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WORKSHOP ON REMOTE SENSING TECHNIQUES WITH APPLICATIONS TO AGRICULTURE, WATER AND WEATHER RESOURCES

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ANALYSIS TECHNIQUES FOR VEGETATION IDENTIFICATION

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ANALYSIS TECHNIQUES FOR VEGETATION IDENTIFICATION

The monitoring of vegetation is a major application of remote sensing techniques, as it can be useful both for estimating agricultural production and forest cover and for evaluating the conditions of vegetation canopy as an indicator of the state of the environment.

In particular, remote sensing offers several advantages over usual monitoring methods for agricultural applications, and its use is consequently continuously increasing.

As a base for understanding the potential of remote sensing in vegetation monitoring, the comprehension of the complex relationships between plants and electromagnetic radiation is necessary.

Light reflectance from plant canopies is an integrated response to various plant structures and soil background. In our lecture, attention will be focused on the spectral properties of green plants, without considering soil influences which are the subject of a different talk.

Plant spectral properties

Globally, the spectral properties of a typical green plant in the .5 to 2.5 Mn range are schematized in fig. 1; the transmittance curves for all mature and healthy leaves are symilar to the reflectance curves but slightly lower in amplitude.

In the visible region of the electromagnetic spectrum, the response of green leaves is fundamentally determined by their pigments (fig. 2). Chlorophyll usually absorbs for the photosynthetic process 70 to 90 percent of the light in blue and about 90 percent of the

light in red, while it reflects green light. The presence ot other pigments, such as carotenoids and xanthophyll, tend to modify this trend slightly by increasing the absorbtance at short wavelengths.

As pigments are the major contributors to spectral properties of leaves in the visible, their quantity strongly affects the appearance of vegetated surfaces, and all the factors which can modify leaf pigment content are readily detectable by remote sensing techniques. On these basis, we can discern between species with different pigment content and, within a single species, among individuals which show pigment variation related to physiological or environmental factors (fig. 2).

In the middle infrared region, green plants present an high plataou of reflectance closely related to leaf structure. The spongy mesophyll strongly scatters near infrared light owing to the disposition of cells and air vacuoles within it; the integrity of leaves is obviously determinant for near infrared response.

In the medium infrared, spectral signature of leaves is very symilar to that of a corrsponding layer of liquid water, and it is therefore greatly affected by leaves water content.

Finally, the thermal infrared response of plants is influenced both by environmeantal factors and by physiological processes regulated by plants themselves, such as photosinthesis, respiration and traspiration, so that it can be considered as a good indicator of vegetation conditions.

Factors influencing plants spectral signature

As already noticed, every single species has a peculiar leaf structure and pigment content, and so a peculiar response which is the basis for species discrimination by remote sensing techniques.

Furthermore, every plant can show a great variety of spectral signature depending on a series of environmental factors, of which we will examine the principal ones.

The internal arrangement of leaves strongly depends on their age, as many plants tend to develop intercellular air spaces and certain kinds of pigments while reaching maturity; a mature leaf will present a slightly different color with respect to a young one, and, overall, an higher near infrared reflectance (fig. 3). As broad leaves senesce, their light reflectance usually increases markedly in the green visible light wavelenght region, because of chlorophyll degradation, while the persistance of anthocyanin and carotene pygments may cause relatively high reflectances in the red and near the blue region of the visible spectrum (fig. 4).

Leaf position and inclination affect the scattering properties of plants canopies, so that diurnal and seasonal variations of those parameters depending on internal and environmemntal factors can be highly relevant (fig. 5).

Leaf damage may be reflected both by pigment content and mesophyll arrangement; in this case it may be noticed that chlorophyll activity and so red reflectance is a very sensitive parameter to plants injury, while mesophyll structure, mainly affecting near infrared reflectance, responds more slowly (fig. 6).

Leaf water stress can be readily monitored by middle infrared reflectance and thermal infrared emissivity (fig. 7), but while the former tends to be associated with istantaneous stress, emissivity, connected strictly with plant physiological processes, can be considered as an integrator of plant conditions over time.

Crop Canopy survey

All the factors that have been mentioned so far must be considered when using remotely sensed data for monitoring vegetation; furthermore, the interaction of electromagnetic energy with plant tissues becomes increasingly complex when dealing with an assemblage of leaves in a crop canopy.

