METRIC AND QUALITATIVE EVALUATION OF QUICKBIRD ORTHOIMAGES FOR A LARGE SCALE GEODATABASE CREATION

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1. INTRODUCTION AND SOME PRELIMINARY REMARKS

The geometric accuracy of high resolution satellite imagery, such as QuickBird or Ikonos, was evaluated in several previous works also carried out by the University of Bologna. The common finding of these researches is that such orthoimages, under specific conditions, could be used as medium - large scale raster maps.
Therefore, to this purpose, they must adequately processed, and their accuracy is depending on many factor, in particular on the geometric correction model adopted for the orthorectification, on the number and distribution of Ground Control Points (GCPs) over the scene and on the accuracy of Digital Terrain Model.
The evaluation of for such orthoimages was always carried out by means of a certain number of sparse Check Points (CPs), evenly distributed over the whole scene, whose coordinates were obtained both from maps and from GPS ground surveys.
In the present work we were interested in evaluating the possibility that these orthoimages could be used not only as products in themselves, but also as an information source both for the creation of new 1:5000 or 1:10000 numerical maps, and for map updating.
For this reason, geometric accuracy, even if evaluated over a large number of CPs, is not sufficient to guarantee a correct detection and interpretation of objects in the image and, therefore, it is not sufficient to assess the accuracy over a limited number of sparse points, but it is advisable to vectorize objects from orthoimages and to evaluate their accuracy with ground surveys. The image quality and its radiometric characteristics are critical aspects for the vectorisation, because they could support or impede the correct photointerpretation of objects in the scene.
For this reason, our main purpose was the evaluation of the effective use and potential of orthoimages for creation or updating of large scale structured GeoDataBase, and, particularly, the work was addressed to building detection.
Regione Emilia Romagna is interested in this application in order to create a GeoDataBase starting from the updating of analogical maps, using high resolution satellite images. This sperimentation was possible thanks to materials (maps and orthoimages) supplied by Regione Emilia Romagna.

2. TEST SITE LOCATION AND MATERIALS

The chosen test site is Castenaso, a town located in the North of Italy, near the city of Bologna. It is a small town with an extent of around 3600 hectares, with a small urban centre, a wide country area and several expanding industrial areas.
Regione Emilia Romagna supplied the QuickBird panchromatic orthoimages of the area, produced in the frame of the project for the 'Regione Emilia-Romagna GeoDataBase' creation and captured with high quality standards. In point of fact, metadata of original images were not supplied, so that they were reconstructed on the basis of the date of collection (2003-07-22) and from information contained in the Digital Globe archive.

