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A CASE EXAMPLE FOR LASER DATA TREATMENT TO STUDY ROCKY FACES WITH PROTECTION BARRIERS.

L. Bornaz [a], C. Porporato [a], R. Mayoraz[b], F. Rinaudo [a], J. D. Rouiller [b]

[a] DITAG, Politecnico di Torino, C.so Duca degli Abruzzi, 24, 10129 Torino, Italy - (leandro.bornaz, chiara.porporato, fulvio.rinaudo)@polito.it
[b] CREALP Rue de l'Industrie 45, 1951 Sion, Switzerland (Raphael.MAYORAZ, Jean-Daniel.ROUILLER)@admin.vs.ch

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ABSTRACT:

LIDAR is a useful technique for natural and architectural metric surveying.
Acquisition is the first step in laser surveying. The second step is the data treatment that is necessary to obtain a correct digital model of the object.
This set of elaborations can be subdivided into preliminary data treatment and creation of the final model.
The first operations provide a single noise-free point cloud in a specific reference system.
The elaborations studied to reduce the noise in laser data due to the location of protection barriers on the rocky faces of the Longeborgne mountain (Switzerland) are here explained.

1. LIDAR SURVEY

1.1 Introduction

Nowadays, the LIDAR technique is frequently adopted to carry out a metric survey in both natural and architectural fields. The terrestrial laser scanner allows complete and dense 3D digital models of the surface of any object to be acquired.
Many users have been interested in terrestrial applications of the laser scanner, but it is not so very easy to achieve its full potential. The LIDAR technique gives prompt data, but this information cannot be used without treatment. It is therefore necessary to handle the scanner data, while considering the aim of the work, in order to obtain a geometrically correct and exact 3D metric model.
This paper deals with an environmental application of the LIDAR technique.
A land survey can sometimes be subject to specific difficulties and can put the operator at risk. These problems are avoidable when a laser is used as it allows a survey to be carried out in a fast way and in safe conditions.
Lasers are very useful for natural hazard and risk assessment where the starting point to evaluate stability properties is a morphological investigation.
As far as the survey of natural object is concerned, a large portion can be acquired in various situations. Compared with other "classical" survey techniques, such as topographic or photogrammetric techniques, laser scanner instruments offer considerable advantages.
In order to carry out a proper survey, it is necessary to plan the survey and consider whether it is opportune to use integrated survey methodologies.
A LIDAR survey allows a great number of points to be recorded in short survey sessions and as the laser beams do not require light to be reflected, night acquisitions can be conducted.
In order to survey the object in a safe way, unmanned survey stations can be installed to achieve multi-temporal acquisitions. Furthermore, the data treatments and elaboration phases can be conducted in different places and at different times, after the survey, in a safe place.
In order to plan a LIDAR application, the acquisition phase, the data treatment and the generation of the final product are considered separately.
In the field of engineering and environmental applications, some rules should be considered so that laser scanner instruments can be used correctly.
The maximum measurement range, the maximum angular resolution, the accuracy of the instrument and the shape of the surveyed object must be considered first of all.
A good planning of the measurement operation is necessary for survey design.
After the acquisition phase, it is necessary to deal with the laser data. Many publications about lasers show that LIDAR data must be treated to eliminate gross errors and any outliers found in a point cloud. This operation allows a continuous surface of the surveyed object to be obtained.

1.2 The acquisition

Acquisition is certainly the first step in laser scanner surveying and it requires some preliminary phases to be taken into consideration. In order to obtain a valuable final result, this phase should be correctly planned and executed. As acquisition is the only action carried out on the field, a real time data check is suggested, according to the kind of application the laser scans.
When the object has a complex shape or when a single scan cannot record the whole object, a series of scans must be

performed. This series has to be correctly planned to avoid hidden areas. The laser position for each scan can be then determined considering all these things. In order to study an object, two or more scans are taken of the same object from different points, in order to eliminate shaded areas.

The acquired data cannot be used directly without treatment. This means that some operations must be carried out on the point clouds.

1.3 Data treatment

The operation known as “preliminary data treatment” concerns data filtering, point cloud registration, geo-referencing and multiple scan triangulation operations.

The noise reduction step is one of the fundamental preliminary operations of the terrestrial laser data treatment. Laser scanner data always have noise that is lower than the tolerance of the used instruments.

