Depending on the demands of a project, these

can be joined in formats and ingested by modelling software. Whilst we had ERT and GPR results available for a relatively small portion of the terrain, our choice to exclusively rely on geomagnetic survey conducted in Vinča, SRTM and photogrammetry record was guided by the desire to represent the wide area of the settlement in an immersive way – to tackle the visualization of the community, rather than small sections provided by other geophysical methods. However, they came in very handy when evaluating the sources we used. How?

Aerial imagery was acquired for the highly-urbanized area that contests the archaeological site on a daily basis: this takes a toll on our intended use of the dataset as a stage in the process of reconstruction. In essence, we needed to get data on the bare ground (or as close as possible to it) which were to be used for generating a continuous surface. Most of the professional software that deals with surface reconstruction from images has an option for exporting data, point clouds, in a format that can be read by standard GIS software (such as GlobalMapper, ArcView, Qgis). For example, *.las* output can be readily filtered in a number of GIS solutions. In this way, it is possible to calculate and extract only the lowermost points in a processed area – points that, based on the parameters that the researcher would find acceptable, could represent bare ground surface. It is worth mentioning that this is, by far, much more straightforward in ALS datasets, when utilizing benefits of the last echo in a signal. For a terrain documented with photogrammetry, an option is available in Agisoft Photoscan to internally calculate the similar output, although it follows the same rules – if a point to be reconstructed is not seen on 3+ photos, it is not possible to get an optimal (if any) result. Thus, when working with a terrain covered in dense vegetation, such as is the case in late spring/summer, it is better to postpone the survey until winter or early spring. This is certainly an aspect that needs to be kept in mind when designing the project.

In the case of Vinča, it was possible to reconstruct the base surface in a portion large enough to commence with the next stage: adaptation of the mesh and the combination with SRTM dataset. The adaptation was necessary due to the fact that the data obtained from photogrammetry software come out as a massive polygon count. Depending on the size of the project, the poly number can reach several millions, and a number of them often represent very even (flat) surfaces that could equally well be represented with a smaller number of triangles/quadrangles. In addition to redundancy, one must think of the poly count budget for the reconstruction project and plan ahead: some parts of the terrain will require more data to work with to be finely modelled and, eventually, the project will reach its poly count budget when hardware limitations will become apparent and will affect the workflow. Whilst there are a number of techniques accessible by different levels of experience that address this, it is generally a good practice to think about optimization whenever possible.

For the Vinča site surface it was necessary to reduce the poly count (of 5,000,000) and remove the traces of modern house positions and any other irregularities that disrupt the flow of the polygons. For this we turned to the MeshLab (Cignoni et al. 2008) designed by Visual Computing Lab – ISTI – CNR. This is a freely available solution that deals with point clouds and meshes (surfaces) for numerous uses – TLS scan registration, meshing, referencing, editing, texturizing, to number a few. Using re-meshing options and various filtering algorithms and decimation algorithms, we were able to join in pre-registered meshes of Vinča aerial survey and SRTM model into a seamless whole, which had an even polygon flow and density adjusted to the specific needs, with a higher number of polys where we needed to tweak the geometry of terrain to a greater degree – notably the position of the Neolithic site.

What needs to be emphasised is that, this is not the only way of solving the transfer of spatial data into a 3D modelling and interaction environment. The terrain itself can be generated using a greyscale image in pair with distortion modifier on ordinary plane surface; the image, in this case, would be a DTM that has elevations codified on a 255 B/W scale, from lowest to highest, where software uses the provided information to generate nuances in the terrain, in a pixel-for-poly manner. A similar technique was reported to be highly suitable when using a LiDAR DTM in Crytek game engine (Challis & Kincey 2013) to represent archaeological content in the form of SEG (Serious Educational Game (Annetta et al. 2013)) where a full-blown phenomenological study of landscape could be mounted, in pair with the interaction of the researcher with archaeological remains present at the site – all within the virtual environment.

