



# An Iris Recognition Algorithm Using Phase-Based Image Matching

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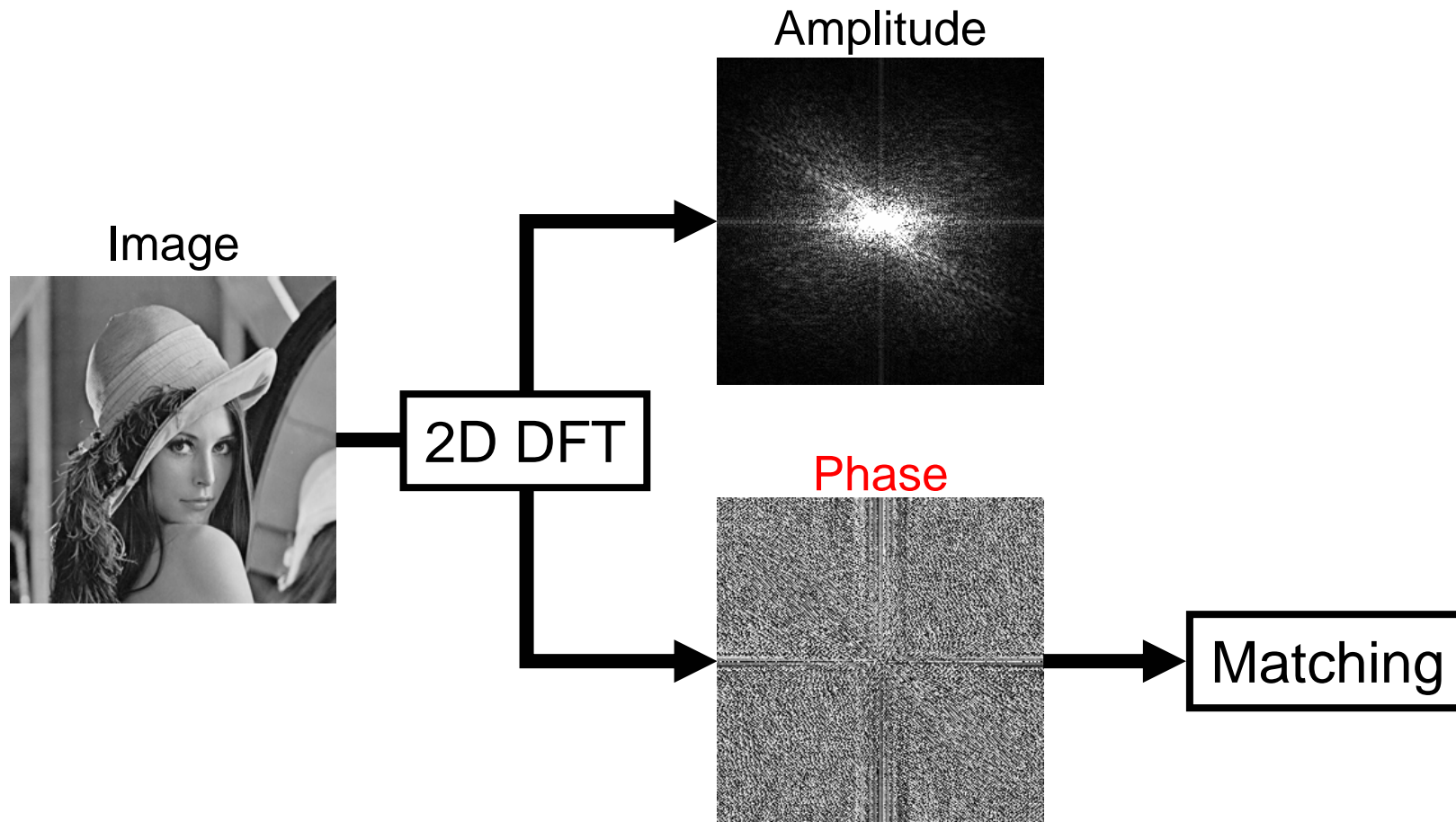
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# What Is Phase-Based Image Matching?

- Using phase components in 2D Discrete Fourier Transforms (DFTs) of given images.





# Biometrics with Phase-Based Image Matching

- Application to image registration

*C. D. Kuglin et al., "The phase correlation image alignment method," Proc. Int. Conf. Cybernetics and Society, 1975.*

- Application to biometrics (fingerprint)

*H. Nakajima et al., "Pattern collation apparatus based on spatial frequency characteristics," US Patent, 1995.*

- Commercial fingerprint verification unit (1998)

- Other successful applications (biometrics)

- Iris recognition
- 3D face recognition
- Palmprint recognition



FriendTouch



ASIC for phase-based image matching



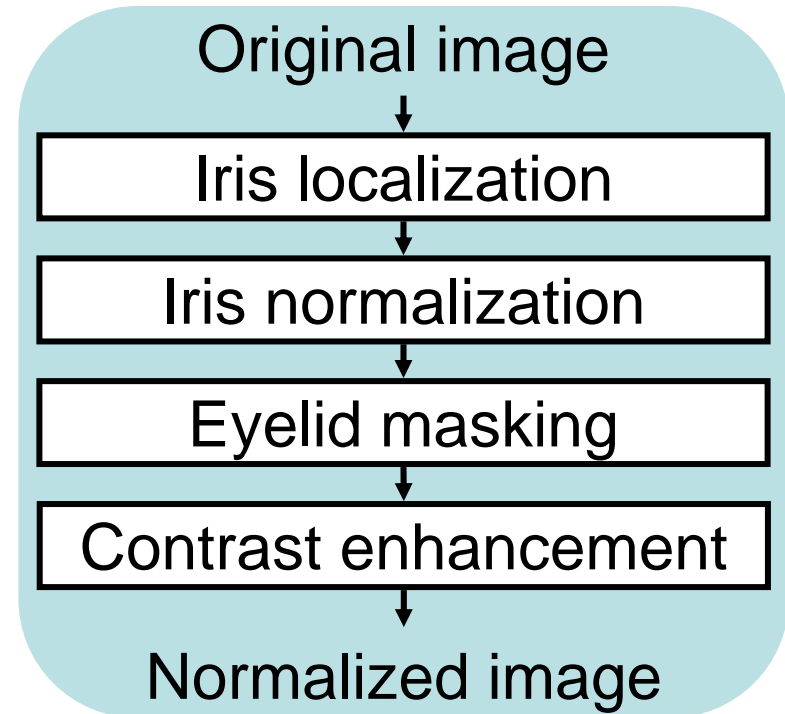
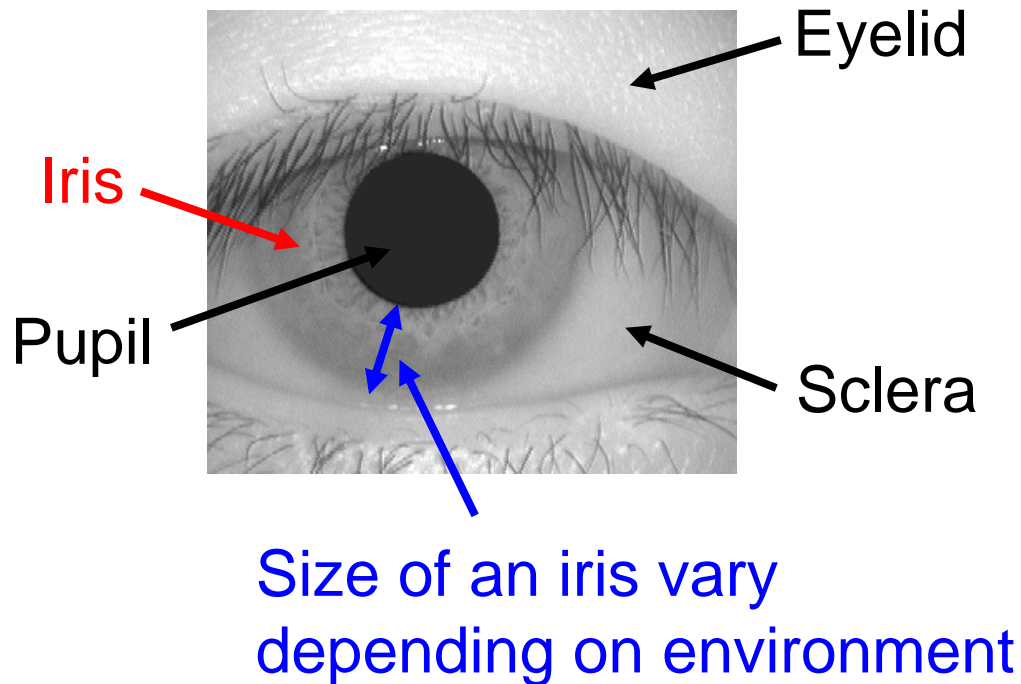
# Outline

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- Background
- Preprocessing stage
- Matching stage
- Experimental results of ICE 2005
- Conclusion and future plans



# Preprocessing Stage

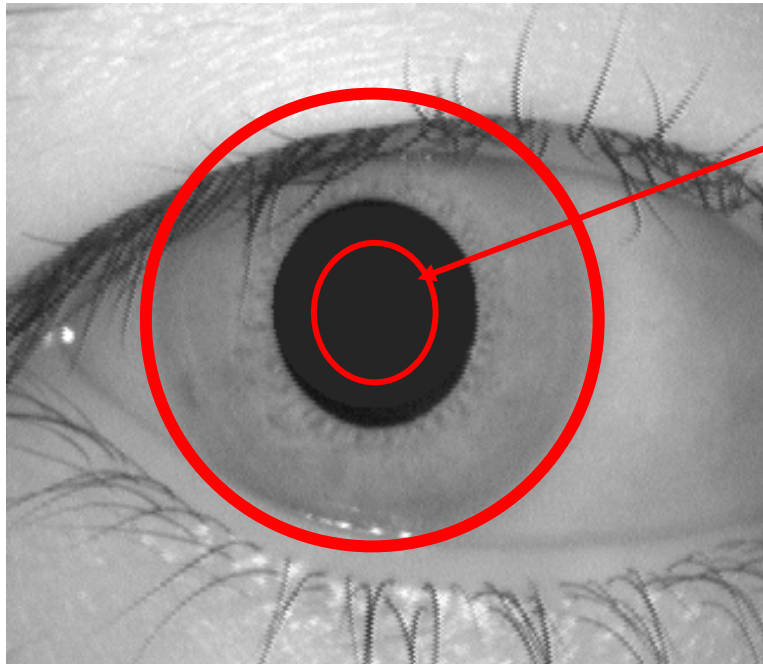


- ❑ Remove the parts that are not necessary for recognition.
- ❑ Normalize iris region to reduce the influence of environmental factors.