In order to obtain a “noise free” model of the object, it is necessary to use specific algorithms that are able to reduce or even eliminate the acquisition errors that can be present in the point clouds. Sometimes it is also necessary to remove any scattered points that do not belong to the object.

In the particular case of rocky faces with irregularities that could produce rock falls, it is common practice to reinforce the stability of the walls using protection barriers. These elements, which do not belong to the rocky faces, represent noise in the laser data if they are acquired and this noise could prevent a correct interpretation of the details. Therefore, to carry out a correct study of rock slabs, it is necessary to introduce suitable data processing sets into the preliminary data treatment in order to eliminate the particular noise caused by the barriers.

Many algorithms have been developed by the research group of the Politecnico di Torino in recent years in order to reduce noise (e.g. the robust median estimator).

A study case concerning a particular noise reduction (noise due to the presence of protection barriers) is shown in the next section.

Environmental field acquisitions often show complex shapes. In this case, a single scan is not enough to completely describe the object and more than one scan has to be made. Each scan has its own reference system: the reconstruction of the 3D model of the surveyed object requires the registration of the scans in a single (local or global) reference system.

In order to obtain the final 3D model of the object, it is therefore necessary to align and georeference the single scans using suitable registration techniques. These steps, realized for the Longeborge survey, are also illustrated.

2. THE STUDY CASE: THE LONGEBORGNE SURVEY

The Hermitage of Longeborgne (Sion, Switzerland) belongs to the municipality of Sion and is located in the village of Bramois. This Hermitage was built in the XVI century on rock in the wide Borne gorge.

Figure 1. The Longeborgne, rocky wall.

The Hermitage is located under a rocky wall. This face presents some irregularities that could produce rock falls (Fig. 1). For this reason, protection barriers were placed in order to reinforce the stability of the wall. A laser survey was planned and carried out to evaluate the stability properties of the overhanging Hermitage rock wall, which could be in danger of sliding.

2.1 The survey

A collaboration between the Politecnico di Torino – DITAG, and CREALP (Centre de Recherche sur l’Environnement ALPin) has led to the laser scanning of the rock wall.

CREALP, which performs research in Alpine regions, is a Swiss organisation that carries out multi-temporal monitoring of critical events concerning rocky walls and in particular for rock falls.

It usually uses classic survey techniques such as photogrammetry and topographic and geomeccanic methodologies.

The aim of the collaboration between DITAG and CREALP was to introduce the laser scanner methodology into the CREALP study cases.

The main purpose of the laser scanner survey was to help geologists evaluate the instability of the rock. Classical geo-mechanical surveys are ussualy carried out by specialized personnel, with alpinist experience, who run certain risks when working on the instable wall. The LIDAR survey allows the personnel to work in safety. The laser scanner productivity is therefore higher than for any other traditional survey instrument (it can acquire millions of points in a short time), throughout the whole day (night acquisitions are possible) and the laser scanner data give a complete description of the object.

2.2 The instruments

Modern laser scanner devices record, for each acquired point, the direction of the laser beam (horizontal and vertical angles), the measured distance and the reflectivity values (the energy reflected by the measured point). This set of information makes it possible to calculate the 3D coordinates of each point using simple geometric equations.

The reflectivity value is connected to the type of material that makes up the object, an aspect that can be of fundamental importance in the analysis and development of automatic algorithms or in a preliminary classification of the materials.

One of the possibilities offered by the knowledge of this set of information is the opportunity of automatically registering (or georeferencing) two adjacent point clouds. To do this, it is sufficient to arrange some high reflectivity stickers (markers) on the object during the scan.

When the laser beam strikes the markers, the recorded reflectivity value is very high and is usually much higher than the one recorded on natural points (for example, rock, wood etc). If this simple property is used, it is possible to automatically identify the position of the markers inside the 3D model acquired with the laser scanner.

