Combined video and laser camera for inspection of old mine shafts

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Combined video and laser camera for inspection of old mine shafts

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Abstract

For the cases where the location of a shaft is known but not its fundamentals characteristics, INERIS has developed a combined video and laser camera to face with problems of characterization of body of shafts or underground cavities.

The system is able to product videos, pictures, punctual manual measures, and automatic measure cycles to establish cross-sections, profiles and contour lines as well as the estimate volume of voids in dry or flooded cavities.

For inspection of shafts, developments are within the framework of MISSTER[1] project (RFCS, Research Fund for Coal and Steel). The work is principally based on the development of the second camera for flooded voids.

The development of the data analysis systems to obtain direct results like cross section and also obtain a direct geo-referenced 3D point cloud to fit into existing GIS is based on field's tests in old shallow mines.

1. STATE OF THE ART

European mining industries and local authorities are dealing with risks and harmful effects due to underground extraction sites. After mine closure, in the "post-mining" period, mining sites may indeed generate consequences that may affect people and goods located in the vicinity of mining works.

One of the main issues is linked with mining works located near the surface (< 100 m). This is notably due to the fact that shallow works often correspond to very old mining period with very high sensitivity to long term mechanical stability. Today, these disused mines may become dangerous.

Currently, most of the systems used to inspect old mine shafts or underground cavities which can be reached by borehole are based on modified video cameras for water wells.

Their most important drawbacks are:

- An important electrical consumption due to lighting
- The weight of the system for deep shafts (which implies to fix it in a vehicle)
- A low viewing distance
- Low quality of video and pictures

[1] MISSTER : MIne Shafts : improving Security and new Tools for the Evaluation of Risks.

- No possibility to target upward with camera

To estimate size and orientation of the underground voids, actual systems are based on manual measures, 3D Laser scanning systems in dry voids or sonar in flooded voids.

Their most important drawbacks are:

- implementation difficulties for 3D Laser systems and sonar
- Only punctual measures for manuals systems

Thus, to obtain a complete state of a void, different systems are required what increases length and inspections costs.

This developed tool does not replace high accurate systems like 3D scanners which product high density point cloud (with thousands of measure points) but must be specific enough for a good initial diagnosis of an underground void or shaft stability.

2. MAIN CHARACTERISTICS OF THE PRODUCT

INERIS has developed a specific camera to face with problems of characterization and localization of old underground cavities or old mine shaft when a direct inspection is not possible or is difficult for safety reasons. This camera can reach cavities from the surface through a borehole or can inspect directly the inside body of shafts.

The objective of INERIS was to develop a multipurpose tool suitable in most of the shallow cavities we have to inspect.

The general specifications of the product were:

- Built in 3 parts (cameras, winder on a trolley, remote control unit) to be transportable in a small van, the total weight is less than 100 kg
- Based on two interchangeable cameras (for dry and flooded voids)
- Can be used directly on its own wheel (photo 1), usable in a house in case of inspection of a shaft underneath a house, (the trolley of the winder was built to get through in standard house door)
- Implementation by one or two no specialist operator
- Independent power supply (small generator, 2000 VA)
- Cameras had to be waterproof, dustproof and shockproof

The system had to be able to product videos, pictures, punctual manual measures, and automatic measure cycles to establish cross sections, profiles and contour lines as well as estimate volume of the void in dry cavities.

Most of the shallow cavities INERIS has to inspect are situated in metallic ores or stone quarries which are rarely concerned by the risks of explosion and inflammation of gas mine.

Thus, the orientation of the probe is fixed by a gyroscopic device to face with the problem of the use of a magnetic compass in metallic ores and it was not built to operate in explosive atmosphere.

3. SPECIFICATIONS OF THE CAMERAS

The first camera (photo 1) is built to work in dry condition or in accidental immersion (<100 kPa). It requires a drilling of 125 mm diameter.

Photo 1 - camera for dry voids

The lightening is composed of 12 ultra high intensity white LED fixed in the body of the camera. The rotating head can move in 360° in the azimutal plane and 155° in elevation (zenith). The head position is located in three directions in reference with the body camera by pitch and roll sensors and a gyroscopic device. The video camera and the laser distance meter are situated in the rotating head.