# Iris Localization

- Based on Dr. Daugman's approach

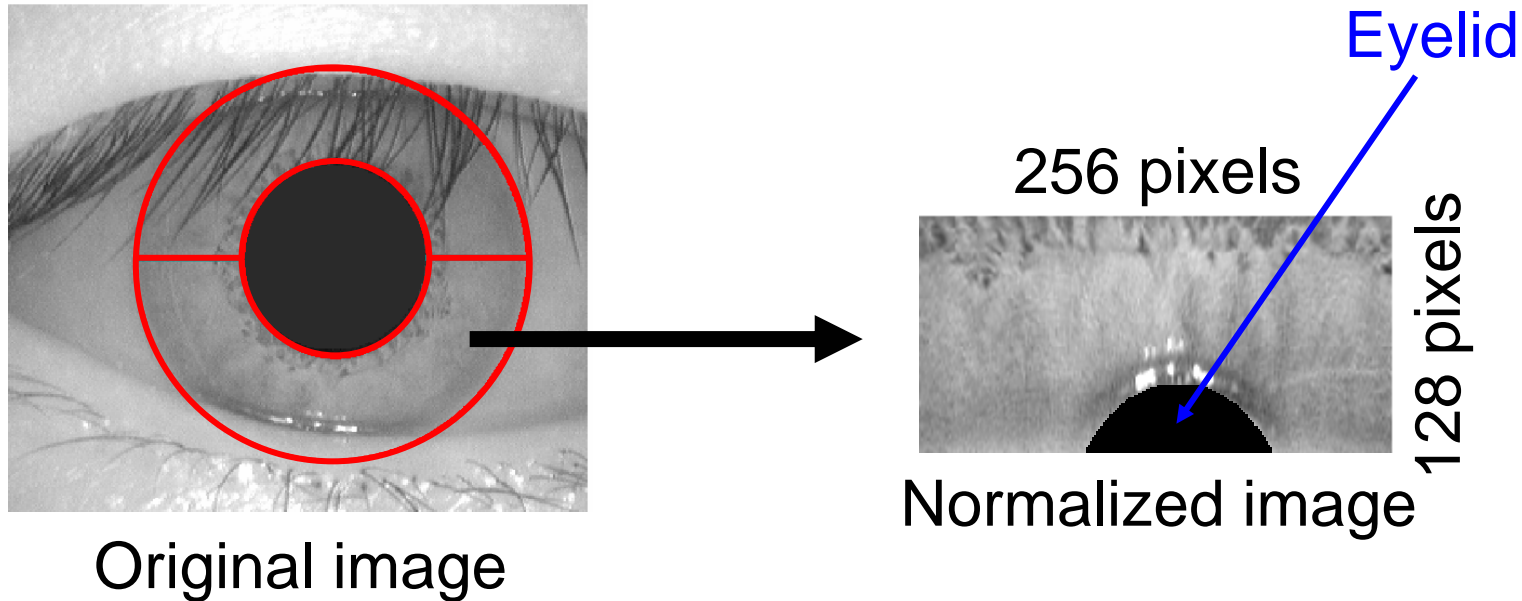


1. Calculate contour integral along the ellipse.
2. Compute integral derivative in the axis direction of the ellipse with increasing the lengths of axes.

- Detect the inner boundary by finding the ellipse which maximizes the derivative.



# Iris Normalization

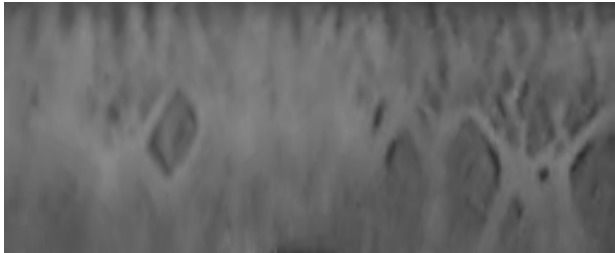


- Use only the lower half of the iris region.
- Eyelid is not necessary for recognition.
- Using the same method for detecting the inner boundary, detect the eyelid boundary.

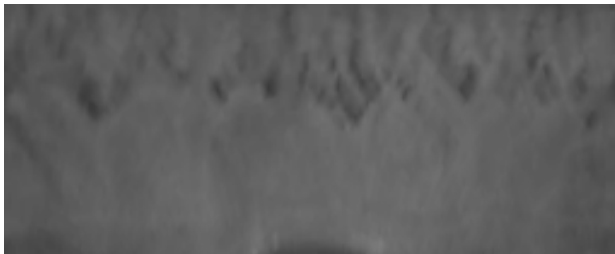
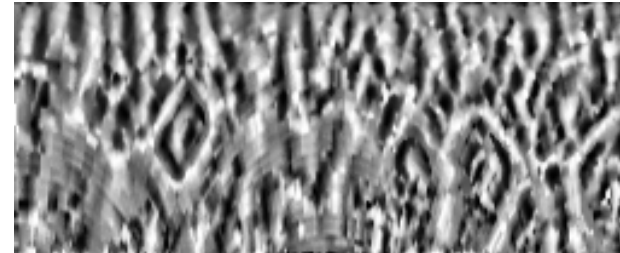


# Contrast Enhancement

Normalized image



Enhanced image

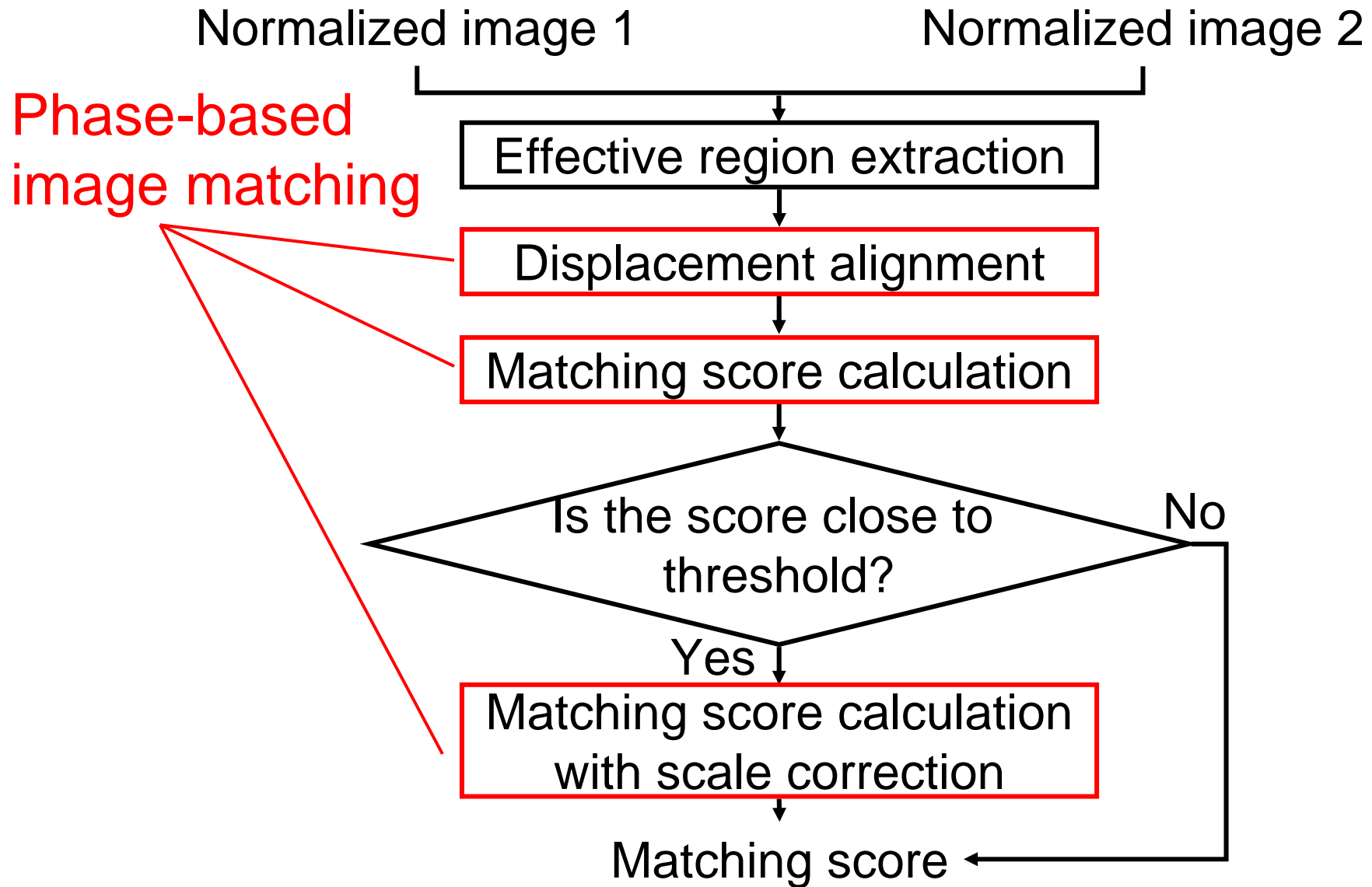


- ❑ In some databases, the normalized iris image has low contrast.
- ❑ Improve the contrast by using **local histogram equalization**.





