Efficient Identification Based on Human Iris Patterns

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Abstract

This paper proposes a person identification system (PID), which works with non-illumination low-resolution eye images. Radial-Scan and threshold methods are used for Iris normalization and Iris segmentation from the eye image respectively. Conventional neural network is used for iris matching. The proposed algorithm works with 96 features of the iris. Space complexity is less and Iris codes are stored in an encrypted file. The Algorithm has been implemented and tested on 1500 iris patterns. Images include normal iris captured under in-door and out-door conditions and from disease affected eyes.

1. Introduction

Intelligent and reliable biometric recognition system has long been an effective goal for any security applications. Physiological or behavioral characteristics are used to accurately identify each person in biometrics [4]. Iris is a protected internal organ whose random texture is epigenetic and stable through life. Hence, it can also serve as a kind of living password. Iris recognition provides real-time, high confidence identification of person by mathematical analysis of complex patterns that are visible within the iris of an eye from 19 to 24 inches distance. Figure 1 shows a sample iris image and the structure of the iris. Its complex pattern contains many distinctive feature such as arching ligaments, crypts, radial furrows, pigment frill, papillary area, ciliary area, rings, corona, freckles and zigzag collarette [4][5]. These spatial patterns in the iris are unique in nature. Iris is more stable and reliable for identification than face, fingerprints, and voiceprints. This technology works well in both recognition and confirmation phases. This is non-intrusive and non-invasive [6]. It does not require physical contact with a scanner. The key issue of the pattern recognition problem is the relations between inter class and intra class variability. That is, classes can be efficiently classified only if the variability between features of a given class is less than the variability between other classes. In iris recognition process, variability of iris intra class features are less than the inter class iris variability. In face recognition, intra class (same face) variability is greater than interclass variability. But in interclass variability is limited because different classes lave same basic set of features. For these reasons, Iris recognition system becomes most promising technique for the person identification in the vicinity of future.

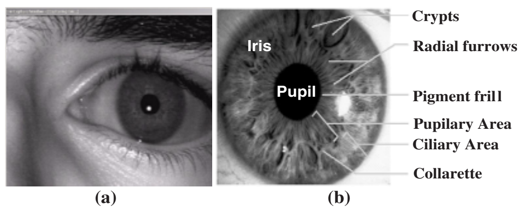

Figure 1. A Sample Eye image and Structure of the Iris

The organization of this paper is as follows: Section 2 summarizes the literature on the previous research. A proposed method for iris recognition is illustrated in Section 3. Experiment and Results are given in section 4. Section 5 gives the concluding remarks on the work.

2. Review of literature

In the process of iris recognition, it is essential to convert an acquired iris image into a suitable code that can be easily manipulated. Li ma et al proposed a method based on Multi channel Gabor filters and near line discriminator [6]. Boles and Boashash [1] calculated a zero-crossing representation of 1D wavelet transform at various resolution levels of a concentric circle on an iris image to characterize the texture of the iris. Iris matching was based on two dissimilarity functions. Wildes et al. [13] represented the iris texture with a Laplacian pyramid constructed with four different resolution levels and used the normalized correlation to determine whether the input image and the model image are from the same class. Daugman [3] used multi scale quadrature wavelets to extract texture phase structure information of the iris to generate a 2,048-bit (256 bytes) iris code. A pair of iris representations is compared based on Hamming distance. In [11], Sanchez-Reillo and Sanchez-Avila provided a partial implementation of the algorithm by Daugman. Shinyoung Lim et al. [12] decomposed an iris image into four levels using 2D Haar wavelet transform. In [2], Circular symmetric and DDA (Digital Differential Analysis) were used for Iris localization and normalization respectively. 360 features were used for classification and classifier design was carried out by WED (Weighted Euclidean distance). In this paper, we propose an iris recognition system, with a compact representation scheme for iris patterns by Gabor spatial filter. Conventional neural network is used for iris matching. Image validity module is included for real image checking to prevent illegal entries.

3. Iris recognition algorithms

The block diagram of the proposed system is described in Figure 2. It consists of the following modules. An important and complex step of iris recognition system is image acquisition. Especially for Indian people, iris is small in size and dark in color. It is difficult to acquire clear images for analysis using the standard CCD camera with ordinary lighting. In this module, the Iris Camera captures user's eye image by passing the near infrared (NIR) wave. Research in iris image acquisition [8], [10], has made noninvasive imaging at a distance possible. The image acquisition phase should consider three main aspects, namely, the lighting system, the positioning system, and the physical capture system. Iris recognition system can work both in out-door and in-door without any hot spot of lighting conditions.

