**Palm vein technology seminar report pdf format**

With the increase in technology threat to personal data and national security had also increased .The methods that were developed to secure important information from outside intervention were not up to safe mark .There was a need to introduce a technology that secures our data more efficiently from unlawful intervention .Fujitsu has developed a palm vein pattern authentication technology that uses vescular patterns as personal identification data .Vein recognition technology is secure because the authentication data exists inside the body and is therefore very difficult to forge. It is highly accurate. This technology can be used in various fields like banking, hospitals, government offices, in passport issuing etc. Business growth will be achieved with these solutions by reducing the size of the palm vein sensor and shortening the authentication time. This paper is about the palm vein technology, its applications, how this technology is applied in real time applications and the advantages of using this technology.How Secure is the Technology ?On the basis of testing the technology on more than 70,000 individuals ,Fujitsu declared that the new system had a false rejection rate of 0.01% (i.e., only one out of 10,000 scans were incorrect denials for access), and a false acceptance rate of less than 0.00008% (i.e., incorrect approval for access in one in over a million scans). Also, if your profile is registered with your right hand, don't log in with your left - the patterns of an individual's two hands differ. And if you registered your profile as a child, it'll still be recognized as you grow, as an individual's patterns of veins are established in utero (before birth). No two people in the world share a palm vein pattern - even those of identical twins differ . In addition the devices ability to perform personal authentication was verified using the following:Data from people ranging from 6 to 85 years old including people in various occupations in accordance with the demographics realized by the Statistics Center of theStatistics Bureau.2. Data about foreigners living in Japan in accordance with the world demographics released by the unitednations.3. Data taken in various situations in daily life including gafter drinking alcohol, taking a bath, going outside and waking up. Abstract Palm vein technology is the world’s first contactless personal biometric identification system. The palm vein authentication technology offers a high level of accuracy, and delivers better results with a false rejection rate (FRR) of 0.01%, and a false acceptance rate (FAR) of 0.00008% or lower, based on Fujitsu research using the data of 140,000 palms. To confirm a person’s identity, it uses the deoxygenated vein patterns in human palms. The pattern of veins in the human palm is complex and unique to each individual. For a better recognition of the pattern before the palm vein recognition, vein enhancement is required. In Proposed method the Karhunen-Loeve (KL) transform and hue-preserving color image enhancement technology is being combined for vein enhancement. The efficiency of Karhunen-Loeve (KL) transform is improved by using parallel approach. Shadow affect is being removed by this method, it can give better visualization results, and also can improve the details of image. Contents  Chapter 1 INTRODUCTION In this generation where people can get information easily and conveniently anytime, anywhere, people are also at risk of being able to steal your personal information. Because of this risk, biometric personal identification technology is used to protect users from waiving authentication. One of the most powerful personal identification technology is the palm vein technique that uses vascular patterns as a determining factor. In palm vein technology, an individual’s vein is logged along with other details in his profile by converting the image into data points. Each time a person logs in to access the Palm Scan to a specific bank account or any secured portal, the captured image is processed similarly to one registered for verification, within seconds. Depending on the verification, the person is granted or denied access. The deoxidized hemoglobin absorbs light with a wavelength of approximately 7.6 × 10 -4 mm in the near infrared region [1]. When you take an infrared image, unlike the observed image Fig 1, only the vein pattern containing deoxidized hemoglobin appears as a series of dark lines (Fig.2). Based on this feature, the vein authentication device converts the black line of the infrared image as a pattern of blood vessels in the palm (Fig.3) and then matches the pattern of blood vessels previously recorded for the individual. Several banks in Japan have used the palm vein authentication technology for customer identification since July 2004. In addition, Fujitsu has integrated the technology into the access control of electronic door lock systems. Fujitsu has developed a palm vein pattern authentication technology that uses vascular patterns as personal identification data. Vein recognition technology is secure because the authentication data exists inside the body and is therefore very difficult