Valorization of Territory of Ancient Mine for Tourism, by using Laser Scanner - The Application of the Laser Scanning in the Speleology and mines

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Key words: Laser Scanning, Photogrammetry,Exploring, Mine, Survey, Virtual Tour, Speleology.

SUMMARY

Combining Laser Scanner and Speleology.
Speleologist, when explore caves or mines, are fascinating from amazing unknow underland world and then, first impulse feel are to discover an understand structure, size, mineral rocks present and find the end of the.
This paper present case study conduct in a Italian mine of Bitumen.
As land surveyor of technical company "Studio Tecnico MT" and Speleologist from "Persephone Exploring Association, I surveyed a Bitumen mine located in Abruzzo, that is a center Italian region, famous for huge mines presence of different minerals.
Through the integration of "Lidar techniques", "GPS survey" and "Panoramic Virtual Tour", the mine was surveyed, analyzed and reported in new accurate way. This survey test was conducted with main focus to improve new survey technique, check quality and capacity of new instruments, and compare new and old results obtained. In the results of article it has been evaluated that new instruments and software to process data, produced more accurate results and more information. Furthermore with Panoramic Virtual Tour is possible to open this world to the touristic market or to people not able to access in caves.

Valorization of Territory of Ancient Mine for Tourism, by using Laser Scanner

- The Application of the Laser Scanning in the Speleology and mines

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1. INTRODUCTION

1.1 Speleology and 3D Laser Scanner

"Speleology (from the Greek spélaion = cave and lògos = speech) is the discipline that deals with the exploration, documentation, protection and dissemination of knowledge of the underground world" (Trombe F., 1952).

“To us it seems more appropriate to see the speleology simply inserted into the human cognitive process: if you dedicate yourself systematically to the enterprise to explore the underground world documenting and describing it as best you can and if, together, the groundwater digging a lattice in your mind, then you are speleologists. Specify more perhaps it is useless, would lose this activity the charm that have its many facets” (Badino G., Bonelli R.,1984).

Laser Scanner 3D represents an exceptionally versatile solution for the acquisition of large amounts of data with significantly reduced measurement times, always keeping very high precision. The 3D Scanner can be considered as an eye that measures everything that is visible from the position in which it is located (Bartolucci D.,2009).

Topographic Survey of a mine, means:
1) Position the mine, that is to determine on the topographic map, the point where the entrance is located;
2) "Taking measurements" of the mine in order to draw it. Given the three-dimensional complexity of a mine, the relief consists not only of a representation in a plan, in fact, multiple views are required, in order to have an unambiguously readable drawing in the three directions of space (Silvestro C.,2006).

1.2 Persephone Exploring Association

I am Land Surveyor, with huge passion for Speleology and I consider myself lucky person because can merge my huge passions, laser scanning and exploration as a speleologist.

I am a member of the board of directors of “Persephone Exploring Association”.

“Persephone Exploring” is an Italian Speleological Association that is focused on coordinates geographic explorations and multidisciplinary studies of a speleological nature

