Application of Terrestrial Laser Scanning in the Preservation of Fortified Caves

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SUMMARY

Fortified caves are unique to mountain ranges of north Mediterranean area, hidden in inaccessible parts of those mountains and served as secret forts for the people. They are not only pearls of defensive architecture but also a great example of symbioses between man and nature.
Research of the Croatian fortified caves plays a major role in the European Union project "Karst Underground Protection". The reason being that, the confirmed number of these objects located in Croatia is second only to France. So far, the existence of more than 50 fortified caves has been established and pending further exploration and documentation. Most of those finds are based on oral conveyance. The significance of preserving cultural heritage for future generations calls for locating and documenting such objects.
Considering the complexity of cave structures, their inaccessibility and the rate of decay a suitable method for collecting comprehensive data was considered to be laser scanning. The advantages of laser scanning over traditional surveying techniques have already been proven in many past projects involving survey of geometrically complex objects lacking significant texture differences.
Laser scanning provides a non-destructive, comprehensive and efficient method of survey that allows experts to conduct detailed inspection, analysis and visualization of complex structures. The progress of laser scanners has ensured that future projects of this type will play a major role in preservation of cultural heritage objects such as these.
This paper describes the importance of subterranean forts to past generations, in light of need for their preservation, and the methodology applied for their 3D documenting and visualization, on the example of objects explored and documented so far. This provides a basis for interdisciplinary geodetic, archaeological, geological and anthropological research.

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1. INTRODUCTION

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Cave fortifications are fairly unknown, but special remains of Croatian history and other countries (France, Spain, Italy, Slovenia, Bosnia and Herzegovina). They are also a geographical uniqueness of the northern Mediterranean mountain ranges - the Pyrenees, the Alps and the Dinarides. They are hidden in inaccessible parts of the mountains and are secret forts, which were always and everywhere build by people, and not by the government. That is, regardless of geographic location and different times and conditions, the rule for all European cave fortifications. They are not only real little pearls of defensive architecture, but also a great example of symbiosis of man and the environment.

In Croatia there are more than 50 such caves with walls. Previous research has established that these walls were built during the Turkish threat and used for sheltering people from the Turkish invaders. Unfortunately, in the historical documents they are not mentioned at all, but their mystery is exactly what played an important role in the survival of the people, so it is understandable that they their position remained undisclosed. Some caves have a wall built at the entrance to the cave, visible from the outside, and some hidden deeper in the cave, at the close of daylight, some have only one wall, and some more walls. All of these caves, hidden or visible, have served primarily as a shelter, but they are also actual small forts. Reaching some of the entrances of those caves is quite easy, some are difficult to access as they were on steep hillsides, but there are others extremely difficult to access, as they were in high cliffs.

Those caves were not concealing a regular army but local population. These caves – refuges become a real small (and a few not so small) forts, and some walls are real pearls of defence architecture. According to their appearance, construction techniques, and data collected and processed, their models for their construction were likely found in surrounding old towns and forts. So there are remains of beautiful masonry walls with defence galleries, towers, loopholes, and then miniature bastions that look like small balconies overlooking the canyon where the cave is located, with a role of guard towers and the lower walled caves that served as a refuge. Some walls can only be found inside the cave, so that there are some real small underground defence systems.

Europe has a small number of fortified caves. Possible reason is that the fortifications were built by those in power, who also denied the less fortunate to have their own forts. Aside from Croatia, France has the largest number of cave fortifications in Europe. It has about 50 forts in the area of Pyrenees and Alps. The Pyrenees area also has them, but less, on the Spanish side. These caves can be found in Switzerland as well. So far, Italy has one known cave fortifications and per two in Slovenia and Bosnia and Herzegovina. They are all generally similar in type and purpose, as well as in architecture design, and it is interesting that the builders were also the same type of people, those who defend themselves against forceful invasions.

Precisely because the cave fortress are still not researched enough, they cannot be approached with systematic documentation, and legal and practical protection of an extremely valuable part of the Croatian and European heritage. In order to preserve and promote that legacy, it first needs to be protected, as a natural value in terms of speleological objects, and in terms of manmade structures, i.e. the walls. All this should be documented appropriately and consistently with contemporary standards to ensure proper formal and legal protection, and subsequently published.
Such publications are important for science and culture, since science serves to provide benefits for the community and not just individuals, and cultural heritage if it is not known, especially if, as in this case, it describes new undiscovered pages of history of the people in this part of Europe.
Considering the complexity of cave structures, their inaccessibility and the rate of decay a suitable method for collecting comprehensive data was considered to be laser scanning. The advantages of laser scanning over traditional surveying techniques have already been proven in many past projects involving survey of geometrically complex objects lacking significant texture differences.
Laser scanning provides a non-destructive, comprehensive and efficient method of survey that allows experts to conduct detailed inspection, analysis and visualization of complex structures. The progress of laser scanners has ensured that future projects of this type will play a major role in preservation of cultural heritage objects such as these.