The used instrument was a RIEGL LMS-Z420 laser scanner with the following characteristics:

- l laser class 1 (safe for the human eye), and class 3R (more power for a longer range);
- maximum acquisition range: 250 m for class 1 and 1000 m for class 3R;
- distance measurement accuracy: ±5 mm (class 1), ±15 mm (class 3R);
- acquisition speed: 6600 – 10000 points/sec.;

- acquisition window: 360° (horizontal) x 80° (vertical);
- angular resolution: 10 mgon.
- wave frequency of the laser beam: almost infrared;
- beam divergence: 0.25°
- Acquisition mechanism: rotation - oscillation;
- Angular resolution of the acquisition: 0.01°

The laser was equipped with a high resolution digital camera (Nikon D1X) that is rigidly mounted onto the laser, so the position of the centre of the camera is known with regards to the centre of the laser instrument. The position of the camera becomes a known position in the laser acquisitions. The used digital camera is a Nikon D1X equipped with a 28 milimeter objective that produces 2000*1320 (medium definition) and 3008*1960 pixel images (high definition).

The digital camera is used to take images to obtain the radiometric information of the 3D model and to give the real colour of the object to the 3D model. All the images were acquired at high resolution.

2.3 The field operations

The studied rocky wall is approximately 100 m long and 60 m high. In order to obtain the digital terrain model (DTM) and the solid images of the object, 3 acquisitions were made.

Laser scans were taken from three different points (shown in red – (fig. 2), to avoid hidden areas, for a complete description of the wall.

Six points are shown in blue where high – reflectivity markers were placed (fig. 2). The coordinates of these points, which were placed on stable parts, were determinated by a Swiss technician.

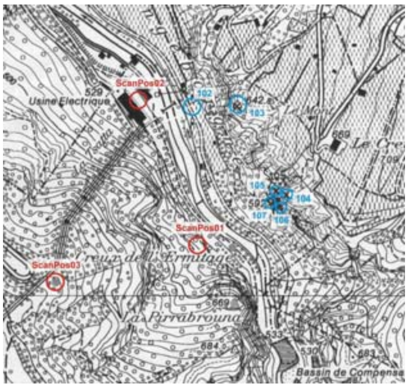

Figure 2. The schema of the Longeborgne survey plan.

The high – reflective markers placed on the wall were used for the registration of the three scans.

ID	E [m]	N [m]	Q [m]
102	597556.210	119358.925	526.984
103	597646.985	119346.880	641.588
104	597739.487	119184.834	661.026
105	597716.474	119193.179	617.814
106	597728.799	119138.717	596.895
107	597724.860	119163.591	593.406

Table 3. The marker coordinates.

The available software does not work very well with such large coordinates. For this reason, the following simplified coordinates were used (which do not modify the orientation or the height of the DTM):

ID	E [m]	N [m]	Q [m]
102	556.210	358.925	526.984
103	646.985	346.880	641.588
104	739.487	184.834	661.026
105	716.474	193.179	617.814
106	728.799	138.717	596.895
107	724.860	163.591	593.406

Table 4. The simplified coordinate markers.

The acquisition of the laser data was taken from 3 scan positions. First, the part where the markers were positioned was acquired using a high angular resolution (0.008 deg correspondents to 8.89 mgon). Second, the acquisition of the portion of the rocky wall, that could be acquired from the laser position, was made with the maximum angular resolution of 0.008 deg (8.89 mgon). The used instrument allows the first or the last reflected pulse to be acquired. All the acquisitions were performed using the last pulse measurement.

The Digital images were also taken from the same laser scan position using the digital camera placed on the calibrated arm.

The acquisition was performed using RIEGL Riscan For software, which is supplied with the used Riscan laser.

2.4 Data Treatment

A specific set of elaborations was realized to study the Longeborgne survey.

The preliminary data laser treatment is a necessary step to:

- Re - align the digital images on the DTm
- Map the Image (texturisation) of the 3D model.
- Filter the data (specifically modified for the examined case in order to remove not only the normal "noise" present in the laser acquisition but also the noise from the protection barriers on the wall);
- Eliminate the useless points (an automatic and a manual part);
- Align and georeference the scans (using a multi scan triangulation approach).

Today, among the software that is available for laser data treatment it is possible to find several data elaboration software packages. Most of this software allows the unnecessary points to be eliminated, the data to be filtered in order to eliminate the incorrect points and it also allows 3D models to be constructed from the point clouds. When a data treatment is made it involves a decrease in reliability. Moreover, all commercial software uses algorithms that are not explained very well to the customers and they do not allow the data quality after the treatment. to be know. This software often does not use enough (sometimes none at all) acquired intensity values from the laser for their plans.