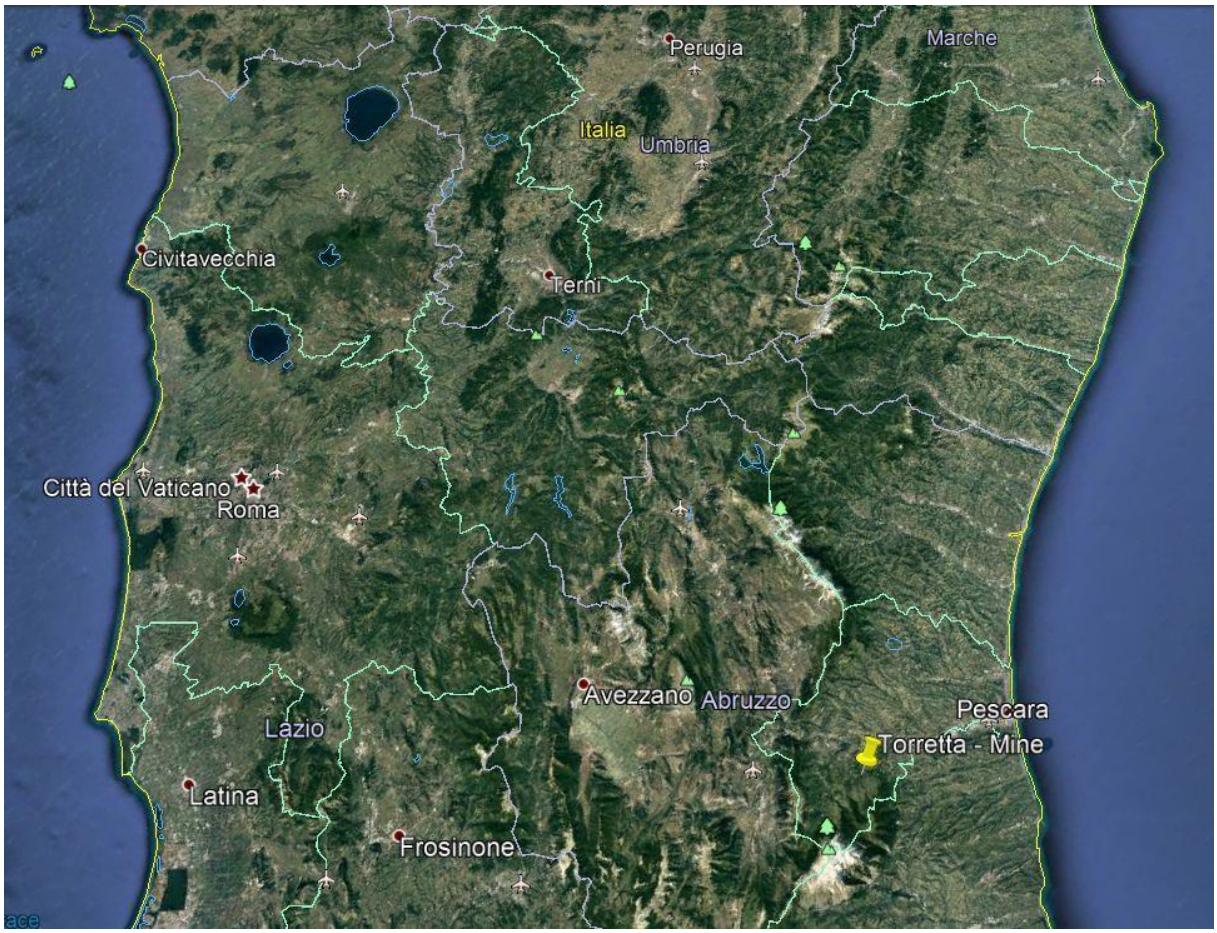
with the aim of protecting, conserving and enhancing the sites that are being explored through promotion and scientific documentation what has been discovered.

1.3 History of the project

Project started in June 2017, when "GRAIM" (Majella Industrial Archeology Research Group) contacted me and "Persephone Exploring Association" to help them on topographical study of a bitumen mine.
Graim speleologist did long research on old documents, listened stories from old people and has been conducting exploration for some years on the naturalistic and anthropic aspects of the "Abruzzese" mother mountain for the historical reconstruction of local human experience.
The discovery took place in the territory of Roccamorice (PE), in Torretta, intercepting a tunnel during the exploration of a natural cave.
Next explorations inside the mine, required specific equipment and also saw the participation of the specialized speleologist on topography survey, photographic documentation, and microbiologist and zoologist studies.
Speleologist provide to walled the old entrance to to restore the original security conditions and to preserve the interior area for a perfectly preserved and defended by human attendance.
The long, unmoving, silent row of carts is extraordinary and suggestive, testimony to the hard and laborious work of the workers of the past in that dark and inhospitable place.
"San Giorgio mine" was called also "Torretta" because one of the entrance was situated close a small town of 100 person named "Torretta".
Torretta is mentioned for the first time in the 1909 "National Mining Service Magazine", it was very important for this rural area, because has given work to families resident around that mountain area.
The fascinating story of the mine, continued till 1951 with the construction of railways, cableways, hydroelectric power stations, large plants for processing the extracted material, after that year was not economically convenient continue the extraction from the mine, because bitumen started to be synthesized from oil.
With historical documents and after firsts exploring of the mine, Graim group decided to start a project for valorization of the mine and relative area, according with municipality and the Majella national park board.

