LIDAR AND PICTOMETRY IMAGES INTEGRATED USE FOR 3D MODEL GENERATION.

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ABSTRACT:

The territorial data acquisition technologies vary second of the final product scale use. So it can be passed that the classical topographical survey or terrestrial laser scanners survey for engineering works, up to the satellite images multispectral analysis for regional scale and over.The classical aerial photogrammetry and LiDAR have a territory nadir (straight-down) vision, however, in many cases, the possibility to have a scene oblique vision can reveal very interesting. The Pictometry technology of images taking comes really meeting to this demand of a different vision of the environment. The system is composed of 5 cameras: one takes picture the territory in nadir way, the others four simultaneously take pictures the territory with oblique frames in 90°directions staggered. This allows to collect a series of pictures with a different point of view from the typical nadir sight. Widening the photogrammetric use of this data type, it is possible to think about exploiting the contained information in the oblique images for the three-dimensional object extraction and the 3-D models construction also in the urban zones where, a lot of times, the purely nadir images doesn't succeed in furnishing all the necessary information to such purpose. In this paper we will present the first result of a work which has the aim to find a way to use the oblique aerial images taken from pictometry system in order to improve 3D LiDAR model for a relatively small areas.

1. INDRODUCTION

1.1 Motivation

In the last years the Geographic Information request growth had implied a quick technologies and software development for the acquiring, the storing, the analysis and the visualization of these information.

In particular, in the sensor and platform case, the navigation system (GPS/IMU), the aerial digital camera development, the high definition satellite images and the high density points LIDAR sensor had permitted to the user to have a great number of information.

At the same time, in the software case: the global information visualization software, the web platform for the data management and analysis and the 3D visualization hardware and software development had permitted to the users to use easily the information. Digital terrain models (DTM) and 3D city models (3DCM) have became one of the most important and attractive products of Photogrammetry and remote sensing. While for many aspects the information acquisition techniques are consolidated, an ample sector of the research is turned toward the practical use of this great massive data structure.

The research aim is that to furnish usable information within the planning: for great works organization in particular environmental, for urban contexts management and analysis etc. The scale of interest will have to go since 500/1000 up to the averages scale 2000/5000.

In this paper, we propose ways to combine information extracted by oblique images with a DSM generated with LiDAR or Image matching. Specifically, we acquire multiple oblique aerial imagery from a Pictometry system using a standard digital camera; orienting the images without initial knowledge of position and orientation, we extract line and segment from oriented image and we use them for improve the DSM.

To such purpose the nadiral or oblique aerial images contained information, once that these are adequately oriented in the space, it can be re-projected on the laser cloud to clearly define an edge or an identifiable element in the images but not noticed by the LiDAR.

The necessary data whole to the development of such models includes, in first analysis, LiDAR data and Pictometry images to which we can add then, where you introduce, for instance cartographic data contents in Spatial DB.

1.2 Technological state of art

The used technology for information acquisition is generally airborne transported. In the last decades close to the traditional photogrammetric aerial camera is affirmed new technologies as LIDAR, radar or more simply the use of oblique digital camera. Particularly the aerial laser scanners (LIDAR) acquisition allows to notice a great massive structure of data, from the 1-4 points /m^2 for the airborne systems up to the 40:100 points /m^2 for the helicopter systems.

Airborne LIDAR has become a rather important information source for generating high quality Digital Surface Models. It offers one of the most accurate, expedient and cost-effective ways of capturing wide-area elevation information to produce highly detailed DSMs.

LIDAR systems collect positional (x, y) and elevation (z) data at pre-defined intervals. The resulting LIDAR data is a very dense points cloud. The accuracy of the LIDAR data is a function of the flying height, laser beam diameter (system dependent), thequality of the GPS/IMU data, and post-processing procedures. Accuracies of ±15cm (vertically) can be achieved.

