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Application of Terrestrial Laser Scanning in the Preservation of Fortified Caves



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Fortified caves - history

- ❖ Cave fortifications are fairly unknown, but special remains of Croatian history and other countries (France, Spain, Italy, Slovenia, Bosnia and Herzegovina)
- ❖ 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.

Fortified caves



- ❖ 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- ❖ Unfortunately, in the historical documents they are not mentioned at all, but their mystery is exactly what played an important role in the survival of the people, so it is understandable that their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.
- ❖ Those caves were not concealing a regular army but local population.




Fortified caves




- ❖ 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, on the Spanish side. These caves can be found in Switzerland, Italy, Slovenia and Bosnia and Herzegovina, but small numbers.
- ❖ 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.

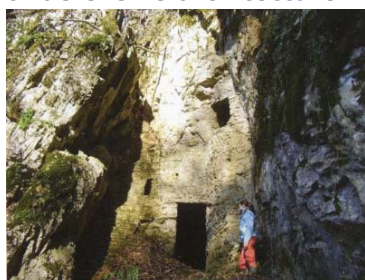


Documentation by 3D Laser scanning

- ❖ 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.
- ❖ 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.

Laser scanning of the cave Kuća

- ❖ Cave "Kuća" 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.



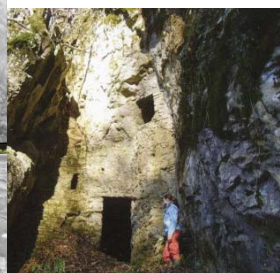
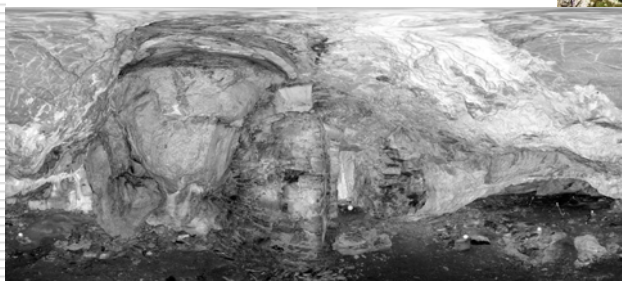
Laser scanning of the cave Kuća

- ❖ 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.

Laser scanning of the cave Kuća

- ❖ 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.

Fortified cave Kuca



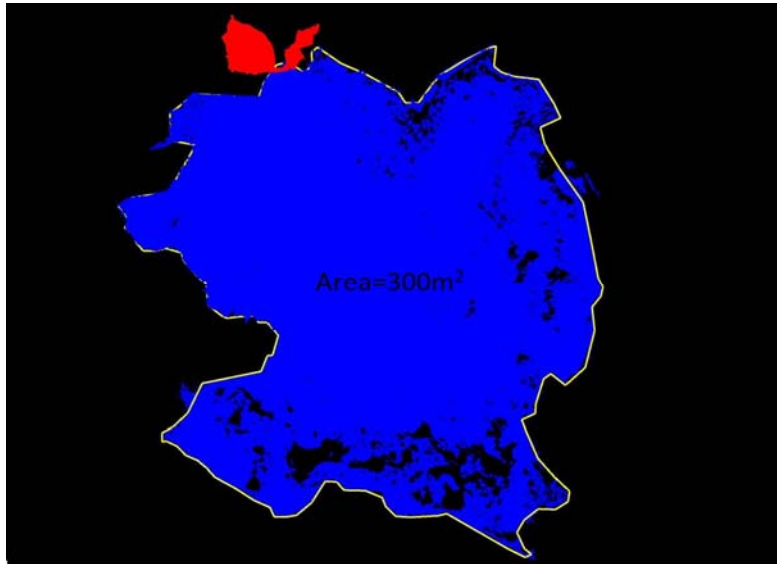
Fortified cave Kuca

This slide displays four images related to the Fortified cave Kuca. The top-left image is a 3D reconstruction of the exterior wall, showing a large rectangular opening. The bottom-left image is a 3D reconstruction of the interior, showing a smaller rectangular opening. The right side of the slide contains two photographs: the top one shows the natural rock structure of the cave, and the bottom one shows a close-up of the rock surface with a grid overlay, likely for scale or measurement.

Fortified cave Kuca

This slide displays two 3D reconstructions of the Fortified cave Kuca. The left image shows a side view of the exterior wall, highlighting its thickness and the rectangular opening. The right image shows a side view of the interior wall, also highlighting the rectangular opening and the texture of the stone.

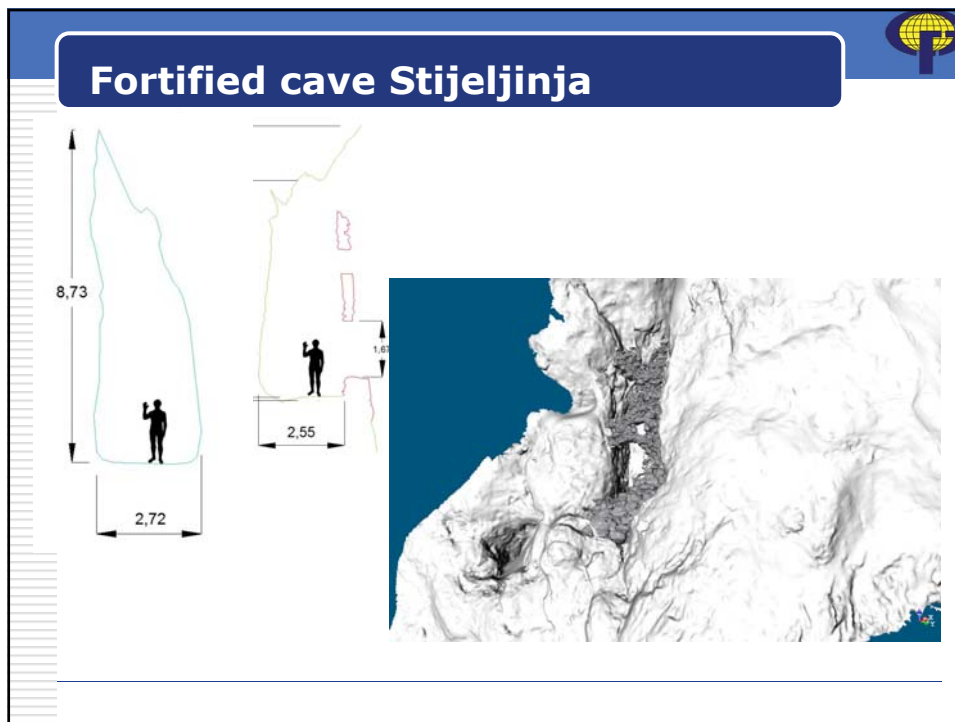
Fortified cave Kuca



Area=300m²

Fortified cave Stijeljinja





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.

Conclusion



- ❖ 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.