THE USE OF LASER SCANNER WITH OTHERS SURVEY TOOLS

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Abstract. *The three-dimensional images has often been used in various industries such as oil and gas, mining, construction, geo-spatial, etc.. These are the result of the use of CAD technology combined with the technology of measurement and survey. Traditionally, teams of surveyors go to the area with measurement tapes and calculators to do 2D drawings to study further, sometimes putting the surveyors in dangerous situations and take a lot of time. But news methods were developed, like total stations and GPS. Nowadays, the most modern methods are the laser scanner. Always new technologies appear, some people speculate if the other ones will disappear. However, like all methods, the laser has advantages and disadvantages. This disadvantages can be solved using other methods simultaneously. This work going to study the use of laser scans with others survey methods*

***Keywords**:* CAD; Reverse Engineering; Laser Scan; Survey

1. INTRODUCTION

The three-dimensional images has often been used in various industries such as oil and gas, mining, construction, geo-spatial, etc.. These are the result of the use of CAD technology combined with the technology of measurement and survey**.** Traditionally, the team of inspectors through the area using a measuring tape and theodolites to measure or to capture data of existing conditions in the built or natural environment. These data are allocated to projects that update the 2D drawings of the plant for further studies. Sometimes it takes a long time, and exposes operators to hazardous conditions. In the last century, several technologies have emerged, facilitating the operations of three-dimensional mapping of points. The choice of technology for survey of points to be used depends on the characteristics of the site, the desired precision and cost, among others. The use of GPS, techniques of photogrammetry, total station and more recently, the laser scanner, simplify the process, saving time, increasing the accuracy of the measures and in the case of GPS allowing the location georeferenced studied. The photogrammetry (and Aerial Photography for large areas) also has the advantage of using images of any format, including not photogrammetric cameras. At the forefront of the process is the laser scanner, which has the greater accuracy and less time for data collection.

Whenever a new technology emerges, some people speculate that the technology will disappear or earlier if the new technology will actually replace the old. For the laser scanner, it was observed that this is not happening, new techniques and methods have been incorporated, to assist the measurements. New technologies have been integrated to the device, such as GPS and digital cameras with high resolution, minimizing weaknesses of technology 3D Laser Scanner (LS3D). This article will detail the use of these technologies, their advantages and disadvantages, and the possibility of integrated use.

2. SURVEY TECHNOLOGIES

There are many technologies that are used to survey. Before discuss of the possibility of integrated use of them, this work going to present a brief description of these technologies together with some applications.

2.1 Survey with theodolites and measuring tape

One of the oldest methods used for the survey of three-dimensional data is the direct method, i.e. through the use of measuring tape and topographic equipments like theodolites (Rodrigo et al., 2006). This method involves stop of production units, large amount of time to survey of points and exposure of operators to security risks, as well as the presence of errors derived from the measurement procedure. It consists of measurements of horizontal distances with a tape measure (Figure 1) and horizontal angles with the theodolites.

Figure 1. Tape measure

The forms, sizes and arrangement of details should be faithfully represented in the plant. It is extremely important determine in the field, the position of points which defines the planimetry of ground and those who will represent the elevations.

A series of preliminary operations are necessary during the implementation of a topographic survey. These can be summarized into 3 stages: recognition of the area, a polygonal survey and details of the plant (UFSC, 2004).

These steps take time and can cause problems such as the interruption of local activities and an exhibition of inspectors to situations of risk. In industrial plants, it is often necessary to measure a large and complex pipelines, which among other things, may be operating at high temperatures or at high altitudes.

2.2 Total Station

Total Station or tachometer is an electronic instrument used to measure angles and distances. The development of instruments for measuring angles and distances as a result brought the emergence of this new instrument, which can be explained as the coupling of the electronic digital theodolite with electronic distanciometer, assembled in one block (Wikipedia, 2009).

The total station is also capable of storing data collected and run some calculations even in the field. With the aid of trigonometry, the angles and distances obtained can be used to calculate the coordinates of the current positions (X, Y and Z) of the items examined, or the position of instruments in relation to known points, in absolute terms. Information can be sent from theodolite to a computer and application software will generate a map of the area.

