*International Journal of Computer Applications (0975 – 8887)*
*Volume 19– No.2, April 2011*

# Fake Iris Detection: A Holistic Approach

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## ABSTRACT
There is tremendous interest in improved methods of reliable and secure identification of people using biometrics. Although, iris is believed to allow very high accuracy, various experiments showed an alarming lack of anti-spoofing mechanisms in devices already protecting many sensitive areas all over the world. This enforces the need for aliveness detection methodology to be quickly introduced. In this paper, all possible types of fake iris has been identified. Previously published work in this field had concentrated only either on active or passive methods for fake iris detection. This has visible shortcomings of detecting only specific types of fake irises corresponding to each method and not of all kinds. This paper proposes a composite method, with promising results, to overcome the shortcomings of existing methods. The FAR and FRR values of the proposed method on realistic database of 160 images are 0.625% and 0.625% respectively. A notable achievement of this work is development of robust iris segmentation algorithm having inherent capability of fake iris detection.

## General Terms
Biometrics, Pattern Recognition, Security, Image Processing, Bioinformatics, Computer vision

## Keywords
Fake iris detection, anti-spoofing techniques of iris, dynamic iris segmentation, liveliness detection, types of fake irises, fake resistive iris recognition.

## 1. INTRODUCTION
Whenever people log onto computers, access an ATM, pass through airport security, use credit cards, or enter high-security areas, they need to verify their identities. Biometric methods, which identify people based on physical or behavioural characteristics, are of interest because people cannot forget or lose their physical characteristics in the way that they can lose passwords or identity cards. Biometric methods based on the spatial pattern of the iris are believed to allow very high accuracy, and there has been an explosion of interest in iris biometrics in recent years [1], [2], [3].

The aliveness detection became a serious and disturbing issue after publishing in 2002 the experiment results by the Fraunhofer Research Institute (Darmstadt, Germany) [3] in collaboration with the German Federal Institute for Information Technology Security (BSI) with well-established face, fingerprint and iris recognition systems. The experiments highlighted an alarming lack of anti-spoofing mechanisms in devices already protecting many sensitive areas all over the world. The Panasonic ET100 iris camera with PrivatelD software was successfully fooled with iris printouts of high resolution (1200x2400 dpi) made with the inkjet printer. The situation became more serious, where the first systematic experiment of iris spoofing was carried out by Tsutomu Matsumoto [5] of Yokohama National University, Japan, and presented in London. In addition, Matsumoto also succeeded in deceiving three commercial iris recognition systems using the same kind of fake iris. In other words, current iris recognition algorithms cannot distinguish fake irises from live ones. This enforces the need for aliveness detection methodology to be quickly introduced to the commercial equipment and generated the need for the research on fake resistive iris recognition.

## 2. TYPES OF IRIS FORGERIES
The eye printouts make quite straight forward iris forgery. The leading iris biometric cameras have difficulties in differentiating between the fake and alive eyes even though the high resolution printout of eye imitation l, as shown in Fig 1.

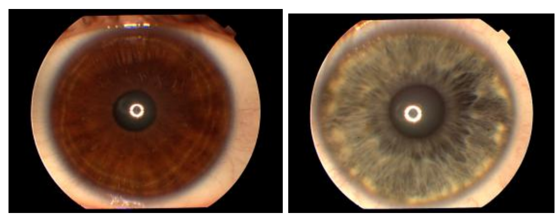

Fig. 1. Eye Printouts on matte and glossy Paper

Next step in iris forgery would be a preparation of an "eye movie", shown in Fig 2, which simulates the real eye behavior blinks, pupil dynamics, eyeball movements, etc.). Naturally, such a movie with a fixed scenario is relatively easy to eliminate, e.g. by requesting and measuring particular eye behavior. On the other hand, the attacker may be able to react on-line to certain requests, hence, additional anti-spoofing methods must be applied.

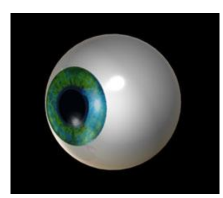

Fig..2. Eye movie

Going further into counterfeit complexity, one may consider an artificial eye, as shown in Fig 3, presented behind the camera lens. The iris pattern may be printed on a plastic or rubber eye model, whose constrictions and dilations may additionally imitate pupil diameter changes and a natural behavior of the iris tubercular meshwork during accommodation.