to forge. It is highly accurate. This technology can be used in various fields like banking, hospitals, government offices, in passport issuing etc. Business growth will be achieved with these solutions by reducing the size of the palm vein sensor and shortening the authentication time. Hand vein is a biometric modality that seems promising as it is acquired in Near 1 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach Infrared light (NIR), which implies that skin variations and dirtiness are less sensible than in visible light. Moreover, the haemoglobin which flows in the veins is sensible to NIR light, this way allowing a good quality of acquisition of the hand veins. It is possible to use either the back of the hand or the hand palm. 1.1 Palm Vein Technology Every individual have unique pattern of Palm veins, so the palm vein pattern is used to authenticate some individual’s identity. The process of authentication and registration is discussed in next topics. An individual first rests his wrist, and on some devices, the middle of his fingers, on the sensor’s supports such that the palm is held centimetres above the device’s scanner, which flashes a near-infrared ray on the palm [6]. Unlike the skin, through which near-infrared light passes, deoxygenated haemoglobin in the blood flowing through the veins absorbs near-infrared rays, illuminating the haemoglobin, causing it to be visible to the scanner. Arteries and capillaries, whose blood contains oxygenated haemoglobin, which does not absorb near-infrared light, are invisible to the sensor. The still image captured by the camera, which photographs in the near-infrared range, appears as a black network, reflecting the palm’s vein pattern against the lighter background of the palm. An individual’s palm vein image is converted by algorithms into data points, which is then compressed, encrypted, and stored by the software and registered along with the other details in his profile as a reference for future comparison. Then, each time a person logs in attempting to gain access by a palm scan to a particular bank account or secured entryway, etc., the newly captured image is likewise processed and compared to the registered one or to the bank of stored files for verification, all in a period of seconds. From security systems for the average family home to protection of personal information, anti-theft devices for cars and other vehicles, and world-wide anti-terrorist systems, relatively safe, low-risk security systems are being sought in a large variety of fields. Biometrics (biological identification), which is able to identify an individual to a high degree of accuracy by using the biological characteristics of the human body, is currently being focused on as the most reliable means of personal identification. Within this field, "vein authentication", which uses image recognition and optical technology to scan the normally invisible vein pattern of the palm, back of the hand, fingers, etc. has the properties of being highly accurate and highly resistant to counterfeiting, impersonation, and other dishonest actions. Numbers and positions of veins and their crossing points are all compared and, depending on verification, the person is either granted or denied access. Dept. of Computer Science & Engg,BIT, Mangaluru. 2 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach Fig. 2.1 Palm Vein Technology 1.2 Registering through palm vein technology The palm vein authentication technology consists of software technology and image sensing. The palm vein sensor (Fig.4) captures an infrared ray image of the user’s palm. The sensor is able to capture the palm image regardless of the position and movement of the palm and the lighting of the infrared ray is controlled depending on the illumination around the sensor. Measuring the position and orientation of the palm by a pattern matching method, the software matches the translated vein pattern with the registered pattern. Fig. 2.2. Palm on Sensor 1.3 Working of palm vein technology 1. One should place his/her palm near to scanner. Dept. of Computer Science & Engg,BIT, Mangaluru. 3 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach Fig 2.3 Palm vein image sensor 2. The scanner makes use of a special characteristic of the reduced hemoglobin coursing through the palm veins it absorbs Near-infrared light. This makes it possible to take a snapshot of what’s beneath the outer Skin, something very hard to read or steal. Fig 2.4 Magnified view of palm vein pattern 3. This digitalized image is matched with the previously stored database and authenticates user identity.The integrated optical system in the palm vein sensor Dept. of Computer Science & Engg,BIT, Mangaluru. 