The Total Station (Figure 2) measuring angles using electro-optical scanner for extreme accuracy of digital bar codes attached to glass cylinders or discs rotating within the instrument. The Total Stations are better able to measure angles below 0.5 ´. The typical total station can measure distances accurate to about 0.1 mm, but most applications require precision of 1.0 mm. Some can measure distances up to kilometers, but some do not have reflectors and can measure distances to objects that are distinguished by color, limited to a few hundred meters.

Figure 2. Total Station

Some modern models allow the operator to control the total station remotely. This eliminates the need for an assistant to hold the light reflector on the point to be studied. The operator holds the reflector himself and control the machine from the point observed.

The main advantages of the system are the least time to survey data compared to the theodolite, and greater precision, especially in the vertical axis, compared to the GPS (Affonso, 2002).

Until some time ago, this method also needed the points to be studied were within the line of sight, but the most modern equipment, which comes with integrated GPS, removed this limitation.

2.3 GPS

The Global Positioning System, popularly known as GPS is an american system of satellite positioning, sometimes incorrectly called the navigation system used for determining the position of a receptor on the surface of the Earth or in orbit. This system allows determination of position, velocity and time of any point on Earth's surface or in proximity, for a suitable reference system - center of mass of the earth (Monico, 2000).

Although the techniques for obtaining data on topography has changed significantly over the past decades, with the gradual replacement of measuring tape, theodolites and levels of bubble by distanciometer, total stations and electronic levels, the results of these observations is still reflected in obtain of the horizontal angles, distances and differences in level.

When performing conventional surveying the final product usually results in the graphical representation of the raised area in a coordinate system local level, defined by the executor, or from a local system arbitrary.

With the advent of GPS (Figure 3) we are able to bind the topographic measurements with data obtained by GPS. The final products of the process are georeferenced points, usually tied to the geodetic system.

Figure 3.Uso of GPS in surveying

The survey of points normally begins and ends at known points raised by use of positioning with GPS, and points intermediate are topographically raised from measurements of angles and horizontal distances, usually using Total Station.

The use of GPS provides a series of advantages, since the points to be studied need not be in the line of sight, in addition, the georeferencing is a growing requirement. But its low accuracy in the vertical axis sometimes necessitates the use of other methods. Moreover, GPS depends of the positioning of satellites in orbit. The geometric distribution of satellites ensures that at least 4 GPS satellites are visible anywhere in the land surface, but depending on the time, the distribution may be inadequate, reducing the accuracy of survey.

The system can not prevent this, but there is a factor PDO (diluition of precision) that can be consulted to see if the accuracy is adequate at that time (Santos, 2005). The larger the volume of solid limited by 4 satellites, the higher the accuracy (Figure 5). Until recently the low accuracy in the vertical axis was a limiting factor, but the most modern total stations, mentioned in previous topic, solved this problem.

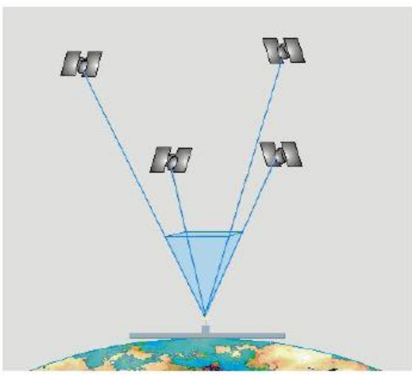


Figure 4. Inadequate disposal

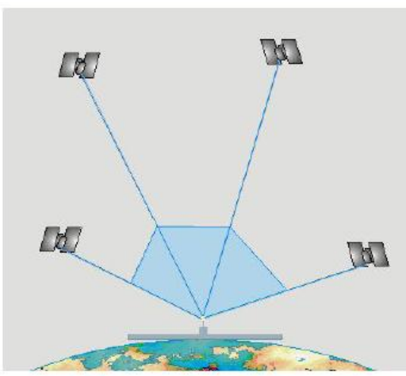


Figure 5. Appropriate provision (Santos, 2005)

2.4 Photogrammetry

The American Society for Photogrammetry and Remote Sensing Photogrammetry define "the art, science and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena (Brito & Coelho, 2002).