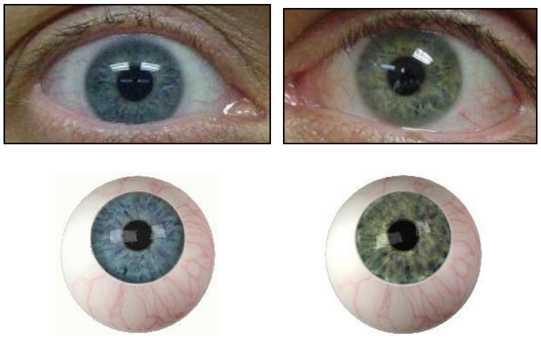

Fig. 3. Real eyes (top) and respective artificial eyes (bottom)

Next, the living eye may be the carrier for artificial contact lens with the iris pattern printed as shown in Fig 4.


Fig. 4. Woman putting artificially printed lens and different coloured and textured iris of same eye

The most sophisticated "forgery" of the iris camera is simply the use of a real eye. Although the use of non-living organ may be very faint, this cannot be excluded, especially, in military scenario.

# 3. EXISTING METHODS OF ALIVENESS DETECTION

To detect fake irises, it is necessary to find a feature that distinguishes between live irises and fake ones. Such features can involve passive measures which rely on involving processing of images to differentiate characteristics of the living eye as opposed to artificial objects. Also they can be active measures involving stimuli by user. Thus, fake iris detection methods can be divided into two broad categories. They are passive and dynamic methods.

## 3.1 Frequency Spectrum Analysis

Frequency spectrum seems to be a straightforward source of information concerning the existence of regular artefacts within the image. The concept of artificial frequencies localization prior to the iris recognition was already suggested by Daugman [6], however no automatic methodology was proposed to materialize the idea for years. Frequency spectrum methodology has an important advantage, namely, it requires no additional hardware, since the same static image as used in the iris recognition may be analyzed. On the other hand, the method has a serious drawback, originating from Shanon's theory. Namely, the method fails once the resolution of the printing device, used for counterfeit preparation is more than twice the resolution of the image acquisition and analysis camera.

## 3.2 Analysis of eye at different wavelengths (Reflectance)

In order to detect fake irises, report used the changing reflectance properties between the iris and the sclera with variations of wavelengths of incident light. Although this method was first suggested by Daugman [7], he did not show how these kinds of features can be measured by image processing. In addition, he did not consider the theoretical reflectance model. Lee et al. [8]. also used this feature to detect fake irises. However, the iris and sclera regions were set arbitrarily. This meant that they could not always distinguish printed fake irises from live irises. To overcome this problem, Lee et al. [8] have proposed a method of detecting live and fake irises based on reflectance properties considering the theoretical reflectance model.

In the live iris, the reflectance of the iris increase as the wavelengths increase from 750nm to 850nm. But the reflectance of sclera decrease as the wavelength increase from 750nm to 850nm. Therefore, the reflectance ratio computed at 850nm, P850 is higher than that at 750nm, P750. In the fake iris, however, the reflectance ratios at 750nm, P750, and at 850nm, P850, did not change as much as those in the live iris when the wavelengths increase. Therefore, report set the criterion for detecting a fake iris as the ratio value between P850 and P750, using following equation.

$$P_{850} / P_{750} = \frac{I_{I\_850}}{I_{S\_850}} / \frac{I_{I\_750}}{I_{S\_750}} = \frac{I_{I\_850}}{I_{I\_750}} / \frac{I_{S\_850}}{I_{S\_750}}$$

Where, $I_{S\_750}$ and $I_{I\_750}$ are the image intensity of the sclera and the iris at 750nm and $_{\_850}$ and $I_{I\_850}$ are the image intensity of the sclera and the iris at 850nm.

## 3.3 Pupil dynamics analysis

Finally, a group[9] of possible anti spoofing mechanisms is based on dynamic (i.e. behavioural) eye features. Fig 6 shows the pupil response to a step light change proposed in [10] consists of two independent channels, whose sum gives the final response. It seems that the dynamic features of the eye observed within certain time horizon should be a result of a certain interaction between the user and the machine. This makes the measurement active. This may include blinks or eye movement forced by an object tracking. One of such features is the pupil dynamics. Primarily, the pupil constriction and dilation partially influences the human eye accommodation process.

