APPLICATION OF AIRBORNE LASER SCANNING IN HIGWAY ENGINEERING PROJECTS IN BRAZIL

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ABSTRACT:

Laser Altimetry, more referred in the commercial sector as LIDAR (Light Detection and Ranging) mapping, is establishing as a common operational tool in the fields of mapping, remote sensing and fotogrametry. LIDAR can to generate quickly dense and accurate digital terrain model. For applications that need digital terrain models with high density and accuracy, as in projects of highway engineering, LIDAR offers only technical capacities, it reduces costs of field operations, and reduces the time of post-processing work if compared to traditional survey methods. Recently it was accomplished in Brazil one of the first surveying for application in projects of implantation of highways using that new technology. This survey was made in a corridor with approximately 22 Km by 0,75 Km in a rural area. Also in that project, a mosaic was generated obtained from ortophotos with the purpose of facilitating the extraction of terrain characteristics. The present paper tells the application of LIDAR data obtained in that project and of ortophotos mosaic in a pioneering project of engineering higway in Brazil. In the made study, it was chosen a stretch with approximately 1,8 Km by 0,75 Km to investigate the applications of products to lidar as DEM and DTM and ortophotos mosaic for a highway project. The direct influence area was evaluated from the highway to be implanted, considering the environmental aspects directly affected for the implantation of the work.

1 INTRODUCTION

To warrant effective attendance of environmental requirements an highway enterprise should be managed according to a system structured that it considers, integrate and articulate all environmental elements, in all activities and technical operations. Thus, there are need of territory physical knowledge, of property and of socioeconomic subjects, because these are fundamental for several studies realized (topographical, environmental, hydrologic, geometric project, of earthwork, drainage and of paving) for a highway implantation project.

In this context, is perceived the importance of detailed knowledge of area where can come to be implanted a highway so that it can alter minimum possible the ambient and to avoid highway operacionality risks. Modern techniques of remote sensing provide the place knowledge and bring subsidies for project realization facilitating hysical knowledge of area where the highway will be implanted. The use of aerial photographies in highway implantation projects is a well accepts practice in highway engineering. The large scale aerial photographies are important in preliminary stages and in final phase of a surveying, because they provide a vision of area showing existent conditions in a particular moment. To observe in them the surface elements and, with that, to establish the relationship among geology, cultural and invironmental factors, is important for assessments of engineering project impacts in environment.

An important product for highway engineering projects that can be obtained from aerial photographies and of photogrammetry is the Digital Terrain Model (DTM). At first DTM was used for the determination of cut-and-fill volumes in earthworks, and nowadays it is used in highway project. Besides, terrain modelling techniques can also be used to create digital models of highway proposed project. Possibility to combine the project and terrain models propitiates a more realist visualization that highway implantation impact can cause in environment.

The technological evolution happened in last decades brought new means of acquiring terrain information, as Airborne Laser Scanning, also known by LIDAR (Light Detection and Ranging). With this technology, it is had an alternative for DTM acquisition. With data acquisition using LIDAR make possible DTM generation in few days, accurately of decimeters, the that mean advantages for higway implantation projects. when compared to traditional DTM obtaining methods. LIDAR also makes possible the construction of Digital Surface Model(DSM).

Same being a great use possibilities presents technology highway projects mapping for projects rodoviários, besides being taken into account the environmental subject, is still small the researches in world that allow a larger LIDAR technology knowledge and of your possible applications. Thus, this study aim at to contribute for a) LIDAR technology, and b) the evaluation of your utilization, making use of LIDAR products, of orthophotos mosaic and of both integration for the thematic analysis of a highway stretch.

2 AREA OF STUDY

The study area comprehend a strip of approximately 1700m of length for 750m of width and it is located in Luís Alves-SC-Brasil municipal district. The new projected highway will have 22 km of length approximately and it will unite sections in growing economical activity to the interligar the paved highways SC-413 to north and BR-470 to south of projected connection. Figure 1 show orthophotos mosaic of study area.

Figure 1 – Orthophotos mosaic of study area.