The main advantages of this method is the realism of the data, to be used in large areas (with the use of Aerial Photography, Figure 6) and recently, the possibility of using digital cameras, which provide the use of films and lowering the cost facilitating the transport. To join the photo, there must be overlap of adjacent images in the photos. After obtained the photos, the union is done by software.

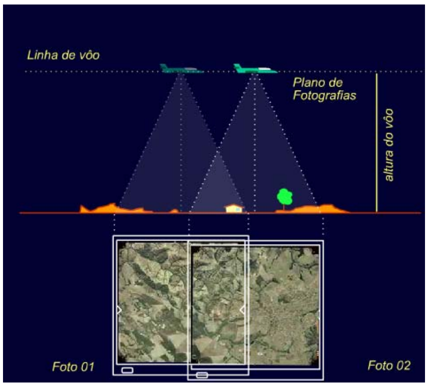


Figure 6. Photos adjacent (IBGE, 2004)

Despite the practicality of the technique, some irregularities may affect the acquisition of images, such as geometric aberrations, affecting the quality or the positioning of objects in the image; chromatic aberration, caused by the decomposition of light, distribution of the focal plane, the dark corners of image, atmospheric effects, as sunny days, causing the appearance of shadows and humidity that reduces the contrast of the final image (Brito & Coelho, 2002).

The photogrammetry can be used with other techniques, for example, discuss the case studies, the use of airbone laser scanner linked to the technique of Aerial Photography.

2.5 3D Laser Scanner (LS3D)

The scanning laser works as a remote sensor that from an optical system - mechanical emits pulses toward a target (Dalmonin & Santos, 2004). Based on the time of return and the direction of the target is possible to calculate the coordinates X, Y and Z of points scanned. Quickly the process generates a three dimensional cloud of points that can be conferred even on the field. The technology LS3D is classified according to the method of measurement, as shown in Figure 7.

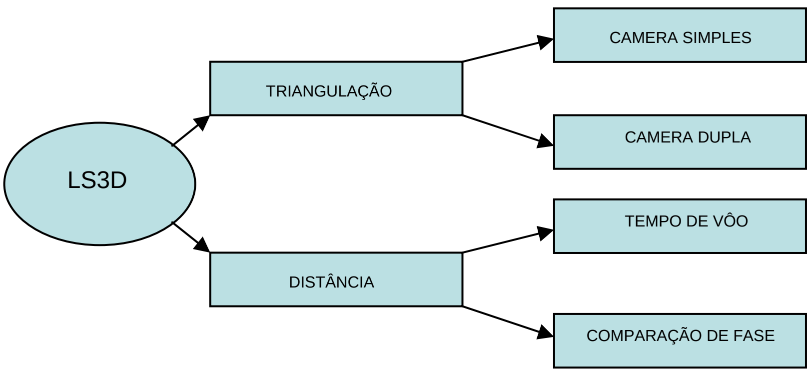


Figure 7. Principles of operation. (Oliveira & Lima, 2008)

Method of Measurement by triangulation: The device that makes the survey has at least one transmitter and a sensor. Known the geometry of the target and layout can be getting the cloud of points. The amount of CCD sensors (Charge Coupled Device) is what differentiates the methods of single or dual camera. This type of system is suitable for reconstruction of small objects or with many details (such as statues and sculptures) and maximum range of operation depends on the base between the laser sensor and CCD sensor (Kaspar, 2004);

Method of measuring the distance: used for mapping large areas. This method is divided in time of flight or path of the laser pulse and the phase comparison.

The method of time of flight means that a counter is started after the emission of an electromagnetic pulse. The pulse is reflected by the object and returns to the receiver while the counter stops counting. Thus, knowing the speed of propagation of the signal it is possible to determine the two distances, and return of the laser pulse (Tommaselli, 2004).

