The Fourth Biometric - Vein Recognition

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1．Introduction

A reliable biometric system, which is essentially a pattern-recognition that recognizes a person based on physiological or behavioral characteristic [1], is an indispensable element in several areas, including ecommerce(e.g. online banking), various forms of access control security(e.g. PC login), and so on. Nowadays, security has been important for privacy protection and country in many situations, and the biometric technology is becoming the base approach to solve the increasing crime.
As the significant advances in computer processing, the automated authentication techniques using various biometric features have become available over the last few decades. Biometric characteristics include fingerprint, face, hand/finger geometry, iris, retina, signature, gait, voice, hand vein, odor or the DNA information [2], while fingerprint, face, iris and signature are considered as traditional ones.

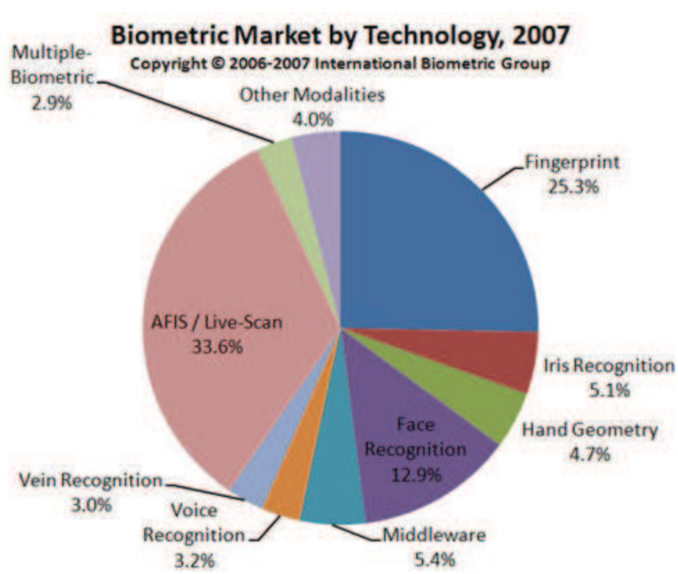

Fig. 1. IBG Biometric Market by Technology [3]

Due to each biometric technology has its merits and shortcoming, it is difficult to make a comparison directly. Jain et al. have identified seven factors [4], which are (1) universality, (2) uniqueness, (3) permanence, (4) measurability, (5) performance, (6) acceptability, (7) circumvention, to determine the suitability of a trait to be used in a biometric application.

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Vein pattern is the network of blood vessels beneath person's skin. The idea using vein patterns as a form of biometric technology was first proposed in 1992, while researches only paid attentions to vein authentication in last ten years. Vein patterns are sufficiently different across individuals, and they are stable unaffected by ageing and no significant changed in adults by observing. It is believed that the patterns of blood vein are unique to every individual, even among twins.

Contrasting with other biometric traits, such as face or fingerprint, vein patterns provide a really specific that they are hidden inside of human body distinguishing them from other forms, which are captured externally. Veins are internal, thus this characteristic makes the systems highly secure, and they are not been affected by the situation of the outer skin (e.g. dirty hand).

At the same time, vein patterns can be acquired by infrared devices by two ways, non-contact type and contact type. In the case of non-contact method, there is no need to touch the device, and therefore it is friendly to individuals in the target population who utilize the systems. In the contact type, the collection type is the same as fingerprint which has already been accepted by most people.

From the customer's point of view, the authentication system is not only high accuracy level for security but also easy to enroll. Vein patterns serve as a high secure form of personal authentication as iris recognition (Iris is known for high accurate rates of authentication, but it is regarded unfriendly by users due to the direct application of light into their eyes), and serve as a convenient form as fingerprint recognition.

On account of the several advantages, vein authentication is not only interested in lab researchers but also in industries, and the products perform well in tests of the International Biometric Group (IBG) [5]. Recently, vein recognition appears to be making real headway in the market, and considered as one of the more 'novel' biometric, which is called 'the Fourth Biometric'.

2. Vein pattern recognition

Nearly any part of vein in human body (such as retinal vein, facial vein, veins in hand) could be used for personal identification, but veins in hand are always preferred [6]. It is usually an uncovered part. Veins in hand are closer to the surface than other organizes, so the traits can be easier detected by low-resolution cameras. In this paper, vein in hand is involved, finger vein, palm vein, wrist vein and dorsal hand vein, and each of them offers stable and unique biometric features.