# Matching Stage





# Phase-Based Image Matching

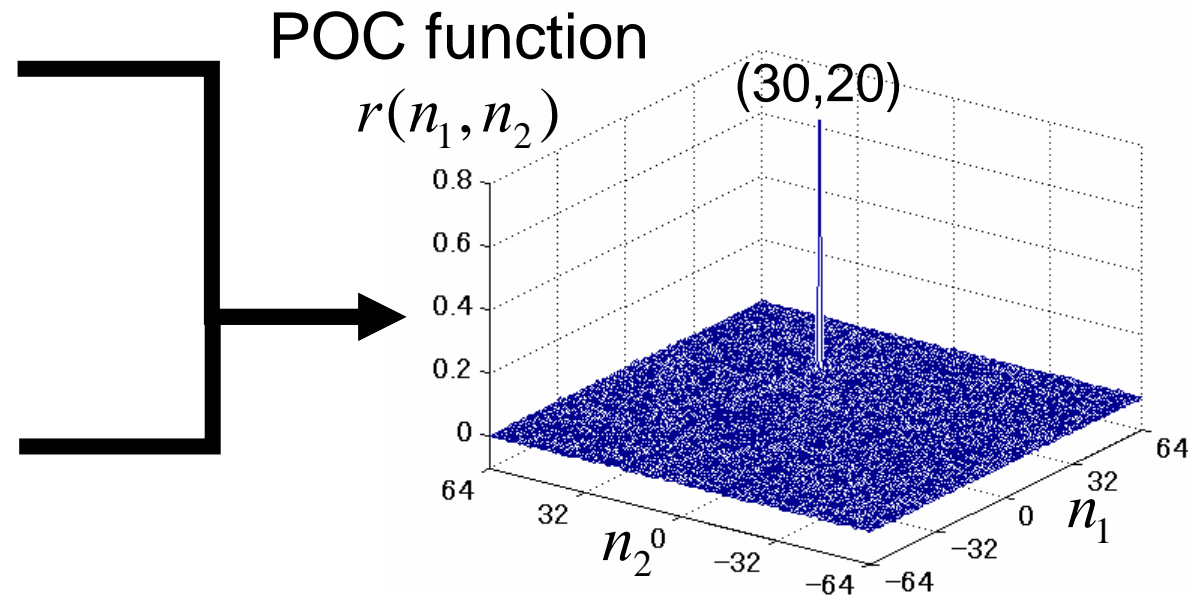
- Phase-Only Correlation (POC) function



Image 1



Image 2



POC function has **a sharp peak like a delta function.**

**Location** of the correlation peak: **Translational image shifts**

**Height** of the correlation peak: **Similarity of images**



# Basic Computation Flow for POC Function

Spatial Domain



$n_2$   
 $n_1$

Input images

$$f(n_1, n_2)$$

$$g(n_1, n_2)$$

POC function

$$r(n_1, n_2)$$

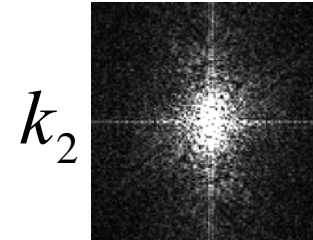
2D DFT



2D IDFT



Frequency Domain



$k_2$   
 $k_1$

$$F(k_1, k_2) = A_F(k_1, k_2) e^{j\theta_F(k_1, k_2)}$$

$$G(k_1, k_2) = A_G(k_1, k_2) e^{j\theta_G(k_1, k_2)}$$

Amplitude Phase

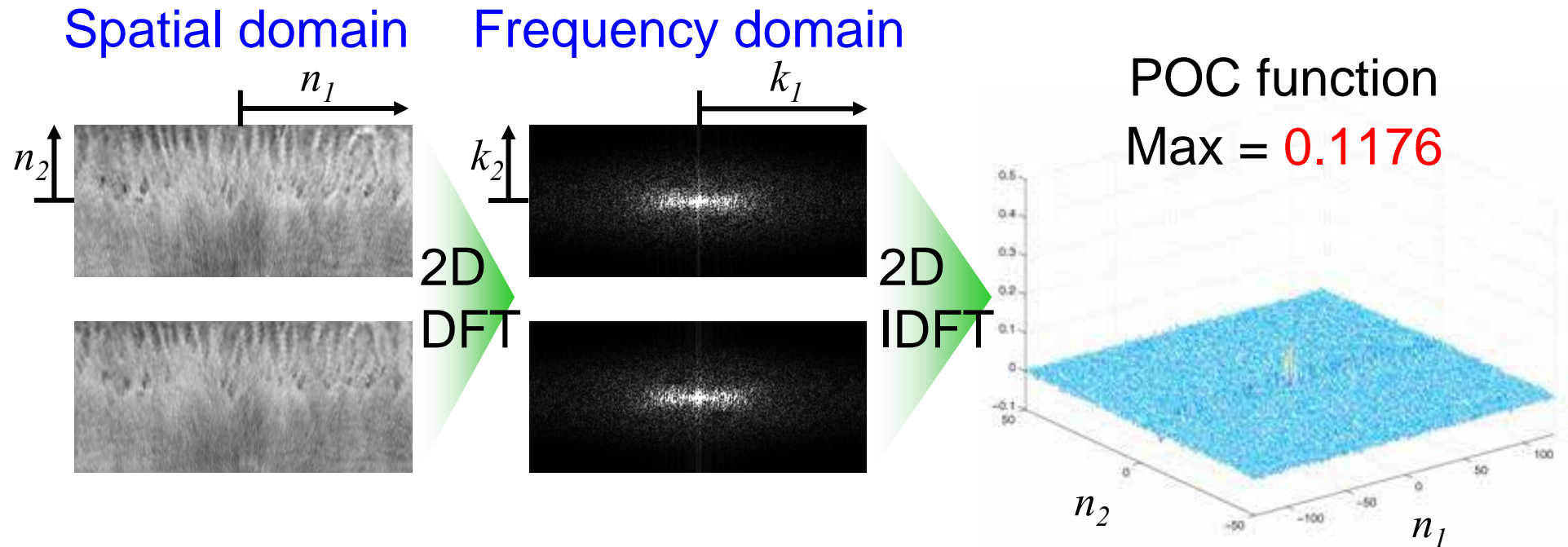
Cross-phase spectrum

$$R(k_1, k_2) = \frac{F(k_1, k_2)}{|F(k_1, k_2)|} \cdot \frac{\overline{G(k_1, k_2)}}{|G(k_1, k_2)|}$$
$$= e^{j\{\theta_F(k_1, k_2) - \theta_G(k_1, k_2)\}}$$





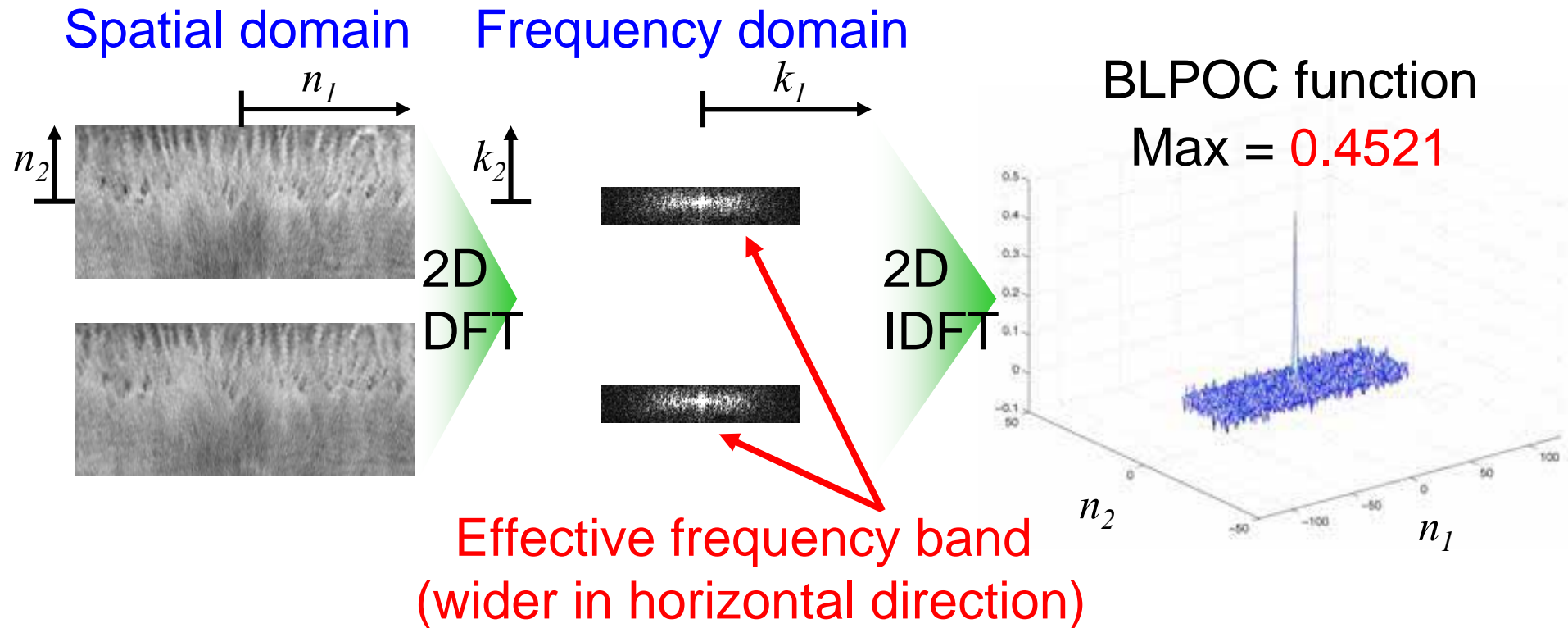
# Degradation of Accuracy



- ❑ 2D DFT of a normalized iris image has unreliable phase components in high frequency domain.
- ❑ The height of the correlation peak is reduced.



