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ELEMENTS FOR THE CONSTRUCTION OF 3D-MODELS FOR ARCHAEOASTRONOMICAL ANALYSIS

G. Zotti, W. Neubauer

During the ASTROSIM project, supported by the Austrian Science Fund (FWF) under grant number P21208-G19, we aimed for a thorough investigation of the archaeoastronomical potential of the Neolithic circular ditch systems (Kreisgrabenanlagen; KGA) which had earlier been prospected in Lower Austria (Melichar and Neubauer, 2010). No trace of these early monumental buildings is visible today on the surface, except for soil and crop marks. Therefore we aimed for the use of virtual models which were to be constructed in a digital terrain model (Zotti *et al.*, 2009).

All archaeological data and a digital elevation model (DEM) were collected in the Geographical Information System ArcGIS 9.3. A part of the DEM was then exported, together with aligned textures showing the magnetograms, a modern map, and feature outlines for the main ring and palisade ditches into Google (now Trimble) SketchUp. In this simple-to-use 3D modelling program, the ditches were cut into the soil and palisades were erected. The model building at that stage did not aim at photorealism with lots of graphical accessories and gadgets, but at a geometrically plausible model. A very helpful property of SketchUp models is the geolocation capability, so that solar illumination and shadow effects can be simulated inside SketchUp, at least for modern dates.

The imported terrain section cannot be so large as to include distant mountains, so a diagram was developed which includes diurnal paths of the stars derived from the Bright Star Catalog (Hoffleit, 1991) for the KGA epoch (including effects of proper motion and precession) and characteristic diurnal paths of the sun at solstices and the cross-quarter days (exactly between solstices and equinoxes), the Moon at its standstill positions (lunistices) and a plot showing the measured horizon line, against which a panorama photo taken on each site had carefully been aligned. All celestial lines show the effects of atmospheric refraction, and the star lines indicate the brightness dependent angles below which the respective star is generally invisible due to atmospheric extinction, to allow an estimate of whether a star can be observed when it is crossing the elevated landscape horizon. Optimally, such a background panorama should be included in a translation invariant background node like a sky box. However SketchUp does not have such an element, and so this diagram was mapped onto a spherical ring which encloses the rest of the model and which is created by a loader plugin developed for that purpose. Care must be taken in this diagram and in the model to account for the difference between geographical/astronomical north and grid north of the archaeological data caused by the meridian convergence, which SketchUp labels as "North Angle". The ring has to be *attached* to the current view camera, so that it is always centred on the viewer to avoid visual errors caused by parallax effects. Standing or walking through the virtual model in SketchUp now always shows the distant mountain backdrop with astronomical information ready for evaluation (Figure 1). The same panorama photograph can be used as landscape background in a desktop planetarium program.

Several available desktop planetarium programs provide nice simulations of the night sky. We selected Stellarium for our purposes: it is free and open-source, so its accuracy can be verified by examining the source code, and with exchangeable constellation patterns and landscape backgrounds it seems very useful for applications in the fields of archaeo- and ethnoastronomy. For added realism, atmospheric refraction and extinction have been contributed (Zotti and Neubauer, 2012a). The biggest innovation, however, was the development of a new plugin, Scenery3D, which allows the combination of a 3D model foreground with an appealing and believable night sky simulation. The simulation also includes shadows cast by the Sun, the Moon and the planet Venus. The geometric accuracy of the simulation has been thoroughly tested with a model of an astronomically oriented modern building (Zotti and Neubauer, 2012b).

The KGA models can be exported into OBJ format and loaded in the Stellarium plugin. Here, the user can move around in the scenery and select standpoints and viewing axes from where to observe celestial processes (Figure 2), or also select an observing location for shadow effects (Figure 3). It had been envisioned to present and demonstrate the expected stellar alignment results of the ASTROSIM project. Although these could not be confirmed after the horizon surveys, we are sure similar research will welcome this plugin as useful tool.