2. FORTIFIED CAVE "KUĆA"

Cave ”Kuća” (Figure 1) is located at the top of a high steep hill that slopes downwards from the village Ponor to a smaller valley where the abandoned village Pecina is located. The cave is not visible until approached at about four or five meters as it is secluded by 10 meters high rock walls. But, the site of this fortified cave leaves any architecture enthusiast breathless. This small cave is a true little pearl of defensive architecture. On the left is a watchtower with a loophole, doors are in the middle and on the right is a nicely built bastion with another loophole. A detailed inspection of the bastion reveals the skill and adaptability of the masons: a door lintel can be seen, the scaffolding holes, holes from the wooden beams that held the inside track for guard access to the loopholes or stairs that lead into the rock that, from the outside, is a semi-circular tower with loopholes are also visible.

Figure 1: Fortified cave „Kuća“

This small fort was, so far, unknown to public and scientists, and was remembered only in the folklore that says it used to have strong iron doors that were taken to Wien. Another interesting information is that the local population, Croats, hid in the cave for a few days and nights in the autumn of 1991. That information is interesting, as much for recent Croatian history, as much as proof of a continual use of the cave, and a confirmation that the information on such a suitable secret location is transferred, in secrecy, from generation to generation.

The cave was used for the pilot project of documenting fortified caves for archaeological research. The goal is to describe the method of spatial data collection for the preservation of cultural heritage and the advantages of laser scanning application for characteristic objects like fortified caves.

3. Field measurements and data processing

Spatial data collection for the purposes of the project was conducted using a terrestrial laser scanner Faro Photon 120 with all the associated equipment composed of multiple tripods, tribrach, portable computer, orientation spheres and a power source. Prior to the actual survey, recognition of the location and the object in question was performed. Station positions were planned to ensure quality and efficiency of the task at hand. In those initial stages of the project a problem presented itself. Thanks to demanding access conditions, the absence of a proper path included, transportation of the equipment proved to be quite a challenge. Fortunately the problem was resolved through the effort of all participating parties present at the site.

Faro Photon 120 is capable of collecting high resolution photo-realistic data (Figure 2) allowing depiction of even the smallest details. Data can be collected on a sub centimetre level, thus providing a clear view of all the details of the scanned object. Unsurpassed in

applications like construction monitoring, as-built survey, restoration studies or forensic analysis of crime scenes, his window of survey currently puts him in first place on the market.

His window of survey is 360° horizontally and 120° (240° two-sided) vertically, the acquisition rate is up to 976 000 pps, with the accuracy of ±2mm at 25 m. This type of scanner relies on a rotational prism or a mirror that revolves around the horizontal axis, and the entire instrument revolves around the vertical axis by 360°.

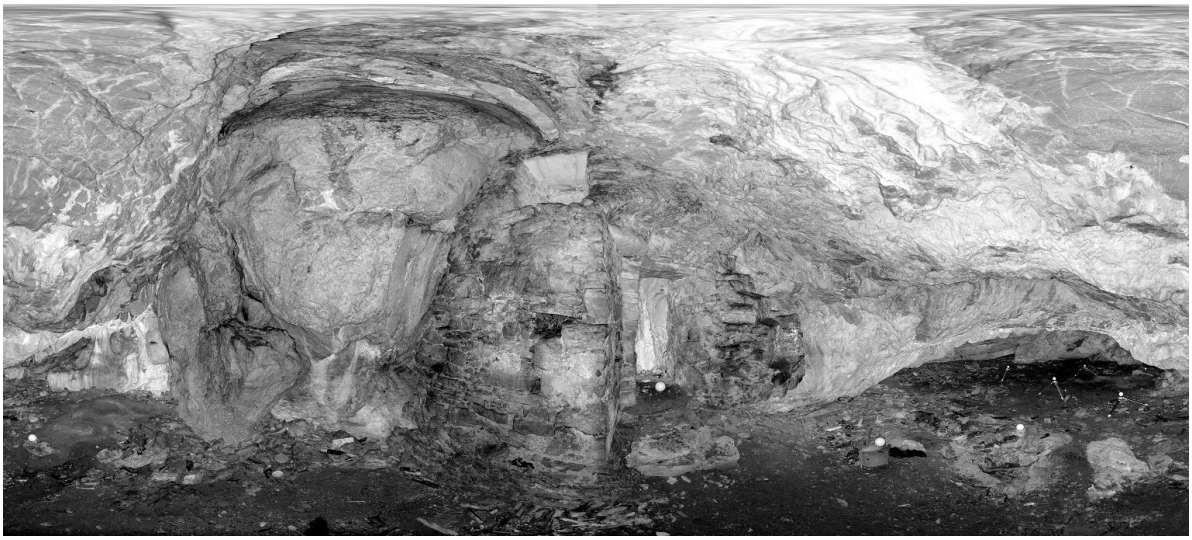

Figure 2. 3D scan of the inside of the cave Kuća

Laser scanning, thus, opens the possibilities of collecting enormous amounts of 3D data on the object. The set of 3D points, thus collected, is called a point cloud. Some applications use that data in its raw form, without any or with minimal subsequent processing. The recorded point cloud allows instantaneous measurements to be conducted using the computer without physically accessing the surveyed object. For simple visualizations or presentations, it is enough to generate topology using automated processing algorithms (irregular surfaces) which generates realistic models of those objects. All laser scanner manufacturers deliver processing software' along with the scanners. For the purposes of this project Faro Scene, Pointools, RealWorks Survey and AutoCAD Civil 3D were used.