3 METHODOLOGY

Thus, this study aim at to contribute for a) LIDAR technology, and b) the evaluation of your utilization. For this was made use of LIDAR products, of orthophotos mosaic and of both integration for the thematic analysis of a highway stretch. Research available materials were: pos-processed LIDAR products file, flight altitude 1,000m, realized in November of 2002; digitasl ortophoto mosaic, flight scale 1:15,000 and scanerized with 0,40m pixel size realized in March of 2002; aerophotogrammetric retitution in 1:5,000 scale.
Steps developed during the research they are described forward. Therefore after, each one is explained.
3.1 LIDAR data treatment;
3.2 land use surveying using photointerpretation;
3.3 generation of Digital Terrain Model (DTM) and Digital Surface Model (DSM);
3.4 creation of slope map;
3.5 thematic analysis of study area.

3.1 LIDAR data treatment

LIDAR data are in three groups: a) calibration data and installation parameters (obtained before the flight), b) measures of laser distances with your respective scanning angles and c) POS data. Those data are processed and integrated, being obtained at the end of this stage a LIDAR point cloud, traditionally presented three-dimensional coordinates in WGS-84 system and LIDAR pulse registration. To differentiate which information correspond to relief or any other geographical phenomenon or object present in studied surface, is necessary to accomplish a data treatment. In case of this study, treatment was accomplished in three main stages: filtering, classification and manual edition of points cloud.
The filtering and classification definition happens in agreement with objective to be reached and not with employed method. Removal of underisable points is considered a filtering operation. Already the task of finding a specific geometric or statistics structure, as buildings or vegetation, is defined as classification (AXELSSON, 1999). Steep of manual edition was added to data treatment being taken in consideration that the automatic filtering and classification method for own algorithms for this end were not capable to present satisfactory results.
To generate a DTM that represents the bare earth in the closest way of the reality, the correct definition of this surface in LIDAR points cloud is indispensable. This does of treatment a very important task and that influences excessively in DTM final quality.
Figure 2 show the developed flow chart for LIDAR data treatment and each stage explanation in sequence.

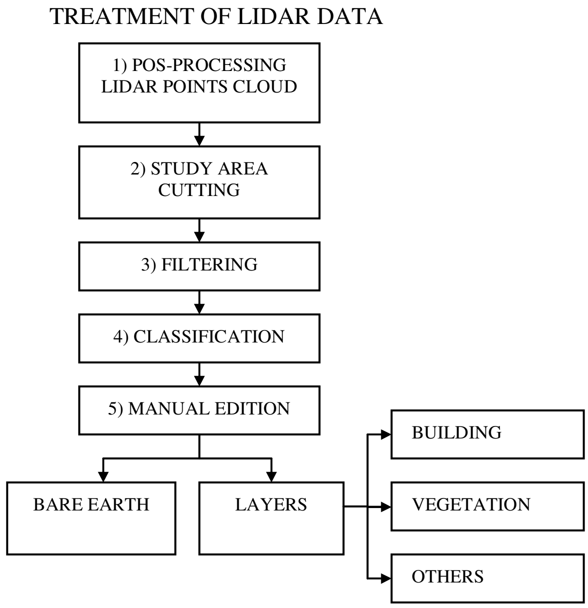

Figure 2. Flow chart of LIDAR data treatment.

Treatment of LIDAR data:
1) Pos-processed LIDAR point clouds: all LIDAR datas Pos-processed are considered properly georreferenciados without filtering or additional analysis.
2) Study area cutting: initially, LIDAR points files were cut out to coincide with orthophotos mosaic that defines direct influence area of environmental impacts. The cutting resulted in a file with 582.407 points.
3) Filtering: an automatic filtragem LIDAR points cloud was accomplished aiming at separating bare earth points and object points. Filtering was made in TerraScan program, that possesses a specific tool for this task. The parameters for tool use (terrain angle, interaction angle and distance) were defined based in result analysis of dozens filtering tests accomplished in study area being used different parameters.
4) Classification: in LIDAR points cloud classification defined in filtering as not belonging to bare earth three layers were created separating principal elements found in study area: vegetation, buildings and others (transmission lines and towers). The main objective of classification went to aid to find points belonging to bare earth that were erroneously defined as objects in the filtering process.
5) Manual edition: in this stage, group of automatically filtered and classified points were analyzed in ArcView GIS. For AXELSSON (1999), in many cases are impossible to LIDAR data interpret unless images are available. The laser points were put upon to LIDAR intensity image and orthophotos mosaic to identify possible erroneously filtered and classified points for

then to correct them. Points that it touch dams were eliminated to avoid that generated mistakes in DTM construction. This was stage that consumed largest amount of LIDAR data processing time. At the end of this stage, it was had the points file that it touch to bare earth and layer point files (vegetation, building and " other ") edited and revised completely. All LIDAR point files were recorded as ASCII X, Y, Z files for they be added later as table in ArcView GIS for DTM and DSM generation.