For all these reasons, the preliminary treatment was made using LSR 2004 software, developed at the Politecnico di Torino - DITAG. This software was especially conceived for the elaboration of terrestrial laser scanner data; all the treated algorithms were studied by the researchers at the university.

This software has been the object of tests and has been explained at international topography and photogrammetry conferences. It is continuously object to integrations and improvements. It is aimed to use the full complexity of the laser data.
With LSR 2004 it is possible to:.

- Eliminate outliers and gross errors;
- Automatically align the 3D models;
- Map image (texturisation) of the 3D model.
- Create a solid image

The studied case introduced another problem. Protection barriers on the studied rocky falls were placed to protect the buildings below. The used laser can record the first or last laser impulse. Using the second methodology during the acquisition, the laser does not store the points that belong to the protection barriers (in part). Since the metallic net had very small links, many of the acquired points from the laser belonged to this net and they therefore represented outliers in the laser acquisition. These points had to be eliminated in a rigorous way. Points that cannot be removed can give rise to many problems during the construction of 3D models. The software available at that time could not be used to resolve this problem. A specific algorithm was therefore conceived by the DITAG research group (an aspect that caused an increase in the times necessary for the data treatment). This algorithm allows 80% of the outliers of the protection barriers to be completely eliminated in an automatic way. The remaining 20% was removed manually using software for the construction of 3D models. This operation is very time consuming, but it allows very good results to be obtained.

2.5 Acquisition details

Acquisition from position 01 (fig. 5):
- acquisition time: 0 h 37 min 55 sec;
- acquired points: 12012296.

Acquisition from position 02 (fig. 6):
- acquisition time: 0 h 13 min 45 sec;
- acquired points: 4865220.

Acquisition from position 03 (fig. 7):
- acquisition time: 0 h 14 min 52 sec;
- acquired points: 4156254.

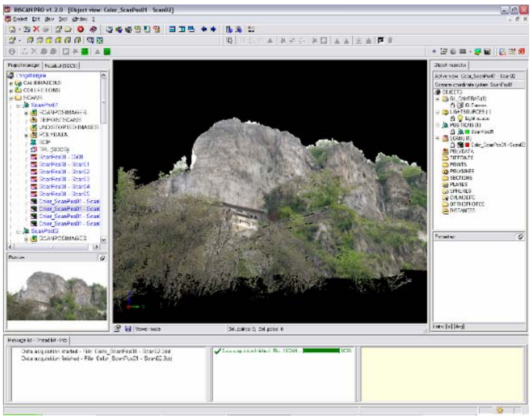

Figure 5. Acquisition Software - RiscanPro - Riegl – scan position 01.

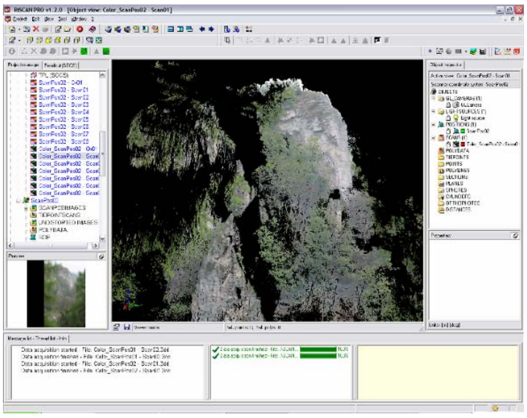

Figure 6. Acquisition Software - RiscanPro - Riegl – scan position 02.

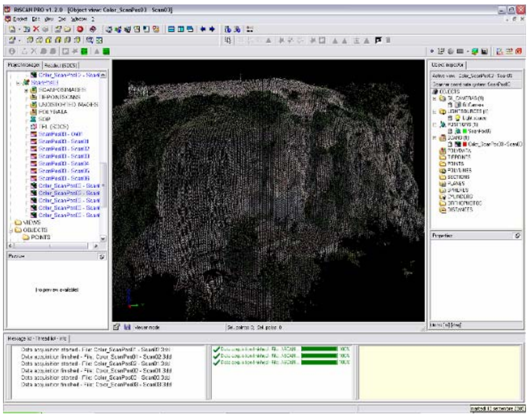

Figure 7. Acquisition Software - RiscanPro - Riegl – scan position 03.