This three-dimensional data wealth allows the surface digital models construction with an elevated degree of detail. Technology allows besides, through the use of appropriate filters, to separate the built by the ground getting so the digital model of the territory.

The classical photogrammetry with the navigation systems development and the use of high resolution aerial digital camera likewise allows to get very accurate territory surface model with the image matching technique. The power to conjugate these two technologies increases notably the possibility to get detailed three-dimensional models and ortho-photos.

Both LIDAR both the classical they have a territory nadir vision, however in many cases the possibility to have an scene oblique vision can reveal very interesting. The Pictometry technology of images taking comes really meeting to this demand of a different vision of the environment from the tall one. This allows to collect a series of pictures with a different point of view from the typical nadir sight.

1.3 Related work

Thanks to the recent evolution of new sensors (digital camera, LIDAR data, high resolution satellites) and the development of efficient algorithms, the automatic production of urban DSMs including buildings and trees is now possible (Maas, 2001; Fraser *et al*., 2002; Zinger *et al.*, 2002). However the automatic computation of 3D vector data is much more difficult because of low-contrasted building contours, hidden areas and complex-shaped buildings (Jung and Paparoditis, 2003). For most applications requiring high quality vector data, a manual or a semi-automatic intervention is necessary (Baillard, 2004).

The combined use of aerial oblique images and 3D data was investigated in various sorts. Some approaches texture mapping a 3D model obtained from aerial and ground-based or aerial laser scans with oblique aerial imagery (Frueh *et al.*, 2004); others are concerned with dense height map reconstruction from aerial oblique image sequences (Le Besnerais, 2007).

In this work, we want investigate the use of information, such line and shape, extracted from oblique images in order to improve the 3D model (generated by LiDAR or Image Matching techniques).

A related problem to this approach is the registration between the two data-set. The most common methods for solving the registration problem are based on the identification of common points. Such methods are not applicable when dealing with LiDAR surfaces, since they correspond to laser footprints rather than distinct points that could be identified in the imagery (Baltsavias, 1999).

Alternative methodologies for the registration of photogrammetric and LIDAR data using three-dimensional, straight-line features (Habib *et al*., 2005).

In this work we would investigate, first the accuracy of this aerial oblique images and if is possible to use them combined with LiDAR information.

Afterwards the registered images can be used with the aim to extract information, such as breakline or facades plan of buildings. So, these information can be integrated in the LiDAR point in order to improve the 3D model.

2. ANALISYS OF REQUIREMENTS

2.1 Pictometry system

The Pictometry technology consists in a system which is composed of 5 cameras: one takes pictures of the territory in nadir way, the others four simultaneously take pictures the territory with oblique frames in 90 degree directions staggered. Oblique imagery is angled view imagery in which four directions are captured so that feature faces and the represented area can be seen from North, South, East and West (Fig.1).

Pictometry comprises two types and two levels of image. Orthogonal images are traditional straight down images, whist oblique photographs are taken at an angle typically between 45 and 60 degrees. “Community” images are flown at approximately 1.500-1.800 metres and have an average resolution of 60 cm/pixel. “Neighbourhood” images are flown at approximately 600 – 750 metres with an average resolution of 15 cm/pixel.

This allows to collect a series of pictures with a different point of view from the typical nadir sight.
The typical characteristics of the system are:

- Average fly altitude 900 meters.
- Orthogonal Camera, focal length 65mm, average footprint 15cm.
- Oblique Cameras, focal length 85mm, average footprint 13-18cm.
- Sensor size 4008x 2672 pixel size 0.009mm.
- Overlap approximately 30%-50%

The system is also provided with a software for the images library management. This system combines aerial images and has the ability to visualize data and to make some analysis.

Figure 1 the straight-down and the four oblique images taken by Pictometry system

The interpretive software programs are not geographical information systems (GIS) as they are understood today. Instead, they are Information Systems that allow for navigation and prolific use of both orthophotos and oblique images.