Biometric features may be counterfeited and criminally used. It is a crucial weakness of biometric system. Iris validity checking aims to ensure that an input image is actually coming from a person instead of an iris photograph, a phony eye, or other artificial sources. Daugman [3] [5], Li Ma [6], Wildes [13] had discussed about this with some possible schemes and did not document a specific method. Biometrics-hoax-resistant method is suggested to overcome this problem. However image validity checking is still limited, though it is highly desirable.

Image prominence checking module solves the problem of how to select an apparent and well-focused iris image from an image acquisition sequence. This involves Gray level checking, detecting inter frame of eyelash, detecting spectacles and truncation of iris. Iris recognition includes seven modules: Image validity checking, image prominence checking, iris extraction, iris normalization, image intensification, Feature extraction and iris matching. Detailed description of each module is as follows.

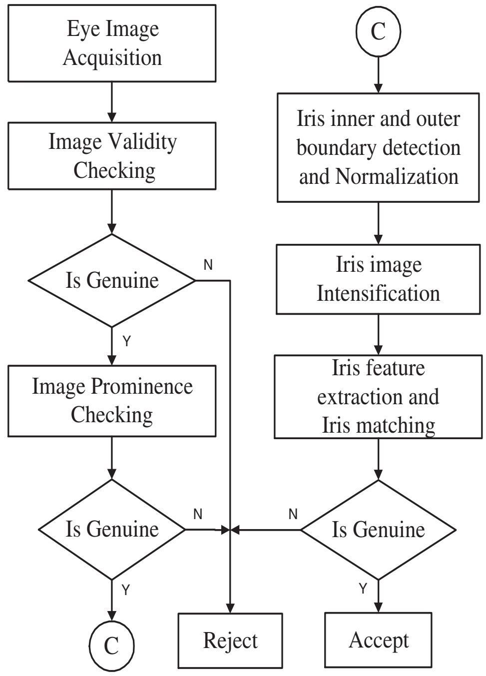

Figure 2. Block diagram of the Proposed System

3.1. Image validity checking

In this module biometrics-hoax-resistant method is used to check iris validity. In this method, NIR echo time is used to find the difference between genuine source and artificial sources. It assures that an input is coming from a real sequence instead of a photograph or other artificial sources. The biometrics capturing devices need to be capable of ensuring that they are inspecting genuine user features (as opposed to a photograph or recording) and that the output signal cannot be substituted. This will help prevent replay attacks from lifted by video-signal for instance by connecting a video recorder to the frame-grabber.

3.2. Image prominence Checking

During Iris image capturing it may produce different types of noise images. Figure 3 shows images of iris in different condition. It is necessary to select image of high quality from an input. Image prominence Checking is an important process of iris recognition to validate the quality of an input eye image. It prevents miss-extraction and false matches in feature extraction and iris matching modules respectively. However, effort on image prominence checking is still limited. Daugman measured the total high frequency power in the 2D Fourier spectrum of an image to assess the focus of the image. If an image can pass a minimum focus

Figure 3. Images of Irises a. Interfered by eyelashes b. Truncation of Iris c. Spectacles reflection

criterion, it will be used for recognition. Here, we present an effective scheme to review image quality by analyzing the spatial domain of the iris image. This algorithm is described is as follows:

- Eye image with blink: This type of eye image does not focus iris properly. The following steps may be applied to check the quality.

Step1:Evaluate Gray level of pixel in the eyelid area.
Step2:If average intensity function I(x, y) of eyelid area is greater than T then Eye data have flashing noise otherwise proceed to the preprocessing module. Eq.1 describes this process.

$$\sum_{i=0}^{N-1}\sum_{j=0}^{M-1} I(x_i, y_j)/M * N > T \tag{1}$$

where N and M be width and height of an eye image, T is a Threshold value for eyelashes and $I(x_i,y_j)$ is gray level values of an image.