3.2 Land use surveying using Photointerpretation

Current land use surveying was accomplished with intention of aiding in study area recognition and analysis.
The expression current land use can be understood as form by which space is being busy for the man and land use surveying in certain area, became fundamental to quantify and to understand the organization patterns of human activity on space (DALE & MCLAUGHLIN, 1990).
A preliminary photointerpretation in orthophotos mosaic was accomplished, being delineated land use areas with different aspects. That material served as base for field study.
After field check, it was studied orthophotos mosaic thoroughly, defining and digitizing the interest classes be obtained in photointerpretation. The defined classes were: built area; exposed soil; cultivation areas; pasture; reforestation; dense vegetation; vegetatio; rivers; dams and roads.

3.3 Generation of Digital Terrain Model (DTM) and Digital Surface Model (DSM)

For studies that involve a highway implantation project, a Digital Terrain Model that describes implantation area closest possible of real situation is very important. For KRAUS & PFEIFER (1998), the derived contours of a DTM only with LIDAR points are poor in geomorphologic details. This happens even if filtering and classification are applied.
Three DTMs were generated for subsequent visual comparison and choose of most appropriate: (1) starting from aerophotogrammetric restitution contour lines, (2) starting from LIDAR points and (3) starting from LIDAR points with addition of breaklines digitizing in aerophotogrammetric restitution.
To generate a DTM or DSM in ArcView GIS it was created a TIN (Triangulated Irregular Networking), that presents as characteristic breaklines addition possibility to model.

3.4 Creation of slope maps

Slope Maps were created to make possible a terrain visualization and analysis considering preservation permant areas due to your slope (BRASIL, 1965) and urbanization suitable areas without restrictions (BRASIL, 1979). These last ones were defined due to propensity of high-of-way and highway close areas disordered occupation, what is today a serious social and environmental problem in Brazil.
The slope maps were obtained from LIDAR points edited manually with addition of natural and artificial breaklines.

3.5 Thematic analysis of study area

Thematic analysis in study area was accomplished through the crossing of slope maps, land use maps and highway geometric project. They were followed recommendations of the Environmental Procedures Manual (DER/SC, 1998), being verified, for instance, existence of preservation permanent area; urbanization suitable areas without restrictions and areas be deforested it for highway construction.
The maps crossing was made in digital ambient in a project in ArcView GIS, what made possible an effective analysis of study area.

4. RESULTS

4.1 treatment of LIDAR data

4.1.1 Filtering of LIDAR points

The amount of defined points through filtering, as bare earth, was of 137.701 points, what represents 23,70% of laser points total in area. And were defined as Objects 443.310 points, what represents 76,30% of laser points total in the area.
Filtering problems found they referred mainly to laser pulse reflection pattern in dams, to elements with small height in relation to bare earth (barrages), areas with accentuated slope, adjacent laser strip and linked objects to bare earth (bridges).

4.1.2 Classification of LIDAR points

Besides making possible the separation of point not beloging to bare earth in different layers, classification aided in identification of points defined erroneously in filtering process.
In classification, 8,423 points were defined as building, while 434.887 points were defined as vegetation and transmission lines and towers.
Although the TerraScan classification routines have separated points in different layers, difficulties were found mainly with relationship to buildings classification. Many points that they touch buildings were not classified as such, while other belonging to bare earth and vegetation were defined for software as being buildings. In some buildings (most with roofs presenting little inclination), all the points were correctly classified.

4.1.3 Manual edition of LIDAR points

Figure 3 show the result obtained after LIDAR point filtering, classification and manual edition of part of study area. The defined points as bare earth were represented in orange color, the defined ones as buildings in red color, referring points to transmission lines and towers are represented in purple color and the defined ones as vegetation in green color.