The comparative analysis of frequency spectrum method, reflectance method and pupil dynamics method had been presented by Andrzej Pacut et al. [9]. The analysis makes it amply clear that effective fake iris detection cannot be done by a single road approach. It requires a holistic approach and must cater for a variety of possibilities. A single method cannot detect all types of fake iris; neither can a particular type of fake iris be detected effectively by all methods equally well. This makes it imperative for a robust and effective fake iris detection system to employ a composite algorithm which is presented in this paper.

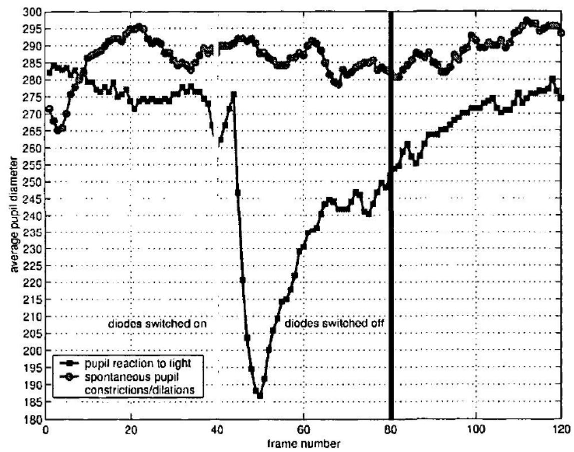


Fig. 5. Variation of pupil size[9]

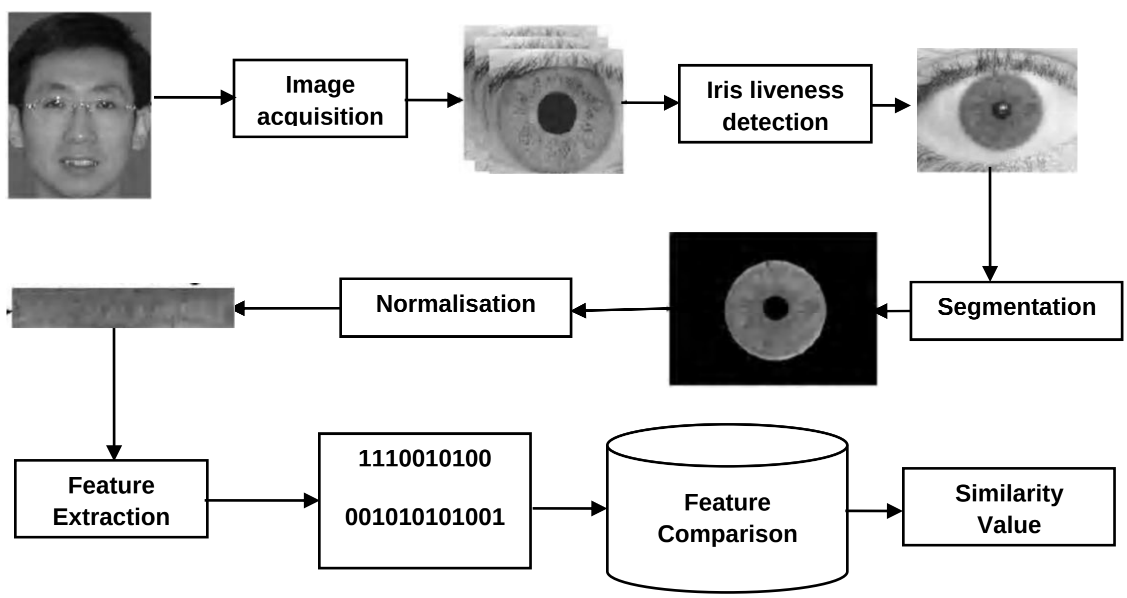


Fig. 6. Typical stages of the robust iris recognition system

## 4. THE PROPOSED SYSTEM

The block diagram of our robust iris recognition system with fake iris detection module is shown in Fig 6, whereas, Fig 7 shows the flow chart of proposed fake iris detection module of our system. It consists of image selection module, preprocessing module is nothing but the iris segmentation unit which extract the iris accurately from eye image and last module test whether iris is fake or alive by using any one of the three methods, namely, active, passive or composite method. If iris in not fake, then iris recognition is carried out by using combination of complex wavelet and rotated complex wavelet method [11].