The geo-referenced imagery allows measurements to be made, including the physical height of objects, elevation of ground surface, distance (taking into consideration terrain traversed), bearing and height.

A first step of this work will be to investigate the accuracy of the information extracted from the Pictometry images. In fact, one characteristic of the system is the possibility to directly measure the point coordinates on the ground plane. This should allow to extract some information directly to the Geo-Referenced oblique images with a considerable time-saving.

Therefore the topic is to evaluate the accuracy of this measures and the quality of extracted coordinates and if it is comparable with LiDAR data precision.

2.2 LiDAR technology

LiDAR is a consolidated technology which utilizes the Global Positioning System (GPS), precision inertial navigation systems, laser-range finders, and high speed computing for data collection. LiDAR systems on airborne platforms (e.g., an airplane or helicopter) usually measure the distance between an object the laser beam hits and the airborne platform carrying the system. Airborne laser mapping instruments are active sensor systems, as opposed to passive imagery such as cameras. With LIDAR, it is possible to obtain elevation information on large tracts in relatively short time; elevation data obtained with LiDAR can be up to 15cm accurate. LiDAR system uses the speed of light to determine distance by measuring the time it takes for a light pulse to reflect back from a target to a detector. A laser emitter can send about 5.000 pulses per second, but due to the high speed of light a detector can sense the reflected pulse before the next one is sent. LiDAR systems produce data that can be used in digital elevation models (DSM). The high density of elevation points provides the possibility to create high-resolution DSM models. LiDAR has been effectively used in several applications.

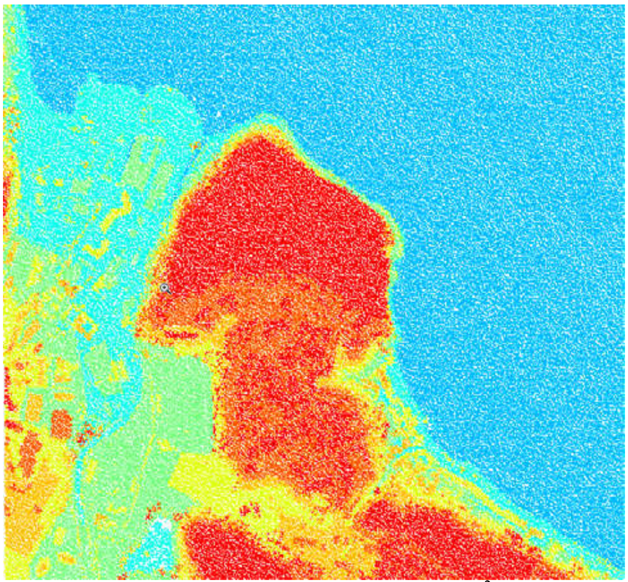

Figure 2. LiDAR data of Lecco city, 1 point/m^2 resolution

One restriction in LiDAR technology is the difficult to model the strong discontinuities, especially in the urban areas moreover the points is inadequate for the complete description of the surface and it is necessary the integration with different objects such as breaklines (Prandi et al. 2007).

In this work will investigate the possibility to integrate the data acquired by LiDAR with some data extracted from oblique Images. It is important to underline that from oblique images should be identified all that features and entities which are not visible by airborne laser data or traditional nadir images.

2.3 Used Data Set[1]

The test area consists in two zones with different characteristic; the first area is a portion of the city of Milan, in this region there are a very dense built-on with much infrastructures such as railways, bridge, ways and canals. The second is a portion of the city of Lecco (lakeside town in Lombardy); which is characterized by a mixture between anthropic and environmental elements.

The Milan test field is composed by a series of pictometry images collected in two different times with 15cm footprint resolution, a photogrammetric aerial strip acquired for cartographic production with 6cm footprint resolution and a vector digital map (scale 1:1000) accuracy about 20cm.