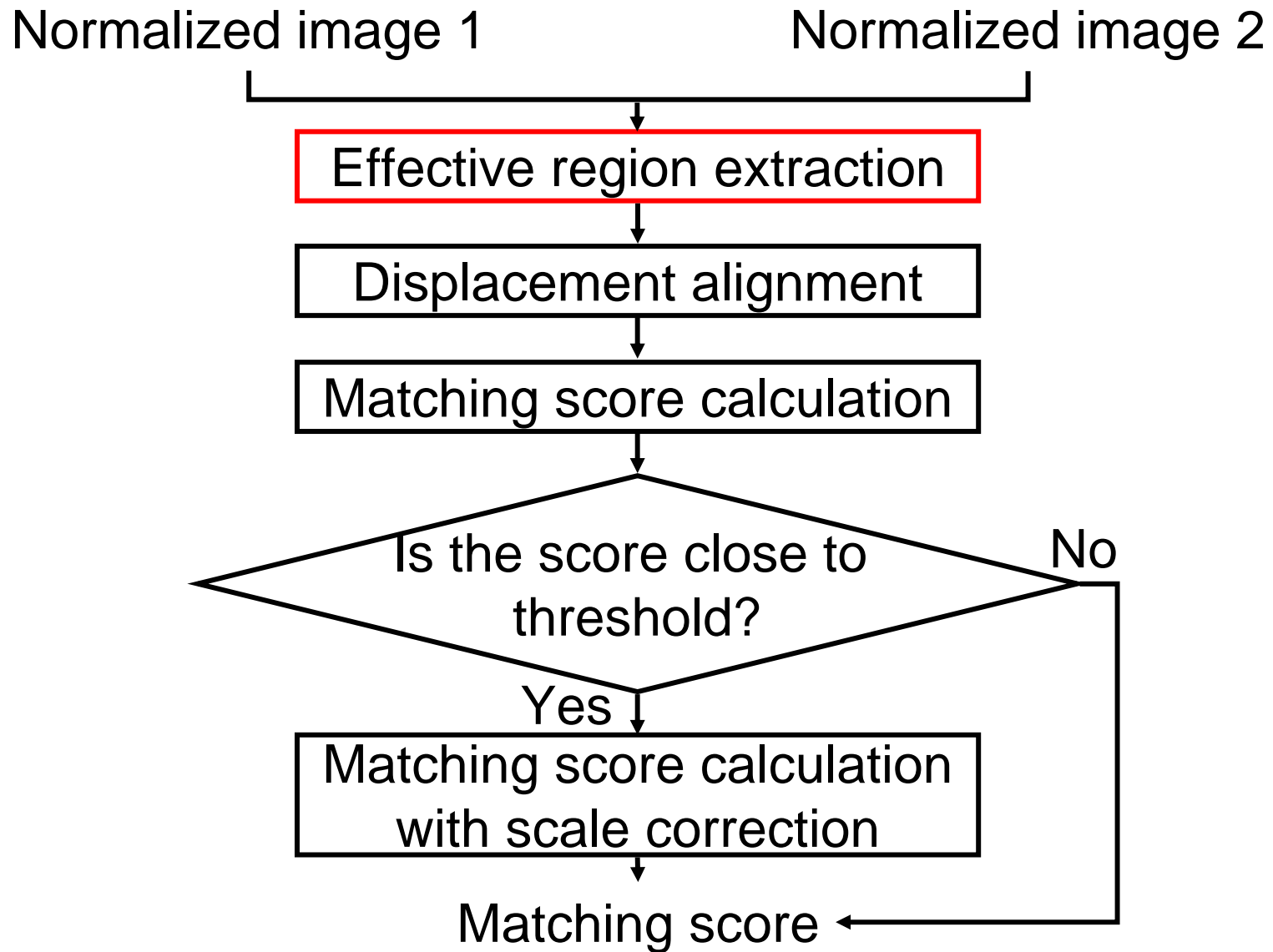
# Band-Limited POC (BLPOC) Function



- Adaptively change the size of 2D IDFT.
- BLPOC function shows much higher discrimination capability than the original POC function.

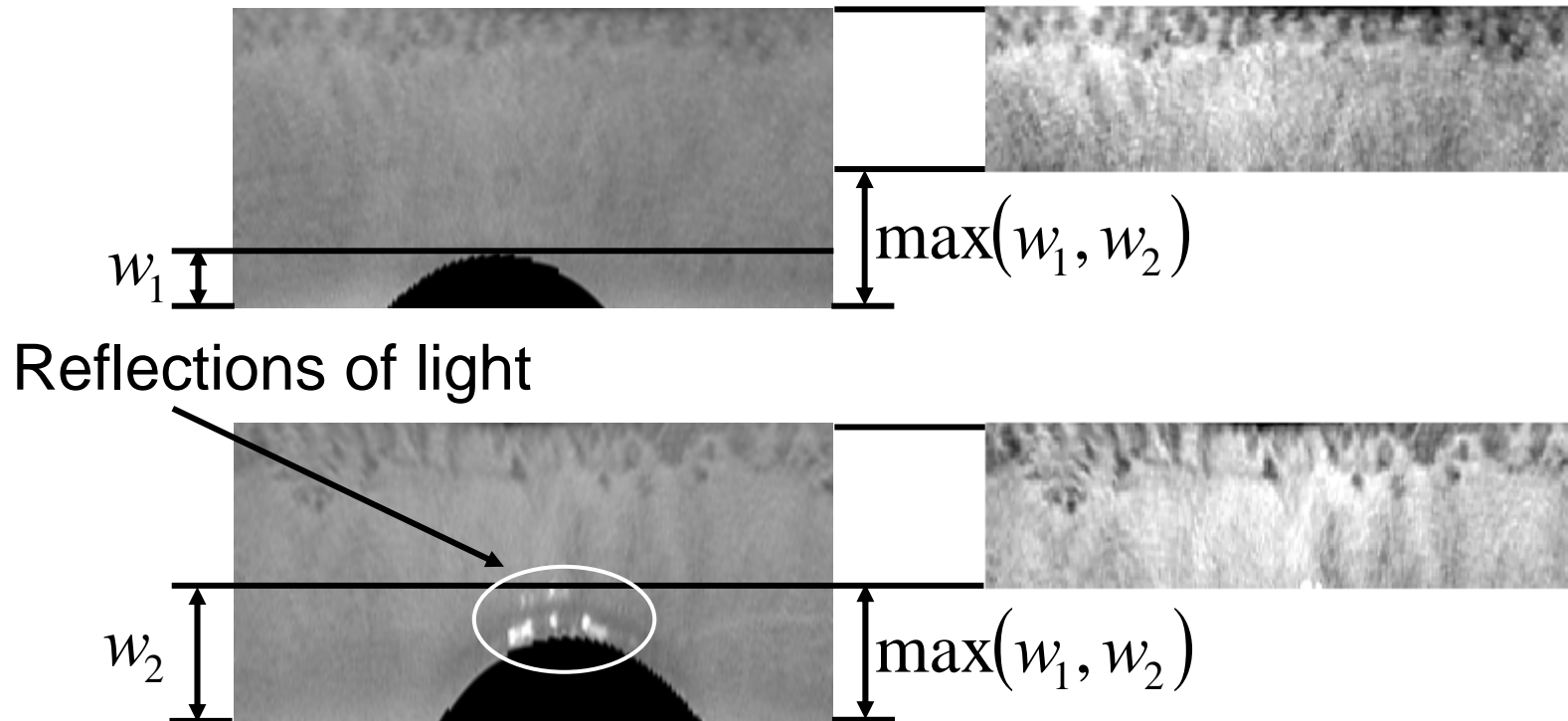


# Matching Stage





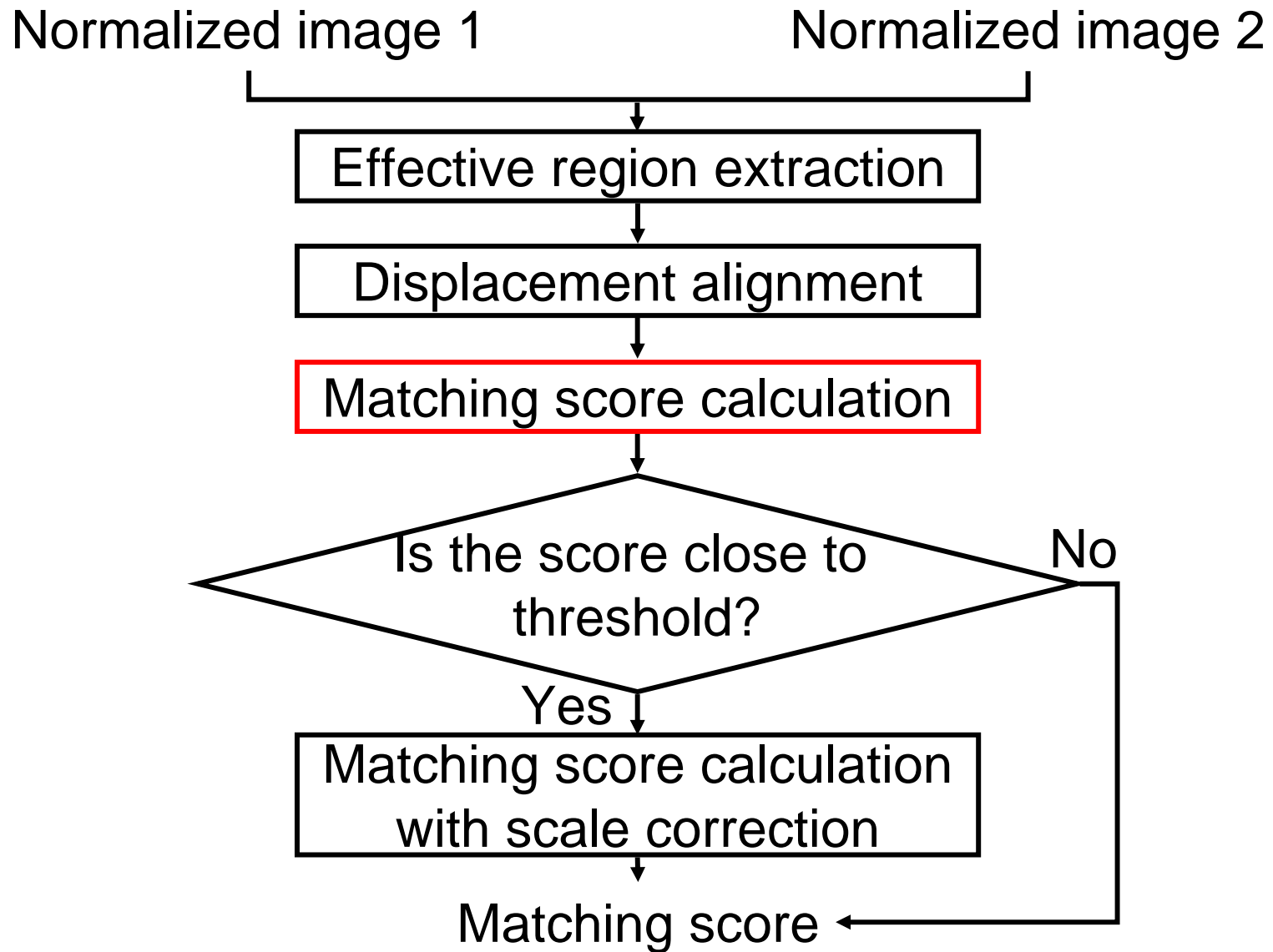
# Effective Region Extraction



- Extract the effective regions of the same size from the two images.
- Align the displacement between the extracted images using the peak location of POC function.