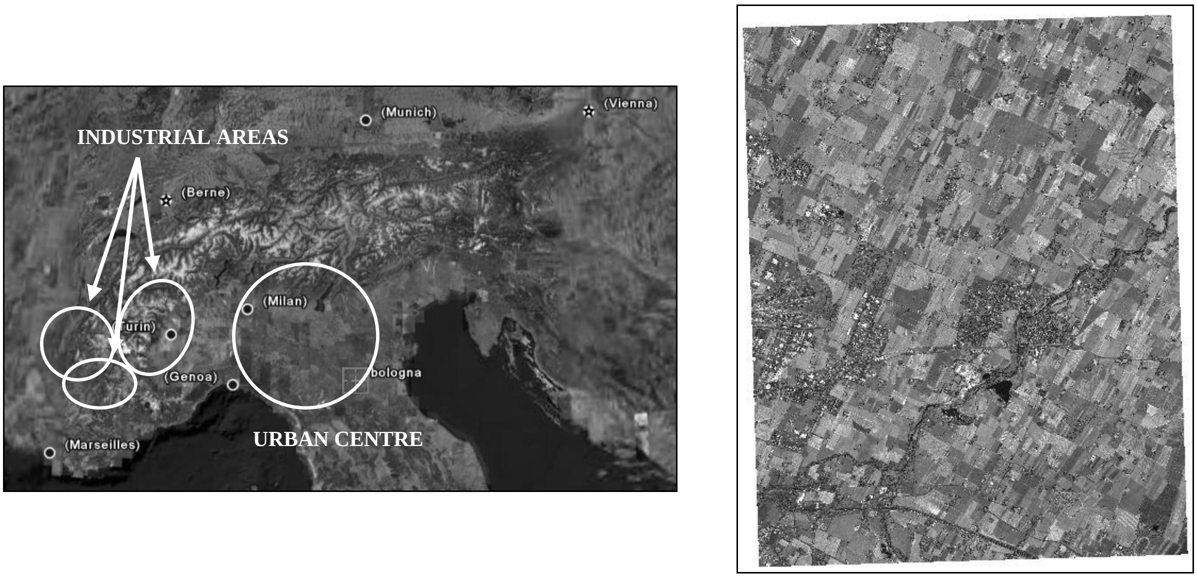


Fig. 1 Test site location and portion of a QuickBird orthoimage relative to the test site

The image quality and its radiometric characteristics are critical aspects for the vectorisation, because they could support or impede the correct photointerpretation of objects in the scene. From this point of view, the most important features are cloud cover, equal to 0%, the environmental quality equal 90% - excellent, low off-nadir angle, fundamental for avoiding perspective effects, equal to 6 degrees and sun azimuth and sun elevation angles, fundamental for shadows interpretation, calculated on the basis of the date and hour of collection and equal respectively, to 140 degrees and 62 degrees.

Images geocoding and orthorectification were performed directly by the Company supplying the images to Regione Emilia-Romagna. For this reason, Regione Emilia-Romagna supplied us six different orthoimages, whose extent coincides with the central portion of original scene. They are corresponding with 6 regional technical maps at 1:5000 scale (CTR5). The GSD of orthoimages is equal to 70 cm. The original orthoimages were in UTM ED50 cartographic reference system, and were reprojected by the Company in the italian projection system Gauss-Boaga. The accuracy, certified by Regione Emilia-Romagna, is less than 4 meters in comparison with the technical map.

It must be underlined that no specific information were supplied about the orthorectification process carried out by the company charged with it.

Certainly GCPs were collected from CTR5 and the DTM were derived from the same maps, supplied to the Company by Regione Emilia-Romagna, but the number and distribution of GCPs and the DTM grid spacing are not known. As well as, after all, nor the software used in the orthorectification process, nor the correction model adopted are known.

3. LARGE SCALE GEODATABASE

Regione Emilia-Romagna, first in Italy, started a project for a 1:5000 GeoDataBase creation, that implies the updating of topographic data (i.e. Technical Map) of the whole region, their complete vectorization and the structuring in a GeoDataBase. The present

work is involved in a larger research addressed to suggest a national standard for GeoDataBase creation.
The GeoDataBase creation starting from the the rasterization of analogic maps is called 'modalità C' (modality C), and it implies different steps:

- ✓ **passage from 1:5000 analogic maps to raster maps for the whole regional territory;**
- ✓ **passage from raster map to vector map;**
- ✓ **updating of vector map using high resolution satellita data (QuickBird) and integration with local data;**
- ✓ **creation of a structured object-GeoDataBase.**

Contents of GeoDataBase is very complex and it is constituted not only by all objects of reality (buildings, road, rivers…), the networks (road, water, electrical….), and all elements of altimetry (contour lines, points), but also by toponymy and the graphic elements needed for the map representation.
The geodatabase is organized in classes (road circulation area, pedestrian passage area, wet area, building, bridge….) populated by objects.
Every class is composed by an alfanumerical component, i.e. tables with attributes of every object of the class, in a text or XML format, and by a geometrical component, that is a file of geometrical primitives in a shape format. Classes are than grouped in layers, defined as a set of objects from one or more classes with homogeneous spatial representation. Examples of layers are shown in the following list:

- ✓ **Polygons: general land cover**
- ✓ **Lines: contour lines, networks, linear vegetation ….**
- ✓ **Points: sparse points, poles, pylons….**

As said, the GeoDataBase geometrical component partially comes from the vectorization of Technical Maps and must be useful to produce new numerical maps of different themes at a scale 1:5000. For this reason, it must respect the rules for numerical maps at this scale. Particularly, in the frame of the use of high resolution QuickBird images for the map updating, it must respect stricter tolerances than those required for 'quick' updating of Technical Maps.
The positional tolerance for traditional Technical Maps obtained with photogrammetric process is set at:

0.4 mm × scale = 2 m at 1:5000 scale

While the positional tolerance for 'quick' updating of traditional Technical Maps is fixed at:

1 mm × scale = 5 m at 1:5000 scale.

