

# **AUTOMATIC 3D VISUALIZATION OF GEO-INFORMATION FOR FIREPREVENTION IN EUROPEAN MEDITERRANEAN AREAS**

Harald STELZL, Oliver SACHERER, Hannes RAGGAM, Andreas WIMMER, Alexander ALMER

Joanneum Research, Institute of Digital Image Processing, Graz, Austria

Phone: ++43 316 876 1768; Fax: ++43 316 876 1720

[harald.stelzl@joanneum.at](mailto:harald.stelzl@joanneum.at)

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## **ABSTRACT:**

The providing of basic data for decision procedures in disaster management is carried out to an ever increasing extent by means of remote sensing methods. Here, not only the accuracy and availability of data, but also an easy and affordable evaluation represents an important factor. That is why the automation of all sorts of processes in data preparation and analysis gains increasingly more importance. Within the framework of this contribution it will be described how basic data are acquired and visualized automatically by means of remote sensing methods for areas, where existing maps and geodata are available only to a small extent. Here, a continuous production line starting from the creation of an elevation model, geo-referencing and classification up to the automated 3D-visualization of test areas in the Mediterranean area is described.

The data processing ranges from the calculation of surface models, digital elevation models (DEMs) and geocoding of high resolution satellite images to classification of vegetation and biomass calculation. Based on these DEMs as well as on optimized parametric sensor models, multispectral as well as panchromatic Quickbird images are geocoded. The classification of vegetation makes use of "pan-sharpened" Quickbird images resulting from data fusion of panchromatic and multispectral images. Biomass data can be calculated from the classification results and forest heights, which are extracted from surface models in order to support fire prevention carried out by local forest managements.

For the presentation of these results 3D landscape visualization plays a crucial role because classification results which may be raster or vector maps using specific colours for different classes are not easy to understand for all users involved into fire prevention. The construction of photo-realistic 3D views and 3D animations based on artificial textures and on artificial ecosystems allows us to realise an easily understandable presentation of the current vegetation situation and possible changes in the future.

Thus the automatic 3D visualization of raster and vector data will be the main aspect of this paper. Based on the landscape model constructed from the above described DEMs and classification results, a strategy will be described making possible the automatic 3D visualization of every vegetation analysis and change simulation without additional effort. Thus the fire fighting services will get an additional innovative tool for planning and decision making.

## **1. INTRODUCTION**

Many tasks in forest and fire fighting services are managed by the use of professional GIS and remote sensing technologies. These systems handle large vector and raster data pools and make possible manifold calculations and analyses necessary for planning and decision tasks. Moreover, two-dimensional and occasionally three-dimensional presentations and visualizations of raster and vector data are feasible. In particular the 3D-presentation of geo-information is a very useful tool for scientists but also for decision makers in forest and fire fighting managements both for the planning of precautionary measures and in general decision procedures.

In the European Mediterranean regions vegetation monitoring is of special interest for fire prevention. The biomass, calculated from the vegetation is the main indicator for risk analyses of forest fires. Within the EU-project FIREGUARD (Monitoring Forests at the Management Unit Level for Fire Prevention and Control), biomass data for test areas in Greece and Portugal are calculated from high resolution remote sensing data. The overall aim of FIREGUARD is to provide detailed information on fuels, terrain, land use and infrastructure to forest and fire fighting services at the forest district and sector levels for application in fire prevention and control.

Thus, the visualization of these results assumes an important role, because not only 2D illustrations like vegetation mapping are applied but also photo-realistic 3D views and animations, which show the current situation as well as possible future scenarios in the concerned areas.

## **2. DATA PRE-PROCESSING**

### **2.1 Surface model generation**

Ikonos satellite stereo image pairs have been used to generate 3D surface models of a vegetation-covered area in northern Portugal (Figure 1) and in Crete. For the stereo processing of the images and their ortho-rectification, the Remote Sensing Software package Graz (RSG, Joanneum Research, 2000) was used, which is specifically designed for geometric processing of remote sensing images. First experiences regarding Ikonos stereo data processing and ortho-rectification were gained in an application related to an Alpine stereo data set (Raggam et al., 2004).