The Lecco test field is composed by a series of pictometry images collected with 15cm footprint resolution and LiDAR data resolution 1 point/m^2 (Fig2, Fig3).

Data set	Oblique Images (pictometry)	Aerial images (Wild RC30)	LiDAR data
Milan	X	X	
Lecco	X		X

[1] The pictometry images, EFS software and LiDAR Data has been granted by CGR Parma (Bloom group) in range of a research project with DIIAR. The aerial images and the digital map of Milan has been kindly granted in use by the Municipality.

Table 1. Used test field and available data set

The first test field will be used in first to test the accuracy of the oblique direct georeferenced images and in then to improve the DSM generated by Image matching from aerial images with the data collected in oblique images.

Some of this data was already used in other research about the 3D city model and the generation of 3D object for GIS, in the previous studies (Brumana, 2006) was emerged that the 3D digital map is not enough to completely define the 3D model of complex scene such as urban areas. It is necessary to use some additional data these can be aerial images, high resolution DSM and also oblique images.

Figure 3. Oblique images of Lecco Lake

The second test field will be used to experiment the opportunity to combine the information in the oblique images and in Laser Data, especially in a region with great vertically development.

In fact, the Lecco lake region is characterized by the presence of high mountain near the cost line, in this case a different view of the territory, such as oblique images, should be an important source of information.

2.4 Evaluation of Data Accuracy

The opportunity to have in a short time the information contained in a aerial survey is a important topic in photogrammetry field. Pictometry system allows to obtain many geo-referenced images quickly after the data acquisition.
In case of public safety applications, the speed at which imagery of a given area (typically a county) can be captured, the ability to integrate the imagery with other third-party systems and the cost savings associated with the oblique imagery metric use, provide many advantages.

Other benefits include the image content which is far more intuitive and information richness is greater than that they obtain from traditional ortho-photography.
For these emergency applications a lower accuracy is enough but, if we want to use this data to extract information and to combine them with other we must be sure that the accuracy is comparable.

In order to test the accuracy of Pictometry images we used the Milan test field as source.

The georeferenced ground positions of higher accuracy, were provided from multiple sources. Most points were checkpoints, used in previous photogrammetric survey for aerial triangulation. This point are very accurate, well-defined and photo-identifiable on the airborne oblique imagery. Other points was obtained directly from the digital map and it was used only as X-Y checkpoints.

We measured the x, y and z coordinates of these checkpoints (fig.4) on each of the 4-view Pictometry images, where visible, to compute errors in Eastings, Northings, and Elevations. For each checkpoint, we also averaged the Eastings, Northings and elevations for all views that were visible; for many, the average resulted from four views, but some points were obscured by buildings, trees, cars, etc., so the average resulted from the mean of three, two, and (in a few cases) only one view.

Figure 4. Direct measure of point elevation in oblique images realized in Pictometry EFS system

All errors were squared and averaged to compute the mean square errors; then the square root was taken of the mean square errors to compute the root-mean-square-errors (RMSEx, RMSEy, RMSEr, and RMSEz). RMSEr is the radial statistic which equals the square root of [$RMSEx^2 + RMSEy^2$]. The results are showed in table 2.

Data set	RMS_X[m]	RMS_Y[m]	RMS_r[m]	RMS_Z[m]
Milan	2.320	5.654	6.142	0.378

Table 2. Accuracy statistics

The average accuracy of the coordinates is 6.142m, this value is acceptable in case of emergency if it is necessary a quick response and a approximate knowledge of the area interested by the phenomena.

Our purpose is to use the 3D data extracted by oblique images into the 3D model of the landscape both urban both environmental. It is obvious that the information directly extracted by Pictometry system is not enough for this aim.
It is significant to evidence the difference between the X-Y and Z accuracy, this is probably due to the data set. The city of Milan morphology is flat and the elevation difference between two point is small if the points are nearest; so a difference in the coordinates value give a little differences in elevation value.