### 4.1 Iris segmentation and Active Method (Pupil Dynamics)

Iris segmentation mainly consist of three steps, outer boundary detection, pupil detection and normalization. Several researchers have implemented various methods for segmentation and localising the iris. Almost all methods stated are based on the assumption that centre of iris (Outer boundary) and Pupil (Inner boundary) is same and iris is perfectly circular in shape which is seldom true. Therefore, the iris segmentation and localization from an acquired image leads to loss of texture data near to pupil and/or outer boundary. The effect is more serious when iris is occlude. In iris recognition system, accurate iris segmentation and localisation from eye image is the foremost important step.

Success rate of any feature extraction algorithm of iris recognition systems is primarily decides by the performance of iris segmentation from eye image [12], [13], [14], [15].

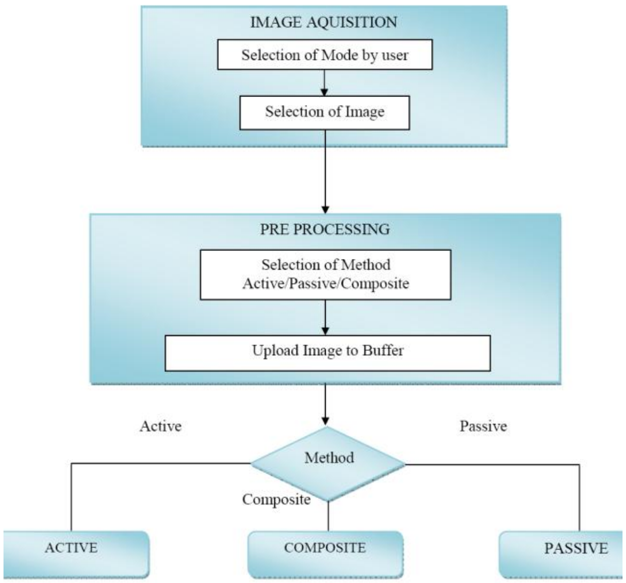


Fig. 7. Block diagram of proposed system

In this paper a robust and efficient method of iris segmentation[14] is proposed. In the proposed method, the outer boundary of iris is calculated by tracing objects of various shape and structure. Outer iris boundary detection method also detects intersection of iris with upper and lower eyelids to ensure minimum loss of iris information. Fig 8 shows the output of this step.

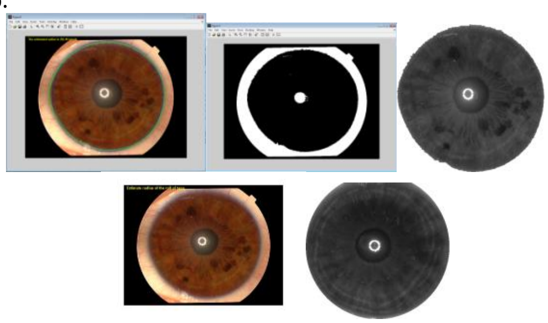

Fig.8. Outer Boundary detection in case of complete circle and incomplete circle

For inner iris boundary (pupil detection), two eye images of same subject at different intensities are compared with each other to detect the variation in pupil size (pupil dynamics). Based on the pupil size variation, the inner boundary of iris is detected. The variation in pupil size is also used for aliveness detection of iris. Thus, this approach is a very promising technique for making iris recognition systems more robust against fake-iris-based spoofing attempts as well [14].
Tracing this inner boundary and selecting region outside inner boundary and below outer boundary will give exact iris with minimum losses. Normalization of this iris image gives the rectangular image, which is used as source input for feature extraction module of iris recognition system. Fig 8 shows the output of pupil detection and normalization steps [14].