The second camera (photo 2) is built to work in flooded condition (max <14 kPa) like in some old mine shafts. It requires a drilling of 100 mm diameter.

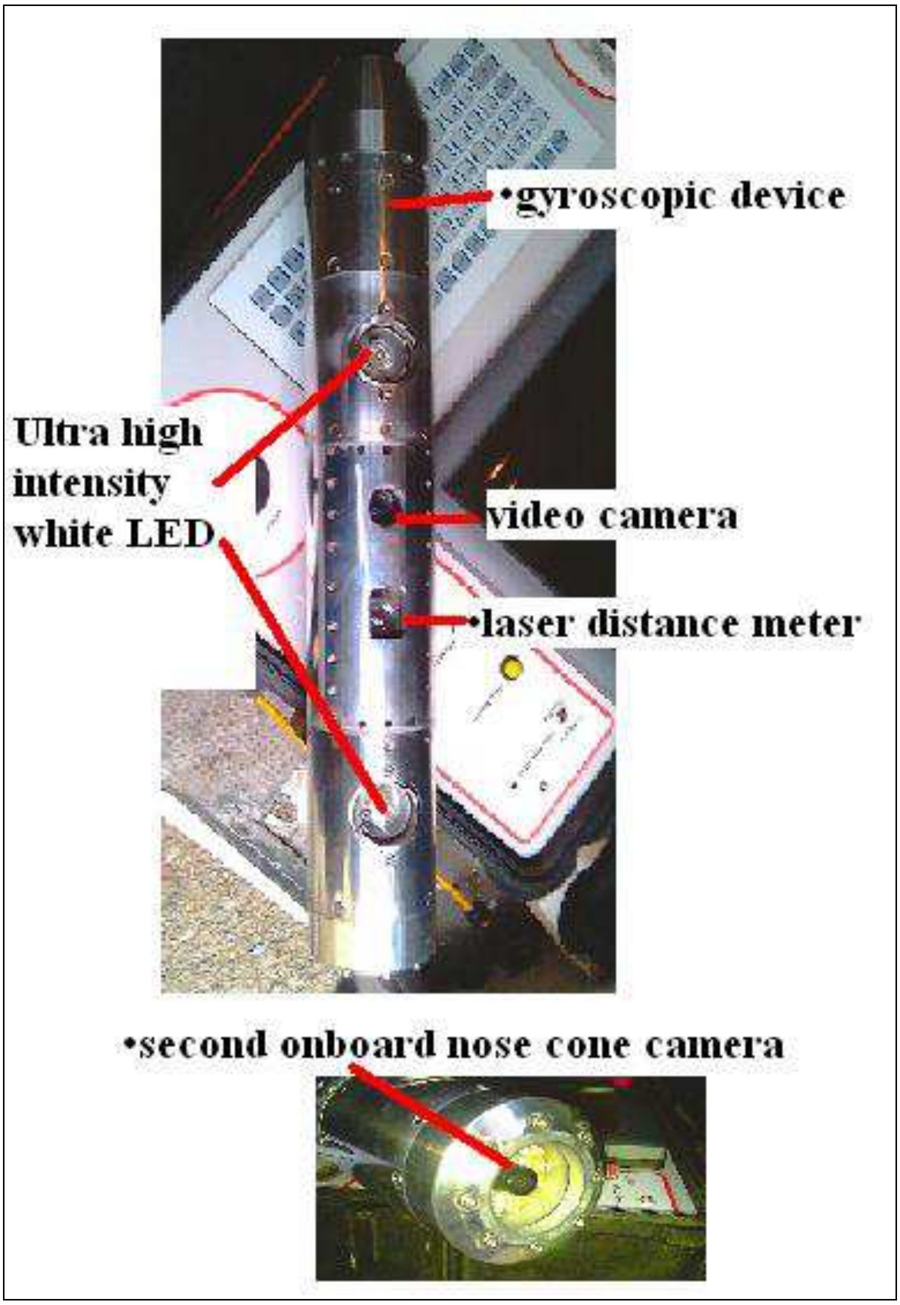

Photo 2 - camera for flooded voids

The body of the camera is totally cylindrical. The rotation of the head in only an azimutal plane (360°) is located in direction in reference with the camera's body and by a gyroscopic device. The video camera and the laser distance meter are situated in the rotating head between 2 directives ultra high intensity white LED.