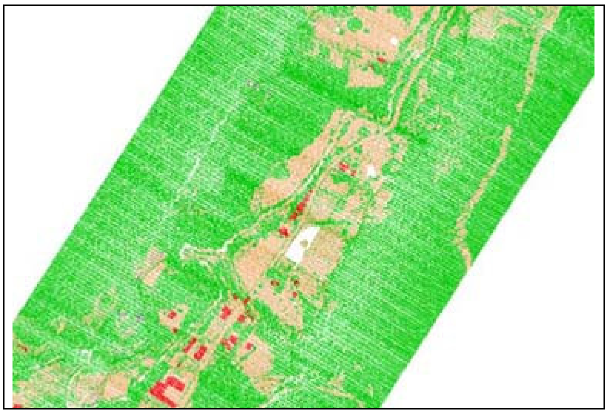

Figure 3. LIDAR points after manual edition.

In table 2 it is had the amount of defined points as bare earth and in different layers before and after manual edition.

Layer	Points before manual edition (1)	Points after manual edition (2)	Number points difference (1-2)	Percentual difference between 1 e 2
Bare earth	137.701	143.470	- 5769	- 4,20
Buildings	8.423	5840	2583	30,67
Vegetati on	434.887	430.515	4372	1,00
Other	-	1186	-	-
Total	581.011	581.011	-	-

Table 2. Comparision between points defined as bare earth and layers befor and after manual edition.

4.2 Land use surveying

Land use surveiyng made in this study is referred to February of 2002, period of aerial photographies taking.
Through the orthophotos mosaic analysis it was possible to define the land use for influence direct and directly affected area for the highway construction. It was possible the identification of improvements as buildings. The LIDAR sensor coming served as complement to orthophotos mosaic for surveying of land use. Shade areas in orthophotos mosaic could be analyzed in LIDAR intensity image and in traverse cuts in 3D points file. In areas with vegetation where was doubts with relationship to class definition, it can differ thin vegetation and dense vegetation with base in observation and measurement of laser point height and density.

4.3 generation of DTM and DSM of study area

The model of Figure 4, where a TIN was generated from contour lines with spacing of 5 m obtained by aerophotogrammetry restitution left to want with relationship to plasticity, but it presents natural breaklines (as streams) very defined.

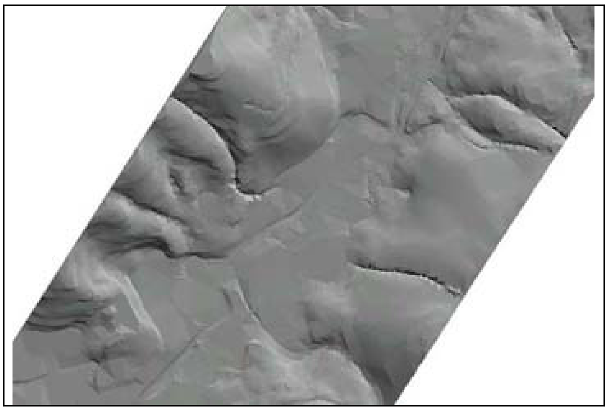

Figure 4. Part of DTM generated from aerophotogrammetric restitution.

Figure 5 show part of a DTM obtained in same area of figure 4, derived from LIDAR points. Due to high points density of commercial systems available today, it presents as characteristic the high plasticity. On the other hand, it presents artificial depressions (due to points filtered and/or classified erroneously by the algorithms as bare earth) and " natural breaklines " don't appear.

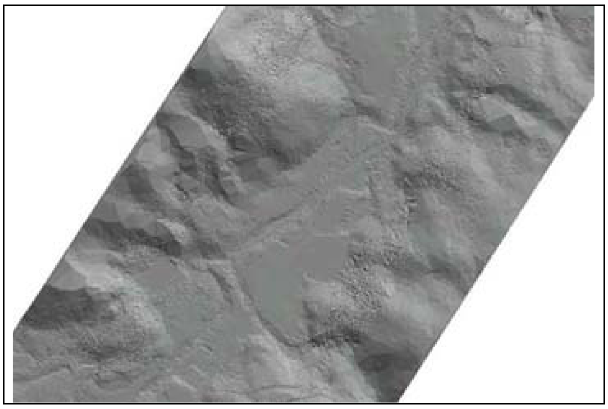

Figure 5. Part of DTM generated from LIDAR points.

