3D-PITOTI: ACQUISITION, PROCESSING AND PRESENTATION OF PREHISTORIC ROCK ART

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ABSTRACT: We present the European research project 3D-PITOTI and its developments of technologies for the acquisition, processing and presentation of 3D surfaces and environments such as the impressive rock art from Valcamonica, Italy. Our developments enable novel ways of studying and teaching about some of the oldest cultural artefacts of our ancestors.

1. INTRODUCTION

The European project 3D-PITOTI develops technologies for the analysis of prehistoric rock art. Such petroglyphs can be found all over the world. They preserve insights to the culture and lives of our ancestors who carved their stories with force and passion into canvases of stone.

Valcamonica, in the Lombardy region of northern Italy, is on the UNESCO list of world heritage sites for its particular wealth of rock art. Tens of thousands artworks span a period from about 4000 BC to medieval times. Many of them show human and animal figures in hunting, fighting and dancing scenes and thus locals call them "Pitoti" (little puppet).

Figure 1: *The Pitoti rock art at Valcamonica often shows animals and human figures. Photo by Hamish Park*

Our developments emphasize the inherent three-dimensional structure of the petroglyphs and their unalterable situation in a particular environment. We are working towards the following contributions: 1. an affordable and portable multi-scale 3D scanning toolkit that captures small details and the surrounding environments; 2. intelligent processing technologies for the automated segmentation and classification of petroglyphs; and 3. interactive 3D visualization techniques that provide groups of researchers and museum visitors with efficient tools for the exploration of large multi-scale 3D scanning data.

Figure 2: *An overview of the 3D scanned valley. Screenshot from the real-time point-cloud renderer, developed in the project*

2. 3D ACQUISITION

Petroglyphs are often found at remote sites and difficult to reach. Consequently, our scanning toolkit must be lightweight and compact. It must support the rapid 3D acquisition of selected artworks at sub-millimetre scale while data on the surroundings are acquired automatically. The captured colour information should reflect normalized material properties without temporary effects of light and shadow during the scanning process.

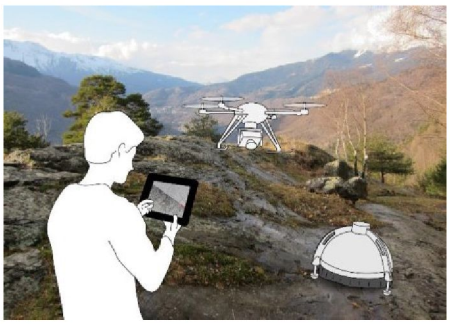

Figure 3: *Illustration of the envisioned scanning process. A micro-aerial vehicle automatically captures the surrounding, while high-fidelity detail scans are acquired with a portable micro scanner. The operating user continuously gets feedback on the capturing process to a mobile device.*

We have developed the first prototype of a portable 3D detail scanner [1] and a system for the data acquisition of the surroundings. The latter is based on automated view planning for micro-aerial vehicles that enables the autonomous acquisition of specified areas of interest. Real-time feedback of the captured area is provided to the operator using an incremental structure from motion technique developed at TU-Graz [2]. First experiments in the field took place in July and September 2014.

3. INTELLIGENT PROCESSING

Large coloured point clouds which are obtained from 3D scanning processes are not very useful in their raw form. The data rapidly becomes too large for interactive visualization and the mere geometries do not support efficient navigation between various points of interest.

Consequently, we are developing processing technologies that create level-of-detail (LOD) representations of the 3D point clouds for real-time rendering and add semantic information. The latter builds on the automatic segmentation and classification of petroglyphs (e.g. human, animal). Additionally, we are developing illustrative visualization techniques to support the analysis of details such as engraved 'pecking' structures.

Figure 4: *Comparison of manual rock-art tracing (above) and automatic segmentation (below) The red areas indicate the identified rock art.*

So far, we have implemented pre-processing methods for creating LOD representation of the point clouds. The semantic analysis supports petroglyph segmentation based on image data [6] and we have evaluated initial demonstrators of illustrative visualization methods with experts from archaeology. Our ongoing efforts aim for the following improvements: 1. the preservation of visual appearance in the LOD structures, 2. the exploitation of 3D information for the segmentation and classification processes, and 3. the adaptation of illustrative rendering techniques for their presentation with immersive 3D display systems.