The positional tolerance for 'quick' updating of vector Technical Maps through satellite orthoimages is fixed as 3 m, less than the traditional 'quick' updating.

4. VECTORIZATION

The image quality and its radiometric characteristics, due to the image capture angle, the sun elevation angle, cloud cover and the characteristics of the captured surface at the moment of imaging, are critical aspects for the vectorisation, because they could support or impede the correct photointerpretation of objects in the scene.
For this reason, a preliminary image enhancement was useful in order to emphasize the objects that were going to be vectorized and to reduce, where possible, the shadows.
The image pre-processing was performed with Focus, a package of PCI Geomatica 9 suite.
Orthoimages were supplied as 8 bit images with a nearest neighbour resampling (fig. 2a). First of all, the images were resampled with a bilinear interpolation (fig. 2b) and,

subsequently, a high pass filter with a 3×3 window was applied. The last filter allowed to perform an edge sharpening of the objects of interest.

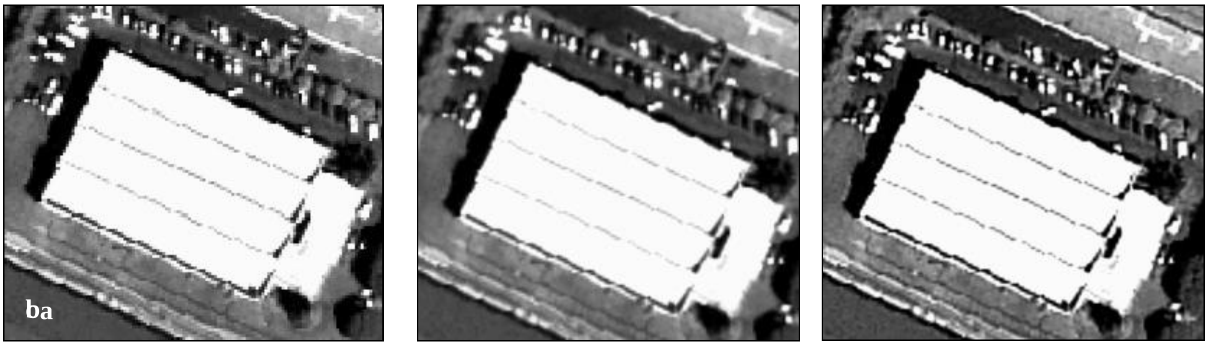


Fig. 2 Image enhancement: a. nearest neighbor resampling, b. bilinear interpolation, c. edge detection filter

Even if in some cases of photointerpretation shadows could be useful, they represented a great problem. The advantage given by the almost complete absence of perspective effects, due to the very low off-nadir angle, that could help not to introduce too strong positional errors during the vectorization of the foot of buildings, was quite cancelled in correspondence to the sides covered by shadows. A contrast enhancement (root enhancement), applied in order to emphasize objects under shadows, didn't get good results in the most of cases (fig. 3).