- Detecting Eyelash: Eyelash interference is serious issue in Feature extraction process. Detection of closed eyelash process can be done as follows:
  Step1:The line detector is used to find out line component between inner boundary and Iris area.
  Step2:If the endpoint of line component is under pupil center then iris area is interfered by eyelash other wise iris is in normal condition. The Line detector kernels are illustrated in Eq.2-3.

$$R_h = -z1+2z2-z3-z4+2z5-z6-z7+2z8-z9 \tag{2}$$

$$R_v = -z1-z2-z3+2z4+2z5+2z6-z7-z8-z9 \tag{3}$$

where z1 - z9 denote gray level of iris pixels, R_h, R_v represent horizontal and vertical kernel respectively.

- Detecting spectacles reflection: Spectacles reflection in iris area is another issue in Feature extraction and classifier design, Figure 3c. Bound a Rectangle on the iris image and check for reflection of glasses in this portion. If reflection of glass is within tolerance level then continued preprocessing otherwise rejected.

- Detect Truncated Iris area: Truncation of iris pattern may present in eye images as shown in Figure 3b. Detection of truncated iris pattern is as follows:

Step1:Bound a rectangle on the eye image.
Step2:Scan the perimeter of a rectangle and count numbers of pixels are satisfied iris threshold value.
Step3:If numbers of pixels are above the tolerance level, then reject. Otherwise proceed preprocessing.Eq.4 describes this process.

$$Trunc(I(x,y)) = \begin{cases} True & Ct(R(I(x,y) <= t_i))) > T \\ False & Otherwise \end{cases} \tag{4}$$

where I(x,y), t_i and T represent iris image, iris threshold and Tolerance level respectively.Ct and R represent count and rectangle functions respectively.

3.3. Algorithm for iris segmentation

Once the image prominence checking is valid, the next step is the iris segmentation process. It is the process to completely and efficiently eliminate pupil, eyelashes and other portions that are not necessary for feature extraction and iris matching module. Both the inner and outer boundary of a typical iris can be considered as circles, but the two circles are usually not co-centric. Detection of inner and outer boundary of the iris image is shown in Figure 4. In this system, threshold values are used for detecting pupil and iris boundaries. Threshold method is an efficient image processing technique for segmentation process. The steps involved in segmentation are summarized as follows:
Step1:Rotate eye image 180 degrees to avoid the detection of thick eye broses as a pupil boundary. The typical iris image is shown in Figure 4a.
Step2:Detect the position of camera flash using threshold value as given by Eq.5.

$$Fh(x,y,r) = \begin{cases} True & I(x,y) > T_1 \ and \ T_2 < \\ & C_8(x,y,r) < T_3 \\ False & Otherwise \end{cases} \tag{5}$$

where x, y and r are co-ordinates and radius of iris image respectively, I(x, y) represents gray level value of pixel,C_8(x, y,r) is an 8-way circular neighbors. T_1,T_2 and T_3 are threshold value of flash, minimum and maximum gray value of camera flash boundary respectively.
Step3: Gray level value is used to detect iris inner boundary. This method is as follows:

- Set top-left corner coordinate of iris image as I(x,y) and check threshold of its eight neighbors. Eq.6 can perform this operation.

$$Pupil(x,y,r) = \begin{cases} True & C_8(x,y,r) < T_1 \; and \; r > T_2 \\ False & Otherwise \end{cases} \tag{6}$$

where C_8(x, y,r) and r represent 8-way circular neighbors and radius of pupil respectively. $T_1$is a threshold value of pupil area and $T_2$is the minimum radius of pupil. If Pupil

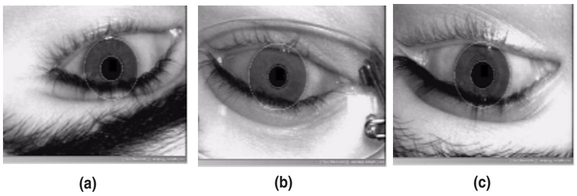

Figure 4. Iris image after Detecting Inner and Outer Boundary

(x, y, r) is true then the following procedure is used to find pupil boundary.
Step1:Let xp, yp are any coordinate in the pupil.
Step2:Increment xp by 1 until right end of pupil boundary is reached. Let that point be x", Decrement xp by 1 until left end of side pupil boundary is reached, Let that point be x'.x=(x'+x") /2
Step3:Increment yp by 1 until bottom of pupil boundary is reached Let that point be y", Decrement yp by 1 until top of pupil boundary is reached, Let that point be y'. y = (y' + y") / 2
Step4:Draw a circle according to pupil boundary threshold. The outer boundary of the iris is more difficult to detect because of the low variation of contrast at the outer edge. It can be detected by 4-way symmetry method. Procedure for detection of iris outer boundary is as follows:

- Each pixel within the pupil is considered as a center and concentric circles are drawn using 4-way circular symmetry method.
- All the pixel values in the boundary of the drawn circle are checked for the threshold value t_i. The circle that contains the maximum number of pixel values which satisfies the threshold value, is the iris outer boundary. Eq.7 accomplishes this process.

$$Ir(x,y,R_{ir}) = \begin{cases} 1 & Max(C_4(x,y,R_{ir})) < t_i \\ 0 & Otherwise \end{cases} \tag{7}$$

where Ir(x,y,R_{ir}) represents the iris position in the image I(x,y), R_{ir} is the iris radius, t_i is the threshold value and C_4(x,y,R_{ir}) is a 4- way Circular method.
Step5:If Eyelashes are seen in iris portion, then they are to be removed from the previously processed image. Eyelashes are masked by threshold value. If eyelash is seen in iris area then those pixels are marked for deletion as given in Eq.8. Figure 5a and 5b show the image after removing inner, outer boundary and eyelashes.

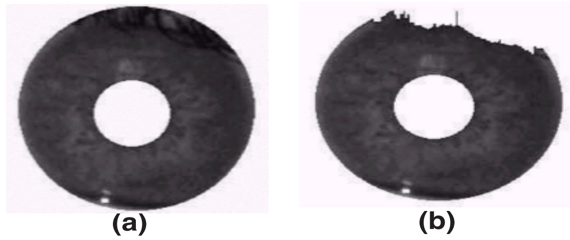

Figure 5. After removing inner, outer boundary and eyelashes.

$$Eyelash(x,y) = \begin{cases} 1 & T_1 < I(x,y) \; <= \; T_2 \\ 0 & Otherwise \end{cases} \tag{8}$$

where I(x, y) represents gray value of pixel. T_1 and T_2 are the minimum and maximum threshold value of eyelashes.

3.4. Algorithm for Iris Normalization

As iris is captured in different conditions like non-uniform illumination, eye blink, pupil radius change due to high lighting etc, it is possible for the output images to be in different size. This variation may affect the results of iris matching. To overcome this issue, iris image has been converted to standard size with width and height as 360 and 48 respectively. Iris dilation or erosion process is also carried out to extend or contract iris strip size when fewer/ higher amounts of data are presented in the iris portion. This process is called iris normalization. In this process, image has been converted to standard rectangle strip using Radial scan method which is used to collect all pixels in iris portion and produced trapezoidal shape image. This procedure is as follows:
Step1: Set any point as a reference point in iris portion.
Step2: Draw concentric circles using that reference point Figure 6a.
Step3: Repeat step 2 until iris outer boundary is reached.
Step4: Collect all pixels, in a circle to construct a trapezoidal pattern (Figure 6b).
Step5: The image right triangular portion is removed and mapped into left portion (from a, b, and c to a', b' and c') of the image. After this process, dilation or erosion module can be performed to form a rectangle strip.
Figure 6-8 describe various steps are involved in iris normalization process.

3.5. Image intensification

Image intensification process is based on spatial domain approach. The original iris image has low contrast and may

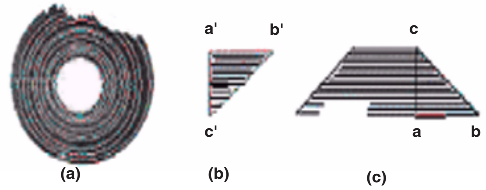

Figure 6. Operation of Radial-scan method.

Figure 7. Output of Radial-scan method

have non-uniform illumination caused due to the irregular position of the light source. These problems may affect subsequent feature extraction and pattern matching. In order to obtain well-distributed texture image, iris image is enhanced using local histogram equalization and high frequency of noises are removed by filtering the image with a Gaussian low-pass filter. Figure 9 shows the effect of applying Gaussian low-pass filter and histogram process. Figure 10a and 10b show the histogram effect on image intensification process.