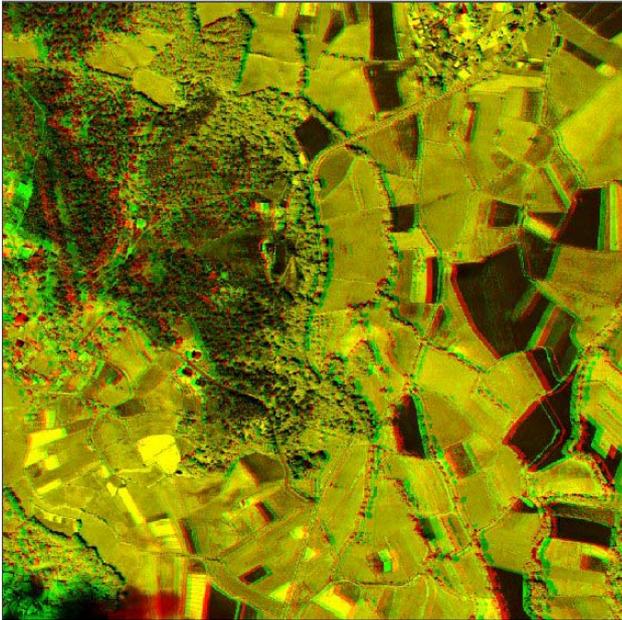


Figure 1: Part of an Ikonos stereo image of a vegetated area of northern Portugal in anaglyph presentation

For Ikonos images, no physical sensor model parameters are provided, but so-called “rational polynomial coefficients” (RPCs) are given instead. For the area in northern Portugal, a set of 14 GPS-measured ground control points has been acquired and used to verify the quality of the RPCs for the Ikonos stereo images, resulting in a location error of about 2 metres in planimetry, but some 55 metres in height. The RPCs were then optimised, resulting in a reduced error of slightly more than 1 metre in planimetry and height.

Using the stereo processing chain of the RSG software, a terrain surface model was derived from the stereo images (Figure 2). In the grey-level based presentation, the forested areas are clearly shown to be elevated above their surroundings.



Figure 2: Digital surface model

## 2.2 Geocoding

Using the generated surface model, corresponding multi-spectral and panchromatic QuickBird images were first geocoded, followed by a pan-sharpening process, where the panchromatic Quickbird image (60 cm resolution) is fused with

the multi-spectral image (2.4 m resolution), leading to an enhanced multi-spectral QuickBird image of 60 cm resolution (Figure 3).

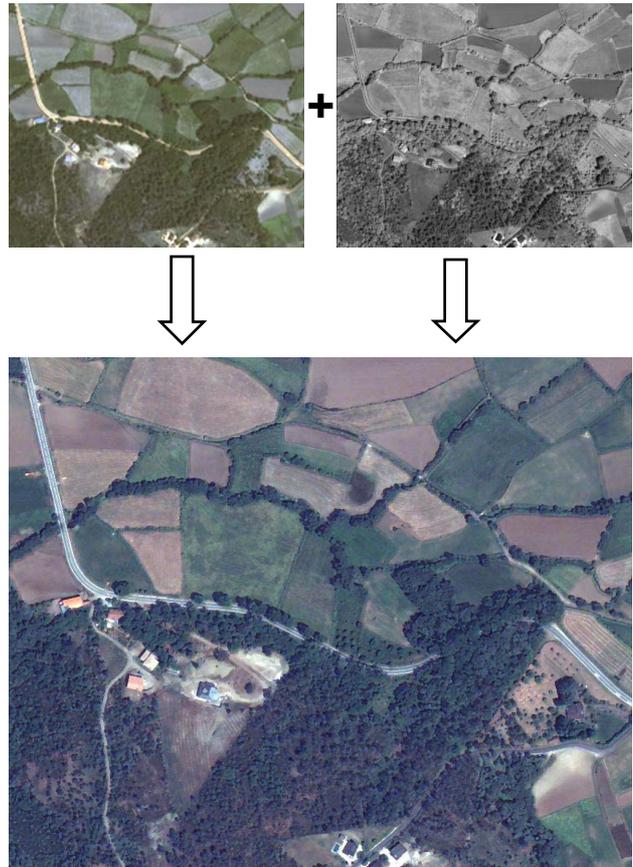


Figure 3: Pan-sharpened Quickbird ortho-image produced from panchromatic Quickbird image (top right) and multi-spectral Quickbird image (top left)

## 2.3 Classification

The extraction of biometric information from the forest cover (e.g., tree species, crown base diameter, and cover) was performed with the use of the pan-sharpened QuickBird imagery.