The initial processing phase entails all actions related to point cloud manipulation, e.g. point filtration (noise reduction), merging and georeferencing. Successful completion of the first stage produces a complex point cloud devoid of noise. The second phase entails deriving elaborate data and 3D modelling (Figure 3).

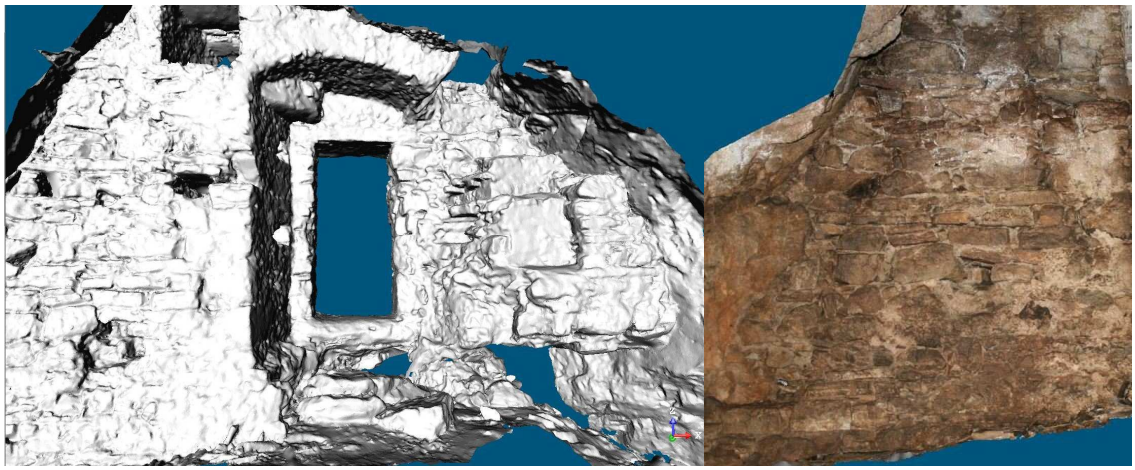

Figure 3. 3D model of cave Kuća

As the cases where an entire area of interest can be surveyed from a single station position are extremely rare, so was the case here as well. Thus, during the survey, multiple station positions were required, which resulted in multiple point clouds, with each in its own coordinate system. Hence, aligning of point clouds had to be performed before any relevant analysis of the cave could be made. Faro Scene application was used for alignment.

All point clouds were imported to allow finding common identification markers. As spheres were used as targets during the survey they had to be identified and their mutual relation had to be determined for each point cloud. As three common spheres are needed for each two neighbouring point clouds to be consistently aligned, field preparations included planning and positioning of both the scanner and the spheres. After sphere identification and point cloud alignment a unified and consistent point cloud was obtained.

4. Conclusion

The main phases of the project are research, documenting and preservation of fortified caves. Through overview of geodetic surveying methods a conclusion was made that laser scanning is the most suitable method for data collection and documentation.
The survey was performed using a phase scanner. Although first generations of laser scanners had an abundance of mandatory additional equipment which made transportation a tedious task, significant progress has been made in their simplification, making it, nowadays, easier to perform such tasks. For example the Faro Focus which is 5 times lighter and smaller has an integrated camera and a simple touch screen control interface which would make the task much simpler. It needs to be noted that this was a research project relying on relatively low funding and thus scarce human and equipment resources, thus only the existing available equipment could be used.
Data collected by laser scanning made a foundation for project documentation, i.e. creation of cross sections, views, floor plans etc. But, they can also be used for regulating property rights on cultural heritage as a distinct autonomous object in cadastral records. Besides documentation point clouds can be used for analysis purposes by archaeologists, speleologists and ethnologists. Thus, floor plan area coverage information can be used to determine the

capacity of the cave. This data also serves further archaeological research endeavours and excavations. Point clouds can also make a realistic and permanent visual identity of the caves for tourism purposes.

REFERENCES

URL1: www.faro.com
URL2: www.udruga-kameleon.hr

BIOGRAPHICAL NOTES

Branko Kordic, born in 1979, graduated from high school in 1997 and enrolled into Faculty of Geodesy the same year. During his studies he already participated in various projects for the economy. After graduation in 2005 he found his first official employment on the Faculty of Geodesy were he started as a professional associate but was, in 2007, employed as a research assistant and started his postgraduate studies. During his employment he authored and coauthored several scientific and expert papers and presented them on domestic and international conferences.
He is currently actively involved in teaching, professional and research projects as well as production and publication of papers.

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