Our next task was to delineate position of the site proper – the central area for which we know most the activities that occurred there. For this we used results of the geomagnetic survey to form a boundary area towards inland where the number of structures was expected to decline in the reconstruction. This was also done using Meshlab, by applying the image alignment filter (Corsini et al. 2009) and the texture projection via parametrisation and projection (Calieri et al. 2002), where the image aligned and projected was a true-ortho imagery of the site containing digitized positions of features identified by geophysics. The issue of correlation between the virtual environment and the information collected through fieldwork is an interesting one; whilst our approach is a very simplified one, an alternative marriage between GIS data and VR via customized tool was proposed previously (Callory et al. 2005) that would give rise to a completely novel approach in methodology of everyday field duties.

Once the positions of features are projected, and the portion of the site removed by geological processes and excavations during the 20th century acknowledged, further modelling required that the missing parts of the terrain be artificially added. This is a point when a choice of 3D modelling and rendering software needed to be made. The current market offers a number of solutions that can be of use; however, from a perspective of an archaeologist, one should first carefully determine the aims of the project or the company practice. The relevant commercial software usually does not represent a great pressure on the budget, but it may be better suited for professional visual artists with specific requirements. Our choice was to use Blender, a freely available solution that already has a large number of users well-familiarized with photogrammetry procedures. Within Blender, several engines for rendering are available, with Blender Cycles as the most intensively developed one. Cycles goes out of its way to present realistic lighting conditions of every scene fed into it; in combination with a comprehensive nodal system of shader, texture and bump effect application to an object/frame, we considered it to be the best available solution for our reconstruction.

Internal sculpting tools were used to edit the terrain, delineate water flow of the Bolečica river, cut paths and create an even surface on slopes where the houses and other structures were to be placed. The missing parts of the site were modelled from the flat surfaces and were given the form of a terrain along the course of the Danube in prehistory, at the time of the final occupation phases of the site. Across the river, which was represented by a plane with a nodal system combining bumps and wave texture with the appropriate colour and reflection, a segment of terrain was added and modelled without constraints.

In general, the only constraints were imposed by the scale and geometry of the terrain that was reconstructed with UAV documentation, and this one, too, was processed in a way to visually remove sedimentation from the periods following the final Neolithic phase.

Once we were satisfied with the result in this stage, we started the application of textures on the landscape. The approach used relied on an unwrapped UV surface that could not be additionally changed (every subsequent change would affect the UV and produce holes in the texture flow, which would be remedied by repeated UV unwrapping, but that would, in turn, cause distortion in image mapping). In the previous step, we modelled the terrain; now, following the curves and intended use of the surfaces (i.e. paths, areas immediately close to the houses, slopes, areas under vegetation), the images were applied. One cannot stress enough the importance of the choice of images that will serve to achieve a realistic depiction of the surface. Whereas it may seem easy to just download any kind of texture from one of the numerous web-based sources, some thought should be given to the local geology and pedology. It hardly makes sense to use craggy limestone to represent fine alluvial sedimentation; also, not all images that correspond to the geological background will give a satisfactory output. There is nothing preventing one from visiting the site and acquiring images of the ground, grassy areas and other details, and building a custom set of textures.

Attention must also be paid to texturizing large landscapes, since several problems arise when working on this task. First and foremost, tiling of the textures; whilst a practitioner will almost certainly use seamless textures (i.e. images that were processed in image editing software in such a way that they are seamlessly repetitive along principal axis), this still does not remove repetition of the pattern of the image. In other words, depending on the scale of the applied texture, tiles will become visible on the surface, especially when looking at it from above or from a distance. Increasing the scale value will solve the problem with "distant" surfaces, but the textures close to the camera will suffer blurring and will be non-engaging for the viewer. Our solution to this problem was to use a composite texture, built of images used to represent different land classes (grass, second grass type, dirt, mud) that could be stored in a single 2048x2048 pixel sized image as RGBA channels, and later separated and multiplied by representative colour (brown for ground, green for grass, etc.). This image was mapped using splatter texture (another example of mapping using greyscale imagery). With the internal tools in Blender, another 2048x2048 image was produced that was coded in nuances from white to black; a specific value on the scale corresponded to the assigned range of particular texture stored in a channel. In this way, we controlled the distribution of imagery across the terrain. The advantage of this is that textures overlie one another without losing the depicting character of a particular land class, but reducing the tiling immensely. Also, in addition to this, the increased scale value textures could be draped on to this (and multiplied) thus further reducing the repetition.