1.4 Project Area

The premise helps me to introduce this fantastic experience in Abruzzo territory and relative mountains located in the center of Italy on the bord with Lazio and Marche (Fig.1).
Majella Territory is wildlife territory, famous under the speleological aspect and also in historical, archaeological, and architectural evidences.
Is a protected area "Majella National Park" characterized by large and compact limestone massif territory that is dominated by mountains, and the 55% of it is over the 2,000 meters.



Pescara is the largest city closer to "Lettomanoppelo" that's the closer village to the mine, located on the hydrographic left of the trench "Fosso Sant'Angelo" in the Majella mountain, approximately at 500 meters above sea levels.
Majella mountain and the trail to the entrance are completely covered and immersive on the woodland.

Fig.1 "Torretta mine" location

2. "3D SURVEY PROJECT"

As an important national multidisciplinary project, that needs advanced, detailed and accurate data, we decide to leave old topographic methods in favor of new way and technology.
Topography in mines was always very important and fundamental topic for understand and collect data about mines world and relative structure. The main purpose was to realize internal and external 3D survey of the mine, of entrance, and of the all work engine and stuff presents in the area, to develop new survey methods in hostile environments.
This project should ensure that new survey methods are, first of all, able to be used in hard condition, moreover can provide better results compared with oldest methods.

The new results should allow to technicians or speleologists or administrations easier understand of the area, and study for develop new projects.

2.1 Software and Hardware

During a preliminary reunion between administrations and exploring associations, was decided to utilize different hardware and software to survey the mine.
It is a new method in this kind of exploration and studies.

For geolocalize the mine was used a professional GPS (Global Positioning System) in RTK survey mode (Real Time Kinematic). Leica Viva GS 15
The Z+F5006h laser scanner (Fig. 2) was used to scan inside and outside the mine and the technical specifications of this scanner are presented in Table 1 below.

(Fig.2 Z+F 5006H)

Scanner	Z+F5006H
Ranging Method	Phase
Field of View (Ver/Hor)	310° / 360°
Laser Class	3R (ISO EN 60825-1)
Range	0.4-79 m
Linearity error	≤1mm
Samples/sec	1.016.027 pixel/sec.
Beam divergence	0.22 mrad
Temp Range	-10/+45 °C
Colour	External
Weight	15.2 kg

(Table 1 Specification of TLS Instrument)

Moreover was applied the photogrammetric technique for accurate 3D model of interesting objects or stuff, and also were realized Panoramic Photos to obtain a 3D Virtual Tour.
Both activities were realized using a professional camera, a tripod and different photographic lens. (Tab.2)

Table-2: Photographic instruments

Instrument	Model-Name
Camera	Canon D700
Tripod	Benro
Lens	Fish- Eye (Samyang) F 3.5 – 8mm *
Lens	Canon F 3.5/5.6 - 18-55mm **

*** Fish Eye lens was utilized for panoramic photos.**
**** Canon 18-55 mm was utilized for photogrammetric models**

Post-processing data was obtained using licensed professional software to extract 3D information from different instruments, and prepare final representations data.
All data require specific software to process it, as an example for Laser Scanner data, first process of filtering and pre-processing was done it with ZF Laser Control, and then alignment creation of sections, plants and video on JRC 3D Reconstructor.
Photographic data need for a different process of post-processing, using “Camera Raw” and “Adobe Photoshop” to improved quality of images, and then using “Agisoft Photoscan” for a 3D model, or PTGui and Kolor Panotour to obtain a Virtual tour.

