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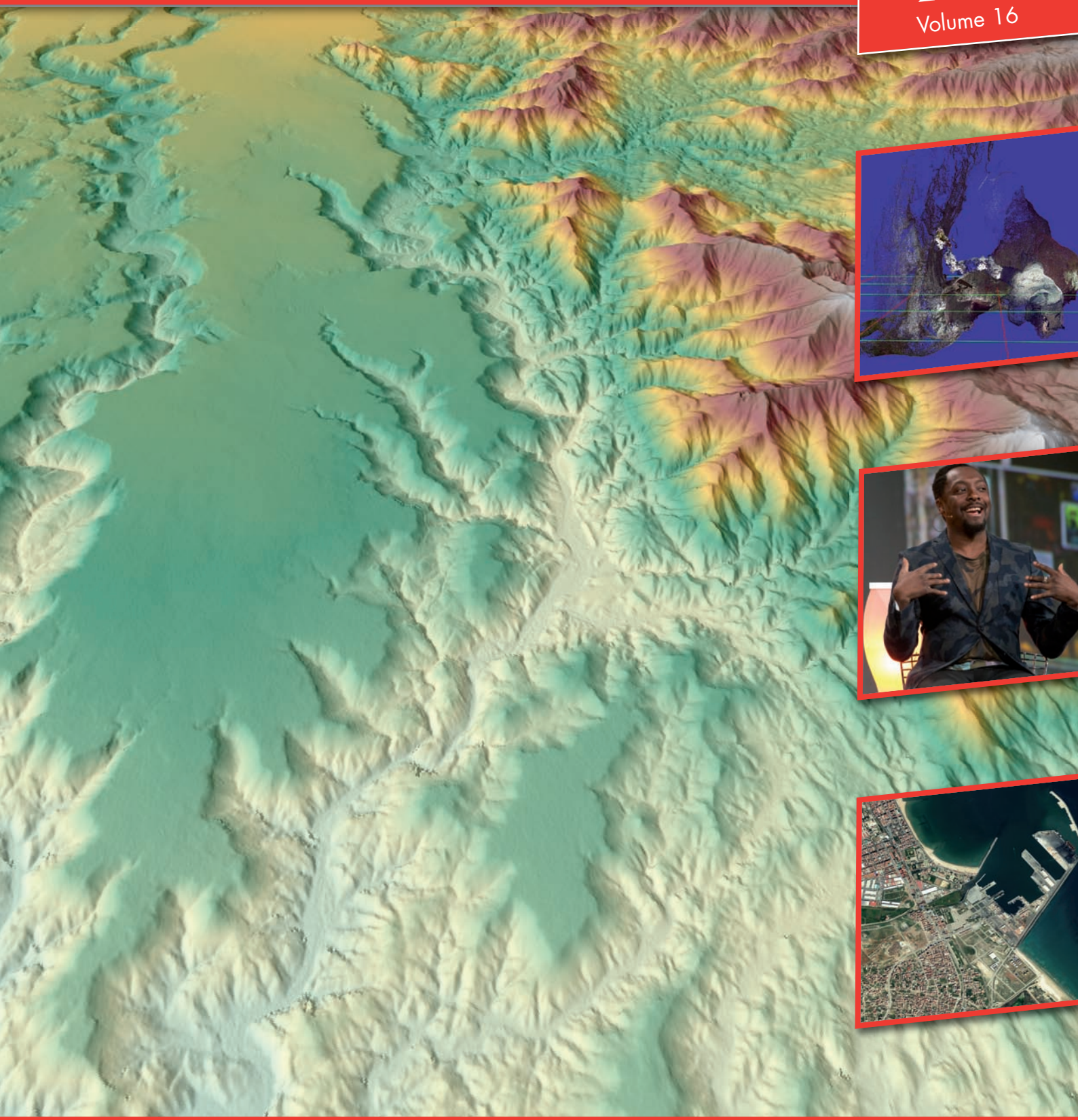

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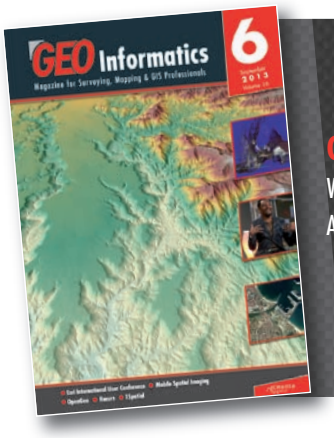

On the cover:
WorldDEM Digital Elevation Model of a landscape in the Al-Hejaz region in Saudi Arabia near Al Hada. © 2013 Astrium Services / Infoterra GmbH