For the pan-sharpening process, the radiometric properties of QuickBird multi-spectral and panchromatic images are quite similar, since the pan-channel represents the same spectral range as the four individual multi-spectral channels. It was therefore straightforward to produce a high-quality multi-spectral image with 60 cm spatial resolution (see Figure 3).

The methodology used in this process is based on a Brovey transformation, where the pan-channel undergoes a histogram matching process relative to the first channel of the Brovey transformed image. This first channel is essentially the sum of all multi-spectral channels and shows, therefore, a high correlation with the pan-channel. The result of the histogram-matching then replaces the first channel of the Brovey transformed image and an inverse Brovey transformation is applied to obtain the final result of the pan-sharpening process. A segmentation process that groups spectrally similar pixels together provides the basis for the land cover classification. This segmentation aims at building larger and hence more stable “units” for the classification process.

The classification of the stands in the imagery was based on very detailed field-collected reference data (including

allometric biomass equations). These data allowed the establishment of suitable training areas for the classifier to distinguish between various vegetation types, such as forests, meadows, pastures, and shrub lands.

A typical classification result is shown in Figure 4, which shows deciduous forests in red and coniferous forests in green colours. Figure 5 shows the improvement achieved by using segment based classification in contrast to a traditional pixel-based approach.

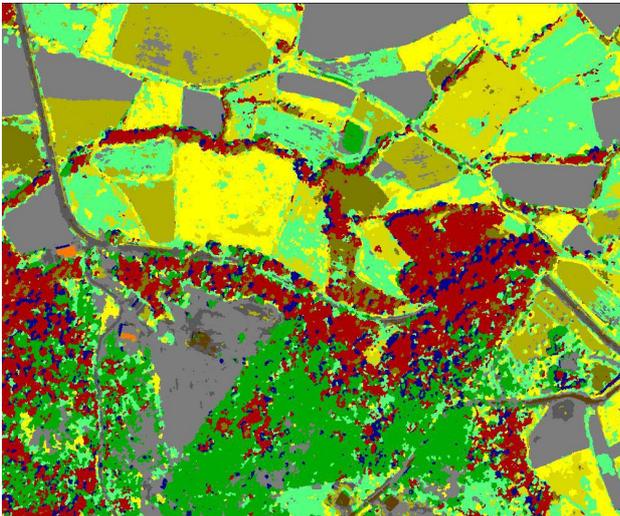


Figure 4: Land cover classification

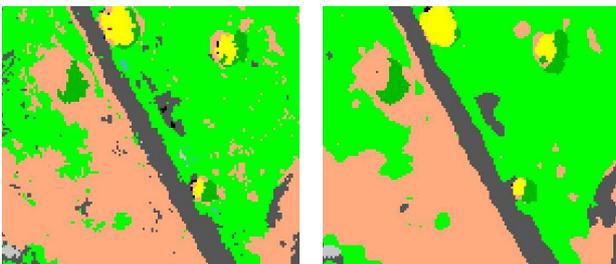


Figure 5: Comparison between pixel-based classification (left) and segment based classification (right)

To extract parameters related to crown base diameter and density, a segmentation based on the land cover classification was performed. The approach of segmenting based on a classification has the advantage to be able to build segments that consist of spectrally rather heterogeneous pixels. This is necessary, since the spectral values of a single tree crown stem from illuminated and not-illuminated parts of the crown, hence a traditional segmentation that aims at combining similar pixels is not advisable.

The final calculation of biomass is then performed, based on the classified tree species and the extracted crown base diameter (or crown area). These parameters create the input for the allometric biomass equations, the accuracy of which is currently undergoing further evaluation.

## 2.4 Vegetation height model

Tree stand heights were determined by subtracting the ground elevation model from the surface elevation model. In the example, the ground elevation model was generated interactively by extracting ground heights from the surface model wherever the classification did not identify vegetation or forest areas, and interpolating a respective raster elevation

model. A superposition of the ground elevation model and the forest mask is shown in Figure 6. Based on this combination the forest height model shown in Figure 7 was finally derived from the height differences between the surface and ground models for the masked areas. The very bright areas show elevations of 10 metres and more and correspond to deciduous forest areas, whilst the areas in light grey correspond to coniferous forest areas that display heights of less than 10 metres. The accuracy of these results is currently being verified with respect to ground reference data.