Parameter other than hemispherical leaf reflectance which can be important in determining crop's spectral signature include:

Trasmittance of leaves

Amount and arrangement of leaves

Characteristics of other components of the vegetation canopy

Characteristics of the background

Solar zenith angle

Look angle

Azimuth angle

These parameters can cause marked variations in canopy responses and so tend to complicate heavely the interpretation of remotely sensed data. Owing to that, the interaction of light with plant canopy is rather difficult to predict on theoretical basis, as many attempts of modelling its behavior have clearly shown. For practical purposes, to develop statistical procedures calibrated on the particular crop of interest is often easier and more rewarding.

Among other things, vegetation conditions are higly dynamic, and the contribution of soil may be relevant when plant coverage is low or however not complete.

As an aid to the interpretation of satellite data a number of vegetation indices have been developed relying on the spectral contrast between the red and the near infrared region, which, owing to the pigment absorbance of red light and mesophyll reflectance of near infrared light, is selectively high for green vegetation.

A very diffuse vegetation index (V.I.) is that of LANDSAT MSS, very symilar to many others derived by different sensors and satellites, as LANDSAT Thematic Mapper, Spot, NOAA and so on:

V.I. = (N.I.-R.)/(N.I.+R.)

Where N.I. = near infrared reflectance and R. = red reflectance.

From this kind of indices, a transformed vegetation index (T.V.I.) has been extracted to avoid working with negative ratio values:

T.V.I.= V.I.+.5

Variable results obtained by several investigators using those and other indices indicate that it may be difficult to predict which is superior in any particular application, and, in any case, they must be used with cautions to avoid dangerous misintarpretations.

The spectral information acquired by remote sensing platforms preferibely concentrated in form of vegetation indices, may be used for discriminating different crops and for estimating plant biomass and phenological stage.

In particular, vegetation indices have prooved closey related to green biomass in a number of works. The precise nature and the coefficents of such relations are dependento on the kind of index used, on the type of crop monitored and on other factors already mentioned, so that their generalization is almost impossible.

To follow vegetation phenology is often an easier task, provided that multitemporal scenes are available; two phenological rhytms can generally be observed during a growing season, the green wave,

associated with spring or early summer emergence of foliage, and the brown wave, related to late summer or autumn ripening and harvesting in agricultural lands and to disappearence of vegetation in natural surfaces.

AGRICULTURAL RESOURCES SURVEY AND MONITORING

The estimation of crop extension, the recognition of crop stress and the timely and accurate prediction of crop yield are obviously extremely important in every country, but the difficulty of collecting this information may present extremely variable.

Regarding crop identification by remote sensing techniques, it has proved of easy application in countries where there are large and homogeneous fields, such as in many areas of U.S.; the accuracy of several inventories using LANDSAT data resulted in fact relatively high. Unfortunately, in several European as well as in many developing countries croplands are generally interspersed with noncroplands, fields are small and numerous crops have symilar spectral responses. In such complex environments, remotely sensed data may hardly provide enough information for crop identification.

So, as the application of remote sensing to crop inventories relies on the ability to detect and identify the crops of interest from spectral data, the main task for research is to quantify and undestand the sources of variation in spectral measurements of crops, and to develop suitable procedures for overcoming the various difficulties which are present in complex areas depending on a number of envrinmental and ontropogenic factors.

The information provided from satellite data for agricultural applications can be principally characterized by the point of view of spectral, spatial and temporal resolution; the different applicability of data acquired by the various available sensors will be illustrated with some examples.

Agricultural inventories by means of high resolution sensors (LANDSAT MSS and TM, SPOT)

Apposetely planned for vegetation monitoring in developed countries, the LANDSAT and SPOT satellites has been widely used for agricultural applications.

The Multy Spectral Scanner Subsystem mounted aboard all LANDSAT platforms provides scenes with a relatively low temporal resolution (every 18 or 16 days), but with a sufficent spectral coverage (4 bands from the green to the near infrared region) and spatial resolution (about 60*80 meters to the ground). It has proved extremely useful in a great number of agricultural and forestry inventories and in surveys of vegetation conditions, but its performances have been superseded by those of the Thematic Mapper, the new sensor mounted on LANDSAT 4 and 5.