Figure 8. Output of iris Normalization process

3.6. Feature Extraction

Feature extraction is a process to extract information from the iris image. These features cannot be used for reconstruction of images. But these values are used in classification. In this method, Gabor filter are used for iris feature extraction. Recently, Gabor filters have been used in rotation-invariant texture classification. In our experiment, we employed a Gabor filtering technique with isotropic 2D Gaussian for rotation-invariant classification. Gabor elementary functions are Gaussian modulated by oriented complex sinusoidal functions. Gabor frequency domain is defined in Eq.9.

$$\begin{aligned} G(x,y) &= g(x,y)\exp(-2\pi j(u\cdot x + v\cdot y)) \\ g(x,y) &= -\exp(x^2+y^2/2\sigma^2), j = \sqrt{-1} \end{aligned} \tag{9}$$

The complex function G(x, y) can be split into two parts, the even and odd filters. G_e(x, y) and G_o(x ,y), which are also known as the symmetric and anti-symmetric filters respectively. The spatial Gabor filter is described in the Eq.10.

$$\begin{aligned} G_e(x,y) &= g(x,y)\cos(2\pi f(xcos\theta + ysin\theta)) \\ G_o(x,y) &= g(x,y)\sin(2\pi f(xcos\theta + ysin\theta)) \end{aligned} \tag{10}$$

Figure 9. After Image intensification process

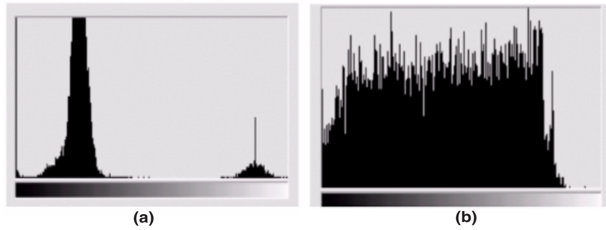

Figure 10. Histogram of before and after applying image intensification process

where G (x, y) is the Gabor filters kernel, g (x, y) is an isotropic 2D Gaussian function, f is the center frequency, q = arctan (U/V) is the orientation. Iris strip of fixed size 360 * 48 is taken for feature extraction process. The central frequencies of Gabor filter used in our experiment ranges from 2 degree to 64 degree, incremented by its power. For each central frequency, filtering is performed with θ = 0 ^{o} to 135^o incremented by 45^o. Total of 24 kernels are generated for each output image. The rectangular strip is divided into 4 sub images. 24 kernels are applied to every sub image resulting in 4 x 24 = 96 feature values. Kernels with maximum number of positive coefficients were chosen for processing.

3.7. Iris Matching

In this module, an iris strip is represented as a 1D feature vector of size 96. Feature set FS$_i$ = $\{$f$_1$,f$_2$...,f$_{96}\}$ is used for recognition process. BPN (Back propagation network) has been used for the iris matching process. For this process neural network models are created as 96 neurons in input layer, two hidden layers each has 12 neurons and one output neuron. Soft-limiting sigmoid function is used for activation of the each neuron in the network, shown in Eq.11.

$$S(I_j) = 1/(1+\exp(-I_j+\theta_j))/\theta_o \tag{11}$$

where Ij j = 1,2,3... N$_j$represents the input to the activation element of each node in layer J of the network, θ_j is an offset and θ_o controls the shape of the sigmoid function. The input to a node in any layer is the weighted sum of the output from the previous layer, shown in Eq.12.

$$\begin{aligned} I_i &= \textstyle\sum_{k=1}^{N_k} W_{jk}O_k \\ E_q &= 1/2\sum(N_q-O_q)^2 \end{aligned} \tag{12}$$

where N_q is the number of nodes in output layer, E_q is the error in the network. In the learning process, the common learning process for BPN is accomplished using random initialization of the weight vectors. In the recognition process, we set the matching threshold level. This determines the error tolerance of the system with respect to the feature for which the network is trained, and used to determine whether the final result is accepted / rejected. For any recognition system that is used for security applications, this error tolerance should be minimal and therefore the setting of this matching threshold is a crucial factor.