2.2 Organization and Procedure

The organization of the topographic survey, had to consider the expected results and the difficulties present on the mine, balance them and obtain the best results.
During the meetings were analyzed different aspects of the mission, starting from number of men must be present and help, to instruments to use and count days necessary to survey.
Beginning step was focused on logistic problems, for create a trail to the entrance easy to be surveyed by GPS and to carry all stuff and instruments, after that was determined the precision and accuracy of the data, with the timing necessary to complete the process.
Project parameters (Tab.3) were determined by taking the following criteria into consideration:

Table-3: Project Parameters

Parameter	Number
Person necessary	5/7
Average Length/Width	From 200 to 400 mt/from 0 to -100 mt
Project Duration	2 or 3 days
Accuracy Results	Subcentimetric
Results	2D/3D design/Virtual Tour/3D Video
Hardware to carry	GPS-Laser Scanner-Camera-Tripods-Batteries

The group of peoples that participated on the mission, were organized in teams with different roles and task to perform as for example:

- Carrying peoples on off-road car closer as possible to the trail;
- Use a machete to make the path free and easy to walk;
- Organize the base camp outside the mine entrance;
- Lighting organization inside the mine.

Fig.3 Equipment

Illuminate the mine was not easy, because the mine was without electricity, it means were necessary people with good electric light to help survey and photographic operation.
From first meeting attention was focused on study the morphology and the vegetation around entrance, through visioning photos and listening experience from first excursionist,then it was decided to not survey area with UAV System (Drone).
Is important to remember that all Speleologist part of the mission, was equipped with safety personal stuff : binding, helmet, carbine, rope, knife (Fig.3).
Last important stuff for the exploration in the artificial cavity or the mines,is the gas detector, necessary to detects the presence of gases in an area.

2.3 The survey

Original program was to have a fully day for survey the trail, the entrance and the mine, but the difficulties from weather and to realize measurements, had suggested to divide in two different days.
On the first day we realized the GPS recording of the trail and the first part of the 3D laser scanner survey, in the second day we ended the laser scanner survey and realized all panoramic photos for the Virtual Tour.

GPS survey realized in RTK mode, has been difficulties because we were in wild mountain with high trees and not excellent phone connection. (Fig.4)
To solve Gps problems we used a high topographic pole to up the to raise the antenna trying to find the best signal for triangulation and best connection. This procedure has required longer time but in the end we surveyed 410 automatic points for a woodland trail of 500 meters with a difference in level above 140 meters. (Fig.5)
Gps hardware was a Leica Viva GS15, with bluetooth connection between antenna and controller, and we were connected on the Italian SmartNet “ItalPos”, that allow precise position correction also in extreme situation.
It is important to remember that we were surveying a mountain trail, therefore we were not looking for centimetre accuracy, and during the post-processing operation we checked all measurement and tried to fix results in the best way.
Some data were out of tolerance and and not used to create the report and trail track on the image below. PIZDUK PIZDUK PIZDUK

Fig.4 GPS connection problems

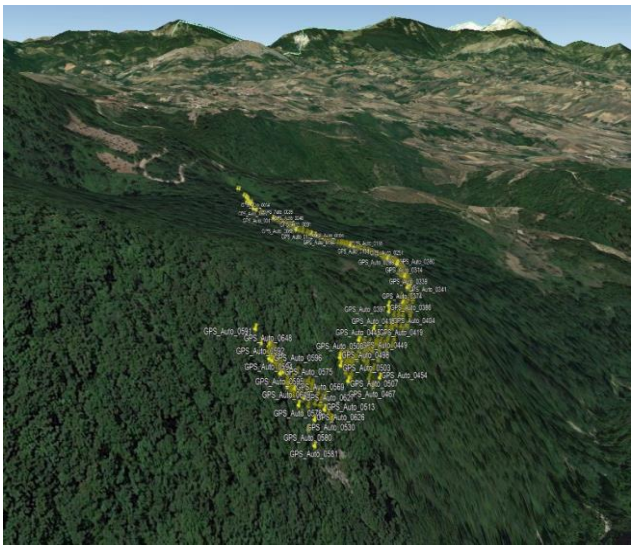


Fig.5 GPS track of the trail

GPS survey ended we started new survey with TLS(Terrestrial Laser Scanner), from base camp area.
The base camp area was located close of the mine entrance, because it's present a metallic structure with engine system that was used to move heavy barrel and carrel from inside to outside in direction to the industry that has working minerals.(Fig.6)

Fig.6 Engine Structure outside the mine

3D Laser scanner survey started from this area, to have a memory and a 3D data of the structure and area, to understand and analyzed morphological critical factor and to organize future project.
The survey team was split in 2 groups, 1st group of 3 people for easier management of the survey's activity: movement of tripod and TLS (weight=15kg), safety walking in progression between railroad tracks, carriages and stones.