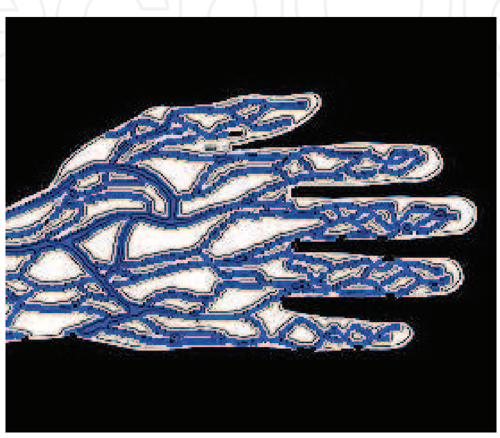

Fig. 2. the venous plexus of the hand

Category	Traits	Universality	Uniqueness	Permanence	Measurability	Performance	Acceptability	Circumvention
Conventional	Face	H	L	M	H	L	H	H
	FP	M	H	H	M	H	M	M
	Vein	M	M	M	M	M	M	L
	Iris	H	H	H	M	H	L	H
	Voice	M	L	L	M	L	H	L
H: High M: Medium L:Low								

Table 1. Comparison of Various Biometric Technologies at Seven Factors [7]

Category	Traits	Anti-Forgery	Accuracy	Speed	Enrollment Rates	Resistance	Cost
Conventional	Face	M	L	M	M	H	L
	Fingerprint	L	M	M	L	L	M
	Vein	H	H	H	M	M	M
	Iris	M	H	M	M	H	H
	Voice	M	L	M	M	H	M
H: High M: Medium L:Low							

Table 2. Comparison of Various Biometric Methods [8]

3. Imaging principle

As veins are internal, their structure cannot be discerned in visible light. Based on the kinds of light of acquisition, a vein image can be classified as X-ray scanning, ultrasonic scanning and infrared scanning. X-ray and ultrasonic are used to capture vein images in medical treatment, but they are not used in identification due to the health case. Until now, researchers used infrared imaging for personal identification.

Infrared (IR) is electromagnetic radiation whose wavelength is longer than that of visible light, and Infrared light has a range of wavelengths lies between about 750nm and 1mm, just like visible light has wavelengths that range from red light to violet. Infrared is commonly divided into 3 spectral regions: near, mid and far-infrared light, but the boundaries between them are not agreed upon.

There are two choices that focuses on imaging of vein patterns in hand by infrared light, the far-infrared (FIR) imaging and the near-infrared (NIR) imaging, which are suitable to capture human bodies images in a non-harmful way.

Some papers had discussed the principle of the FIR and NIR imaging methods. In the FIR method, superficial human veins have higher temperature than the surrounding tissues. For NIR light method, the principle could be explained by photobiology. In biology, there is a "medical spectral window", which extends approximately from about 740 to 1100 nm. The light in this window could penetrate deeply into tissues. Because blood and surrounding tissues have different effect on the NIR light, we could use a CCD camera with an attached IR filter to capture images in which vein appears darker.