# Matching Stage

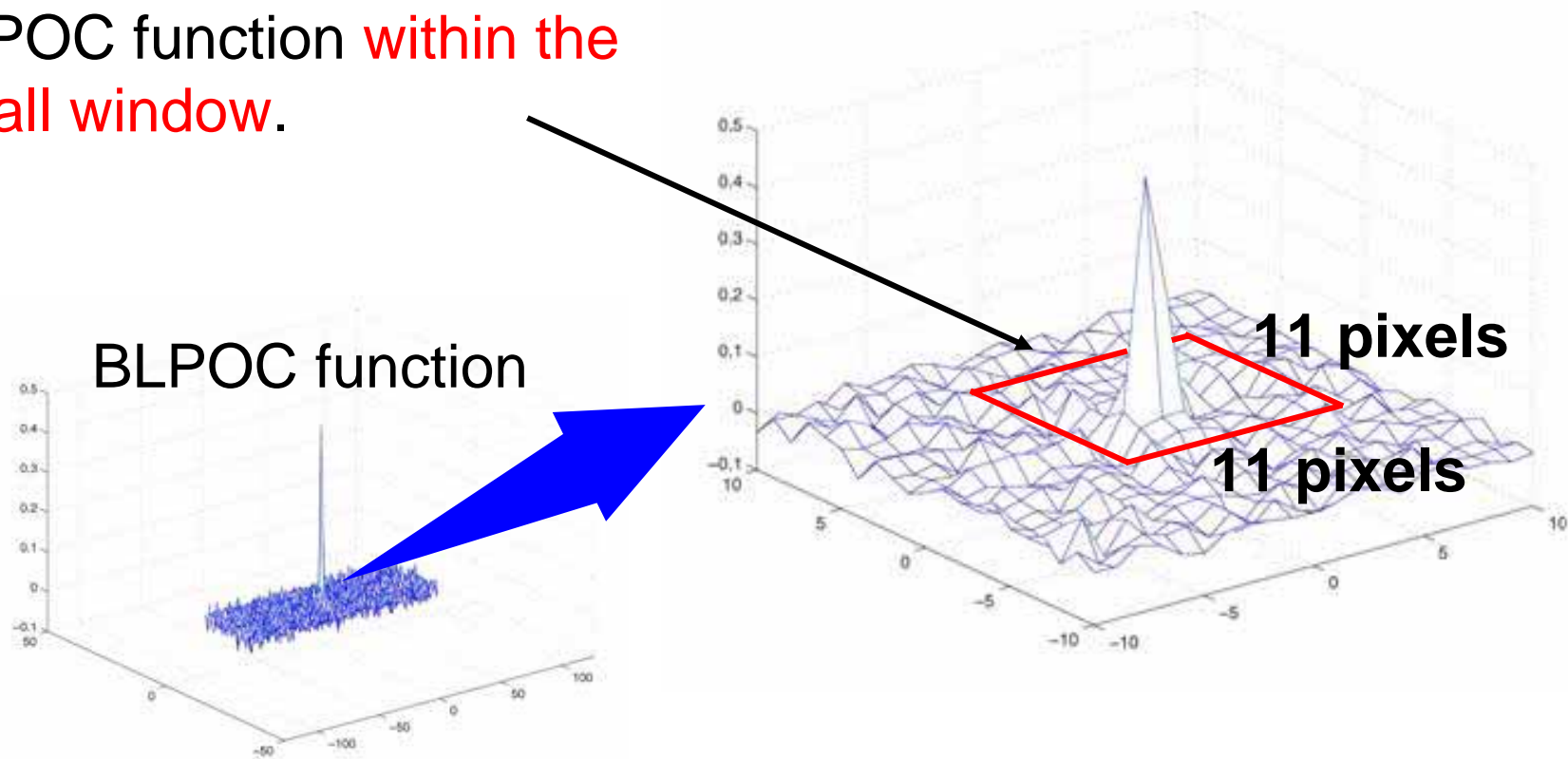






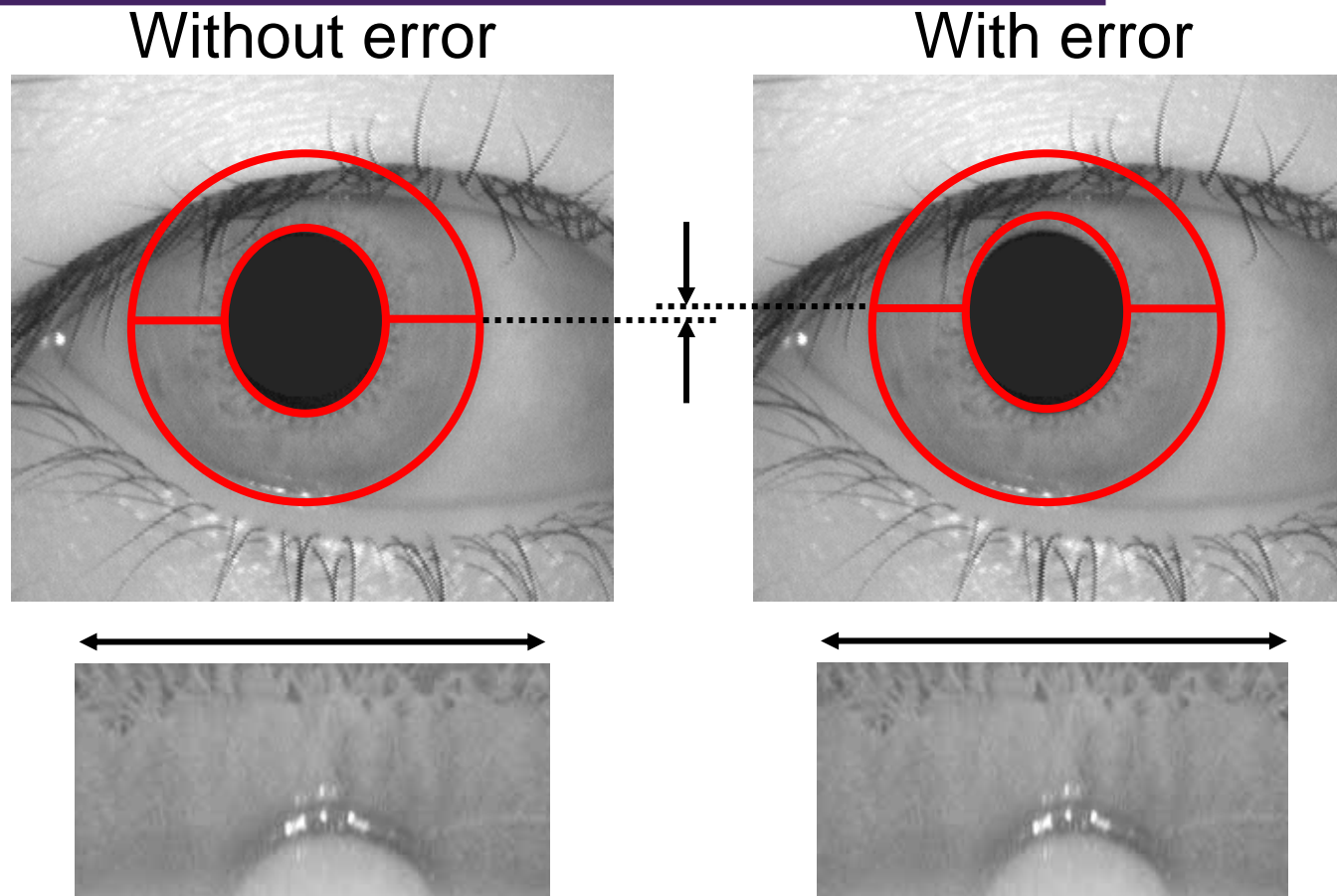
# Matching Score Calculation

Calculate the matching score as the maximum value of the BLPOC function **within the small window.**





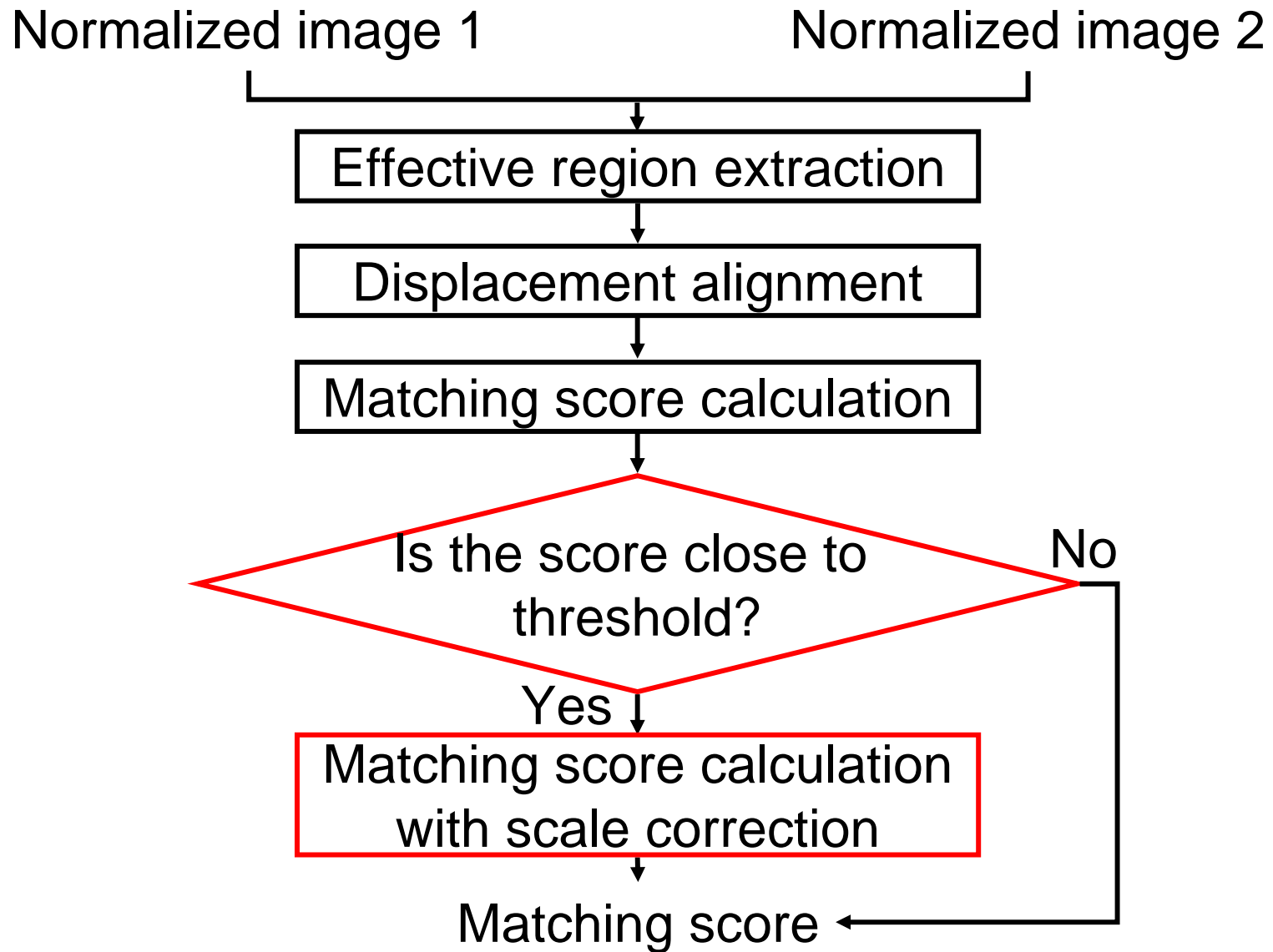
# Error in Iris Localization



- ❑ Error in iris localization causes slight scaling in horizontal direction of the normalized iris image.
- ❑ In the case of genuine matching, this reduces the peak.