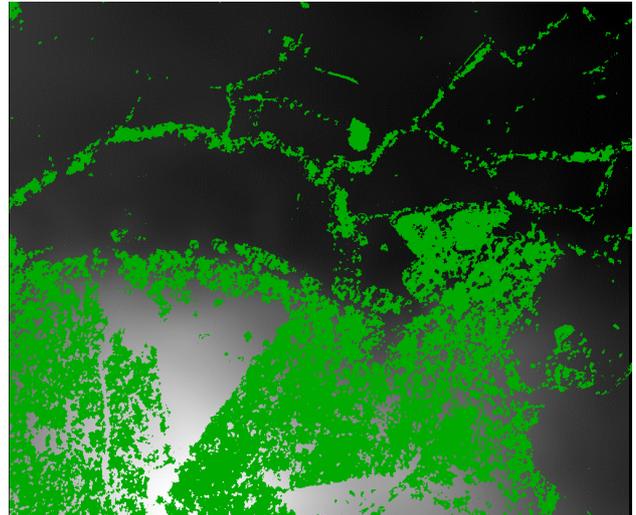


Figure 6: Ground elevation model, superimposed with forest mask

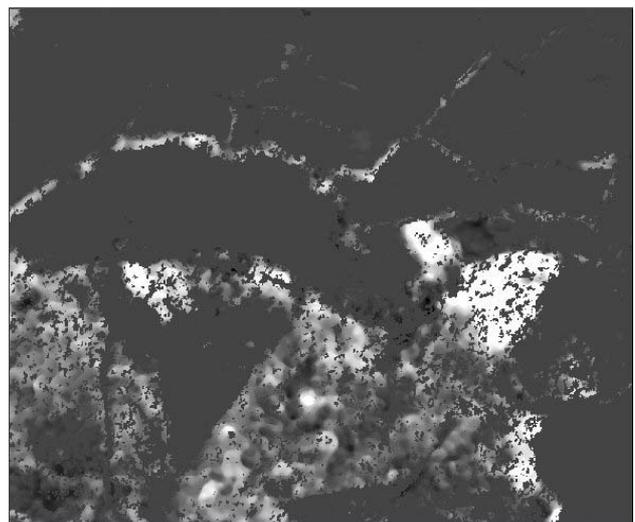


Figure 7: "Vegetation" height model

The vegetation height model and the classification results are the basic data for the biomass calculation which is a main indicator for fire prevention measures.

## 3. AUTOMATIC 3D-VISUALIZATION

The results described in Chapt 2 were among other things the basic material for the creation of 3D landscape models and thus for the 3D visualization of the situation on site as well as for the simulation of changes. Consequently, beside maps and statistic evaluations also photo-realistic 3D views and animations for

decision procedures within the forest managements could be generated directly.

Subsequently, examples for the Greek test site “Anopolis“ on Crete will be described (Overview, see Figure 8).



Figure 8: 3D view of Anopolis, generated from DGM and multispectral Quickbird scene

### 3.1 Development of artificial ecosystems

The basis for the 3D visualization of the zones of interest was the development of a complete 3D landscape model generated from remote sensing data as well as additional geo-information. (see Almer, Stelzl (2002)). For the texturation an object library was developed, containing all necessary forms of vegetation like trees, scrubs or meadows, but also all existing soils like clay, gravel or earth. The object library made possible the combination of particular objects to artificial ecosystems aimed at simulating distributions such as mixed forests. The construction of this database as well as the 3D visualization based on this construction was carried out using the animation software “Visual Nature Studio 2“ (VNS) of the American company “3D Nature“. Both real 3D objects and 2D images may be used as artificial objects. Vegetations can be simulated very appropriately with 2D objects and save above all rendertime. The 2D images are always rotated in an upright position towards the optical axis of the camera and by means of shading a pseudo 3D visualization is accomplished. Objects such as houses, bridges or dams have to be applied as real 3D objects (e. g.: from Lightwave 3D, Maya, etc.) to guarantee a realistic visualization (see 3D Nature (2003)).