Second group was organized for photo documentation, lighting of the mine and to clean where possible the way for the survey.
29 scan position were necessary to survey external area, and first part of the mine, because last part was underwater. (Fig.7)
Laser Scanner survey was done using a tripod and a Z+F 5006H laser scanner, connected with a smart-phone controller by wireless connection, without a colour data (RGB data).(Tab.4)
Scans position were realized and organized to have the best overlapping between each one and create the most accurate 3D model, for study it and realize plants and sections.
Difficult were the scans on the entrance because it was from a small sub-horizontal hole, that request particular attention to connect inside and outside scans positions.(Fig.8)

Table-4: Laser Scanner Data

Parameters	Value
Number of Scans	29
Super-High Resolution Scans	4
High Resolution Scan	25
Color Data	Reflectance data
Number of points surveyed	315’806’346 points
Mine length	225,00 mt
Mine Max Height	3,65 mt

Fig.7 Internal Survey

Fig.8 Entrance Survey

We decided to use higher resolution for 4 scans in the entrance area to have more details and points in common between internal and external scans. (Fig.9).

Pixel pitch

	Ultrahigh	Superhigh	High	Middle	Preview
10m	1.6mm	3.1mm	6.3mm	12.6mm	50.3mm
25m	3.9mm	7.9mm	15.7mm	31.4mm	125.7mm
50m	7.9mm	15.7mm	31.4mm	62.8mm	251.3mm
80m	12.6mm	25.1mm	50.3mm	100.5mm	402.1mm
Scantime	13.3 min	6.6 min	3.3 min	1.6 min	24 sec
Filesize	4.5 GB	1.1 GB	289 MB	72 MB	4 MB

Fig.9 Resolutions level and corresponding scanning durations

Virtual Tour is simulation of existing place, composed of a sequence of spherical images to have an uninterrupted 360 ° panoramic view. We decided to apply this technique to share with everybody view of places difficult to visit.
For realize 360 ° panoramic photos we used a special mechanical arm with 360 ° rotor "Nodal Ninja3" on which we installed a Canon D700 Camera with “FishEye” Samyang 8mm f.3,5.(Fig.10)
Panoramic photos are obtained up of 6 horizontal photos, with a 60° step between them, in order to ensure a good overlap between the images, and at least one vertical photo to receive the ceiling/sky data. All photos must be shot from single point of observation, rotating the camera and the lens around the phase center, for it we employed special stuff Nodal Ninja that is a mechanical head with a rotor that allow it. Fish eye is a Circular lens photo with a view angle of 167° that allow to obtain spherical images. .(Fig.11)
We realized 14 panoramas, to create an interactive and complete virtual walk, starting from external area with engine machine to the internal part with rails and all stuff inside. (Tab.5)

Table-5: Virtual Tour Data

Parameters	Value
Hardware	Camera Canon D700
Stuff	Topographic Tripod
Stuff (2)	Nodal Ninja
Sensor	Fish- Eye (Samyang) F3.5 – 8mm *
Number of Panorama	14
Photos for single Panorama	7 = 6 horizontal + 1 Vertical
Panorama Average Size and Format	30MB - .jpeg

(Fig.10 Nodal Ninja)

(Fig.11 Photo 360° in 2D view)

Photogrammetry technique was utilized to create 3D models of special interesting elements, looking to create a digital database for a projection in a museum or for a 3D printing to create the same models.Survey planning was realized to obtain a good accurate 3D model with a realistic texture and GSD (ground sample distance) not extreme. The photo capturing technique it has been the classical one, rotating around the object with a fixed angle to obtain an overlapping of 60%. (Fig.12).*