4 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach uses this phenomenon to generate an image of the palm vein pattern and the generated Image is digitized, encrypted and finally stored as a registered template in the database. Problems in the raw image of palm are the uneven illumination and low contrast due to the residues during the image acquisition process. It is difficult to extract features for vein recognition if the raw image has less quality. The raw image is normally enhanced prior to extracting feature to improve the image quality and facilitate feature extraction. To improve the image quality and visualize the enhanced image, we present a palm vein enhancement methodology. Firstly, a hyper spectral camera is used to get the palm data in specific spectral bands. Secondly, Karhunen-Loeve (KL) is utilized to transform to enhance the spectral feature at 850nm. Thirdly, a color image of the enhanced palm can be generated by using a color-matching function (CMF). Finally, the palm vein image can be further enhanced by hue-preserving color image enhancement technology. The proposed method is robust to shadow effect, can significantly improves the image quality comparing to traditionally image enhancement methods and give a better visualization by presenting enhanced results with a color image. It is thus suitable for giving a better human machine interface of access control used in internet of things, information security, etc. 1.4 1.4.1 Performance metrics of biometric system False acceptance rate (FAR) The probability that the system incorrectly matches the input pattern to a nonmatching template in the database. It measures the percent of invalid inputs which are incorrectly accepted [5]. 1.4.2 False rejection rate (FRR) The probability that the system fails to detect a match between the input pattern and a matching template in the database. It measures the percent of valid inputs which are incorrectly rejected [5]. 1.4.3 Equal error rate or crossover error rate (EER OR CER) The rate at which both accept and reject errors are equal. The value of the EER can be easily obtained from the ROC curve [5]. The EER is a quick way to compare the accuracy of devices with different ROC curves. In general, the device with the lowest Dept. of Computer Science & Engg,BIT, Mangaluru. 5 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach EER is most accurate. Obtained from the ROC plot by taking the point where FAR and FRR have the same value. The lower the EER, the more accurate the system is considered to be. 1.4.4 Relative operating characteristics or receiver operating characteristics (ROC) The ROC plot is a visual characterization of the trade-off between the FAR and the FRR. In general, the matching algorithm performs a decision based on a threshold which determines how close to a template the input needs to be for it to be considered a match[5]. If the threshold is reduced, there will be less false non-matches but more false accepts. Correspondingly, a higher threshold will reduce the FAR but increase the FRR. 1.4.5 Failure to enrol rate (FTE OR FER) The rate at which attempts to create a template from an input is unsuccessful [5]. This is most commonly caused by low quality inputs. 1.4.6 Failure to capture rate (FTC) Within automatic systems, the probability that the system fails to detect a biometric input when presented correctly [5]. 1.4.7 Template capacity The maximum number of sets of data which can be stored in the system. 1.5 How secure is the technology? On the basis of testing the technology on more than 70,000 individuals , Fujitsu declared that the new system had a false rejection rate of 0.01% (i.e., only one out of 10,000 scans were incorrect denials for access), and a false acceptance rate of less than 0.00008% (i.e., incorrect approval for access in one in over a million scans). Also, if your profile is registered with your right hand, don’t log in with your left - the patterns of an individual’s two hands differ. And if you registered your profile as a child, it’ll still be recognized as you grow, as an individual’s patterns of veins are established in utero (before birth). No two people in the world share a palm vein pattern - even those of identical twins differ. In addition the devices ability to perform personal authentication was verified using the following: Dept. of Computer Science & Engg,BIT, Mangaluru. 6 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach 1. Data from people ranging from 6 to 85 years old including people in various occupations in accordance with the demographics realized by the Statistics Centre of the Statistics Bureau. 2. Data about foreigners living in Japan in accordance with the world demographics released by the United Nations. 3. Data taken in various situations in daily life including after drinking alcohol, taking a bath, going outside and waking up. 1.6 Features of palm vein technology 1. The human palm vein pattern is extremely complex and it shows a huge number of vessels. 2. The biometric information is located inside the human body, and therefore it is protected against forgery and manipulation. 3. The position of the palm vein vessels remain the same for the whole life and its pattern is absolutely unique. 4. The enrolment of the palm vein pattern can be done without any physical contact to the sensor. 5. Skin colour, skin dirtying, surface wounds, skin humidity, skin temperature, aging do not have major influence to enrol and to authenticate the palm vein pattern correctly. 6. Palm Secure is based on a near infrared method, and it has no negative influence to the health. 7. Since it is contact less and uses infrared beam, it is more hygienic. 