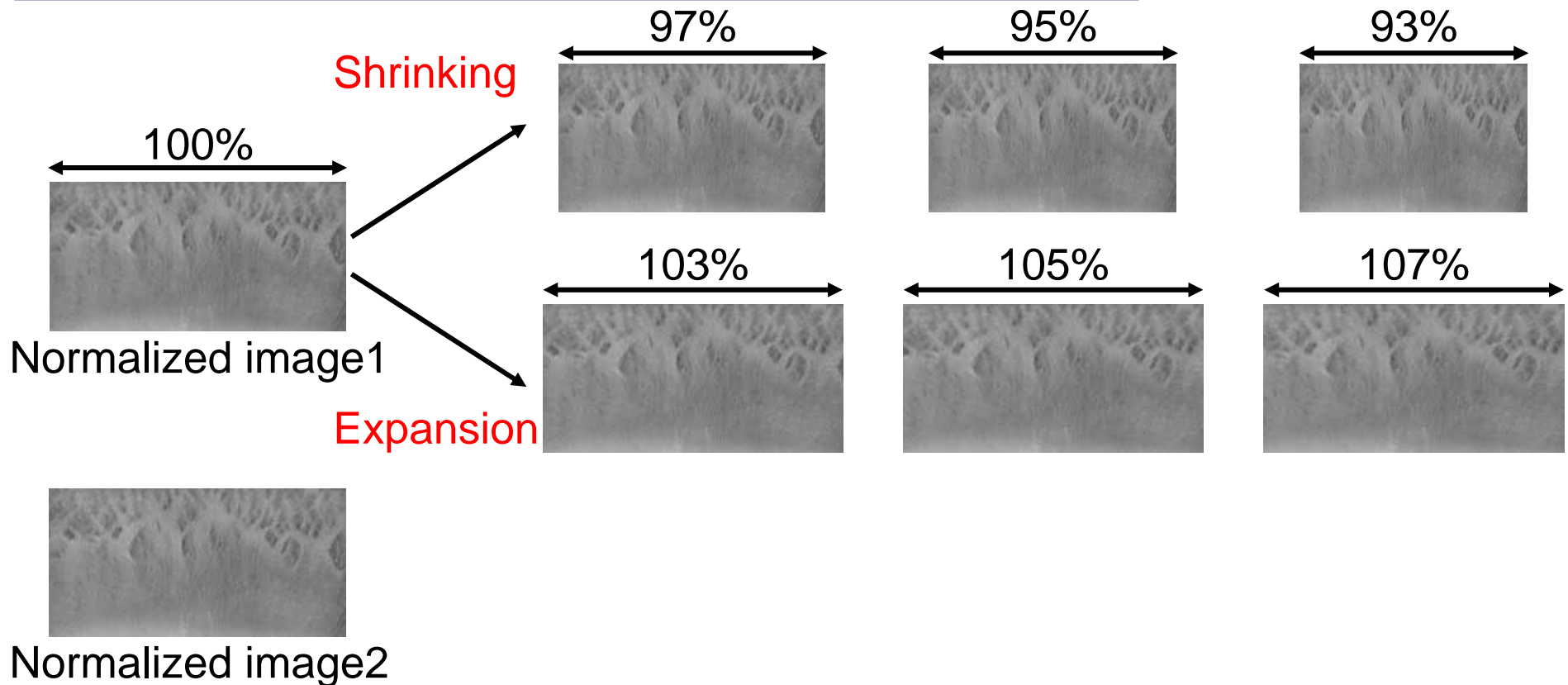


# Matching Stage





# Scale Correction

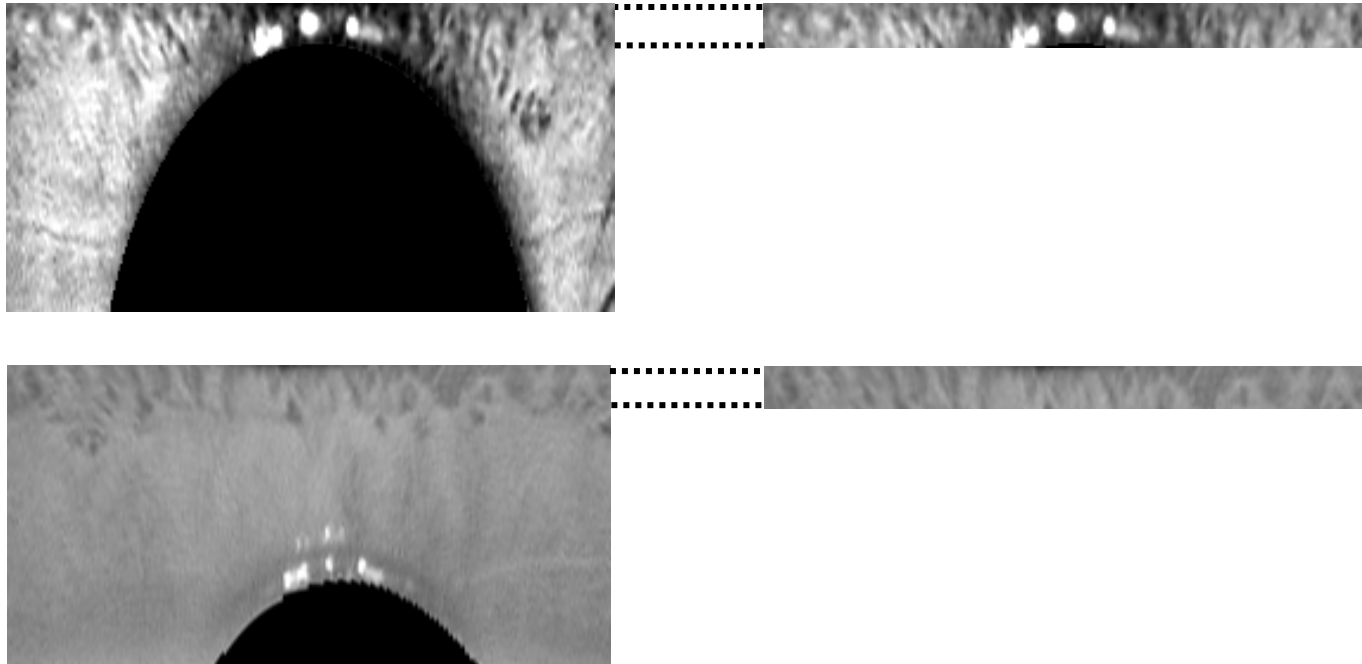


- ❑ If the matching score is close to the threshold, generate a set of scaled images and calculate matching scores for the generated images.
- ❑ Select their maximum score as the final matching score.



# Possible Problem in Matching Stage

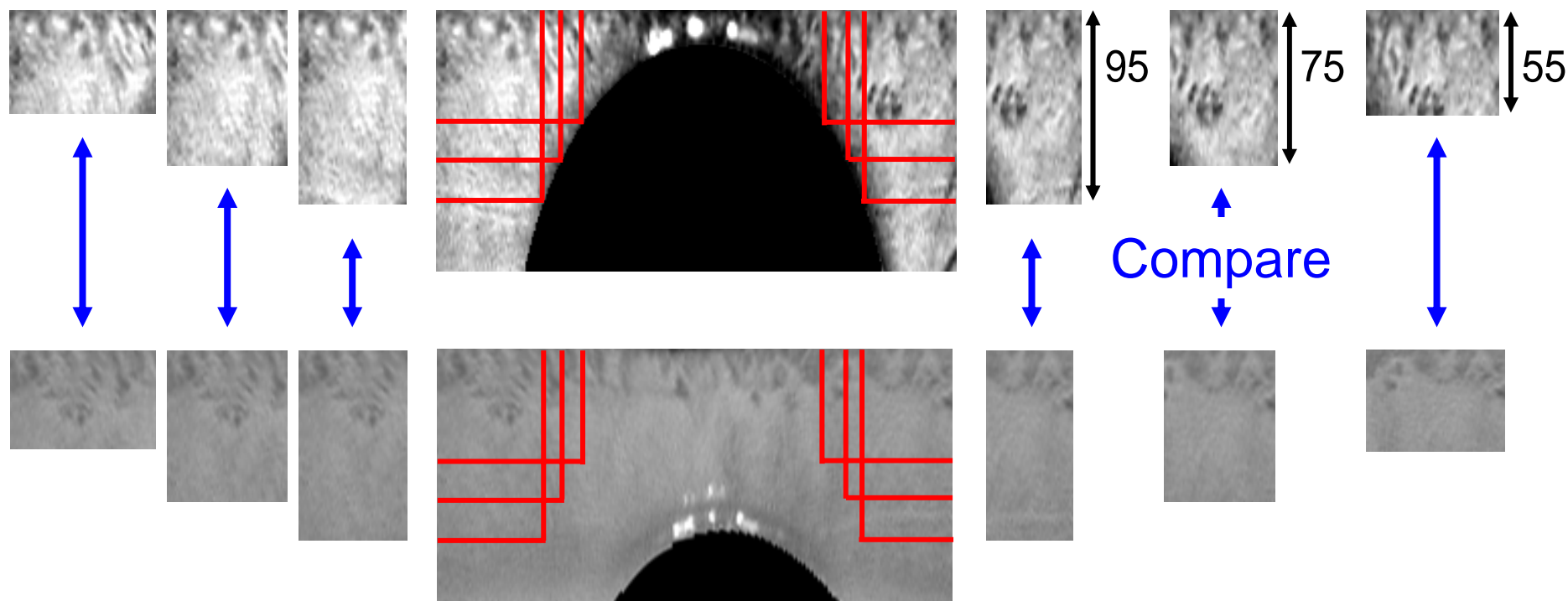
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- ❑ A problem may occur when the most of the normalized iris image is covered by eyelid.
- ❑ **Extracted region becomes too small to perform image matching.**



# Multiple Sub-Regions Extraction



- **Extract multiple effective sub-regions** from each iris image by changing the width parameter.
- Matching score is calculated by taking an average of matching scores for the sub-regions.