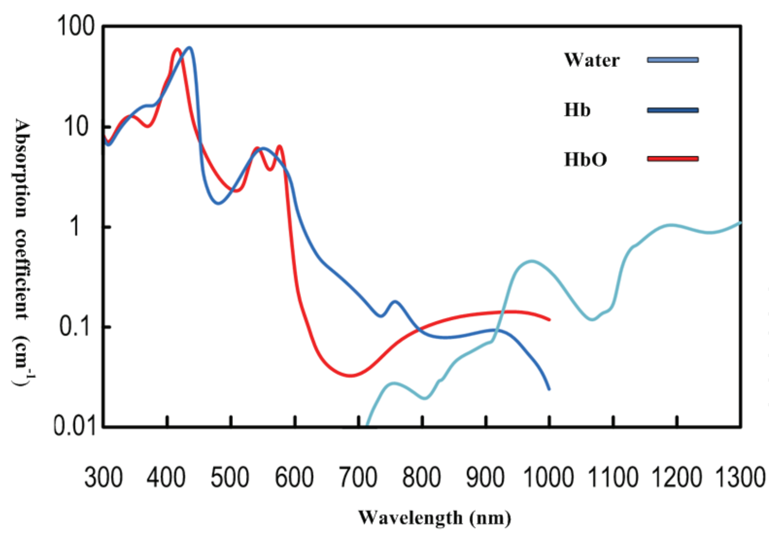

Fig. 3. the venous plexus of the hand

3.1 FIR Way

The human body temperature is about 36.85°C, and the temperature of surface of human veins is higher than that of the surrounding parts. Therefore when the FIR light irradiates hand, the hand vein structure is thermally mapped by an infrared camera at room temperature. The captured image shows a gradient of temperature between surrounding tissues and the back-of-hand veins.

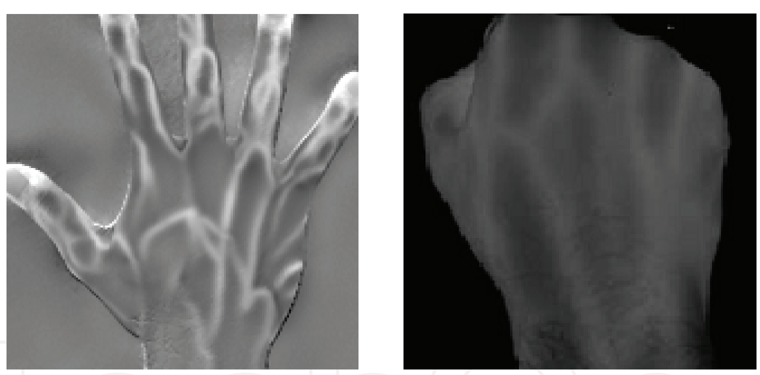

Fig. 4. FIR images of dorsal hand vein

In literature [9], it is proved that the captured FIR image of the back of hand has good quality, which means containing more useful information, but FIR vein image at palm and wrist have poor quality. Whilst this method deeply affects by the humidity and temperature of surrounding, as well as the users' perspiration does.

3.2 NIR Way

Near infrared wavelength is between about 700 nm to 1400 nm, and we can use the same observing methods as that used for visible light, except for observation by eye. The NIR light is not thermal. NIR scanning device cannot penetrate very deep under the skin therefore the device will recognize the superficial veins and rarely the deep veins.
In the NIR way, the light of specific wavelength is almost completely absorbed by the deoxidized hemoglobin in vein while almost penetrated the oxidized hemoglobin in the

arteries. Oxygenated and deoxygenated hemoglobin absorb light equally at 800 nm, whereas at 760 nm absorption is primarily from deoxygenated hemoglobin [10]. Then the veins appear as dark areas in an image taken by a CCD camera. Near-infrared (NIR) spectroscopy is a noninvasive technique that uses the differential absorption properties of hemoglobin to evaluate skeletal muscle oxygenation.

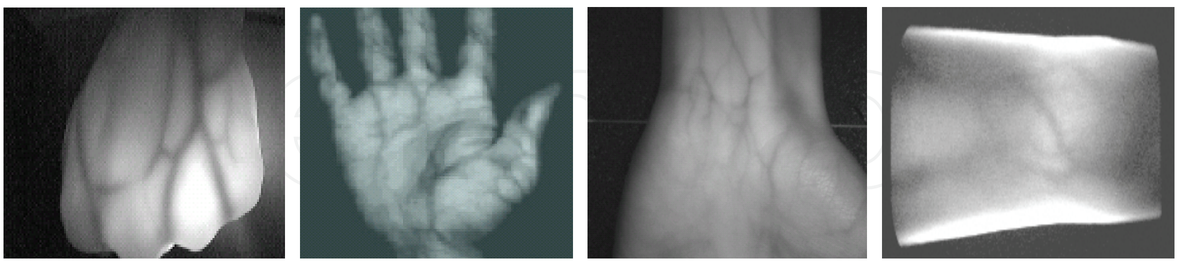

Fig. 5. NIR images of hand vein of four different parts, dorsal hand, palm, wrist, and finger vein.

NIR method is not a temperature based technique since normal body temperature or surrounding temperature cannot interfere with this method. The FIR method is often used in hand-dorsa vein imaging, and NIR method can be used in all veins imaging in hand. In order to benefit the processing, the captured images are always the grayscale image.