The next step was the choice of lighting. For this, too, multiple options exist – some of the useful methods are building a skybox/skydome and lighting it with a combination of sun lamps or, and this was our choice, to illuminate the scenery with a HDR panoramic sky image, which simulates effectively behaviour of the daylight – a single small source of light in combination with the dissipation and reflection of light from the sky/terrain.

Having defined the land classes, site position and boundary in virtual space, it was possible to start "populating" it with content. In order to achieve a realistic look, and engage the viewer, we relied on the palaeovegetation distribution proposed by the archaeobotanist.

However, numerous classes of plants that could be expected in the area of the Late Neo-lithic settlement in Vinča would be indistinguishable to an untrained eye, and would affect the visualization to a very small degree, but the attempt at generating a separate model for each species would have not been feasible. Instead, we represented classes of vegeta-tion rather than individual species (e.g. reeds and elm- resembling models for the Bolečica riverside vegetation and for the area along the Danube, generic birch and oak models for hilltops and slopes, bushes for the forest undergrowth, and so on). Regarding classes of medium to large vegetation (bushes, trees, reeds etc.), free models for Blender Cycles are available for download, created by various digital artists whose only requirement is to be cited. Grass is presented using particle systems, which significantly add to hardware re-quirements but are irreplaceable when fine geometry needs to be shown.

Generic features that were to represent houses and other structures were modelled at the very end. This process relied mostly on the personal experience with the excavated Neo-lithic structures and their "projected" look. Also highly informative were relevant ethno-graphic sources and the repository of comparative remains of wattle-and-daub structures (particulary those available in 3D format). Our goal was to create the feeling of an ancient settlement, whilst avoid dealing with overly intricate details of house design for which there is no supporting material evidence. A pair of features (F01/06 and F03/03), of which one comprises a house floor and remarkably well preserved walls and an oven and, adjacent to this one, another feature of similar level of preservation, but different in size and internal structure, were reconstructed in Blender. This was done on the basis of photogrammetric models of the two features; we found this approach to be most productive as it made the entire process much more deliberate and intuitive. We also relied on a tentative recon-struction previously designed for feature F01/06 (Đuričić & Đorđević 2008). Several other features (e.g. benches, ovens, strewn animal skin, rubbish pits) were added in order to generate a more compelling impression of the settlement environment.

As a concluding remark, we would emphasise that the described process represents only one possible route; practitioners with different experience opt for different approaches, either concerning software or the concept. We would like to stress that, by and large, only a very constrained way of conducting similar projects will ignore the creative aspect of the process. Artistic drive can become overwhelming in the course of the work. This in no way should be seen as a flaw but, instead, as a welcome addition to the discussion of ancient communities. In virtual reconstruction, we project ourselves into past and bring about new readings of the material that we know so well and see so often.

Data acquisition – UAV survey

For collection of images, SenseFly eBee UAV was utilized. The total time needed to cover the area was less than 2 hours, and the photos were taken at midday.