# ICE Experiment (Fully Automatic)

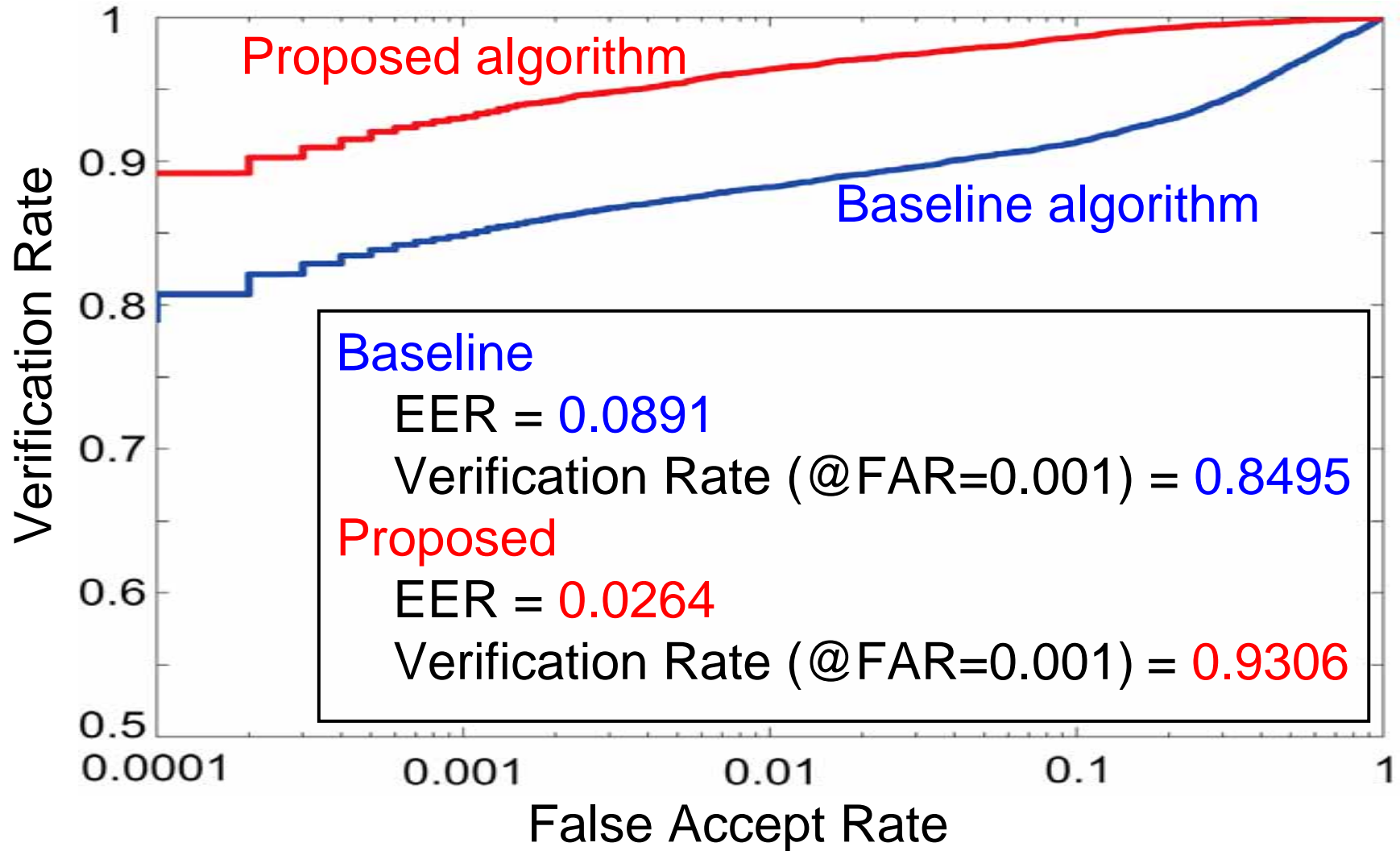
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- Experiment 1 (irises from right eyes)
  - 1425 iris images (124 unique eyes)
  
  - Evaluation of the genuine matching scores
    - All the possible combinations: 12,214 attempts
  
  - Evaluation of the impostor matching scores
    - All the possible combinations: 1,002,386 attempts



# Results

## ROC curve

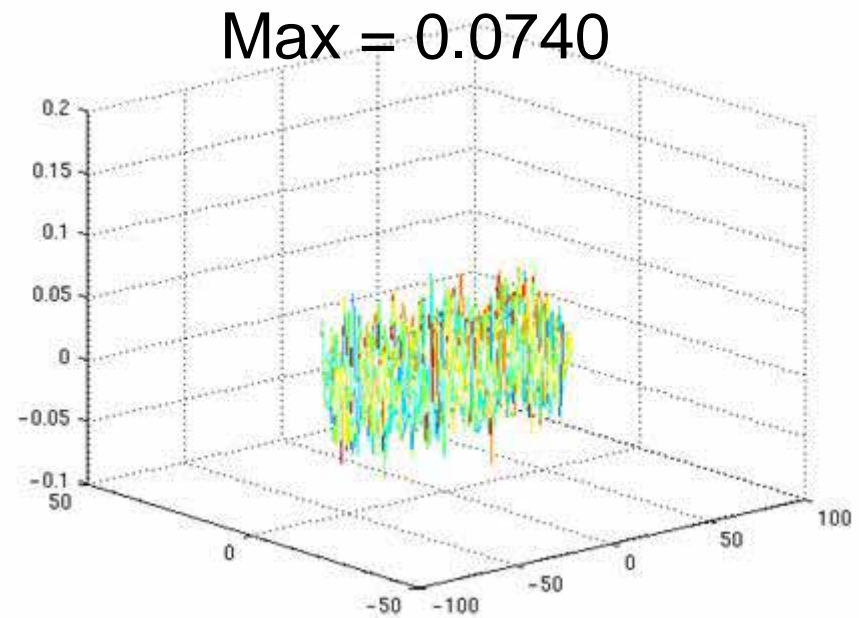
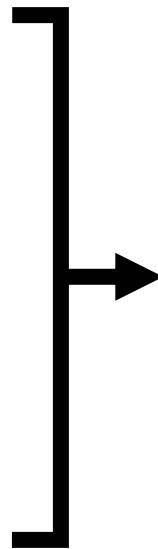
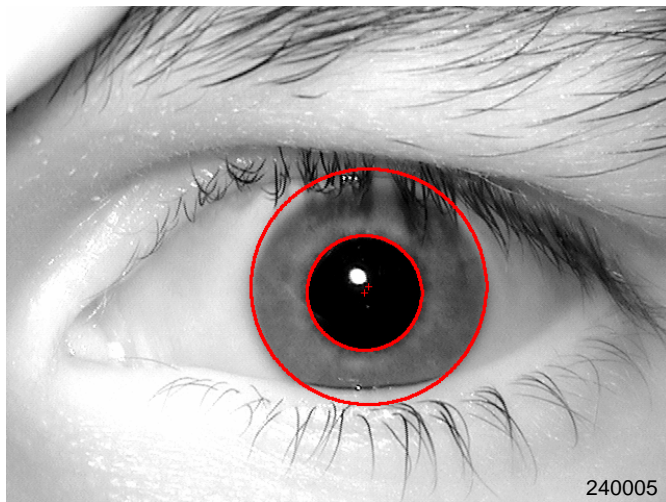
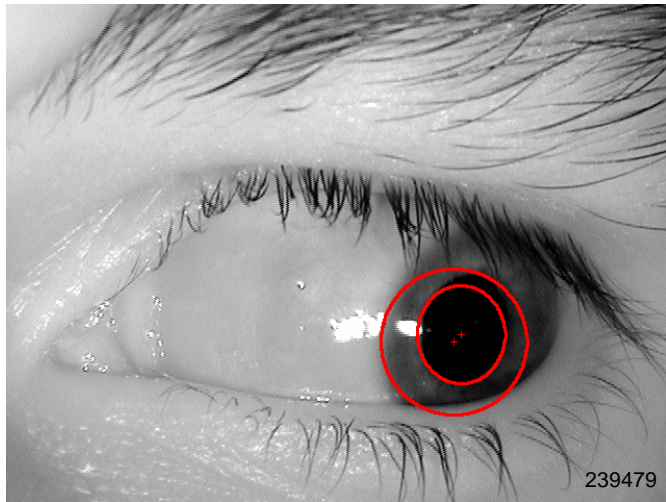