1.7 What happens if the registered vein gets damaged? There may be a chance that the palm we had registered may get damaged then we cannot use this technology, so during the time of registration we take the veins of both the hands so that if one gets damaged we can access through the second hand. When hand get damaged up to large extent we can get veins because deeper into the hand veins are obtained. When we apply this method we can maintain complete privacy. Dept. of Computer Science & Engg,BIT, Mangaluru. 7 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach Registering vein pattern of both palms simulteniously 1.8 Methods to solove these problems Fingerprints, faces, voice prints and palm veins. Among these, because of its high accuracy, contact less palm vein authentication technology is being incorporated into various financial solution products for use in public places. Each of these systems has merits and demerits. In the case of fingerprints, direct contact of the finger with the fingerprint-image-extracting sensor causes degradation in performance, especially in factory construction sites where good-quality fingerprints are hard to obtain due to oil from the finger, moisture, dirt, etc. For retina scanner, users must place their eye close to the scanner, causing an uncomfortable feeling and concerns of privacy. With hand-shape recognition devices, problems may arise with users who suffer from arthritis or Rheumatism, leading to poor performance. Compared with the other physical characteristics, palm vein authentication has been developed to resolve these problems. Dept. of Computer Science & Engg,BIT, Mangaluru. 8 Chapter 2 LITERATURE SURVEY A paper published by Sahar Bayoumi, et.al [9], introduced a new methodology for Palm Vein recognition by adopting PCA. Inorder to capture Palm vein images of dorsa, infrared camera have been used. PCA is applied to extract distinct features which are generated as vector of features. A matching process is then applied to find the best match from the dataset to recognize and authenticate the person. Experiments show that there system is able to recognize human with accuracy 85% in real-time based on supervised recognition. Y Hao et. al [10] proposed a new contactless palm print authentication system by using feature level image registration and pixel-level fusion for improving the verification performance. The major steps involved are: • A sequence of multi-spectral hand images is obtained • Pre-process each image independently to achieve coarse localization of ROIs • Each sequence of images are further refined through feature level image registration • Fused image is produced as output. The main advantage is that, it can be used for pixel-level fusion of multispectral images and Fast recognition possible as no extra memory consumption required. Drawback of this method is that, it is not efficient while using image registration. Two new contact-free palm vein representations, namely Hessian phase information from the enhanced palm vein patterns during the preprocessing stage and the orientation encoding of palm vein line-like patterns using localized Radon transform where proposed by Yingbo Zhou, Ajay Kumar [11] which have been used for Forensic, Military based and online business applications. They have also used CASIA Dataset for analysis. This method helped to enhance the efficiency of feature extraction of palm vein patterns. The main steps involved are: 9 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach • Preprocessing stage which includes ROI segmentation and Image enhancement • Feature extraction and representation using Hessian, LRT, LPP and ordinal representation • Matching score generation using cosine similarity • Score combination using the four representations Z.khan et.al [12] proposed a Contour Code, a novel orientation and binary hash table based encoding for palmprint recognition. It facilitates simultaneous matching to the database and score level fusion of the multispectral bands in a single step. Main advantage includes normalization of scores which is not required before fusion and this single methodology can be used for the extraction of both the line and vein features. Major steps involved are : • Preprocessing hand images • Identifying region of interest • Contour Code representation derived using a two stage filtering approach to extract only directional features • Contour Code which is binarized into an efficient hash table structure Multispectral palm print verification results on the PolyU and CASIA databases show that the Contour Code achieves an EER reduction upto 50%, compared to state-ofthe-art methods. An automated finger-vein verification system using the mean curvature was introduced by Lin Zhang et al [13]. The mean curvature at a point on a surface is, roughly speaking, the mean of the surface curvatures in all directions. Treating the intensity surface of an image as a geometric object, this method views the vein pattern as valley-like structures. By a valley-like structure we mean a long channel, like a gutter, whose cross-section forms the shape of U or V. Its inversion is referred to as a ridgelike structure. The set of points with negative mean curvature is determined to be a valley-like structure. The mean curvature has been used in other applications for determining the degree of ridge or valley-likeness. A promising new approach based on local texture patterns is proposed in [14]. First, operators and histograms of multi-scale Local Binary Patterns (LBPs) are investigated in order to identify new efficient descriptors for palm vein patterns. Novel higher-order local pattern descriptors based on Local Derivative Pattern (LDP ) histograms are then investigated for palm vein description. Both feature extraction methods are compared and evaluated in the framework of verification and identification tasks. Extensive experiments done by L.Mirmohamdsa deghi et.al on CASIA Dept. of Computer Science & Engg,BIT, Mangaluru. 