The method from comparison of phase uses the variations of the wave emitted laser to perform the measurements. The distance of the equipment to the object is measured precisely by comparing phases of the waves sent by the equipment (Kaspar, 2004).

Its main advantages are the time of data survey and the precision, as disadvantages we have the reflectivity of the material (i.e. plaster and black objects are not perfectly located) (Jacobs, 2005).

After completing the three-dimensional survey, the clouds of points are treated in computers to be viewed. These clouds can be treated by CAD software, facilitating the application of modern engineering techniques, such as reverse engineering and making the file interchangeable, since the CAD files can be modified by various programs (Oliveira & Lima, 2008). To increase the realism, it can override the photos in the cloud of points.

3 INTEGRATED TECHNOLOGIES FOR USE WITH LASER SCANNER

As shown previously, the various survey methods have different advantages and disadvantages. There are several ways to resolve or minimize them, like the integration of GPS with total station. Nowadays, some modern tools have been manufacturing with internal GPS, allowing the geoprocessing. Several manufacturers of Laser Scanners have models in their catalogs with this facility. Furthermore, it is important to emphasize that in applications involving use of aircraft (in applications of altimetry with LS3D or Aerial Photography), GPS is used as a guide (Silva, 2008). The images obtained by LS3D technology can be used with CAD technologies, which allow a good visualization and subsequent interpretation of data. If you need a more realistic picture, the LS3D can be used in conjunction with photogrammetry. The pictures obtained are superimposed with the cloud of points obtained by laser, giving each point the color of the corresponding pixel in the picture. Below we discuss some case studies.

3.1 Using Laser Scan with image

During years of operation the plants suffer a series of changes that are multidisciplinary (mechanical, electrical, instrumentation, etc.), which often are not recorded in its technical documentation, generating high rates of rework, high maintenance costs and reduce the levels security (Oliveira & Lima, 2008). This lack of information difficult the repair operations or replacement of defective parts.

To document these parts or rebuild, you must obtain the updated drawings of the plants. Traditionally the team of inspectors through the industrial units using a measuring tape and theodolites to get data. But news methods based on laser technology were developed, like total stations and Laser Scanner.

In our case, we use the 3D Laser Scanner in order to collect data quickly and efficiently. The capture of data occurs without physical contact between the instrument and the objects reducing the operator's exposure to hazardous conditions. To increase the realism and help the CAD modeling, it can override the photos in the cloud of points.

3.1.1 Area of study

Laboratory of measurement evaluation in oil (LAMP, shown in figure 8), is located on the campus of UFRN in the Lagoa Nova neighborhood (Natal / RN). The function of the laboratory is doing research in the area of automatic measurement of flow and BS & W (Basic sediments and Water).

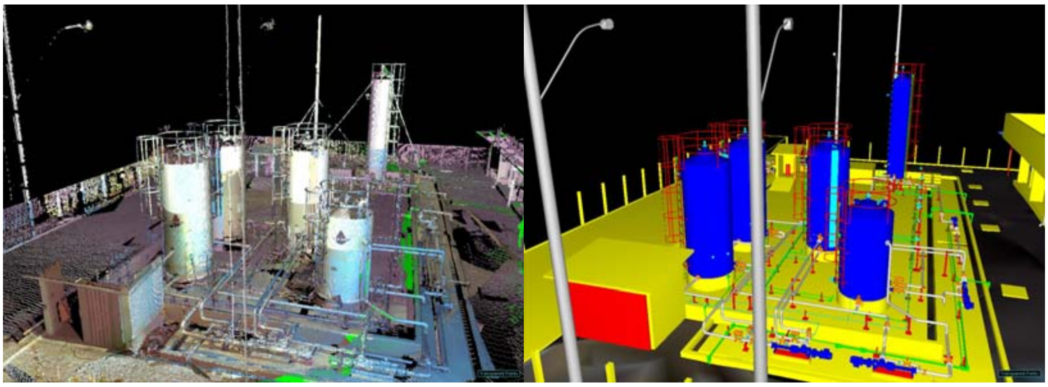
Figure 8. tanks of the LAMP

3.1.2 Method

The method used consisted of scanning the area and later in the overlap of the photos in the cloud of points. Before starting data acquisition, it should prepare a work plan, defining the locations where they will put the foundations of the scanner and the targets used for union of the cloud of points obtained by different bases.