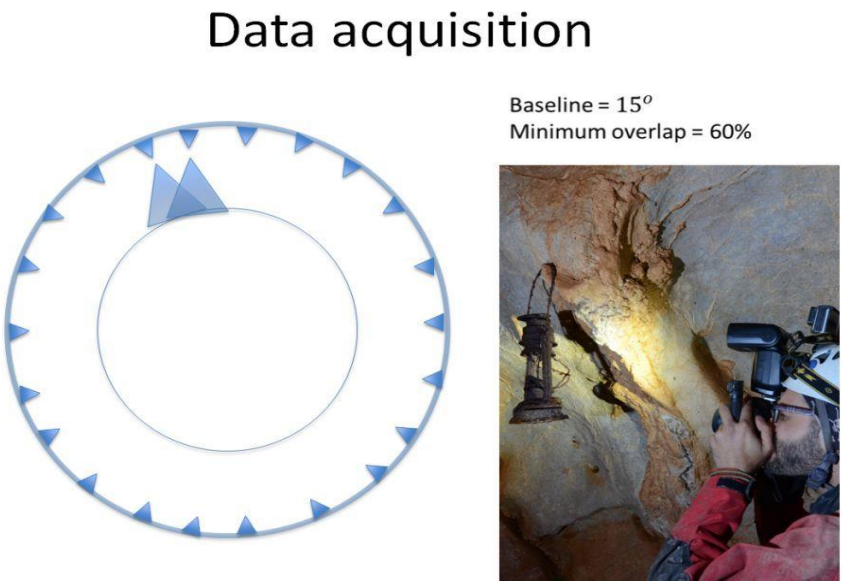


Fig.12 Photogrammetry Data Acquisition

* in the photo and author of the 3D model of the lamp, is Mr. Mattia Iannella Phd Researcher from L'Aquila University and member of Persephone Exploring.

2.4 The post processing

Ended the survey's mission, results were processed in office using professional software.
Gps software used was "Leica Geo Office", to compute alla Gps data and create an accurate survey of the trail. (Fig.13)

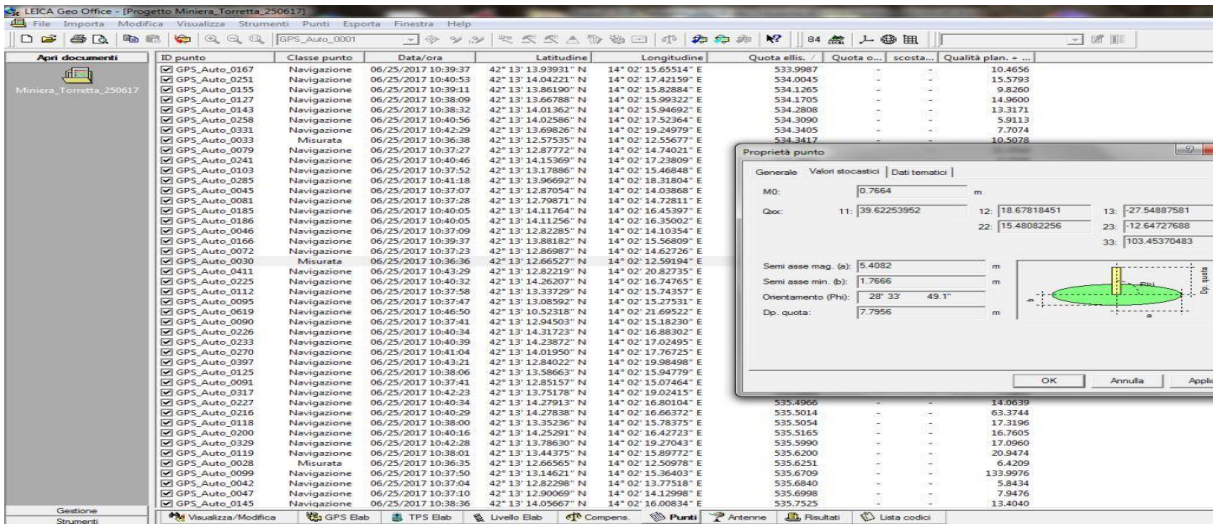


Fig.13 Leica Geo Office, Gps data processing

Results of Gps analysis is the map of the trail, useful in future for clean and prepare everything for arrive of tourists.
Example: removing plants and install lights and safety stuff for a touristic walk in the woodland for arrive to the mine entrance.