4. Experiments and Results

The implementation has been done in java and the time efficiency has been based on observation made on Pentium IV 2.4 GHz machine with 256 MB RAM. Experimentation were performed with different eye images in different criterion like normal, contact lens, spectacles, diseases etc., Capturing eye images in different situation provides a more challenges to this approach. 1500 iris patterns are taken and features were extracted and stored in an encrypted file. These feature sets were referred as fs_1,fs_2...fs_{1500}. Iris image database details are listed in Table 1.

Table 1. Iris image with different criterion

Normal Iris image				
Age	Gender	% of Class	Duration	Location
10 – 20	Male Female	10 10	15 to 90 days interval	30% out door 70% In door
21 – 40	Male Female	25 15		
> 40	Male Female	30 10		
Iris with eye glasses / contact lens				
Age	Gender	% of Class	Duration	Location
21-60	Male Female	50 50	15 to 90 days interval	100 % In door
Disease affected eye				
Age	Gender	% of class	Duration	Location
40-60	Male Female	50 50	15 to 90 days interval	100 % in door

This algorithm was tested in two different phases of operations, namely, recognition phase and confirmation phase. In recognition phase, a person feature set was sequentially chosen and compared with remaining set of 1500 feature sets. That is an iris feature set is compared with many irises feature sets. BPN threshold values were adjusted according to the different criterion of irises. During the training, the error tolerance allowed for the system is 0.00047. In the recognition process, the matching threshold is set which adds to the total error tolerance of the system. The matching threshold has been set to 0.0000124 based on experimental results. This gives an overall error tolerance of 0.0004824. This algorithm provides Non-matching ratio (NMR) of 99.21 and Matching ratio (MR) of 0.79 in normal criterion. The Results of recognition phase are given in Table 2. Confirmation phase is based on one-to-one matching. To perform this phase of operation, a feature set was trained and compared with same set of feature in different time and conditions. This phase provides Genuine Accept rate (GAR) of 99.21 and False Accept rate (FAR) of 0.79 in normal condition. Table3 shows the results of confirmation phase.

Table 2. Iris Recognition phase Results

Criterion	NMR	MR
Normal eye	99.21%	0.79%
Eye with Spectacles and contact lens	98.66%	1.34%
Disease affected eye	99%	1.00%

4.1. Space, Time and ROC Analysis

Storage requirement for iris matching is considerably reduced in this new approach. 96 features were used to classify different persons. That is, 96 * 16 bits = 192 bytes are needed per iris. Totally, 1500 eye images features were extracted and stored in 281.25 KB of an encrypted file. The execution times for the image prominence checking and iris recognition processes were measured and listed in Table 4. Receiver operating characteristics curve (ROC) is illustrated in Figure 11. ROC shows that this proposed system can efficiently work in different conditions.

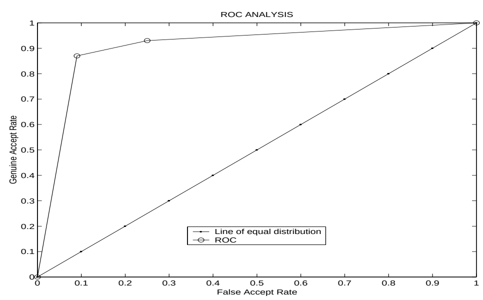

Figure 11. ROC Analysis of the iris system

Table 3. Iris Confirmation phase Results

Criterion	GAR	FAR
Normal eye	99.21%	0.79%
Eye with Spectacles and contact lens	98%	2%
Disease affected eye	98%	2.00%

Table 4. Time complexities of iris recognition processes

Steps in iris recognition process	**Time(Seconds)**
Eye with blink and Detecting eyelash	0.35
Truncation iris and Spectacles reflection	0.40
Detect flash and Remove eyelashes	1.2
Normalization-Dilation- intensification	2.5
Feature extraction and Recognition	4.0

5. Conclusions

This paper proposes a person identification system (PID) that works with non-illumination low-resolution eye images. The proposed algorithm requires 96 features for identifying a person. This algorithm uses Gabor filters to extract features of iris. Each iris image is extracted and then a fixed length feature set is obtained. Conventional neural network is used for iris matching. This method has proven that the spatial domain image processing operations can be used for iris prominence checking and feature extraction. Compare with other methods, the space complexity of this method is considerably reduced. In this approach, Image validity checking module is used to prevent any illegal entries stored in an iris-encrypted file. This algorithm provides accuracy of 99.21 % in normal criterion.

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