This third generation radiometer, though acquiring images with the same temporal resolution as MSS (every 16 days), presents a complete spectral coverage (7 well separated bands from blue to thermal infrared), and a high spatial resolution, which make its data particularly applicable for agricultural classifications in variable and disomogeneous terrain.

Finally, the french satellite SPOT shows an even higher spatial resolution (20*20 meters), but a rather limited spectral coverage (3 bands from green to near infrared), and its principal applications may be in topographic mapping for highly variable zones.

In our center, we have worked mainly on TM data processing, of which some results will be showed.

Agricultural inventory (Umbria)

This is a typical example of agricultural classification in an European zone by means of data acquired by a high resolution sensor.

In fig. 8 we can see the general features of the considered zone as appearing by the first medium infrared channel (band 5) of a TM scene acquired on 11 July 1985; this is an area of Umbria (Central Italy) around the Tevere river with a preveling agricultural destination at the bottom of the valley and covered mainly by forests in the upper zones.

The information reported by band is already sufficent to discriminate visually the principal cover types, but the automatic classification, carried out by computer processing of the original digital data relying upon some ground control points, used all the 7 TM bands.

The final result of the classification process is shown in fig. 9; the cover types identified were bare soil (white), corn fields (jellow), alpha-alpha fields (brown) and broadleaved woods (red).

Forestal inventory (Trentino)

In this case, dealing with some forestal areas of Trentino (Northern Italy), the main problem for the discrimination of the various cover types using a TM scene of 22 August 1985 was related to the topographic disomogeneity of the region. Owing to differences in slope and aspect of the examined surfaces, their spectral signatures were strongly variable and so diffucult to discriminate (see fig. 10).

This problem, common to many forested areas, was overcome by means of an apposetely developed statistical procedure trained on some ground references, which was capable of classifying the different

woody surfaces isolating the portion of spectral information related to differential insolation.

The results of the classification process are shown in fig. 11; the 5 dominant forestal cover types were discriminated with an high level of accuracy.

Land use mapping in semiarid terrain (Sardinia)

This final example of TM data application concerns a mediterranean environment in Northern Sardinia. This kinds of environments present some features characteristic of semiarid terrain, related to the disomogeneity of the vegetation cover and of the soil background.

The land use mapping of such a territory was possible using a particular maximum likelihood classification process, always trained on ground references. Fig. 12 shows a colour composite obtained by TM bands 1, 4 and 5, and fig. 13 illustrates the final classification of the same area considering 5 cover classes, (prairie, thick and sparse shrublands, reafforested and cultivated areas); also in this case, the final accuracy resulted over 80%.

Use of Metheorological Satellites for estimating green biomass and agroecological parameters.

Some meteorological satellites, particularly the TIROS-NOAA series, originally planned and created for athmospheric studies, has proved useful for estimating green biomass and some important agroecological parameters over large areas. Owing to their relatively low spatial resolution (about 1.1*1.1 Km at the nadir) and their high temporal frequency, they are in fact suitable for evaluating parameters such as temperature, thermal inerthia and evapotraspiration at large scale.

A number of works have shown that those satellites have their maximum utility in developing countries, where the information regarding wide territories is often scarse or completely lacking. Regarding this, a well known application of NOAA-AVHRR data is the estimation of green biomass in equatorial or tropical regions.

Vegetation estimation in desert and semi-desert areas (Niger)

As we have seen, vegetation indices are particularly suitable for estimating the quantity of green biomass over large areas. In this case, we used 2 NOAA AVHRR scenes taken in the 2 most representative phenological stages of plant annual cycle (August and December) to characterize vegetation belts in a sub-saharian zone of Niger.

In fig 14 and 15 we can appreciate the different extension along the course of Niger river of green vegetation; in August, at the end of the rainy season, green vegetation extends considerably towards north. It is clear that such monitoring tecniques can result very suitable for following the desertification process in such zones.