Laser scanner post processing follow the step below:

- Import raw data in "Z+F Laser Control" and JRC 3D Reconstructor to elaborate data and for caltulation of normals.*
- Alignment of 29 scans using "JRC3D" ICP Algorithm (Iterative Closest Point)**(Fig.14);
- Unify and subsample of all point clouds in a unique point cloud, to easier manage;
- Creation of Plants, Sections and Views necessary for correct draw;(Fig.15)
- Creation of of Mesh,Report of Volume and Area Calculation;
- Video of 3D navigation of Point Cloud;
  https://www.youtube.com/watch?v=19SnT_zMp78

*"Normals" compute is necessary to calculate directions of all points respect an hypothetical plane, to create a better 3D visualization of the point cloud.
**To have a diffusing and minimizing global registration error is important to set as reference Central scans, and connect the other scans around.

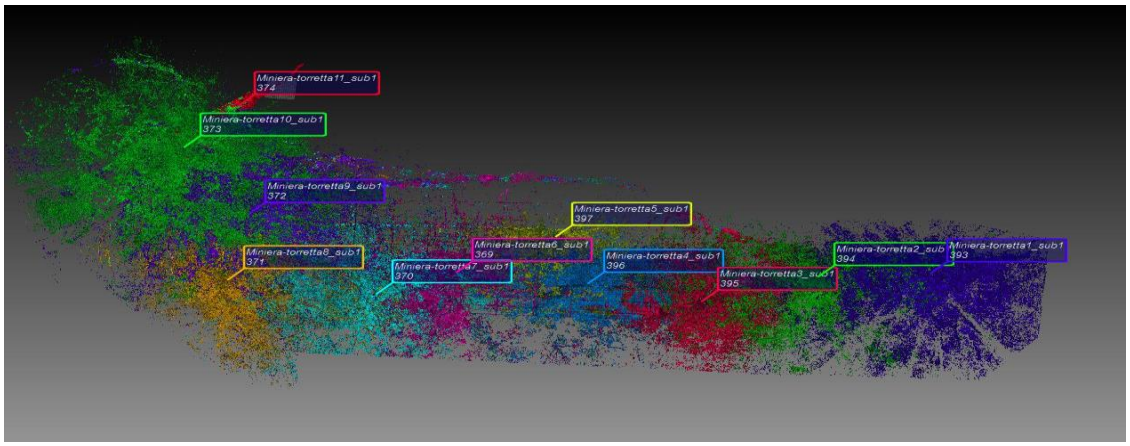


Fig.14 Aligned Scans

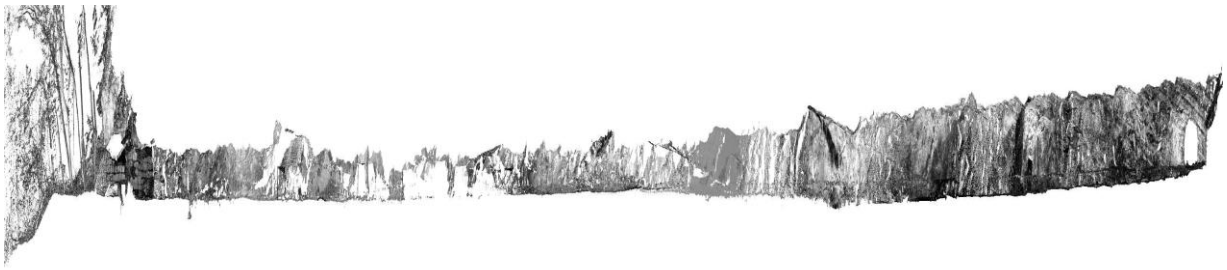


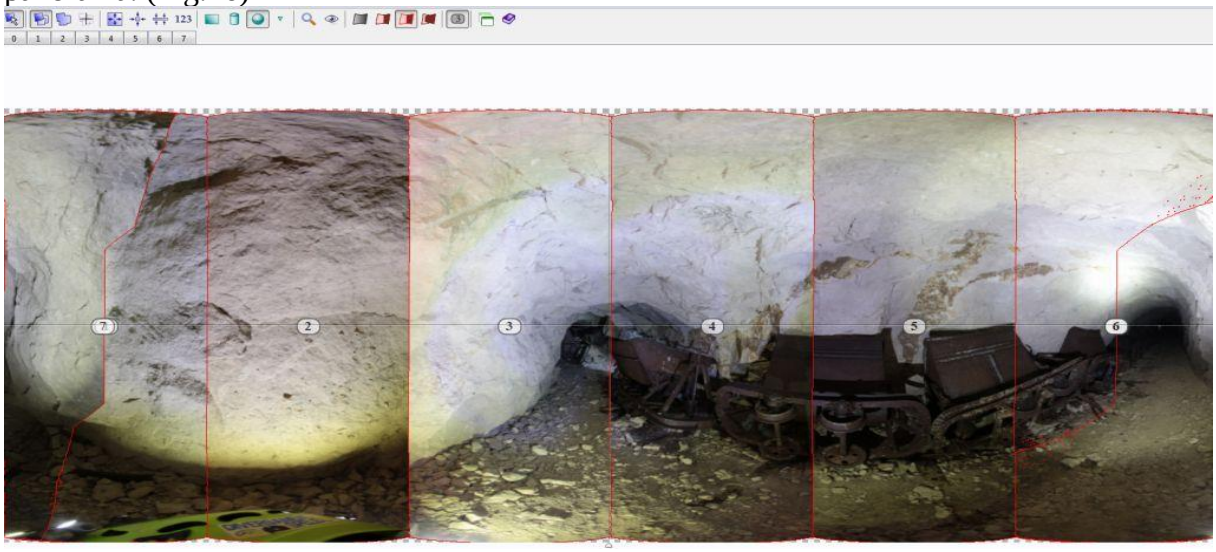
Fig.15 Example of Orto-photo - Section

Virtual Tour post processing, start with the elaboration of each single photo on Camera Raw or Photoshop(Tab.6):

Table-6: Adobe Photoshop post processing follow below criteria

White Balance	Contrast	+15	Brightness	-100	Shadows	+100	White	+20
Exposure	Black	-20	Clarity	+20	Saturation	-10		

Then Import in “PT-Gui” software 7 photos (each panorama) to align and create spherical panorama. (Fig.16)



(Fig.16 Example of Panorama Creation)

Once all 360° spherical images have been made, is possible to create a virtual tour using “Kolor Panotour” software, that allow to create inter-connections between panoramas, add information, music and create an .html link for share on web-site; (Fig.17)