2.6 Details of the preliminary data treatment

The data filter has already been explained in the previous pages. The data that follow are relative to the filtered DTM orientation phase.
Acquisition from position 01. Alignment results of the scans:

ω	18,6992	[gon]
φ	-29,5183	[gon]
κ	34,4330	[gon]
X	626,2225	[m]
Y	84,7380	[m]
Z	536,1027	[m]

Table 8. Rotations and Traslations of the model.

G.C. Point	σ_x	σ_y	σ_y
4	0,001213	0,007316	0,007316
6	0,011162	0,00304	0,00304
3	0,017354	0,01497	0,01497
7	0,007364	0,022882	0,022882
5	0,012343	0,027496	0,027496

Table 9. Ground control point deviation.

σ_0 a priori	1	-
σ_0	4,4534E-04	-

Table 10. Statistic convergence parameters.

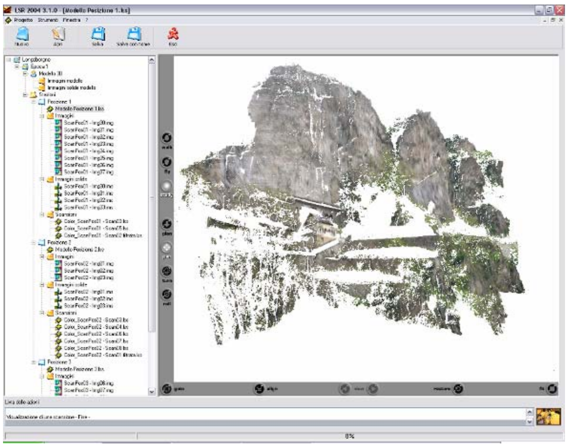

Figure 11. Software LSR 2004 for the data treatment. Point clouds – scan position 01.

Acquisition from position 02. Alignment results of the scans:

ω	-6,8408	[gon]
φ	-14,1566	[gon]
κ	-37,6072	[gon]
X	460,4071	[m]
Y	354,5689	[m]
Z	530,5071	[m]

Table 12. Rotations and Traslations of the model.

G.C. Point	σ_x	σ_y	σ_y
1	-0,01187	0,024515	0,024515
2	0,006468	-0,030877	-0,030877
4	0,023322	0,026738	0,026738
3	-0,01792	-0,020375	-0,020375

Table 13. Ground control point deviation.

σ_0 a priori	1	-
σ_0	9,1124E-04	-

Table 14. Statistic convergence parameters.

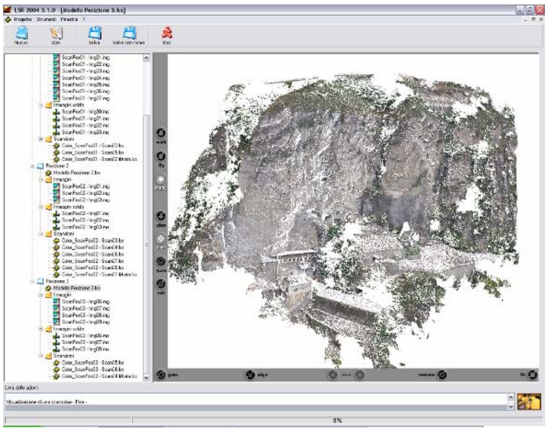

Figure 15. Software LSR 2004 for the data treatment. Point clouds – scan position 03.

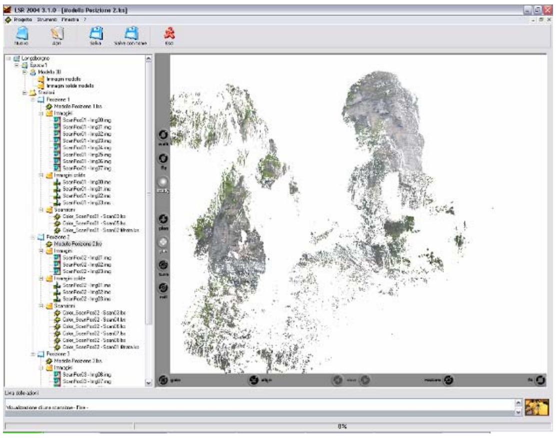

Figure 16. Software LSR 2004 for the data treatment. Point clouds – scan position 02.