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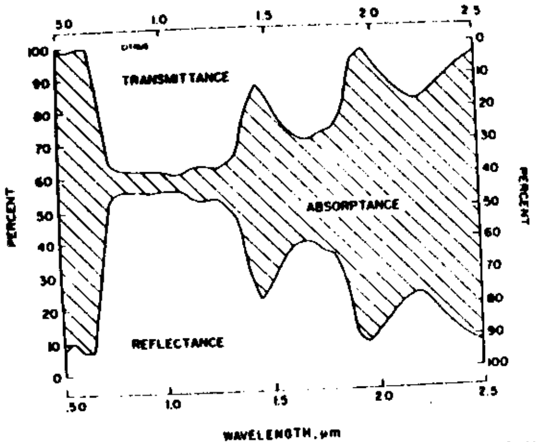


Fig. 33-24. Diffuse reflectance (data corrected for MgO standard decay), transmittance, and absorptance [100 − (percent transmittance + percent reflectance)] of the upper (adaxial) surface of a mature orange leaf. Each spectrum is an average of 10 leaves.

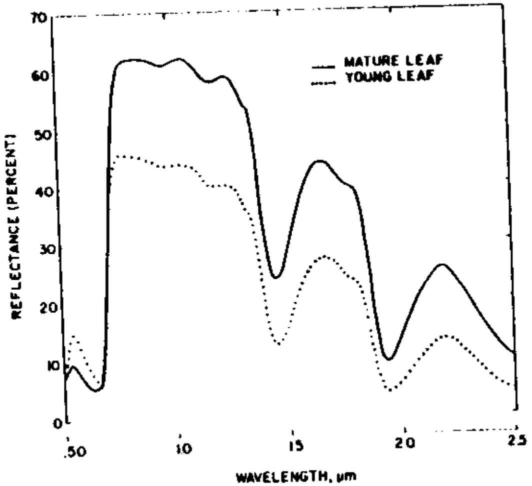


Fig. 33-26. Diffuse reflectance of the upper (adaxial) surfaces of young (bottom dotted line spectrum) and mature (upper solid line spectrum) orange leaves.

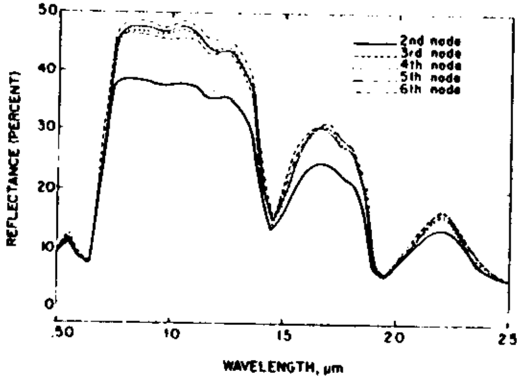


Fig. 33-27. The effect of cotton leaf nodal position on light reflectance. Leaves representing nodes 2, 3, 4, 5, and 6 basipetally had after emergence ages of 20–25, 29, 33, and 35 days, respectively. Each spectrum is an average of seven leaves.