A second onboard nose cone camera used to view the borehole with an additional white LED light source is situated in the front of the body.

4. USE CONDITIONS

The first case is the inspection of cavities and shaft from the surface to 140 m deep when the winder is directly at the top of the shaft (photos 3 and 4) or at the top of a borehole (photos 5 and 6).

Photos 3 and 4: two examples of inspection of a shaft directly from the winder on its wheels

Photo 5 - inspection of a cavity through a 200 mm diameter nude borehole directly from the van

Photo 6 - inspection of a cavity through a 140 mm diameter tubed borehole directly from the van

The second case is by using a suspended pulley or a tripod to guide the probe in the center of a larger shaft or when the shaft or the borehole cannot be reached with the van or the trolley.

When the use of a tripod (photo 7) or a deviation pulley is needed, the reachable depth is directly affected by the distance between the winder and the centering system.

Photos 7 and 8 - Inspection of an inclinated shaft through a 125 mm diameter borehole, the distance between the winder (in the van) and the tripod is about 80 m.

5. EVALUATION OF THE OPTIMAL OR ACCEPTABLE WORKING CONDITION OF THE PROBE

In all case, the minimum access size of a void is 100 mm. The maximum depth which can be reached is about 140 m.

When the diameter of the access in the shaft or in a void is more than 140 mm and the void is dry, the system (based on camera 1) is able to product video and pictures, manual laser measures and automatic laser measures (3D point-cloud).

When the diameter of the access is between 100 and 140 mm and the void is dry, the system (based on camera 2) is able to product video and pictures and manual laser measures in an azimutal plan.

For an access between 100 and 140 mm and a flooded void, the system (based on camera 2) is only able to product video and pictures.

The depth of the void is established by a mechanical counter, coupled with an electronic counter which measures the length of cable paid out by the winder. The 0 value of the depth counter is fixed by the operator. If the winder cannot be positioned on the top of the void, the reachable depth is directly affected by the distance between the winder and the centring system.

6. DATA AND VIDEO ANALYSIS

Using the control software, the operator can produce a full report during inspection. Whenever an anomaly is encountered, he can choose a description of the fault from the list proposed (to which he can make additions according to his particular needs). A digital photograph (photos 9 and 10) of the void is then taken automatically by the video acquisition card and printed in the report.