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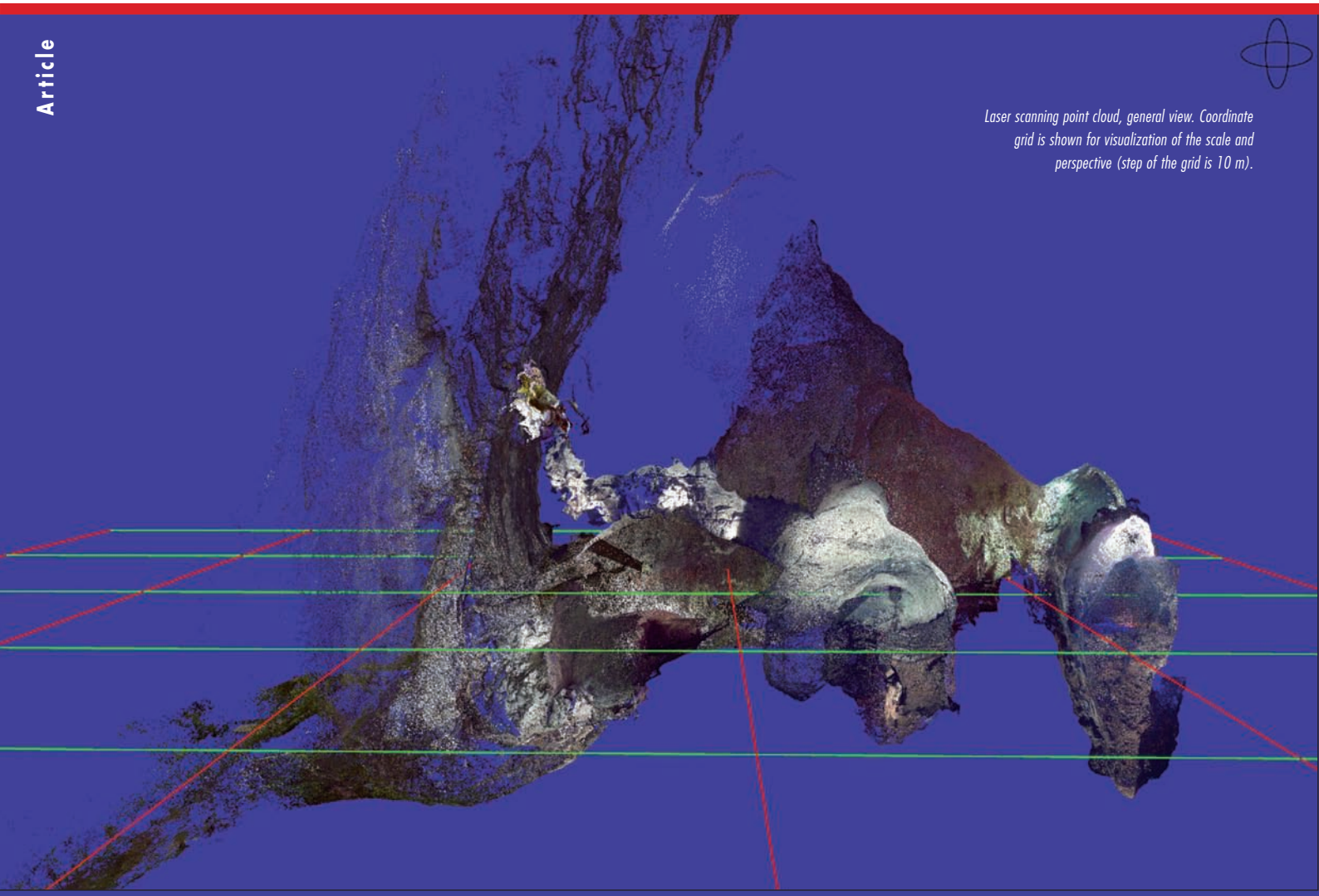


Laser scanning point cloud, general view. Coordinate grid is shown for visualization of the scale and perspective (step of the grid is 10 m).

By Mikhail Anikushkin, Aleksandr Bobkov and Andrey Leonov

This article presents the results of the project «Virtual Denisova Cave in the Altai Mountains». A virtual 3D model of Denisova Cave was developed based on laser scanning, as well as interactive stereoscopic 3D presentation for visualization of this model and additional information, both online and on Virtual Environment systems.