Acquisition from position 03. Alignment results of the scans:

ω	-5,1093	[gon]
φ	10,7435	[gon]
κ	23,9459	[gon]
X	329,0373	[m]
Y	22,7468	[m]
Z	770,0681	[m]

Table 17. Rotations and Traslations of the model.

G.C. Point	σ_x	σ_y	σ_y
2	-0,000842	-0,001682	-0,001682
1	0,007422	0,003515	0,003515
3	-0,009732	-0,048211	-0,048211
4	-0,039755	0,029842	0,029842
7	0,042907	0,016536	0,016536

Table 18. Ground control point deviation.

σ_0 a priori	1	-
σ_0	1,2778E-03	-

Table 19. Statistic convergence parameters.

The result of this treatment is a complete digital model of the rocky wall that can be modelled using classical commercial software.

Figure 20. Complete DTM model of the rocky wall.

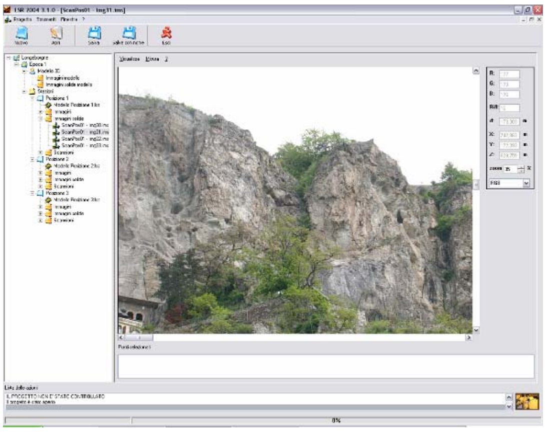

Figure 21. Software LSR 2004 to create and use the solid image. Solid image: ScanPos01 - Img31.jpg.

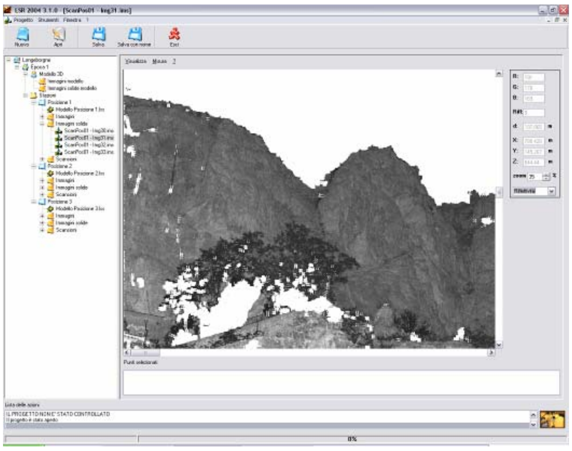

Figure 22. ScanPos01 - Img31.jpg original image.

After the preliminary treatment a precision of the point coordinates of about 5 cm for every point can be expected

2.7 Solid images

A set of solid images was realized using the DDSM laser and the acquired digital images. The solid image is a new product in the topographic field. It is a bi-dimensional digital image in which all the information of the DDSM is introduced. The solid image allows the 3D point coordinates on the image to be measured in a bi-dimensional way.
The produced solid images are:

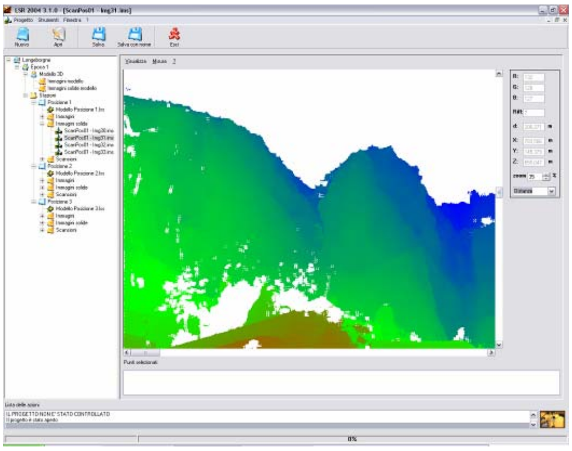

Figure 23. ScanPos01 - Img31.jpg image of the material reflectivity.

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