4. Vein pattern extraction

Because the temperature, illumination, locus and angle vary each collection, the captured digital picture varies each time. In order to provide 'better' input for automated image processing and realize a robust system against some fluctuation, some form of normalization should to be done aforehand. Conventional preprocessing algorithms can do this work. Then the vein patterns are extracted after noise reduction and normalization.

Several algorithms have been carried out to separate the vein patterns from the image background. The captured images contain shading, noise and vein patterns, moreover, the vein patterns are not salient. The more the information of veins is extracted and preserved, the better the accuracy is. So the appropriate processing extracting the vein patterns is important for the authentication system. Recently vein of hand extraction algorithm has been widely studied.

Wherever the veins are, in finger, wrist, palm or the back of hand, the various forms of vein patterns extracting algorithms usually fall into four broad categories: tracking-based, transform-based, matched filter method and thresholding method. Here we will describe some work on each of these areas.

4.1 Tracking-based

The tracing algorithm is based on repeated line tracking the vein from initial seed-point in the captured NIR image, moving pixel by pixel along the dark line in the cross sectional profiles [11]. In figure6, there is a certain position 's', and the left is its cross sectional intensity profile of finger vein image. Tracking direction is determined by the position of deepest point in the cross sectional. This method can extract vein patterns from low quality NIR images, but it is sharply affected by the temporal change of widths of veins.

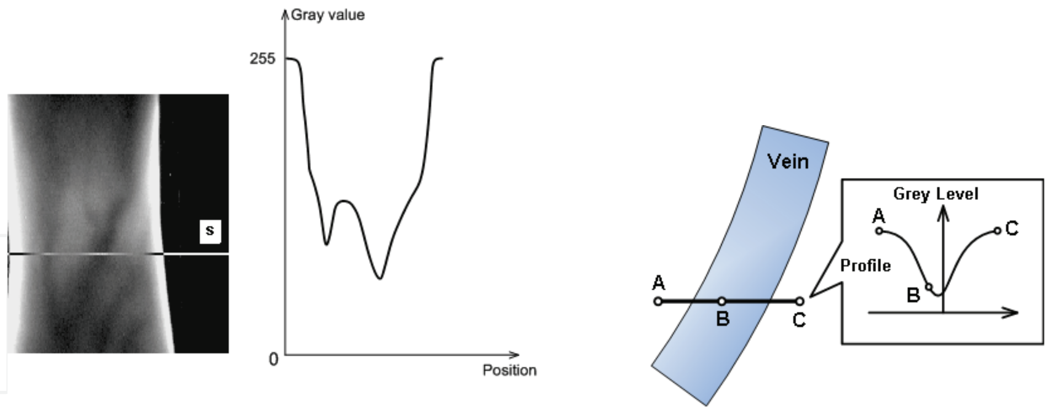

Fig. 6. cross sectional intensity profile of finger vein image

4.2 Transform-based methods

The captured image always has low contrast and contains noise, so contrast enhancement and noise reduction are crucial in ensuring the quality of the subsequent steps. Transform-based methods can convert image to a certain domain in which it is more suitable for extracting the patterns. Wavelet, which supports multi-resolution analysis, is one of the appropriate methods for vein structure and feature extracting. The wavelet multi-resolution approach employs a wavelet basis to analyze at different resolutions and increase resolution from coarse to fine, so the content of image in each scale can be understood. Vein patterns are well structured objects consisting of line-like veins and areas in between. The wider veins can be analyzed in the lower resolution, and the thinner veins can be analyzed in the higher resolution.

In paper [12], dyadic wavelet transform is adopted to extract finger vein patterns from background. Image is transformed from spatial domain to wavelet domain, and the grayscale image is changed into wavelet coefficients, which contain vein patterns wavelet coefficients and noise wavelet coefficients. The vein pattern variance of coefficients is larger than that of noise, and with the increasing of wavelet scale, the noise variance decreases.