DTM generated from integration of LIDAR points and aerophotogrammetric restitution elements (figure 6) it had for objective to join characteristics of two previously produced models: the high plasticity and density of dtm obtained from LIDAR points and the morphologic quality of DTM obtained from aerophotogrammetric restitution. Areas in DTM borders should not be considered, therefore they present inherent mistakes to TIN structure construction. To avoid this, is always due to cut out a larger area than the one that will be analyzed and to accomplish the cut after TIN structure construction. DTM generated from integration of LIDAR points and aerophotogrammetric retitution elements it was chosen to be used in the subsequent stages of study.

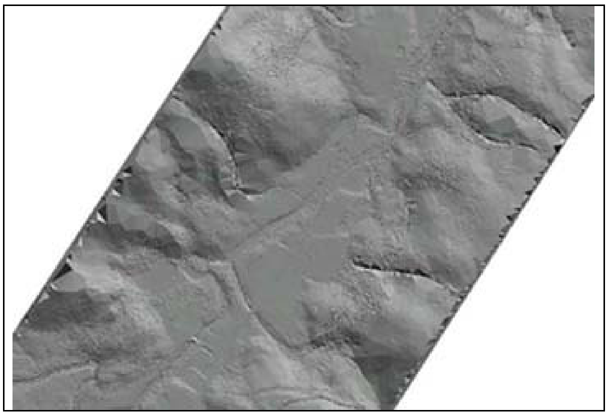

Figure 6. Part of DTM generated from integration of LIDAR points and aerophotogrammetric restitution elements.

Comparison among altitude measures obtained with LIDAR sensor and for aerophotogrammetry: With the objective of doing a comparison among altitude measures of bare earth LIDAR points with the coming contour lines in aerophotogrammetric restitution, altitudes of two models were measured at several places in study area. It was determined LIDAR located in classes that it composes the land use map and exactly where passed the 5 in 5m contour lines presents in aerophotogrammetric restitution to avoid of contour lines values interpolation. In ArcView GIS, were put on the themes " mosaic ", restitution " and " DTM LIDAR points".

Examining the table 3, it can be concluded that LIDAR points difference with contour lines of the restitution is not uniform and tendentious along study area. To know which is more perfected is necessary measures in field with conventional topographical equipments.

Land use	Contour line altitude (m) (1)	LIDAR point altitude (m) (2)	Altitude difference (m) (1 – 2)
Exposure soil	145	144,75	0,25
Exposure soil	115	114,89	0,11
Dense vegetation	135	136,04	- 1,04
Thin vegetation	185	184,66	0,34
Reforestation	135	131,17	3,83

Table 3. Comparison among altitude measures obtained with LIDAR sensor and for aerophotogrammetry

4.4 creation of DTM and DSM with highway Simulation

The creation of DTM and DSM with the highway simulation done through the addition of highway geometric project in TIN structure of study area and subsequent 3D visualization, it was constituted in excellent base to study the highway in environment in that will be implanted.
The simulation provided the visualization of areas where cuts-and-fill should be accomplished. Adding orthophotos mosaic to DSM, it is had a product that provides highway crossed areas visualization, making possible to verify areas be deforested, the higway influence in possible fauna corridors and the situation of vegetation along streams be highway crossed.

4.5 Slope map

The slope map (Figure 7) it went useful to aid in environmental analysis. It was applied to aid in preservation permanent areas definition, to define urbanization suitable area without restrictions and for rural properties analysis.