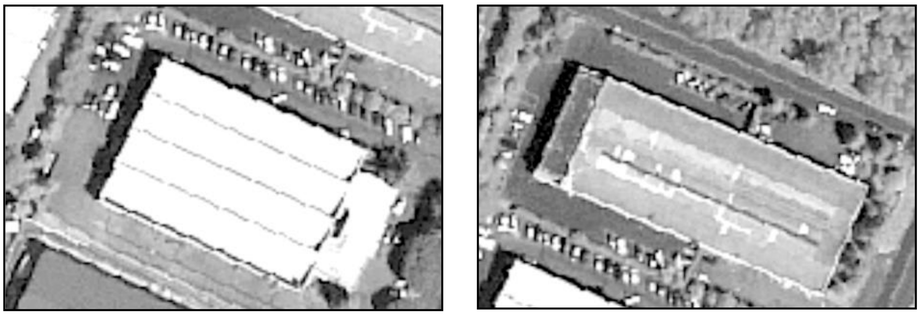


Fig. 3 Image enhancement: examples of root enhancement for eliminating shadows

The vectorization process was performed in ESRI ArcGis 9.1 environment (ArcMap) in order to obtain a shape file of the vectorized objects. Shape file in fact is the required format for geometrical component of the GeoDataBase and is the standard format of ESRI product. It allowed not to transfer files from one format to another and to avoid loss of data.
Two different tests of vectorization were performed. During the first test an operator vectorized the panchromatic images without the help of any additional data; in the second case, instead, just for improving the visual interpretation, penalized by the lack of the colour, the operator made use of the coloured images from Google Earth. It must be underlined that they are pan sharpened images obtained from the bundle images (one pancromathic layer and four multispectral layers) collected by Digital Globe on behalf of Regione Emilia-Romagna, that, however, owns only the panchromatic scenes.
Obviously, since this kind of images are not projected they can't be absolutely used for metrical purposes, and their use was exclusively addressed to better understand the

shape of objects and to clarify uncertain cases, especially due to the presence of vegetation or buildings of complex geometry.

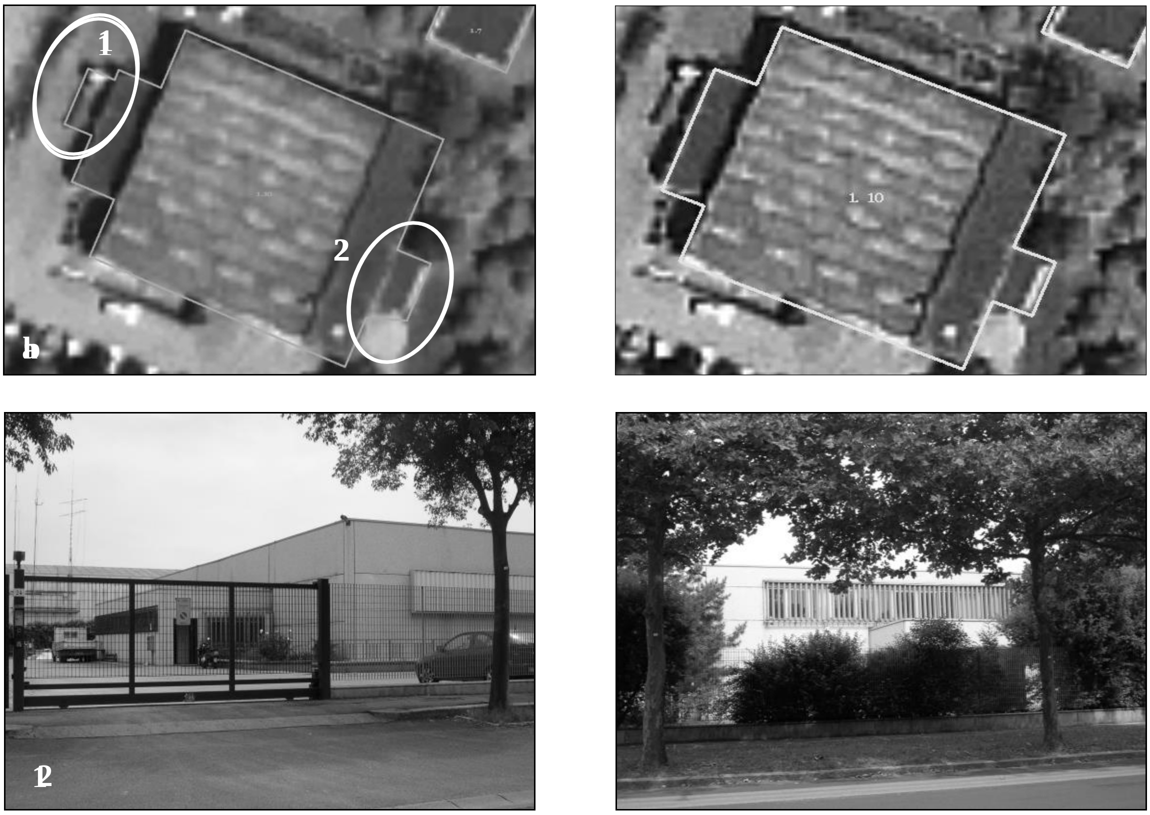


Fig. 4 Shape differences in different tests of vectorization: a. panchromatic image b. panchromatic image and coloured image help. In the pictures above particular of vectorized objects

In the first case the operator vectorized buildings of three different areas, two industrial and one urban, using an average visual scale 1:500-1:300. The operator detected 43 and 40 objects respectively in the industrial and urban areas. The vectorization proved difficult overall in the area with a thick vegetation and in the urban area with high buildings. In the second case the operator detected over the same areas 43 and 39 objects respectively. The help of colour allowed to detect an error in the previous vectorization in the urban area.