For presentation of some project results to a wider audience in a visually more attractive system, a virtual environment including the two adjacent Kreisgrabenanlagen at Pranhartsberg is currently being developed with the Unity3D game engine, which allows the inclusion of, and motion along, larger virtual landscape areas derived from a DEM, but where the astronomical components have to be developed from scratch.

The Multimedia presentation will be based on videos exported from ArcGIS and SketchUp and screen captures from Stellarium and Unity3D.

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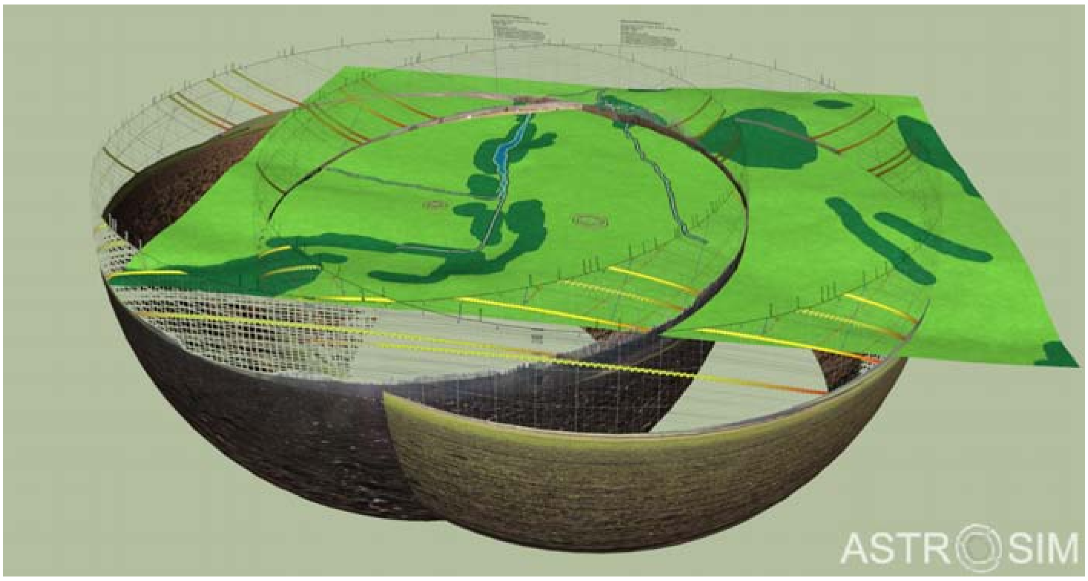

Figure 1: *Spherical rings textured with panorama photographs taken on site, enriched with diagrams of astronomical information, are used as horizon backdrops for each KGA in the SketchUp models. Such a ring is usually attached to the view camera and so encloses the scene without causing parallax errors.*