# Unsuccessful Matching (genuine matching)

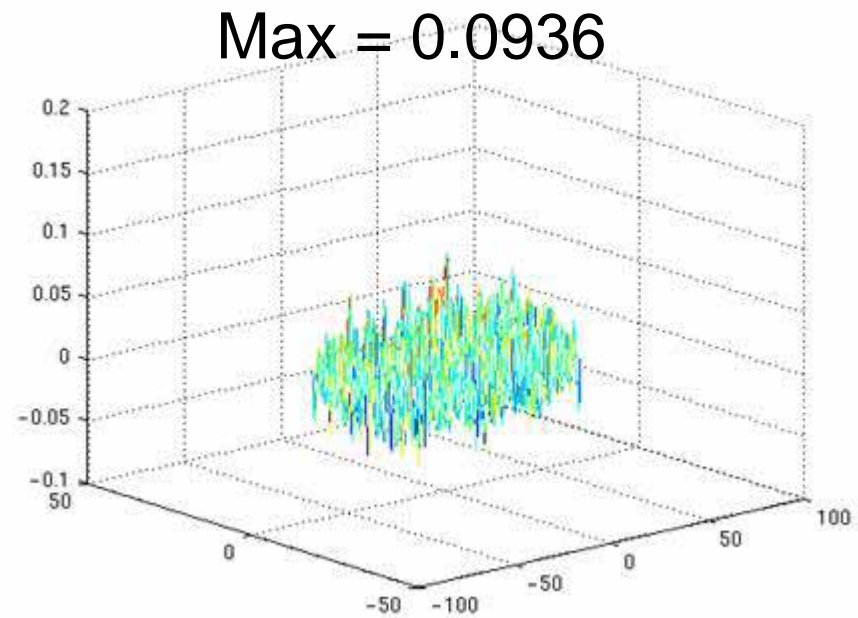
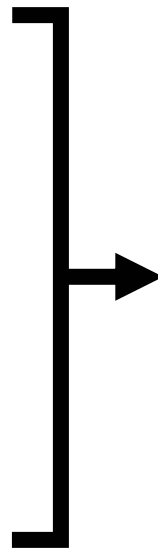
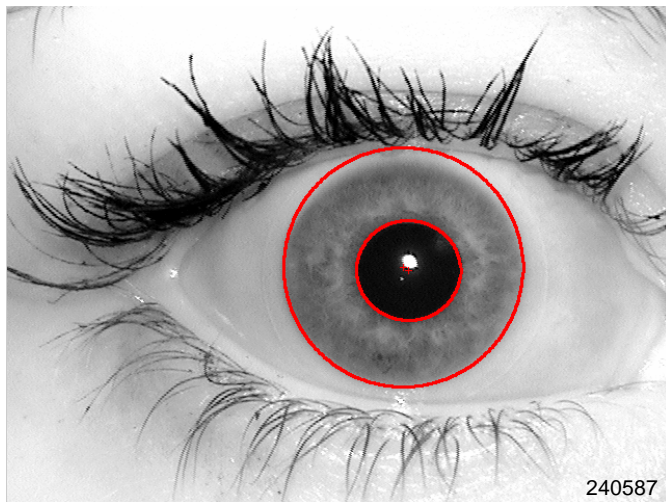
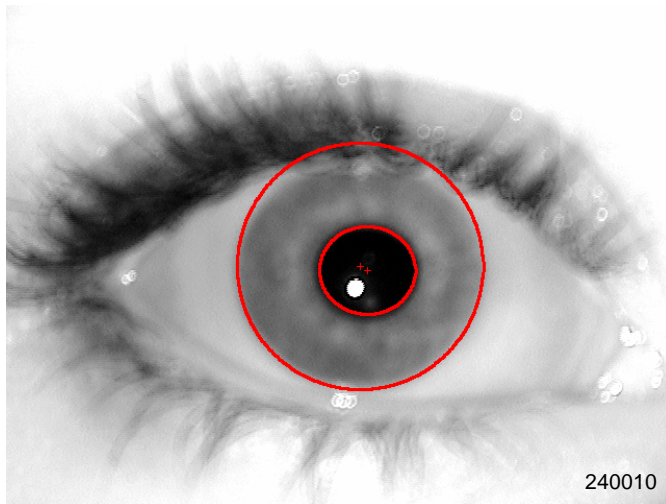
- Miss-localization (Non-orthogonal)





# Unsuccessful Matching (genuine matching)

## Defocused





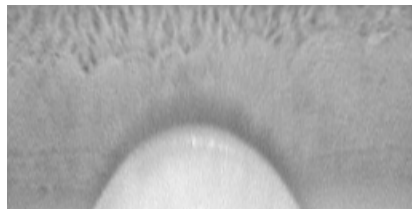
# Implementation Issues

- Proposed algorithm assumes that the use of iris image directly in the system.
  - Increase in the size of iris data
  - Low security of actual iris recognition system
- Reduce the size of iris data.
- Prevent the visibility of individual iris images.

## 2D Fourier Phase Code (2D FPC)

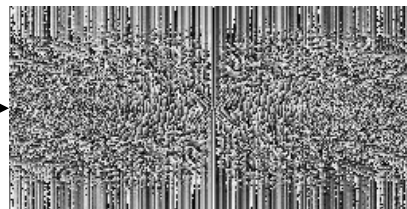
➔ Quantized phase spectrum of normalized iris image

Normalized image



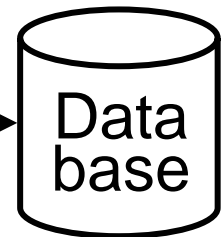
2D DFT

Phase



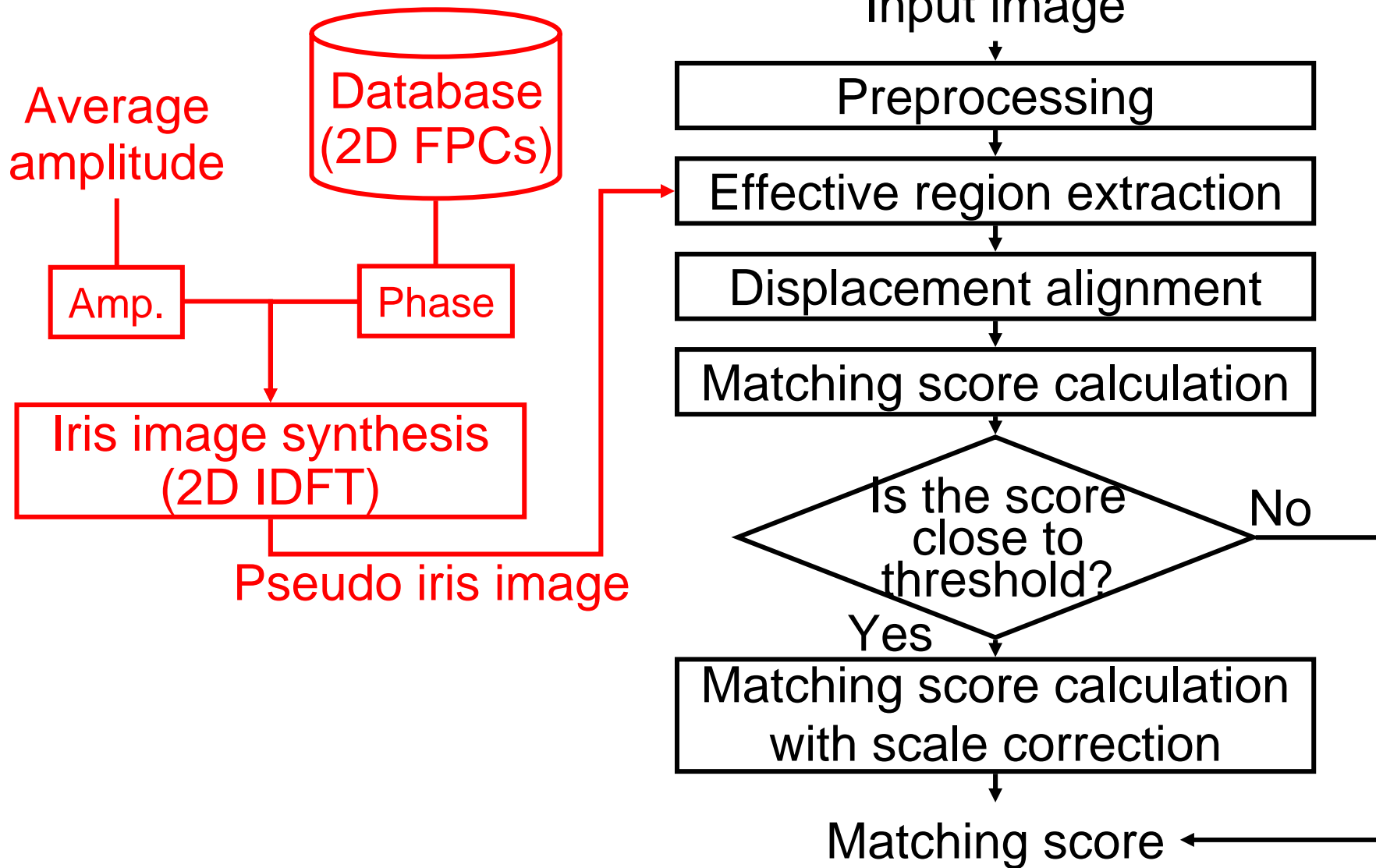
Quantization

Data base



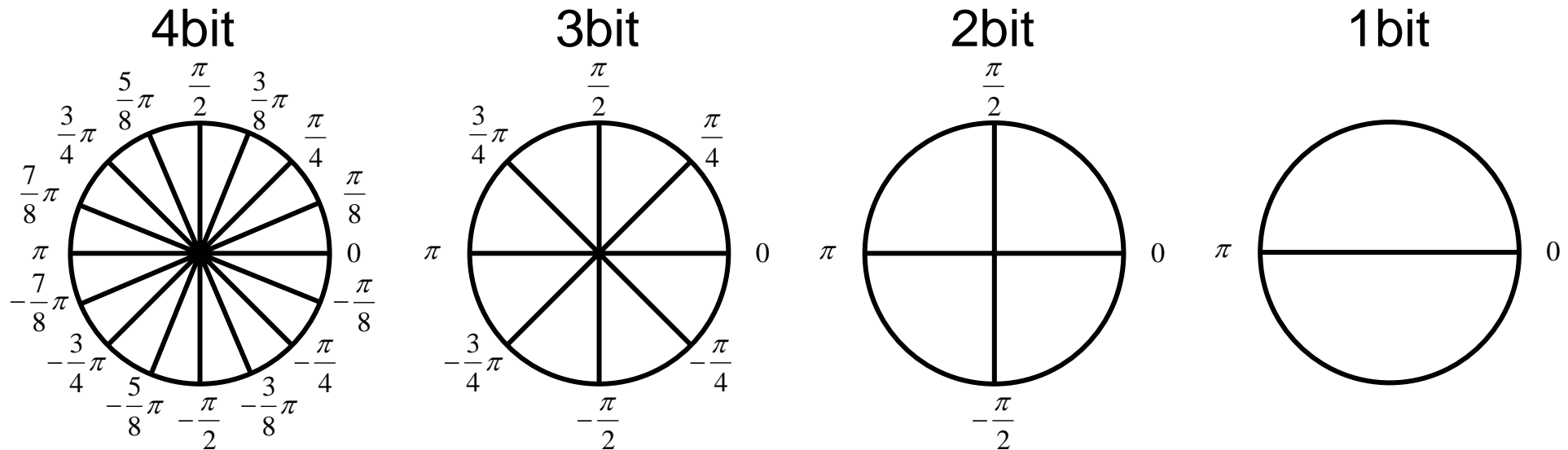


# Iris Recognition Algorithm Using 2D FPCs





# Phase Quantization and Size Reduction



- Data size of an iris image  
 $256 \times 128 = 32$  Kbyte
- Data size of 2D FPC
  - with 4-bit quantization: 8 Kbyte
  - with 3-bit quantization: 6 Kbyte
  - with 2-bit quantization: 4 Kbyte
  - with 1-bit quantization: 2 Kbyte



# Conclusion

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- Experimental evaluation demonstrates that the use of phase components of iris images makes possible to achieve highly accurate iris recognition with a simple matching algorithm.

## Challenges for ICE 2006

- Non-orthogonal iris image matching
- Defocused iris image matching