In general, for simple geometry, overall in the industrial area where buildings are well separated, of rectangular shape, with well distinguishing roof covering, it was quite simple to detect and recognize objects in both cases, with and without the help of coloured images. In case of complex geometry the help given by the colour image proved very useful to discriminate vegetation or other objects, like as shown in figure 4, where a truck was changed for a building, and to reconstruct the real shape of buildings in critical cases. It's important to remember that panchromatic and pan sharpened images come from the same image bundle.

Even for urban area for simple geometry of rectangular shape it was quite simple to detect and recognize objects in both cases, with variable differences but largely within positional tolerances. Also in case of complex geometry the help given by the colour image proved fundamental to discriminate vegetation and shadows and to reconstruct the real shape of buildings.

However, in case of complex geometry, above all concerning urban areas and high buildings, the help of colour image is not enough and a ground reconaissance is necessary to understand the real shape.

5. COMPARISON OF RESULTS

In this section the results of comparison between the two cases of vectorization are shown.

As previously said with respect to the number of vectorized buildings, with the help of the colour images an error of vectorization was found and an object was excluded. Regarding the differences in shape of buildings, substantial differences were found in 25 buildings in the urban area and in 21 buildings in the industrial areas.

Moreover, a comparison between coordinates of corners of vectorized buildings in the panchromatic image and in the panchromatic image with help of colour image was carried out, taking in account only corresponding corners.

Table 1. Comparison of vectorization

	Urban			Industrial		
Number of points	226			342		
	D_EST (m)	D_NORD (m)	Delta (m)	D_EST (m)	D_NORD (m)	Delta (m)
Mean	-0.08	0.11	0.65	0.00	0.16	0.62
RMS	0.61	0.44	0.39	0.48	0.53	0.39
Max	1.45	1.22	1.84	1.48	2.08	2.18
Min	-1.76	-1.49	0.03	-1.20	-1.19	0.03

Table 1 summarizes the results of comparison. It shows that the mean of absolute differences, is quite similar both for industrial and urban area, and it's about 1 pixel, with maximum values always within the fixed tolerances.

6. REPEATABILITY OF VECTORIZATION

A further test of vectorization was performed by a second operator in order to test the repeatability of vectorization. In this case the operator used only the panchromatic image. The number of found buildings is the same in both cases, but substantial differences in shape were found: 14 buildings in the urban area, 15 in the industrial one. A further qualitative and quantitative analysis of differences is in progress and the results are not related in this paper.

Table 2. Number and percentage of different in shape buildings

	Urban	Industrial
Number of vectorized buildings	40	43
Number of different buildings	14	15
%	35	34.9

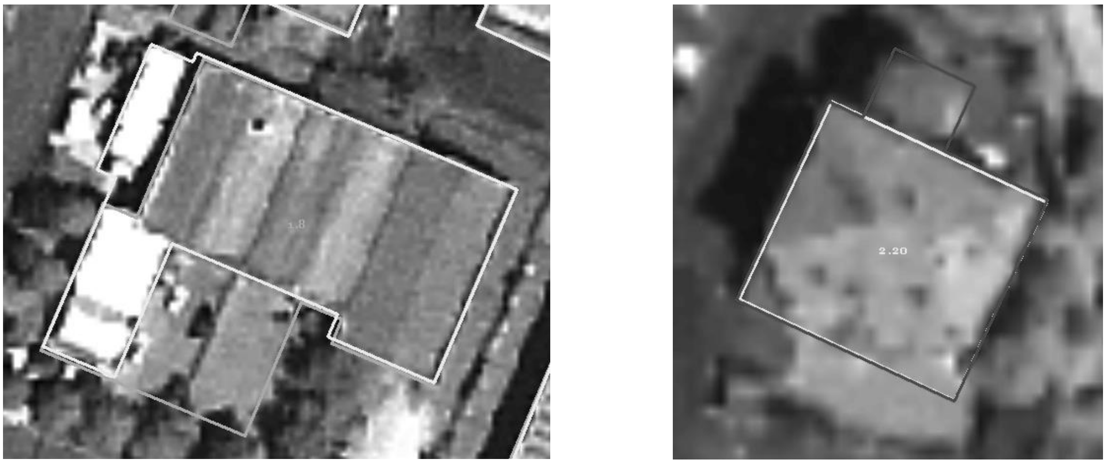
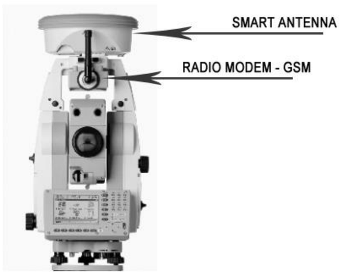