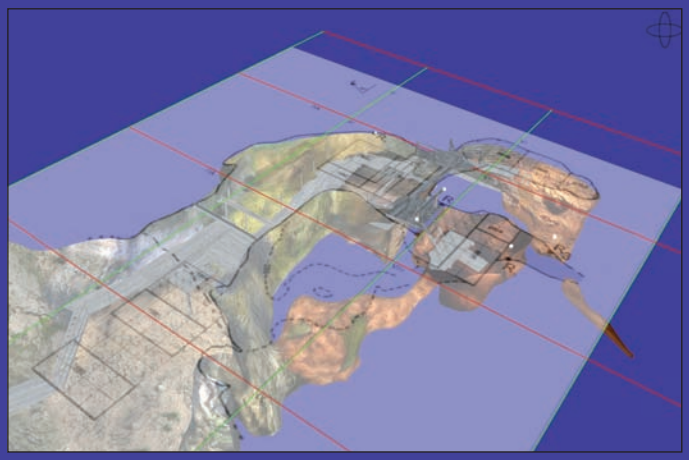
A 3D Documentation Project in Russia

Data Capture, Modeling and Representation

Denisova Cave in the Altai Mountains (Siberia, Russia) is a world famous Paleolithic site (51° 23′ 51.29″ N, 84° 40′ 34.34″ E). Archaeological excavations have been carried out here on a regular basis since 1982. More than 20 cultural layers were revealed and more than 80,000 finds were collected. In 2008, a new branch of human evolution was discovered based on finds in the Denisova Cave. So it was a challenging task to digitally preserve this unique object using up-to-date methods of 3D documentation: i.e. to create a virtual (digital) 3D model of the cave and the most important finds, and visualize the results of archaeological research based on this model.

Laser scanning and 3D modeling of a cave

In August 2012, we performed laser scanning and detailed photography of the cave. 37 scan stations were made; full point cloud contains about 50 millions of points. After this we created a textured polygonal 3D model based on the results of the laser scanning and photography. The model consists of 88254 polygons: 86000 of the cave and 2254 of artificial objects (decks, rails, and stairs). The resolution of the texture varies for the different parts of the model from 30 to 100 thousand pixels per 1 square meter of the model surface. Thus we have created a detailed 3D model of a cave which preserves its geometry and appearance with high accuracy and resolution.



Model of the cave, cut at 0 m level. Archaeological scheme of the cave is overlaid

Model of the cave, an excavation in the east gallery.

Referencing of the 3D model

The created 3D model was referenced in an archaeological coordinate system (ACS). This system is used by archaeologists for the spatial referencing (registration of location) of finds. The X axis of the ACS is turned 62 grades clockwise from the North direction, the Y axis is perpendicular to X, and the Z axis is vertical. The origin of the coordinates of ASC is located in some virtual point in space near the cave entrance. ACS is fixed in the cave by five permanent marks in the cave's walls. These marks were scanned during the laser scanning. During post processing, the model of a cave was converted in ASC. The accuracy of referencing was about 5 cm (mostly because of errors of marks localization in ASC). Thus we provided a means to compare the 3D model and existing archaeological schemes, and directly transfer the existing archaeological database into a virtual space of the 3D model.

Laser scanning and 3D modeling of finds

We also scanned, photographed and modeled several finds made in the cave (stone implements). The created models of the items consist of about 50 thousands of polygons. During texturing, we used normal maps which were built based on more detailed models (500 thousands of polygons). Thus we achieved high visual realism and resolution of the virtual models with a relatively small number of models and textures. This is particularly important for interactive visualization in stereo mode.

Development of an interactive presentation

In order to visualize the created 3D model of the cave, we developed an interactive 3D presentation (software based on OpenSceneGraph). The presentation supports both mono- and stereoscopic visualization. It provides visualization of a point cloud, 3D model of the cave, 3D models of finds, 3D models of wooden decks, rails and stairs, as well as visualization of the spatial distribution of finds in different archaeological layers («cloud of finds»). It also supports visualization of additional data: cardinal directions, axes and grid of ASC and the location of permanent marks of ASC. The 3D model of the cave can be virtually cut at any horizontal layer; this option helps to analyze visually the geometry of the cave and localization of finds.

The presentations have four windows: «Globe», «Cave», «Cloud of finds», and «3D model of an item». The user can switch between windows arbitrarily. In the «Globe» window, the user can explore the virtual globe with an embedded model of a cave, and analyze the location of a cave and surrounding landscape. In the «Cave» window, the 3D model of the cave and other objects are presented. In the «Cloud of finds» window, only the location of archaeological finds is visualized (coordinates of finds, surfaces of archaeological layers, spatial orientation of finds). In the «3D model of an item» window, the user can explore 3D models of finds and switch between them.

Conclusions

The created 3D models and software can be used for presentations, as well as for research tasks (for example, visual analysis of stratigraphy and deposition of sediments). The presentations can be also used for virtual travel in the cave, including free online tours. It is especially important to have this information for remote and hard to access heritage sites, such as the Denisova Cave in the Altai Mountains.

Acknowledgements

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