- Camera type: CANON IXIUS 127 HS (geocoded photos - RGB)
- Covered surface: 1 km2
- Flight speed: 11-21 m/s
- Flight height: 100m (5cm/pix)

- Format: jpeg
- Total number of photos: 984
- Overlap: 70% / 70%
- Number of collected GCP: 7 (mean err: 1.5 cm) (Trimble R4)
- Figure 13 *Flight plan and trajectory of the drone used to acquire digital elevation model of Vinča Belo Brdo.*

(Contractor was tasked with full range of processing – production of orthophoto and DSM.)
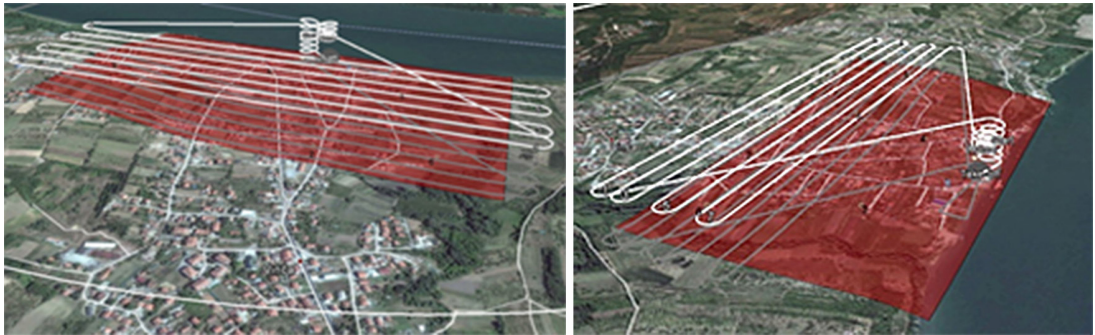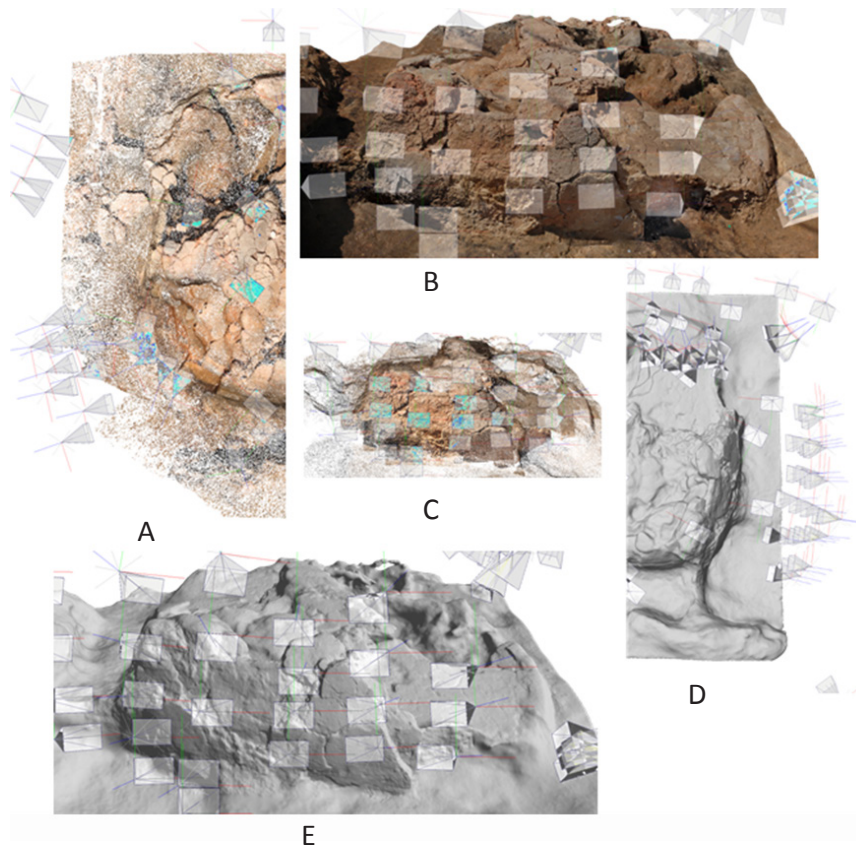

Figure 13. Flight plan and trajectory of the drone used to acquire digital elevation model of Vinča Belo Brdo.

Figures 14 (A-E). Elements of photogrammetry used in producing virtual reconstruction of the kiln at the site of Vinča.

Figure 15. Virtual reconstruction of the latest horizons of Neolithic Vinča.