Fig. 5 Differences between vectorization performed by different operators

7. FIELD SURVEY AND RECONAISSANCE

A crucial element for the validation of results is the comparison with field data. It's necessary to detect a methodology that allows to perform measurements of the actual position on the ground of objects detected in the images in a quick and inexpensive way. This operation allows the final field trial.

The methodology involves the use of a Continuously Operating Reference Stations GPS Network built up by DISTART in the east side of the Emilia Romagna region. The system allows the measurement of coordinates in NRTK modality with just one receiver at centimetre level. Because of the surveying points (building corners) can not be directly occupied, the survey must be performed also with a traditional total station. Therefore, a field survey was performed using the SmartStation Leica, a total station integrated with a GPS that allows distance measurements without prism.



The survey method adopted with SmartStation involves the following steps (Fig. 6):

- ✓ **determination of GPS coordinates of two stations (S1, S2);**
- ✓ **bearing of the second station to the first one;**
- ✓ **detail survey from the second station and traverses.**

The GPS survey was performed using a GPS-NRTK network and it allowed to obtain a detail survey already framed in a global reference system.

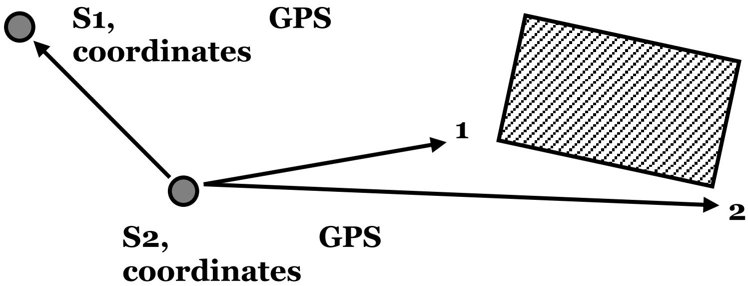


Fig. 6 The SmartStation Leica and a sketch of a method of survey

The coordinates obtained by the NRTK Spider Net System are in WGS84(ITRF2000) system. In order to make comparison with vectorized data, they were transformed first from WGS84(ITRF2000) to the national WGS84 frame, called WGS84(IGM95) and, subsequently, from WGS84(IGM95) to the cartographic italian system Gauss-Boaga using parameters for the transformation between the two systems.
Table 3 summarizes the comparison between coordinates of surveyed corners and vectorized corners. The field survey confirmed, for those objects well recognizable, that absolute differences are within fixed tolerances.

Table 3. Comparison between accuracies

	PAN IMAGE			PAN + COLOUR		
	D_EST (m)	D_NORD (m)	Delta (m)	D_NORD (m)	D_EST (m)	Delta (m)
Mean	-0.95	-0.41	1.20	-0.93	-0.16	1.29
RMS	0.64	0.54	0.58	0.73	0.70	0.48
Max	0.43	0.64	2.61	1.44	1.85	2.11
Min	-2.58	-1.54	0.22	-1.80	-1.27	0.19

8. CONCLUSIONS

The results of field survey confirmed the correctness and accuracy of geocoding and orthoprojection of supplied orthoimages. Moreover, the analysis of geometrical accuracy proved that orthoimages could be used for 1:5000 – 1:10000 technical scale map updating being accuracy always whithin fixed tolerances.
The use of panchromatic images is not sufficient for a correct detection and interpretation of objects and their shape: the use of projected orthoimages generated by data fusion is very expensive but it is not possible a correct photo-interpretation process without the information from colour.
Field survey and integration can be performed in an economic and accurate mode through the combined use of GNSS receivers and total station, using a NRTK network.

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