10 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach Multi-Spectral Palm print Image Database Vl.O(CASIA database) identify the LBP and LDP descriptors which are better adapted to palm vein texture. Tests on the CASIA datasets also show that the best adapted LDP descriptors consistently outperform their LBP counterparts in both palm vein verification and identification. A paper published by J.C. Lee [15], developed a reliable and robust palm vein identification system for real-time personal identification by applying a low-cost NIR CCD camera-based palm vein device to capture the palm vein images. A preprocessing algorithm extracts a rectangle area (ROI) from a palm vein image for feature extraction. To represent a low-resolution palm vein image and match different palm vein images, they extend the use of 2-D Gabor filter to represent a palm vein image using its texture feature, and apply a normalized hamming distance for the matching measurement. In addition, they proposed a new technique called directional coding to code the palm vein features in two bits representation. This method represents the biometric features in bit string format which enable speedy matching and convenient storage. Using this representation, the total size of a palm vein feature is reduced to 2520 bits. In their palm vein database of 4,140 palm vein images from 207 different palms, they achieved high recognition rate (greater than 99%), and its equal error rate is 0.4%, which is comparable with all other hand-based biometrics, such as hand geometry and fingerprint verification. There are different palm vein extraction techniques using texture descriptors. Most commonly used method is using Local Binary Pattern. It extracts contrast information only. Another texture based descriptor called LDP extracts directional information. In order to increase the efficiency, Local directional texture Pattern descriptor[8] is used in our proposed method which extracts both directional as well as contrast information. SL NO: AUTHOR TITLE YEAR METHOD 1 Timo Ahonen et al Face Description with Local Binary Patterns 2006 Using LDP to extract features. 2 Ying Hao et al Multispectral Palm Image Fusion for accurate contactfree palm print recognition 2008 Make use of feature level image registration and pixel-level fusion method Dept. of Computer Science & Engg,BIT, Mangaluru. 11 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach 3 Lin Zhang et al Finger-KnucklePrint Verification Based on Band-Limited Phase-Only Correlation 2009 To align FKP images, local convex direction map used and BLPOC method to register the images 4 Anil jain et.al Information fusion in biometrics 2010 Multimodal fusion scheme using face, fingerprint and hand geometry feature 5 Yiding Wang et al Hand-dorsa Vein Recognition Based on Coded and Weighted Partition Local Binary Patterns 2010 CWPLBPPartition Local Binary Patterns (PLBP) by adding feature weighting and error correction coding (ECC). 6 Ajay Kumar et al Contactless Palm Vein Identification using Multiple Representations 2010 Two new palmvein representations used : Hessian and localized Radon transform (LRT) 7 Zohaib Khan et a Contour Code: Robust and Efficient Multispectral Palm print Encoding for Human Recognition 2011 Contour Code, a novel orientation and binary hash table based encoding for palm print recognition 8 Andrzej Drygajlo et al Palm Vein Recognition with Local Binary Patterns and Local Derivative Patterns 2011 LBP and LDP used 9 W Song et a A finger-vein verification system using mean curvature 2011 For robust feature extraction, mean curvature method used Dept. of Computer Science & Engg,BIT, Mangaluru. 12 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach 10 Jen-Chun Lee A novel biometric system based on palm vein image 2012 2-D Gabor Filter for local feature extraction and bit string representation called Vein Code for extracting pattern of palm vascular 11 D. R. Kisku et al Human Identity Verification Using Multispectral Palmprint Fusion 2012 Use Gabor wavelet followed by colony optimization. Training done using SVM 12 Sahar Bayoumi et al PCA-based Palm Vein Authentication System 2013 Applying PCA on each image 13 Wenxiong Kang et a Contactless Palm Vein Recognition Using a Mutual Foreground-Based Local Binary Pattern 2014 Improved MFLBP method used. Normalized gradient-based MPC algorithm and k-means method utilized for texture extraction 14 Adin Ramirez Rivara et. al Local Directional Texture Pattern Image Descriptor 2014 Texture feature extraction using LDTP descriptor 15 Min A Methodology for Peng,Chongyang Palm Vein Wang,Tong Enhancement and Visualization 2016 Vein enhancement method combining Karhumen-Loeve(KL) transform and hue-preserving color image enhancement technology Dept. of Computer Science & Engg,BIT, Mangaluru. 