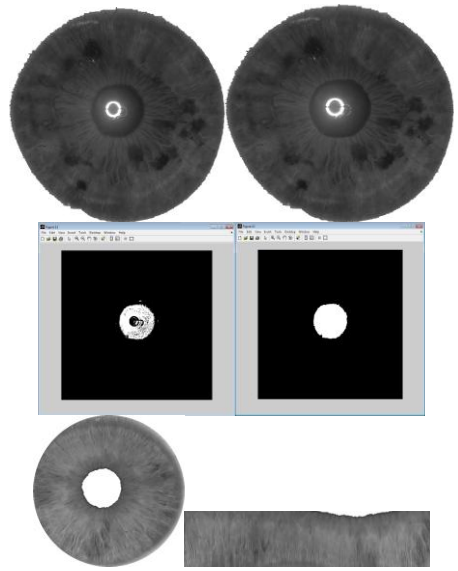

Fig. 9. Inner boundary (pupil) detection and normalized iris

The algorithm is tested on UPOL database [16] of 384 images of both eyes of 64 subjects. The success rate of accurate iris localisation from eye image is 99.48% with minimal loss of iris texture features in spatial domain as compared to all existing techniques [14]. This method is based on the pupil dynamics. Thus, accurate iris segmentation and fake iris detection which are essentially required for iris recognition system are achieved in the same algorithm. This is the novelty of this method.
Pupil dynamics method uses two images at different light intensities (illuminations) as shown in Fig 9 which are having different pupil size. Following steps are involved in the pupil dynamics method.

- Calculate radii and centers of each image.
- Outer radius (iris radius) is always same.
- Calculate variation in inner radius (pupil radius) of two images.
- If variation in the inner radii is above threshold, then image is real (live) image else fake image.

The change in the pupil size is a measure for detection of real iris or fake iris. This method is capable of detecting rubber eye, printed eye lens and dead eye as fake iris but unable to detect eye movie as fake iris. Result for eye print out is contentious.

## 4.2 Passive method (Wavelength reflection coefficient method)

This method is based on the reflectance properties of material as discussed in earlier sections. For higher efficiency and better results this method has been adopted with modifications. In existing reflectance based methods, two images are used, whereas, in this work three images have been used instead of two, third image is the original image termed as base or reference image which is captured at visible light. Other two images have been captured at 750nm and 850nm wavelengths as shown in Fig 10.

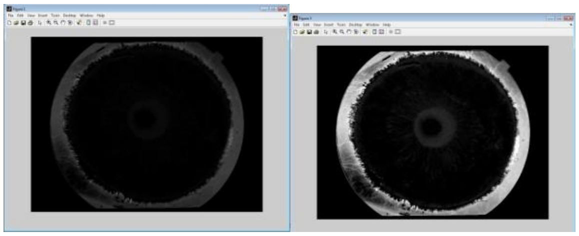

Fig. 10. Image at wavelength 750nm and 850nm

The reflectance of the iris is also affected by the amount of melanin in the anterior border layer. The reflectance of melanin slightly increases as the wavelength of illumination increases from 750nm to 850nm [19]. Therefore, the reflectance of the iris also increases when the wavelength of illumination increases from 750nm to 850nm. The sclera is a dense and fibrous structure. According to previous work [8], the reflectance of the sclera slightly decreases as the wavelength of illumination increases from 750nm to 850nm. As a result, the reflectance ratio of the iris to the sclera is greater at longer wavelengths than at shorter wavelengths. However, for fake irises produced by printers and found in photographs, the iris and the sclera are made from the same material. This means that they show similar changes in reflectance as the wavelengths. Therefore, the reflectance ratio of the iris to the sclera does not change when wavelength of incident light varies. In case of artificial eye, iris and sclera are made up from different materials than the natural eye. Therefore, the change of the reflectance ratio of the iris to the sclera is not the same as that of live irises. In short, if one measure the change of the reflectance ratio between the iris and the sclera with variations of wavelengths of incident light, it is possible to detect fake irises.

In this work, corresponding areas like iris and sclera are detected and localized using iris segmentation technique as shown in Fig 6. The original image at visible light is base image and it acts as reference image to relate the intensities of images at 750nm and 850nm wavelengths. From these results, the reflectance coefficient in each case has been calculated. Imperial experiments has been carried out on the database and it is found that the variation in coefficient for real eye is from 0.01 to 3.76 and whereas for fake eye it varies from 6.8 to 17.62. Therefore, the threshold value to differentiate between fake and real eye is set to 5, below 5 images are assumed to be real and above this as fake.