Measurements were then made with certain precautions, such how to prevent the transit of people on site. While the laser is able to remove mobile barriers (cars, pedestrians, leaves, etc.) during measurements, the photos should be taken without this interference.

The figure 9 shows the cloud of points modeled in CAD software and figure 8 the point cloud obtained by the color picture (Oliveira & Lima, 2008).



Figures 8 and 9. Images of the point cloud with true colors and the CAD file obtained after scanning the LAMP

3.1.3 Discussions

The LS3D is a viable alternative in some situations where a high level of details is required for complex geometries and/or congested areas. For example, if the objective is to document the existing conditions in a process plant with many pipes and objects so that it is possible to locate all pipes and equipments, the using of LS3D to get the data would be more viable than traditional survey methods which gather data one point at time.

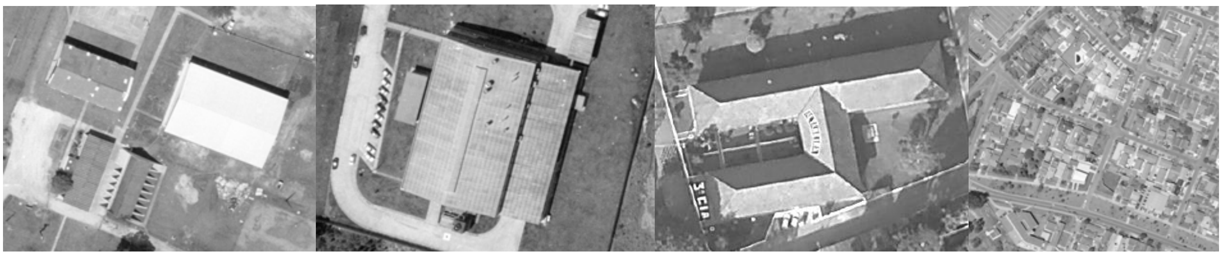
3.2 Using Laser scanner and high spatial resolution orbital image

Currently, the three-dimensional modeling of buildings has allowed the development of essential products to the activities of engineering devoted to urban planning. The data from airborne laser scanner system has been used for this modeling to explore the big amount of three-dimensional points collected in its survey. The problems pertaining to the three-dimensional modeling of buildings are related to the majority of buildings that have complex roofs. In general, it appears that the identification of the roof bounds don't have automatic efficient solution. The extraction of trees using only the laser scanner data is another difficulty that has been made by researchers (Botelho, 2007). One possibility of resolving this and other problems is the combined use of data from airborne laser scanner and infrared spectral bands of satellite imagery of high spatial resolution. The use of a data source alone - laser scanner or spectral images - don't result in products that supply all the needs of professional producers of Geoinformation (cartographers, public and private managers, agents, tourism, etc.). To solve this lack of information, it's necessary the use of two or more sources, for example, the laser scanner system, which has a limitation on the values of intensity, this problem can be solved with the orbital images that have a better spectral resolution.

As previously mentioned, there isn't an efficient automatic solution to these problems using only the laser, but some researchers propose different methods (based on complex algorithms) with the use of data from both technologies. Among other benefits, the spectral images obtained by photos allow separation of buildings and vegetation.