4. 3D VISUALIZATION

Figure 5: Initial scans by the project member Arctron 3D GmbH provide a raw overview of the valley with a resolution of approximately 0.1 m (left), detail scans of dedicated rock-art areas with a resolution of approximately 5mm (center), and high-resolution scans of detailed rock art with a resolution of approximately 0.1mm (right). The resulting point clouds involve several billion points and are thus too large for ad-hoc rendering. Our real-time point-cloud renderer achieves interactive framerates by exploiting level-of-detail (LOD) data structures and out-of-core data management. The inset in the detail visualization (right) shows how non-photorealistic rendering techniques can directly be applied as an interactive lens to gather a better understanding of the visualized structures. Here, the color-coded orientation of surface normals indicate the curvature.

The digital acquisition of physical artefacts offers convenience and novel perspectives, but remote analysis is also prone to misinterpretation resulting from missing accuracy and context. Showing the objects of interest and their environment with immersive 3D displays can provide an almost one-to-one correspondence to the physical situation that may serve as a reliable reference for computer-supported data analysis.

Visualization technology is most useful for analysis and presentation if it serves multiple users, but most immersive 3D displays consider only individual users. Moreover, the technical features and the geometrical setups of the involved displays afford different types of usage, each of which is beneficial for a specific type of analysis. Consequently we are working towards multi-display environments that provide multiple users with individual perspectives on a shared representation of the scanned 3D scene.

Based on 3D projection technology developed at Bauhaus-Universität Weimar [3] we have set up two multi-user 3D displays: a tabletop and a large vertical screen. Novel multi-user interaction techniques have been developed that allow the individual exploration of data subsets under various viewing conditions without losing its relation to the context [4]. We are currently implementing a framework for combining multiple 2D and 3D displays to a joint visualization space.

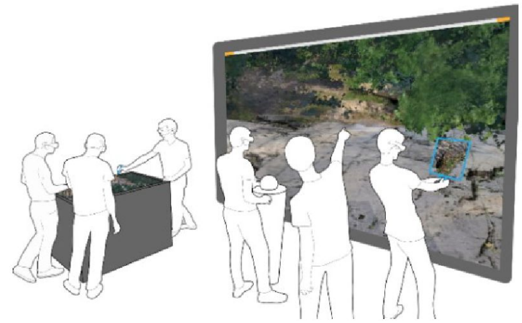

***Figure 6:** Illustration of the 3D-Pitoti Scientists Lab. A large 3D screen affords the exploration of the 3D scanned environment from an egocentric perspective, while the 3D tabletop better supports a bird's-eye viewpoint. Both displays can be used effectively for the analysis of geometric details. The system supports virtual "photos" for the individual capturing and preparation of interesting perspectives and content transfer between physical display devices.*

***Figure 7:** Early tests with the implementation of the 3D-Pitoti Scientists lab at Bauhaus-Universität Weimar. The real-time point-cloud rendering system has been integrated in the multi-user capable 3D rendering and interaction system Guacamole [5]. Here, two users inspect the detailed structures of a rock-art figure, while another one, explores the surrounding.*

5. CONCLUSION

We present the current state of progress of the ongoing European research project 3D-PITOTI. Our developments contribute to the development of novel technologies for the 3D acquisition, processing and visualization of our cultural heritage.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Höll, T., Holler, G., Pinz, A.: A Novel High Accuracy 3D Scanning Device for Rock-Art Sites. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Technical Commission V Symposium, XL-5.* 2014, pp. 285-291.

[2] Hoppe C., Klopschitz M., Donoser M., Bischof H.: Incremental Surface Extraction from Sparse Structure-from-Motion Point Clouds. *BMVA 2013*, Bristol, UK, 09.-13. Sept., BMVA Press, pp. 94.1-94.11.

[3] Kulik A., Kunert A., Beck S., Reichel R., Blach R., Zink A., Froehlich B.: C1x6: A Stereoscopic Six-User Display for Co-located Collaboration in Shared Virtual Environments. *ACM Transactions on Graphics* 30, 6, Article 188, 12 pages.

[4] Kunert, A., Kulik, A., Beck, S., Froehlich B.: Photoportals: Shared References in Space and Time. *ACM CSCW 2014*, Baltimore, USA, February 2014, ACM-Press, New York, NY, USA, pp. 1388-1399.

[5] Guacamole software framework. Available from: <https://github.com/vrsys/guacamole> [19.10.2014].

[6] Seidl, M., Breiteneder, C.: Automated petroglyph image segmentation with interactive classifier fusion. *ICVGIP 2012,* Bombay, India, 16.-19.Dez 2012, ACM Press, NY, USA. pp. 66:1–66.