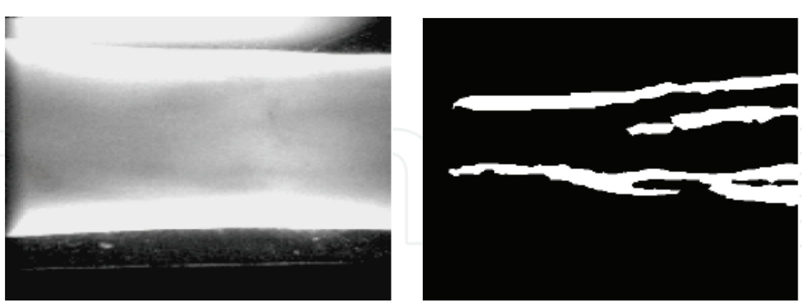

Fig. 7. extracted vein pattern by transform-based method

4.3 Matched filter method

By observing the cross sectional profiles of vein patterns, some researchers proposed an intensity profile model to detect vein patterns. Several models have been presented to describe the cross sectional profile of vessel [13-15]. The gray-level profile of the cross section is approximated a Gaussian shaped curve, which is prevalent used, whilst the matched filter is utilized to detect vein patterns. Since vein patterns may appear in any orientation, a set of cross sectional profiles in equiangular rotations is employed as a filter bank.

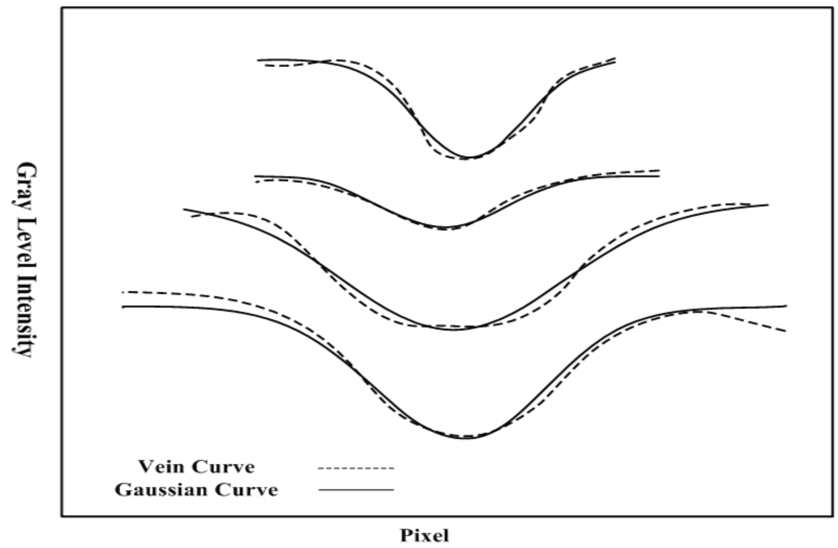

Fig. 8. the cross sectional profiles and the fitted Gaussian curves

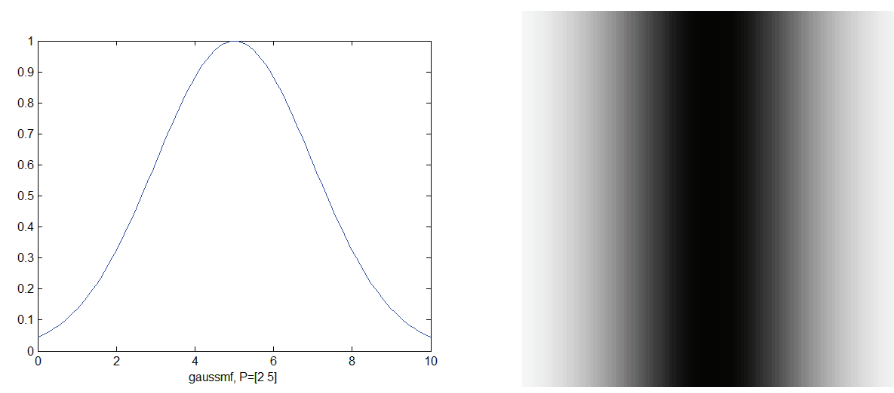

Fig. 9. the matching filter in 1-D and 2-D

4.4 Thresholding method

Intensity thresholding is usually utilized to obtain a better representation of shapes of the vein patterns. In the IR image the different location has different intensity values of the veins. Hence applying a single global thresholding is inappropriate. Via adaptively adjusting local thresholding, we can choose different threshold values for every pixel in the image based on the analysis of its surrounding neighbors [9], then, separate the vein patterns from the background, after that the desired vein image is extracted.