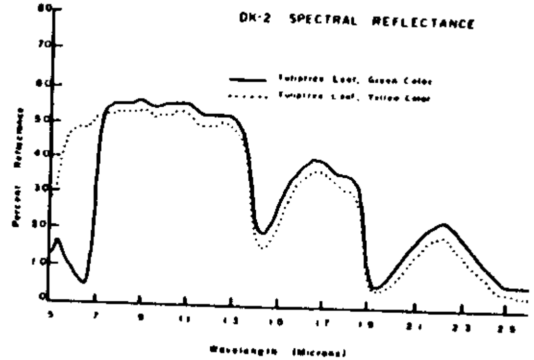
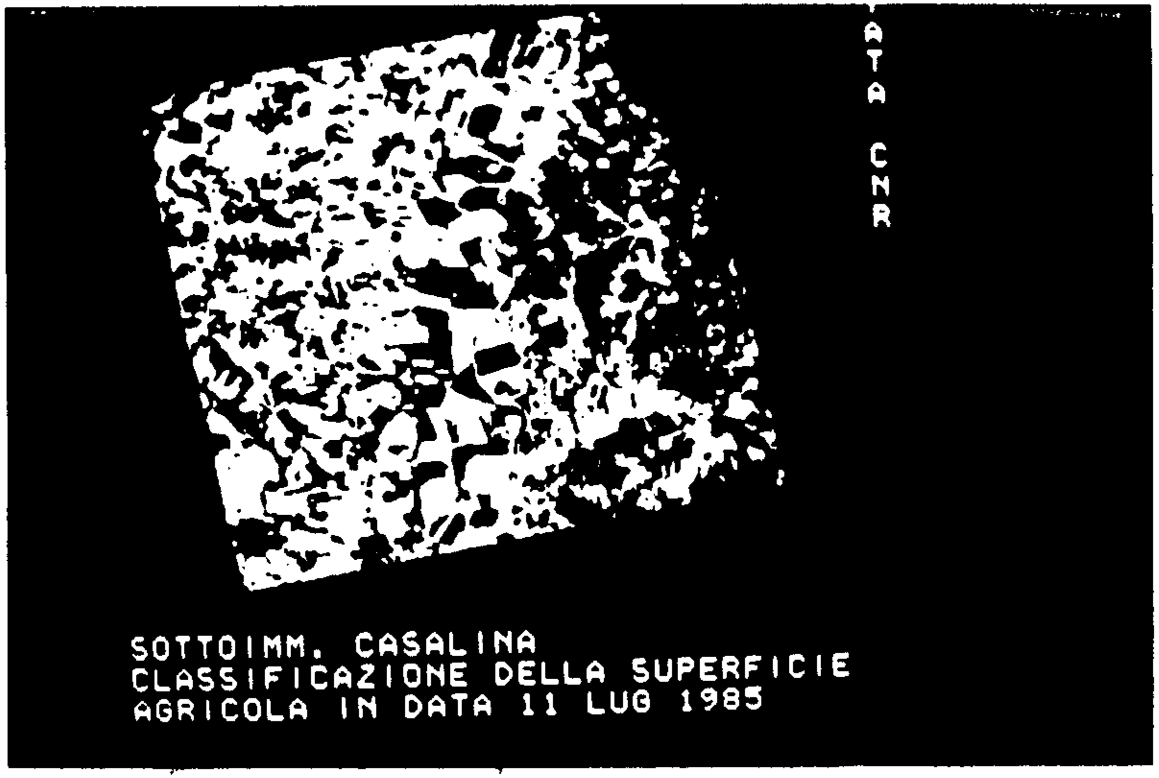


Fig. 33-31. Spectra from green and yellow Tuliptree leaves.