Photos 9– example of digital picture taken by the acquisition card

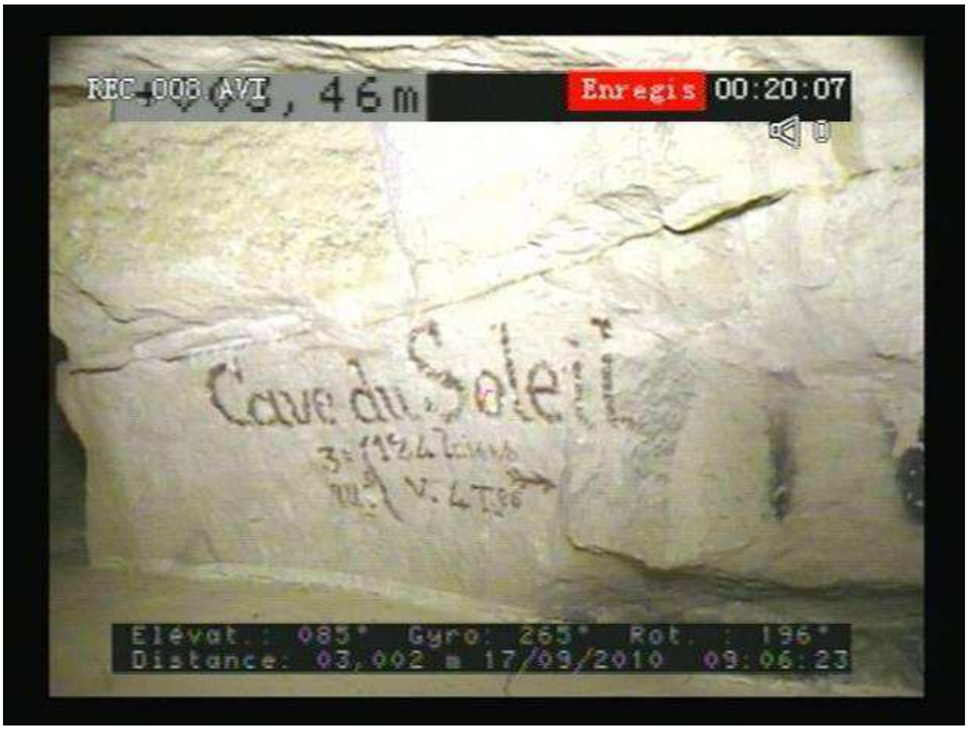

Photo 10 – example of digital picture taken by the acquisition card

The second part of the software is built to automate measure cycles (max 1800 measuring points at each cycle) of the laser distance meter (figure 1). This 3D scanning process products a data file containing series of 3D coordinates, what we call a 3D point cloud.

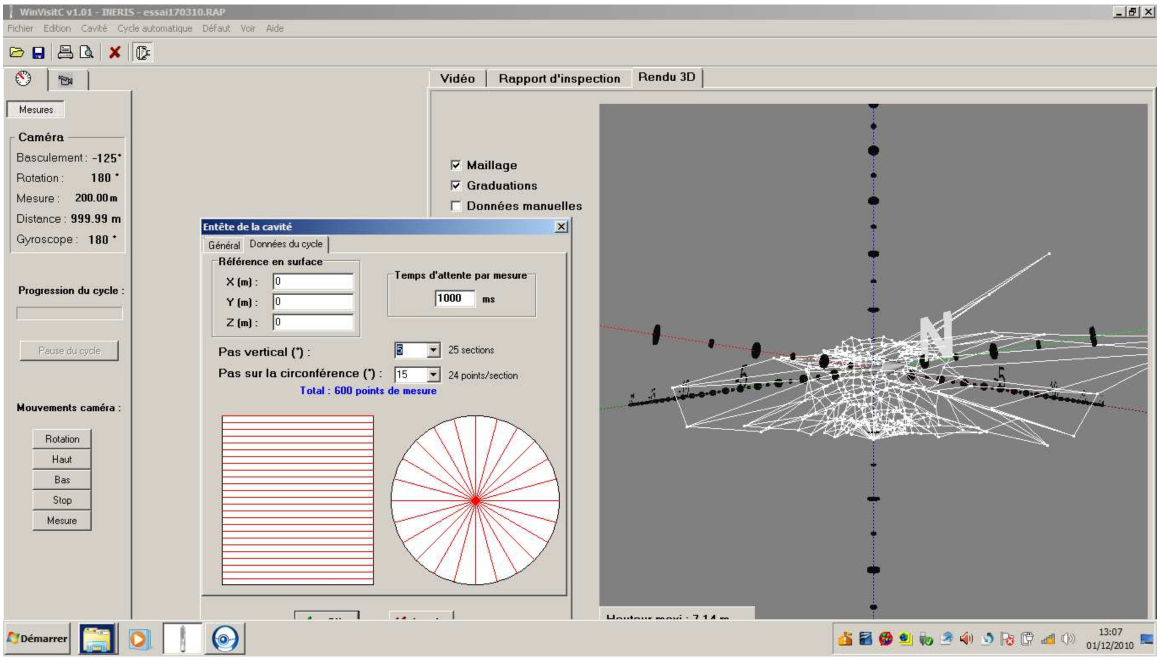

Figure 1 – remote control software

A 3D point cloud of less than 10 000 points cannot be correctly exploited in specific 3D analysis softwares like Polyworks®(InnovMetric Software). In any case, the use of such specific software requires particular abilities.

Our objective was to make visualization and analysis in GIS. Currently, the 3D point cloud is exported in software like ENCOM DISCOVER 3D® (figure 2) and MAPINFO® (figure 3).