Within the framework of the project FIREGUARD 2D, textures for the specific local vegetation had to be built up almost completely, because the textures available in VNS were not appropriate for the visualization of the Mediterranean vegetation. From respective photos of the local vegetation (trees and scrubs) particular objects were released in Adobe Photoshop and integrated into the object library of the visualization software. A sufficient resolution of these photos and an exact release (clear separation from the background) had to be paid attention to. Thus, objects for artificial ecosystems such as cypress, pine or maple woods, or different shrub forms were created. But also the soil and the understorey were modelled accordingly in order to design these ecosystems in a realistic way. For all needed soils (clay, gravel, earth, etc.) 2D textures were created from photos in combination with particular texture instructions. Thus, for instance realistic gravel

textures could be generated from different gravel photos, combined with each other by means of fractal noise. To be able to model an uneven ground structure more appropriately, also “Bump Mapping“ was applied. Additional understorey for the artificial woods in turn was accomplished by the integration of 2D images of understorey vegetation (scrubs, grasses, etc.) into the modelled wood ecosystems (Stelzl et al., 2004).

### 3.2 3D visualization on the basis of raster classifications

For the presentation of the classification results, 3D landscape visualization can play a crucial role in their interpretation, as colour-coded classification results generally are not intuitively easy to interpret. The construction of photo-realistic 3D views and 3D animations, based on artificial textures and ecosystems, allows the realisation of an easily understandable presentation of an existing landscape and its changes.

The classification results of the area of Anopolis were visualized by generating artificial (virtual) ecosystems. In conjunction with the produced digital surface models, virtual 3D landscapes were built up so as to give the user a photo-realistic impression of the terrain and its cover. Every identified image class was connected to a virtual ecosystem, using the assigned grey value of the classification. After the generation of all necessary classes within an area, all changes in surface features were visualised automatically by importing the new or changed raster classification.

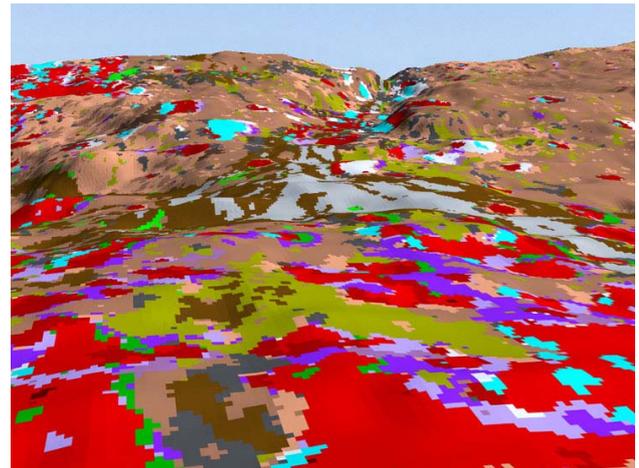


Figure 9: From a 3D view of a classification result to the 3D view with artificial ecosystems

Figure 9 shows the comparison between the classification results draped over a DEM and the virtual 3D landscape that has been modelled using artificial ecosystems.

This visualization technique makes possible scale independent modelling of 3D landscapes, because the artificial ecosystems are modelled in high detail, using overstorey, understorey, and ground textures. Figure 10 shows a 3D view with a camera position 1 metre over ground. The artificial ecosystems include enough details for such perspectives.



Figure 10: Very high scaled 3D-view

### 3.3 3D visualization on the basis of vector data

However, the automated visualization of changes can be applied much more efficiently together with interpretations or classification results in vector form. Considering the possibility of attributing all classification data (e.g. in shape-files), the direct access to these attributes in 3D visualization suggests itself. To test this within the framework of the project FIREGUARD, beside raster classification also a visual interpretation in ArcView was generated. Thus, the same soil areas were delimited with polygons, which were endowed with values relating to the attributes vegetation form, height and density. In the animation software, these attribute values were consequently linked to the objects in the data base by means of calculation rules. Thus, a considerably more powerful tool for the automated visualization was created than those based on raster classifications. The distribution and scaling of artificial objects for the design of ecosystems thus was not carried out within preprocessing (see Chapt 3.1) but in an automated way by accessing the attributes in the shape-files. Thus, every change of geodata could be visualized immediately. Changes concerning polygon extensions or changes in tree heights were automatically included into the 3D model. The calculation time for an updated 3D view was only a few minutes. Figure 11 and Figure 12 show the changes in the 3D landscape as a result of the change of the tree height in the shape-files (Stelzl et al., 2004).