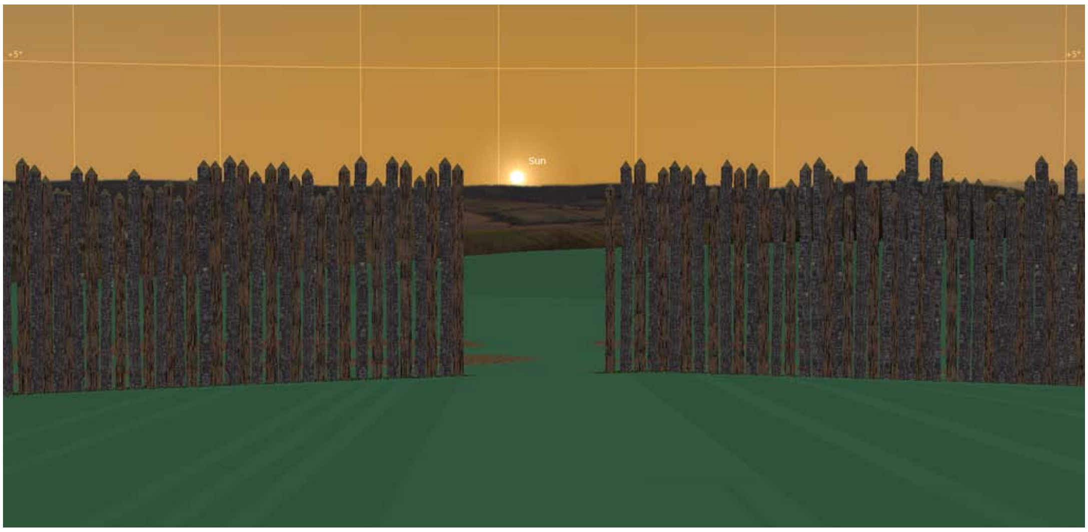

Figure 2: *Summer cross-quarter sunrise in KGA Puch, simulated in Stellarium with the Scenery3D plugin. Although the azimuths of this and the opposing entrance fit to the astronomically defined dates just between solstices and equinoxes, they represent at the same time the direct downward slope line and thus fit to most of the other KGAs for which no astronomical connection could be confirmed.*

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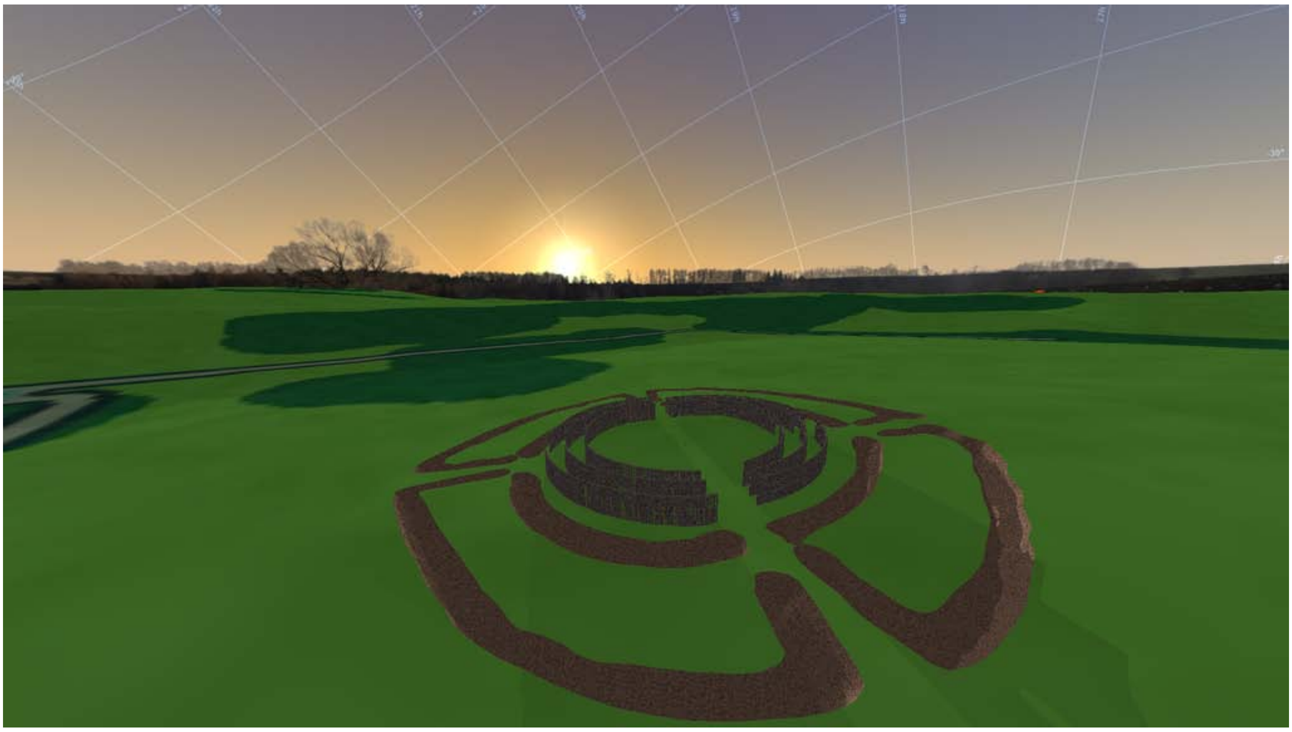