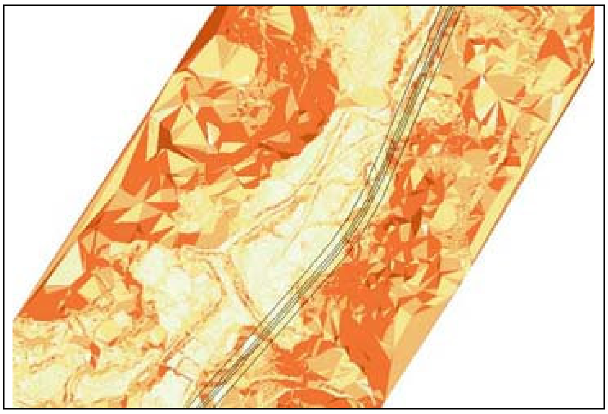

Figure 7. Slope in study area.

4.6 Thematic analysis of study area

The thematic analysis of study area was accomplished following recommendations ofn DER/SC (1998) on the themes soils, water and natural resources. Fragile environmental areas were located and quantified.
The highway, so much as any other linear infrastructure, interferes excessively in the general behavior of water resources of area, increasing risks to water courses that crosses. The risks are associated as much to drainage of residues deposited on pavement as for potential pollutant discharge risk due to accidents with dangerous products charges (DER/SC, 1998).
The 3D visualization of DTM and water courses sobreposição it can come to be an excellent tool to aid in location and visualization of susceptible areas to environmental problems being considered the water theme. In illustration 8, it can be verified in some places excessive proximity of highway to Braço Serafin river.

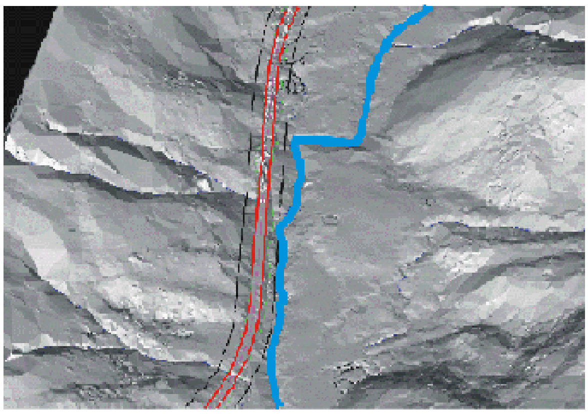

Figura 8. Streams inside right-of-way.

Through the land use map and slope map sobreposição, is observed that inside right-of-way aproximatelly 1000 m2 of dense vegetation are in areas with superior slope to 25º. For BRAZIL (1965), it is prohibited the shallow cut of these areas. It was also possible to observe existence of approximately 600 m2 of ciliary forest, characterizing area of permanent preservation (BRAZIL, 1965) and classified (CONAMA, 1985), as ecological reserve.
DER/SC (1998) it recommends to locate sections where, considering the inclination, exist erosion risks. The erosive processes can, direct or indirectly, to provoke soil or local ecosystem degradation. The relief can be easily analyzed with LIDAR products, that supplied data for making of large scale slope maps.
Examining the slope map, it is had the slope in study area varying from 12 to 30%, in the hillsides prevails slope class from 30 to 47%. inside right-of-way, on a side of the highway (plane and appropriate areas to urbanization), it is had Braço Serafin river very close or inside right-of-way (view figure 8). On the other highway side prevail slope superior to the 30%, what characterizes not appropriate area for urbanization due to slope (BRAZIL, 1979).

5 CONCLUSIONS

LIDAR points file, ally to LIDAR intensity image was constituted in excellent data source for elaboration of land use map. In areas with shades in the orthophotos mosaic, it was healed doubts due to possibility of obtaining of object height measures with relationship to ground in way simple, direct and without use of any complementar equipment. Besides, it made possible information updating above land use and occupation contained in the ortofotos mosaic. However, orthophotos mosaic supplied terrain and vegetation covering information that could not be extracted of LIDAR products.

The difficulty of laser beam in penetrating closed coverings, together with LIDAR sensor difficulty in defining natural and artificial breaklines influenced excessively in final quality of DTM generated from LIDAR points cloud.

The product generated by DSM, orthophotos mosaic and highway geometric project integration made possible a high quality visualization of highway project. This product can be used as much visualization element for customer project presentation as for public hearings.

Filtering and classification algorithms of LIDAR points were not sufficiently efficient for present acceptable results through automatic processes. The manual edition with aid of images (ortophots mosaic and LIDAR intensity image) it went essential to increase the filtering and classification quality of LIDAR points cloud.

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