BANDA 5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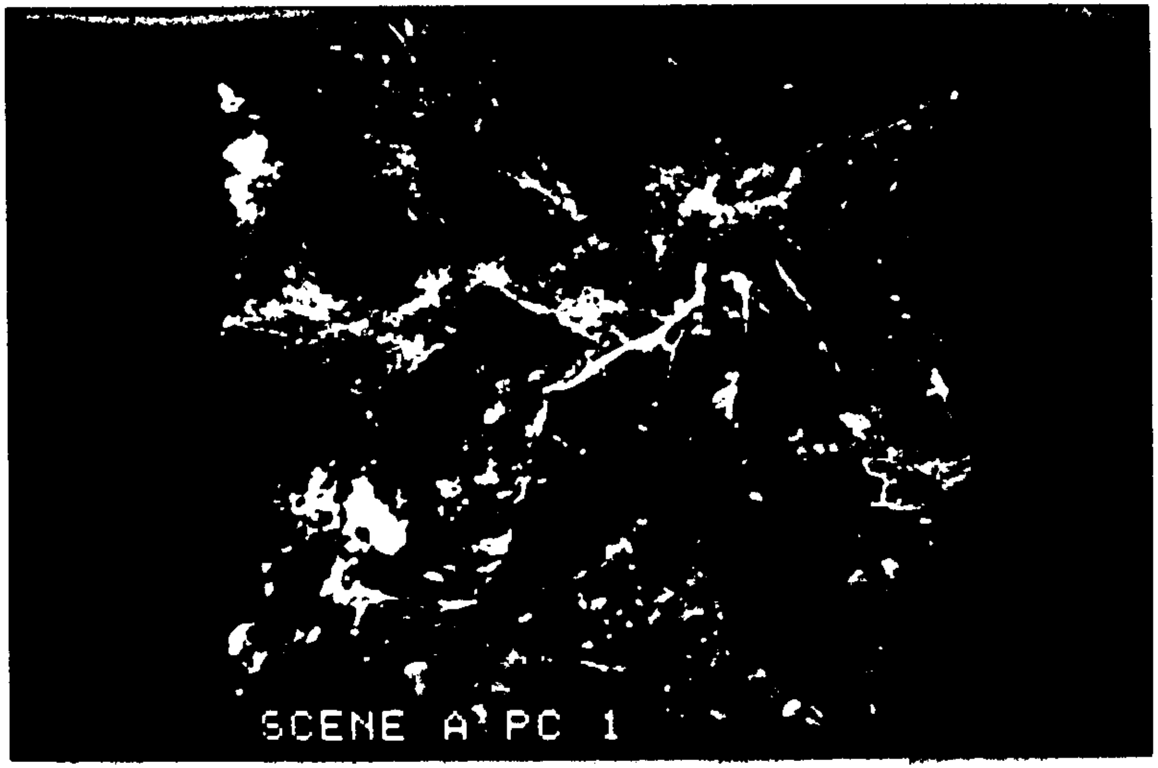
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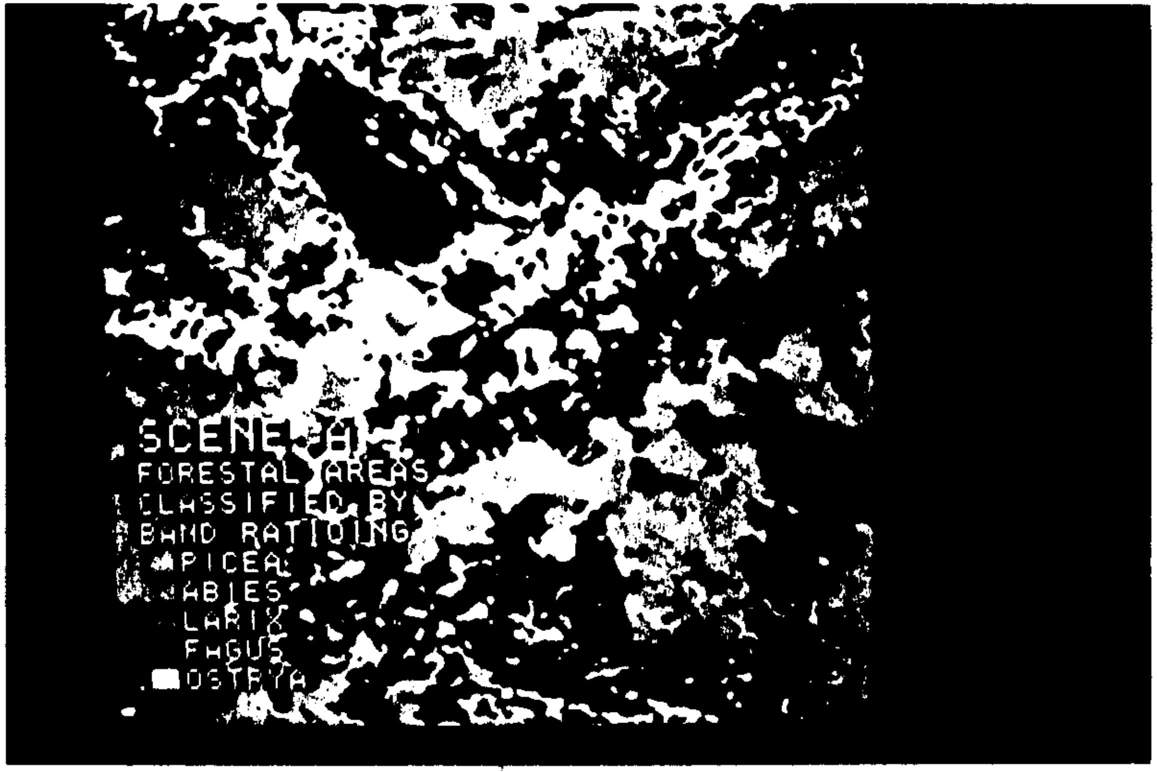

SCENE A
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