13 Chapter 3 SYSTEM DESIGN AND IMPLEMENTATION 3.1 The hyper spectral imaging technique The ‘classical definition’ of hyperspectral imaging is that the number of bands involved is more than 10, and any lower than that is referred to as multispectral imaging. It can generate images in continuous and narrow spectra from visible to infrared ‘regions with the aid of spectrometer. It takes image on 100 to 10000 continuous narrow bands [9], and contains much more information than traditional imaging technique. A hyper spectral image cube has 3 dimensions: two for space and one for wavelength. Fig. 8 is an image cube of a palm. It is illustrated that there is a 2D image with spatial dimensions of x and y on each narrow band (λ). Fig.3.1 An image cube of a palm 14 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach 3.2 Palm vein image visualization and enhancement by using modified KL Transform The first step of the enhancement method is effective visualization, that is based on the method proposed in [3].The color enhancement method suggested in reference [3] was effective for visualizing the multispectral image features. However, the wavelengths that is proposed in [3] are within visible range (425nm to 710nm), which will bring a shadow enhancement problem. Fig. 9 shows a palm image (Fig 9 (a)) and the enhancement result (Fig 9 (b)) of the palm image by using the method in [3]. Fig. 9 (b) shows the deep shadows that appear in center of the palm. The wavelength selected for the enhancement which is in the visible region lead to shadow affect . Veins and shadows are enhanced together. In our work, the methods in [3] is extended to nearinfrared band for palm vein image enhancement to reduce the shadow enhancement problem. Fig 9: (a) Original palm image (b)Enhanced image 600nm The raw image cube obtained in this work is then transformed into an N rows and M columns matrix, where N=16 is the number of bands and M is the number of pixels of each 2D image at each waveband. The enhanced signal value vector for j-th pixel gnew j (N-dimensional vector) is gnew j = w(g j − s j ) + g j (3.1) where (N-dimensional vector) is the pixel values of the j-th pixel in the original image cube at N wavebands, w is an N*N matrix for enhancement, s j is the principal component of the j-th pixel, which is estimated using Karhunen-Loeve (KL) transform as sj = i=1 X αi j ui + g¯ (3.2) m Dept. of Computer Science & Engg,BIT, Mangaluru. 15 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach where m is the number of basis vectors used in the estimation (m T, c/T of iterations are needed to encode all N bands of a hyperspectral image. These two conditions can be expressed as follows: c ≤ T, No. of iterations = 1, No. of threads used, t = c c > T, No. of iterations = c/T, No. of threads used, t = T OpenMP is a utilization of multithreading with shared memory that uses the forkjoin model of parallel execution. All OpenMP programs begin as a single process: the master thread. Until the fork section, the master thread executes sequentially. FORK: a team of parallel threads are created by master thread. The "fork" section is marked and enclosed by a parallel region construct i.e. #pragma omp parallel, which then is 17 Palm Vein Technology and Enhancement of Vein Patterns using Parallel KL Transform Approach executed in parallel between the other threads. Multiple parallel regions are possible, and each should end with a "join" section where all the parallel threads synchronize and terminate, leaving only the master thread. All threads in the parallel region execute independently, and variables can be shared among threads, which require careful programming to avoid data-sharing conflict between threads[5]. The implementation of the KL Transform using OpenMP in this work is based on a single program multiple data (SPMD) construct that involves replicated execution with the body of code executing in a replicated fashion across multiple threads. The replicated execution in each thread encodes a cluster of bands using a common syntax in SPMD to create a cyclic distribution of loop iterations (with ’a’ being a variable) as shown in the algorithm. The omp_get_num_threads() returns the total number of threads available, whereas the omp_get_thread_num() returns the current thread number. The #pragma omp critical will only be executed after all the parallel regions above are completed causing the writing of the output i.e. encoded hyperspectral image. The principal component s j of the j-th pixel, shown in equation 2 which is estimated using Karhunen-Loeve (KL) transform can be executed parallel by the following algorithm #pragma omp parallel { total_threads=omp_get_num_threads(); thread_no=omp_get_thread_num(); gs=g[j]-g; #pragma parallel for for(a=thread_no;a

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