We must give up the way of a direct and rapid use of the images but, it is necessary a intermediate step which consist in the orientation and registration of the oblique images.

2.5 Images Orientation

The image orientation process consists in to find the camera's 6 parameters: Y, X, Z, Omega, Phi, Kappa. Camera orientation requires some scene knowledge, usually some control points, for relating the camera coordinate systems to the object coordinate system. Identification of control information cannot easily be automated especially if the position of the images in the space is totally unknown, if the overlap between the images is not much and if the orientation angle between two pictures is big. In recent years many work was realized for the automatic registration of the images (Forstner and Gulch, 1999).

In the case of pictometry images the boundary condition are not good due the position (in our case) is unknown, the overlap is about 30%, the orientation angle between two directions is about 90 degrees.

In this situation is difficult to obtain a good automation in the orientation process and also the manual procedure requires some attentions.

To obtain a good results is essential the knowledge of the interior orientation of the cameras. The pictometry system use two different cameras one for the straight-down view and one for the oblique views. The used camera was calibrated and the parameters are report in table 3.

Parameters	Camera	
	nadir	oblique
Pixel Size [mm]	0.009	0.009
C [mm]	64.8258	84.4937
X_p [mm]	0.3843	0.5195
Y_p [mm]	-0.3391	-0.3600
K1	$4.38553e^{-6}$	$8.32433e^{-6}$
K2	$-9.5613e^{-9}$	$-9.76607e^{-9}$
K3	$-3.047e^{-021}$	$-5.3268e^{-12}$
P1	$-1.4691e^{-25}$	$5.46611e^{-26}$
P2	$-2.032e^{-025}$	$1.98325e^{-25}$

Table 3. Interior orientation parameters of cameras

For the registration process we use Photomodeler software, that allows to orient the images with any orientation. The process is time-cost and is not simple due to the particular geometry of the pictures.

Figure 5. Oblique Image collected tie point, image are 90 degree direction (S-E) staggered. The interpretation of the images and the recognition of homologues point is not simple

The geometry of the cameras position are not excellent. The problem is the placement of the cameras, in fact there are four main position (N-S-E-W) where the system acquire several overlapping photographs taken while moving the camera in one of four cardinal direction. The output is a series of images concentrates around a direction, for examples all the photo taken in W direction are nearest, but with an approximate 90° degrees angle between the two other nearest different directions (N-S).

This geometry doesn't allow a simple solution of the photogrammetric block and sometimes the solution is not stable and it is enough to add a single photo for the not convergence of the system.

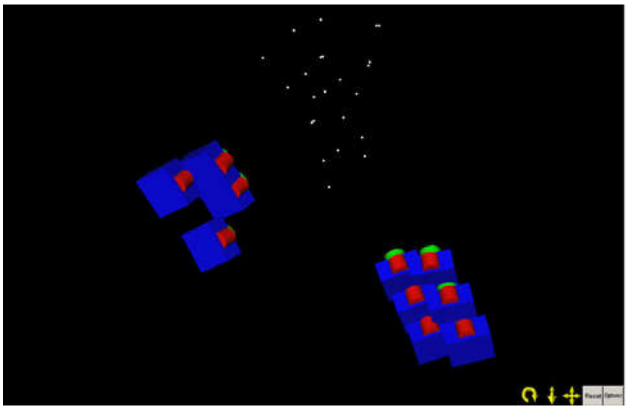

Figure 6. Result of camera orientation, the 10 photos are taken in two 90° direction (S-E). It is possible to see as the camera are nearest for one specific direction.

Another problem, specially in the lake images, is that a big part of the images is take up from water and it is difficult to obtain a good placing of tie-points and the overlap is very short.
All these factor give back the orientation process time-cost and complicated. In these condition, if the camera exterior parameters are unknown, it is difficult obtain a good automation in automatic orientation of the images. The images has very different prospective and is not simple to recognize the homologous points.