3.2.1 Area of study

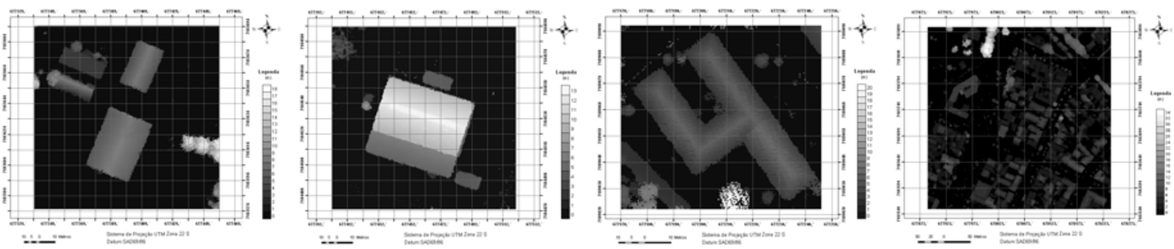
To represent situations of everyday urban, Botelho (2007) selected four areas of study. The first and second area are within the campus of UFPR, Jardim das Americas neighborhood and Botanical Garden (Curitiba/PR), that facilitates the verification of the survey method used, because there are data from direct measurement. The feature of the first area is four buildings with isolated and well defined edges, the second one was selected to characterize the combination of buildings, the third area is the buildings that have different edges and the last area is located in Jardim das Americas neighborhood, near the campus of Centro Politécnico UFPR. These areas can be seen in Figures 10 to 13.



Figures 10, 11, 12 and 13. Selected areas (Botelho, 2007)

3.2.2 Method

The methodology used (Botelho 2007) consisted of: pre-process the cloud of points of the laser scanner, making an interpolated regular grid with the height of objects, drawing and labelling the edges of these objects so that the buildings become representative when compared to a real; separate the buildings from vegetation, using for this the band infrared image orbital; create vectors of buildings to find their edges and to model the building through the three-dimensional points that represent the ends of the ridge and corners. The DMS (Digital Surface Model) of the 4 areas can be seen in Figures 14 to 17.



Figures 14, 15, 16 and 17. DMS of the 4 areas studied (Botelho, 2007)

3.2.3 Discussions

The edges are not defined by the laser because the beam emitted can reach the edges of buildings or other objects, requiring the assistance of another complementary method. The photogrammetry complements the data of the laser, increasing the realism and facilitates understanding of data.

3.3 Rodovia SC-414

The roads are a category of applications that deeply affect the development and planning, interfering in the environment both in its construction phase, as during the operation. The precise knowledge of the environmental conditions of the area where the highway will be located is a determining factor in the quality of road project in both technical and environmental (Schafer, 2004).

Over the decades it has been used techniques of photogrammetry for this purpose, but with the appearance of laser scanner made it possible to obtain data more accurate and complete.

The aerial photogrammetry has been used for preliminary studies in the construction of roads since the decade of 50. With the introduction of new techniques such as color film from the 80s, appeared new advantages, such as:

- The ability to examine large areas of land ensures that it will be less likely to be neglected the best local to build the highway;
- A complete inventory of all the features of the land surface in a certain place and at a right time can be provided;
- Shapes and cuts the section of road can be developed without invading private property. Therefore, owners don't suffer disorders and evaluation of the land isn't affected during the investigation of leasing the road.

With the advent of modern digital photographic cameras, the process was even faster, but there was a drop in the quality of the images (Schäfer, 2004).

The use of the airborne laser scanner in the process, the mapping of the irregularities on the surface was facilitated thanks to the precision and speed the process. The aircraft can fly along the route of the highway, resulting only in the mapping of areas of interest and providing a digital map of ground with high spatial resolution, capturing information on pavement, drainage system and vegetation.

3.3.1 Area of study

The area discussed (Schafer's 2004) in this case is located in the state of Santa Catarina, in an area where studies have been performed to deploy a new highway (SC-414), aiming to join the SC 413 and BR 470 (Figure 18).