5. Pattern matching

The extracted vein patterns of the input image can directly be compared with the templates. A certain distance is defined to calculate the similarity between the template and the input patterns. But when the template is not small, the comparing time lasts long.

After pattern extracting process, most systems are interesting in eliciting skeletonisation of the vein patterns. Then Vessels can be represented by the number of intersections, the total segment length, the longest segment, and the angles found in the image, the distribution of the vein, and other statistical features. Hausdorff distance, SVM, and nearest neighbor are adopted as matching algorithm by researchers.

6. Database

Recently, significant work is continuously being done in vein recognition algorithms both in academy and industry. However, the conclusion of each work is usually achieved on their own databases but not the sharable databases. Large sharable vein databases are required to evaluate and compare various algorithms.

Vein pattern data collection is an expensive and time-consuming work. There are some inconveniences in large databases collection [16]. Firstly, it is expensive both in terms of money and time; secondly, it is tedious for both the technicians and for the volunteers; thirdly, due to privacy information, it is difficult to share data with others. Though the real images cannot be replaced, the synthetic vein images have proven to be a valid substitute for real vein for design, benchmarking and evaluation of vein recognition systems. A synthetic like-vein image method is requested.

Based on the cross sectional profiles of vein patterns, the vein pattern can be synthesized in semiautomatic way as figure10. Firstly, lines which look like vein patterns were drawn by hand [17]. Secondly, according to the different cross sectional profile models, the like-vein patterns can generation by programs.

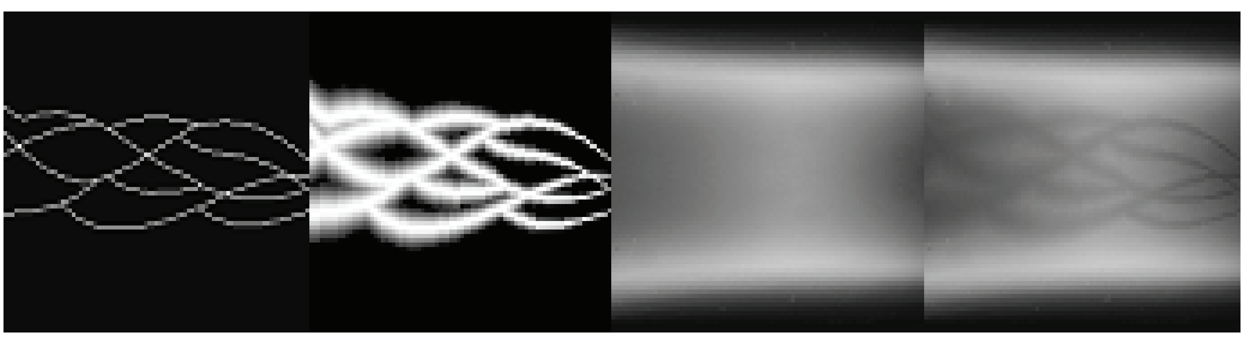

Fig. 10. synthesis finger vein image of normal pattern

7. Application of vein recognition system and future work

Vein recognition technology has some fundamental advantages over fingerprint systems. Vein patterns in hand are biometric characteristics that are not left behind unintentionally in everyday activities. Vein patterns of inanimate bodily parts become useless after a few minutes. Hence, nowadays, vein recognition system is regarded a mainstream technology. IBG expects it to play a larger role and comprise more than 10% of the biometric market [18]. Nearly all major vein authentications are manufactured in Japan and Korea, and the application of these manufactures are used in Asia. In Japan and some other countries, such products spread particularly in the financial sector.

a b c

Fig. 11. a) Hitachi's Finger Vein device; b) Hitachi's Finger Vein ATM; c) PalmSecure by Fujitsu

The recent launch of vein recognition technology is successful. Nevertheless, some research issues need to be addressed in future. For one thing, work continued across the vein imaging device to make it cheaper, more accurate and robust. For another thing, the quality of vein IR image is affected by the relationship of intensity between the IR light and the ambient light, as well as the ambient temperature. Moreover, the sharable large databases should be founded for a thorough evaluation on the efficacy of different vein recognition algorithms. Lastly, vein trait is able to conjunct with other biometrics in a multi-modal system.

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