After the orientation process we con obtain a series of georeferenced images with a sub-meter RMS in points re-projection.

2.6 Feature extraction

After the orientation process, the subsequent step is the extraction of information from the oriented images.

The oblique images must attend as a source of a different or additional information respect to the straight-down ortho-images. The most important characteristic of the oblique pictures is the different point of view respect the traditional nadir photos.

There are two general research line to develop, one is related identification of important object to extract, another is related to the next possibility to automated the extraction process.
It is evident that the feature extraction must be addressed to the elements and shape which are not visible from the orthogonal-view. The object class most significant are the building facades,

the walls all that elements which have a big vertical development.

Figure 7. Manual Feature extraction, a vertical wall

Due to the complexity of aerial images, different view angles and occlusion, straight edge matching for 3-D generation is a difficult task in photogrammetry and computer vision (Zhang 2003).

These difficulties are amplified with the use of oblique image, for this reason a manual extraction of the elements will be investigated in order to select some elements and to verify the possibility to insert them in the general 3D Model.

Anyway the automation in the extraction process is a important topic in photogrammetry. The first step, after the registration process, is the recognition of the features. A methodology can be the automatic individuation of the edge with edge detector like Canny filter. The second step is to use this edge to generate the features, the main problem, if the image are already oriented, is the individuation of the homologous line in different photos that is a complicated image matching task.
Due the complexity of this task at this step of work we are investigated only the possibility to manually generate the objects and in future, to insert, them in the model.

3. CONCLUSION

In this paper we have presented the first result of a work which has the aim to find a way to use the oblique aerial images taken from pictometry system in order to improve 3D LiDAR model for a relatively small areas.

In first we investigated the accuracy of Pictometry direct georeferenced images and we compared it with the LiDAR accuracy. A direct use of the information extracted from the images is not possible because the accuracy is about 6 meter in the X-Y direction, for this reason a second part of the research is dedicated to the orientation of the images which is necessary to improve the quality to the 3D coordinates extracted by the images. The orientation process have some problems due to the particular geometry of the photo taken. The pictometry system have a short overlap between the images (30-50%) and the photo are taken in four direction (N-S-E-W). For these reason we obtain a series of images which are relatively nearest, if taken in the same view direction, and with a 90°degrees angle respect the images collected from other directions. In these conditions there are a small angle between the point and the solution can have a not good accuracy.

Once registered the images the extraction of features has been done. The particularity of Pictometry images is the different point of view, for this reason it is important to dedicate a meticulous attention to the typologies of the extracted objects. We are interested to all the elements which have a main development in vertical direction and are difficulty to identificate both in ortho-images both in LiDAR data. The object class can be include building facades, walls, docks seaside.

Due to the particular geometry of the images it is very strong to automate the recognition process of the feature in the image, in fact also the semantic interpretation of the scene is complex with the perspective is very changing trough two different images. So the feature extraction is manually done and it is realized with the aim to evaluate the possibility to use the data combined to the LiDAR data generating a 3D model for relatively small areas.

The first result are good in terms of accuracy of the data extracted and for the information and resolution of oblique images. The work still have to examine the integration and the registration of the data extracted from the images with the Laser data especially in case of dense point cloud.

A future topic would be the improvement in the automation in the examination of the image contained with the aim to help the feature extraction.

In conclusion these first analysis of the photogrammetric use of Pictometry and the subsequent use combined with LiDAR data shown some interesting opportunities but the challenge must be the improvement and the reduction of manual work. Another topic which can do and advance in the sense of a more accurate use of the oblique image is the change in the flight plan and in the data acquisition. A bigger overlap and more attention at the geometry of the photogrammetric taken can be drastically reduce the time in the orientation process.

Only handling these problems and the challenge in automation the photogrammetry use of oblique aerial Multiple-image can be a cost effective alternative to vertical stereo aerial photography and optical satellite imagery for analysis of relatively small areas.

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