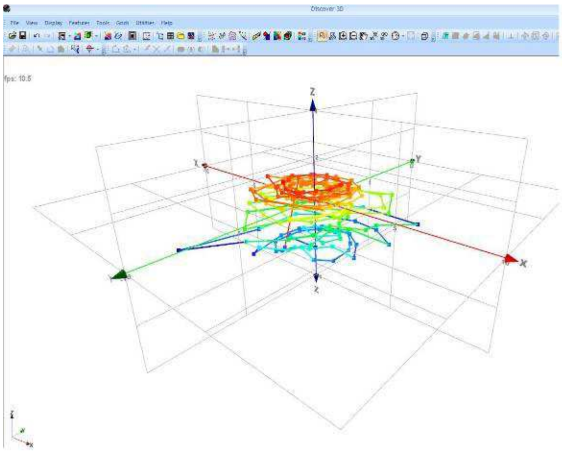

Figure 2 – analysis of point cloud in DISCOVER 3D

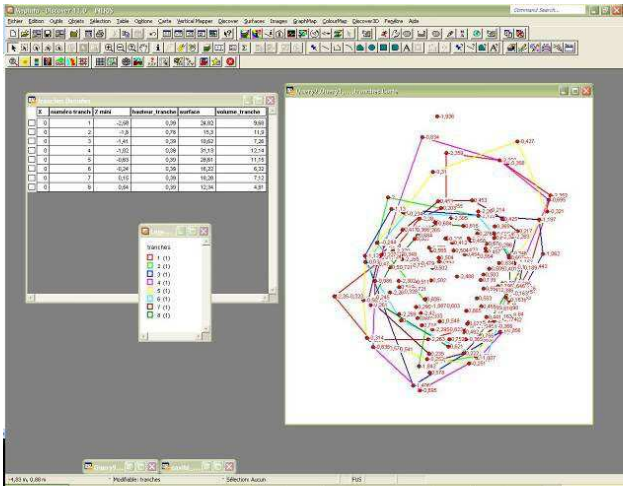

Figure 3 – evaluation of the sizes of the void in MAPINFO

Finally, after positioning of the borehole or the shaft with GPS, the result is projected directly on a map in the GIS to verify the goods on surface situated in the vicinity it can be also used to product hazard and risk map.

7. <u>FIELD TESTS: EVOLUTIONS OF THE SYSTEM</u>

The current developments are carried out along two axes.

The first part of development concern old shaft characterization.

7.1 SHAFTS CHARACTERISATION

Tests are realized in the state of MISSTER project. It is a European Project within the framework of RFCS (Research Fund for Coal & Steel). It is a three years research project that aims to develop innovative cost-effective tools to:

- Enhance the understanding of hazards that may affect mining shafts
- Optimize safety conditions for active shafts maintenance and disused shaft treatments

The project partners include research institutes, universities and mining companies from France (INERIS), United Kingdom (University of Nottingham and Mines Rescue), Poland (Central Mining Institute (GIG) and Kompania Węglowa (KWSA)), Germany (DMT) and Spain (GEOCONTROL).

The actual developments are part of a work package including INERIS, GIG and KWSA whose objectives are the design, the construction and field's test of probes, to deal with the characterizations of old mine shafts.

These tests are at the time in progress and are based on the second camera.

The second part of the development concern INERIS activities to face with problems of old abandoned shallow mines mainly with the estimations of the sizes and volumes of voids.

7.2 OLD SHALLOW MINES CHARACTERISATION

In these cases the voids are generally reachable by a borehole.

The current development based on field's tests of the data analysis systems aims to obtain direct results like cross section and also direct geo-referenced 3D point cloud to fit into existing GIS directly by the operator.

The first results of the field's tests of our camera were not in accordance with our expectations because of the swaying of the camera due to inertia during automatic rotation in a void. The maximum number of point measured was only 800 and not 1800 as predicted.

The solution could be to create a new type of cycle to increase the number of 3D point.

In order to solve this problem, the proposal is to change the automatic measure cycle. In present, the unfolding of a measure cycle is:

- The elevation is fixed at one value (increment each 5°)
- Measure during a 360° rotation of the head (the head need to be stop at each measure)

The modifications of the software are based on the observation of inertia of the head of the camera during a measure cycle.

The new measure cycle we propose is the following:

- The rotation (azimutal) is fixed each 3 or 5°
- Measure during the elevation of the head (increment each 3 or 5°)

A manual measure cycle will also be developed in order to product a point cloud based on manual pointing of the rotating head of the camera.

This version is currently in development and will be tested in April or May 2012.

Somme other modifications resulting from the field's tests are proposed. For example, the addition of a stabilized power device in order to protect data acquisition in case of loss of the electric power supply by.