## 4.3 Composite Method

Table 1 shows the result of fake iris detection by active and passive method. It is very clear from the experimental results that nither active method nor passive method is capable of detecting the fake irises of all kinds alone. Therefore, there is a need to develop a new algorithm that covers and detects all four classes of fake iris. This composite method is a solution to this problem. This method is a combination of existing fake iris detection techniques with certain modifications required to improve the efficiency of algorithm as part of software implementation

**Table 1. Fake iris detection by active and passive methods**

| **Type of fake iris \| method** | **Active method** | **Passive method** |
|---|---|---|
| **Eye print out** | Contentious | Detect |
| **Eye movie** | Not detect | Detect |
| **Rubber eye** | Detect | Contentious |
| **Printed eye lens** | Detect | Contentious |
| **Dead eye** | Detect | Not detect |

# 5. RESULTS

The original UPOL database of 64 subjects contains 3 x 128 iris images (i.e. 3 x 64 left and 3 x 64 right). The images are: 24 bit - RGB, 576 x 768 pixels, file format: PNG. The irises were scanned by TOPCON TRC50IA optical device connected with SONY DXC-950P 3CCD camera [16]. The proposed algorithm is implemented in MATLAB7.0, on PIV-3Ghz, Intel processor with 512MB RAM.

## 5.1 Database creation and testing methodology

As discussed in section 2, fake irises can be of five types. They are namely; eye print out, eye movie, rubber eye, printed eye lens and dead eye. For the purpose of the paper these are the terms that will be used to refer to these five types of fake irises. UPOL iris image database has been used for the research work. It consists of realistic iris images of 800 X 600 resolution of 40 subjects which are challenging for iris segmentation [14], [16], [17], [18] due to very low intensity gradient at the inner and outer boundaries.

Since images of all five kinds of fake iris could not be obtained, NASK, Biometric Laboratories Warsaw, Poland has helped us in creating the fake images from original UPOL database images. Four folders have been employed to simulate for the fake irises of various types. The four main folders are *images1*, *images2*, *images3* and *images4*. The images in images1 folders are those of real irises. They are the ones that are from the UPOL iris database[16]. The contents of *images2* folder will be detected only by passive methods as fake iris and can be termed to be simulating eye movie. The folder *images3* has images that are detected to be fake, by active methods alone and are simulating fake irises such as, printed eye, printed eye lens and dead eye. The final folder, *images4* has images that are detected as fake by both active and passive method. These images can be said to be simulating printed eye, rubber eye and printed eye lens.

Each folder has forty subfolders posing as forty inputs. Each of these numbered subfolders contains four images each. The images have common names, namely, *1.png*, *1_inc.png*, *DSC001.jpg* and *DSC001_2.jpg*. The images *1.png* and *1_inc.png* are used for fake iris detection using active measures, namely pupil dynamics, while the images *DSC001.jpg* and *DSC001_2.jpg* are used for fake iris detection using passive measure, namely the wavelength reflectance method.

A total of *160* images were tested to generate the statistics stated below. The images in this pool consisted of *120* fake iris images (folders *images2*, *images3*, *images4*) and *40* real iris images (folder *images1*). FAR and FRR are used as performance measurement parameters.

## 5.2 Results of Segmentation Algorithm

For testing the fake iris and live iris, we used 160 images of 40 subjects in four different folders as stated above. The proposed segmentation algorithm accurately extracted irises of 159 images out of 160 images giving a success rate of 99.375 % that too with very minimal loss of iris texture features as compared to existing methods, especially for high contract iris images.

## 5.3 Results of fake iris detection using passive, active and composite methods

In this experiment, we have used images in four folders as explained above. The images in one folder are real iris and images in other folders are fake images of various types. Images from all the four folders are inputted to detect fake iris using active method, passive method and composite method. The performance of each method is evaluated with the help of False Acceptance Rate (FAR) and False Reject Rate (FRR). In this experiment, FAR means probability of failure to detect fake iris and FRR means probability of considering live iris as fake iris. FAR and FRR characteristics of composite method of fake iris detection is shown in Fig. 11. Table 2 shows the values of FAR and FRR with respect to detection of real iris versus fake iris for passive, active and composite methods, which are also shown in Fig 12. The results are also compared with our implementation with existing results [9] in the literature. The result of passive method is only available.