Figure 3: *Shadow simulation in Stellarium with the Scenery3d plugin. The sun, rising over a nearby ridge, casts its first rays into the centre of KGA Pranhartsberg 1 around the winter cross-quarter day. However, the ridge may have eroded over the last few millennia, so the applicability of this observation as date mark cannot be given with any certainty. On the other hand, again, the orientation of the entrances seen to the right and left here seem to be closely related to the terrain slope.*

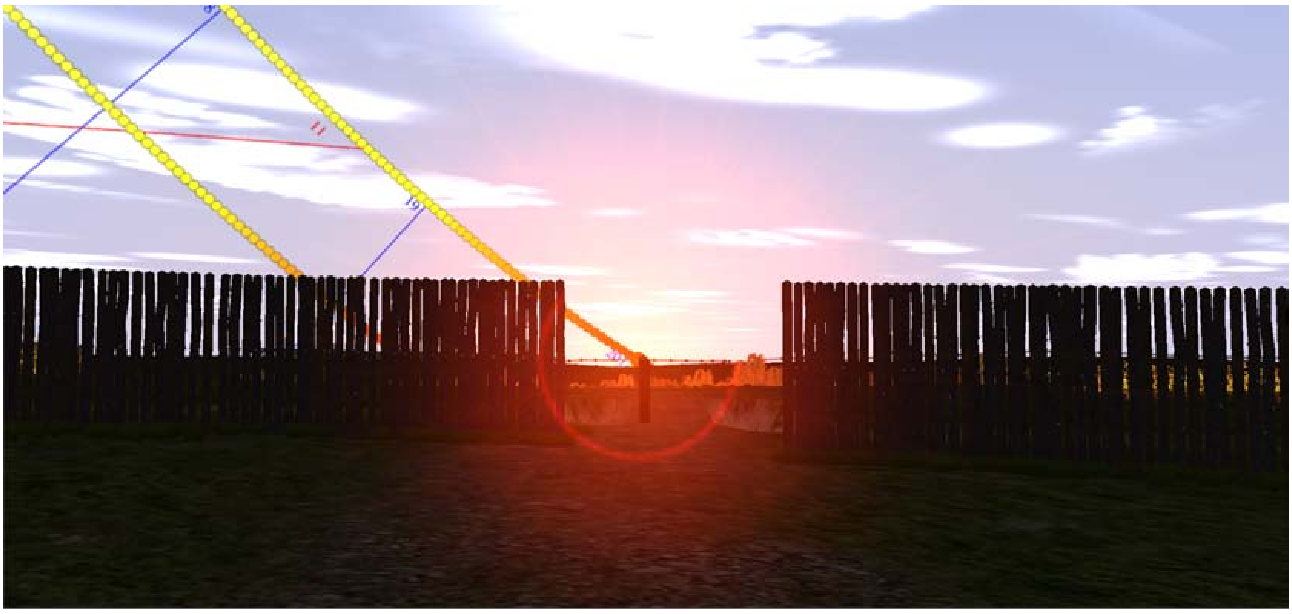

Figure 4: *A sunset simulated in Unity3D. The sun sets in the direction of the northwestern entrance path of the KGA Pranhartsberg 2 on the day of summer solstice. The magnetogram hinted at two postholes for posts which may have further enhanced the orientation aspect. However, this is the only KGA with such a clear solar orientation which is not co-aligned to the terrain slope. The diagram of solar paths (showing the tracks for summer cross-quarter and summer solstice) is similar to that of Figure 1 but has been reprojected and attached to a skybox, and the various diagram elements (alt-azimuthal grid, declination lines, and solar, lunar, and stellar tracks) can be switched on and off to allow interactive demonstrations and a more natural look of the sky.*