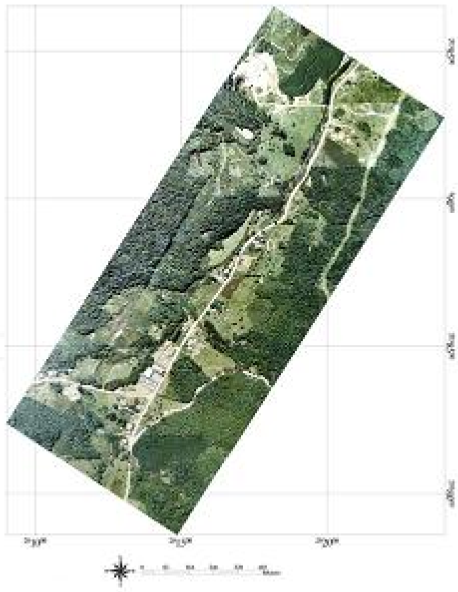


Figure 18. Area orthophoto mosaic (Schafer, 2004)

3.3.2 Generation of digital terrain model (DTM) and digital elevation model (DEM)

The contours derived from a TDM only with points Laser Scanner geomorphologic are poor in detail (Kraus & Pfeifer, 1998). The contours produced from a low quality geomorphological MDT show, even with the implementation of filtering and rating. Even by applying filtering and classification, the contours derived from a MDT have a low quality. The solution found by Schafer to generate a DTM that describe in more approximate the area of study was to generate three MDTs subsequent visual comparison and choose the most appropriate: from the level curves of the refund aerophotogrametric; Laser Scanner point cloud; and Laser Scanner points with the addition of breaklines transformed into vectors in aerophotogrametric refund. The data of the laser was not used in the DEM. DEM and MDT models can be seen in Figures 19 and 20.

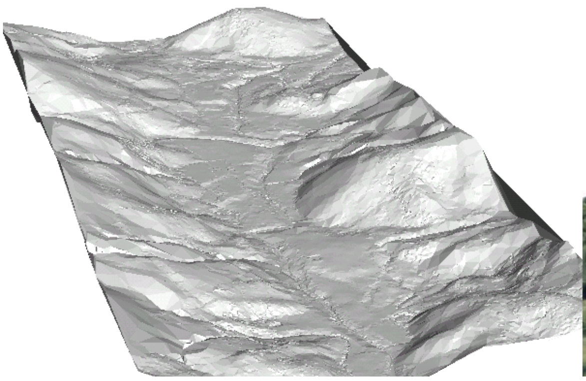


Figure 19. DTM

Figure 20. MDE plus orthophotos mosaic

3.3.3 Method

Having chosen the company that would make the survey data, several steps were performed in parallel (field-work, mosaic of orthophotos, the point cloud acquired with laser and aerophotogrametric recovery) to finish the work in the shortest time possible. The mosaic of orthophotos (treated for viewing photos orthogonal, ie no effect of perspective), was used for the creation of MDT / DEM with simulation of highway SC-414 and 3D visualization. The point cloud treated to create the model MDT / DEM. After joining the data of the refund aerophotogrametric, the elements of natural and artificial ground was added, allowing the creation of maps of slope. After the overlap of all data, it was possible to create a file with the current use of land (obtained in the fieldwork), registration technical, DEM / DTM and slope.

3.3.4 Discussions

The use of laser has an economy of time and increase the precision of the process, but the individual use of technology does not solve all problems, and also presents flaws characteristics such as reflection of the beams emitted in water depths. The junction with the photogrammetry allowed a better study of the conditions of ground, more realistic images and it is a known technology since the 50's, making it easy to find experienced professionals in the business. Moreover, without the use of GPS would not be possible to perform aerial measurements.

4 CONCLUSION

The laser is the most modern technology in the survey of points, achieving levels of accuracy and time better than the other methods, the possibility of remote use increases the levels of security, avoiding exposing professionals to risk situations. Still, as seen in previous examples, this method still has defects, that need the help of other methods. The union with photogrammetry is of fundamental importance for the realism achieved by facilitating the understanding of the public. Furthermore, with the increasing need for integration of data, not just the laser, but all other technologies for the survey of points to look for integration with GPS, allowing the georeferenced data. The GPS is also key to lifting operations using aircraft such as the Aerial Photography and airborne laser scanner. From these data it is clear the trend of full use of technology without replacing the oldest.

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