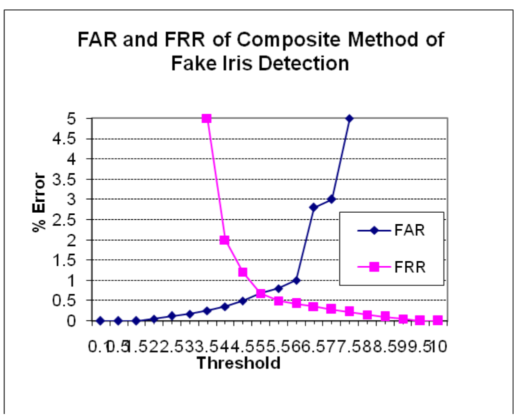


Fig. 11. FAR and FRR of composite method of fake iris detection

**Table 2. Results of Fake iris detection methods.**

| **FAR / FRR** | **FAR** | | **FRR** | |
|---|---|---|---|---|
| **Methods** | Existing [9] | Implem-ented | Existi-ng [9] | Impleme-nted |
| Passive | 046 | 23.75 | 0.28 | 1.25 |
| Active | - | 24.3 | - | 0.625 |
| **Composite** | **-** | **0.625** | **-** | **0.625** |

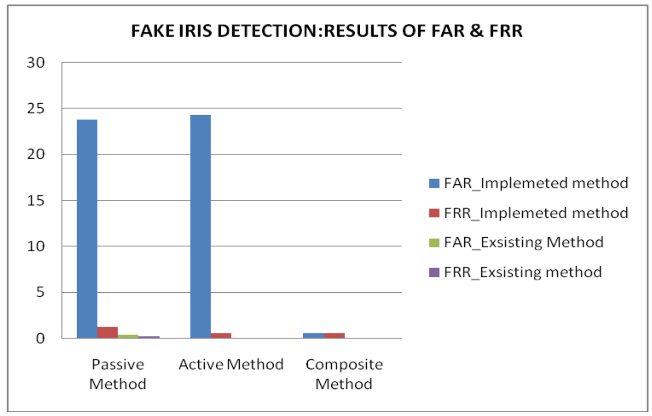


Fig.12. Comparative results of Fake iris detections

## 5.4 Results of iris recognition system

As shown in Fig 6, features of live iris are extracted using combination of Dual Tree Complex Wavelet Filters and Rotated Complex Wavelet Filters to create iris templetes and test images are compared with the help Canberra distance to evaluate the performance of our iris recognition system[11][21]. The FAR and FRR characterstics of iris recognition system by using only real (live) iris is as shown in Fif 13. The Equal Error Rate (EER) of the system for real iris images obtained with the help of proposed fake iris detection method is 0.26% and recognition rate is over 99 %.

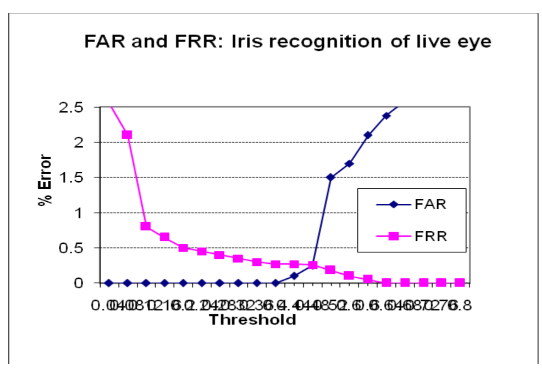


Fig. 13 FAR and FRR of iris recognition system using real (live) eye images.

## 6. CONCLUSIONS

Images of UPOL database are more challenging for iris segmentation than CASIA and UBIRIS database because of it's very low intensity gradients at boundaries of iris. We have proposed the novel algorithm [14] of accurate iris segmentation of actual shape without loss of iris data using pupil dynamics which is also inherently capable of certain types of fake iris detection. The

For implemented *active method*, obtained FAR and FRR values are 24.3% and 0.625%, respectively. For implemented *passive methods*, obtained FAR and FRR are 23.75% and 1.25% respectively. The large FAR values can be attributed to wide scope of database used to simulate fake irises. The FAR and FRR values of the *composite method* are 0.625% for both.

Previously published work in this field had concentrated only on active or passive methods for fake iris detection. This has visible shortcomings as illustrated. This paper proposes a composite method, with promising results, to overcome the shortcomings of using a single approach.

The results obtained by the active and passive methods individually are dismal as compared to previously published work. This is since the fake iris possibilities considered are of a far greater quantum in this work as compared to earlier work.

## 7. ACKNOWLEDGMENTS

We thank Dr. Adam Czajka, NASK, Biometric Laboratories Warsaw, Poland, for providing us with database of real and fake iris images without which this research work would not completed. We are indeed grateful for his constant advise and continuous support.

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