Consequently, the direct visualization of every change, reflected either in the raster classification or in the vector attributes, may be carried out without delay and placed at the disposal of the participating decision-makers.



Figure 11: 6 m maximum height of pine forest (from shape-file)



Figure 12: 10 m maximum height of pine forest (from shape-file)

However, beside the visualization of changes also the simulation of planning methods can be realised automatically. By defining artificial objects such as roads, routes, dams or buildings within the object library an automatic integration of such objects is possible. By accessing the object parameters in the data base (e.g. type and width of road, pavement) an automatic visualization may be realised without any problem. For example, importing information about a new road leads to a new 3D model, as shown in Figure 13.



Figure 13: Automatic visualization of a planned road

### 3.4 3D Animations

Animations like virtual flyovers or terrestrial walks can be produced from artificial landscape models in order to present landscapes in an interesting way. So as to generate an animation, many single images (frames) must be rendered and combined to form an animation file (e.g. mpg-file). It is vital to define a flight path and to determine the variable view direction along this flight path, as well as the equally variable flight height. Starting from a standardised frame rate of 25 images per second, 1000 separate images must be rendered for a 40 second animation. Figure 14 shows 4 different frames of an animation.

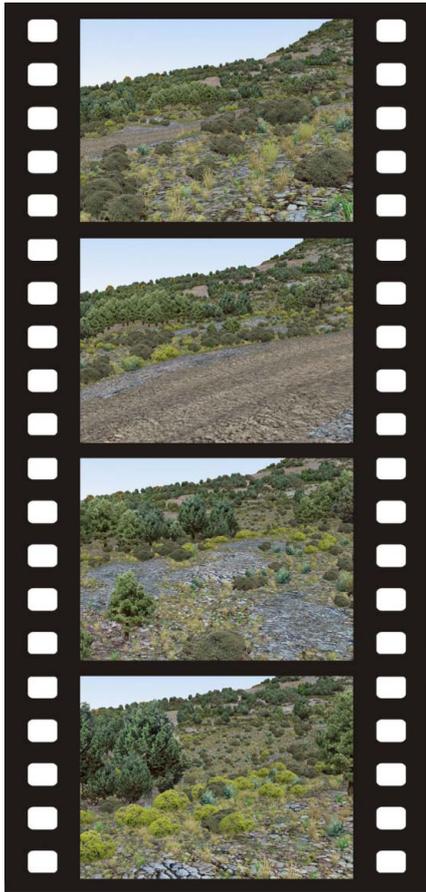


Figure 14: 4 frames of a virtual terrestrial walk (every 3 seconds)

The animation makes use of the “keyframe-animation” technique, in which all the necessary parameters, such as flight height, view direction, banking, sun light, etc are fixed for a small number of points (keyframes). The values for the frames in between are calculated from interpolation between the keyframes, which is normally done by a cubic spline interpolation. This ensures that the flying path is smooth and realistic.

Anti-aliasing techniques have to be applied to the render process in order to avoid flickering in the final animations. These single images have been rendered using a frame size of 352 x 288 pixels (1/2 PAL resolution).

For the generation of animation files, the frames have to be coded into a movie format. Different compression rates have to be used for online and offline application in order to produce a useful data size. The movie formats currently used are mpeg-1 and mpeg-4.

The creation of videos is of course quite time-consuming and can not happen in real time. However, the virtual flyovers and walks gave a sound overview of the character of the landscape as well as of density and form of the vegetation. Thus, these 3D animations may as well serve as a supporting tool for fire prevention.

### 4. OUTLOOK

The approach described here offers a general interface between processing and 3D visualization of geo-information. Consequently, an automation of the visualization process was realised, making possible the presentation of the results of surveys and analyses in an appropriate way. It is crucial here that after the creation of the basic data (DGM, geo-referencing, classification) and the construction of the required object libraries (artificial ecosystems) every section and every change in an area can be visualised immediately without additional work. By this means, an innovative tool for planning and decision making in the range of fire prevention is made available to forest managements, civil protection groups and decision makers.

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