(Fig.17 Example of Virtual Tour)

CONCLUSIONS

This project create a new method to survey the mine, and new method to visualize the area and the mine structure, useful for organize and create a program for new touristic development.
Certain data results between old and new methods of survey in the mine are not comparable, for quantity ,quality and speed of producing it.
Terrestrial Laser Scanner, is very delicate and sometime not comfortable to manage in the mine because sometimes there are: hard progression, climbing, water or mud.
Not in every mine is possible to apply this kind of survey method. In opposite when morphologic features allow to apply TLS obviously is the best approach to measure and geo-localize the mine.
Virtual Tour is an interesting new method to study and visualize cave. It's easy to realize and less expensive then TLS method, moreover results are friendly user and more interesting for everybody, especially for new generation.
In conclusion with right professionals speleologist and upgrade of new technology, mines or caves can be mapped in 3D to have a more complete result, and to have a better study and knowledge of the status.

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BIOGRAPHICAL NOTES

Started working as a 3D modeler in some Italian company, become a licensed surveyor in 2010 and began a freelance adventure, from 2014 is co-founder of "Studio Tecnico MT". Specialized in Land survey and TLS during the years participate in different construction projects in Russia, Kazakhstan, Spain, UAE.

In 2011 attended to "III° International Training Course in Topography for Young Surveyor" organized from FIG in Athens, and in 2012 attended to "First FIG Young Surveyors Conference" in Rome.

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