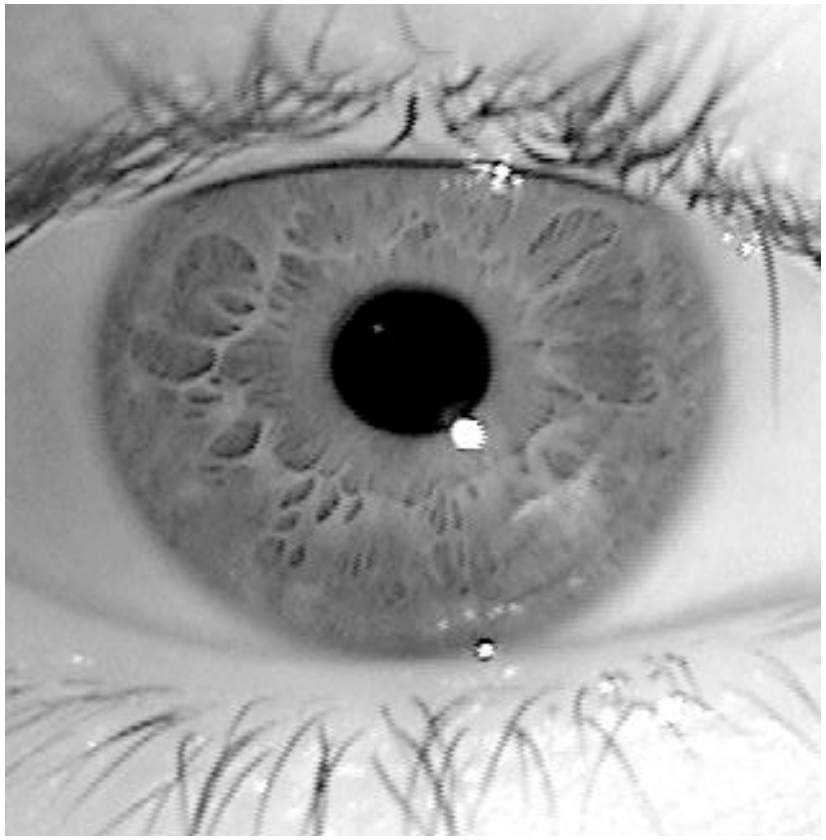

The Best Bits in the Iris Code

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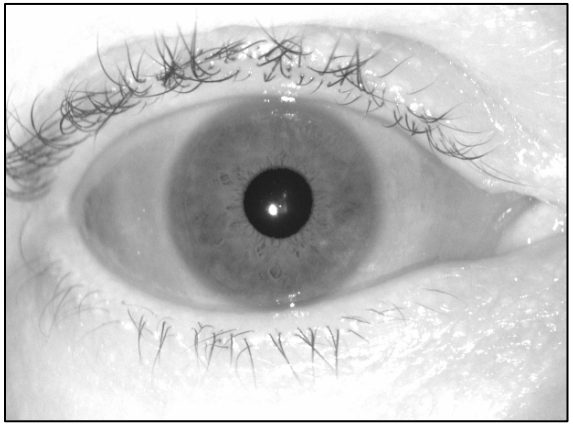
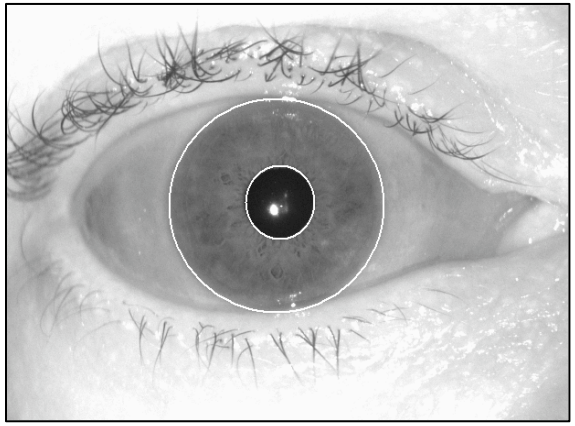
Where do the bits in the iris code come from?

Acquire Image



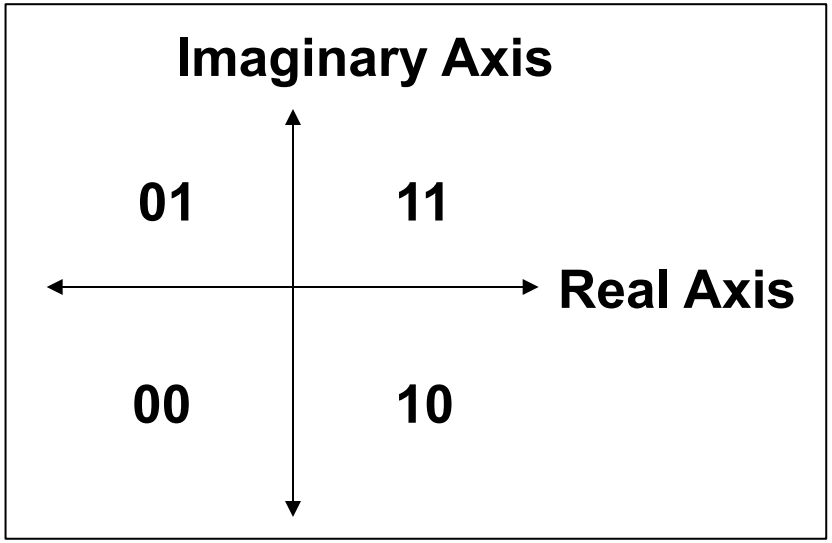
Segment Iris



“Unwrap” the Iris Region

Apply filter to normalized iris

Quantize complex filter response



11111110101000000000101…

Compare two aligned iris codes using Hamming distance, masking regions covered by eyelids.

11111110101000… **11111010101010…**

$$HD = \frac{\left\| (codeA \oplus codeB) \cap maskA \cap maskB \right\|}{\left\| maskA \cap maskB \right\|}$$

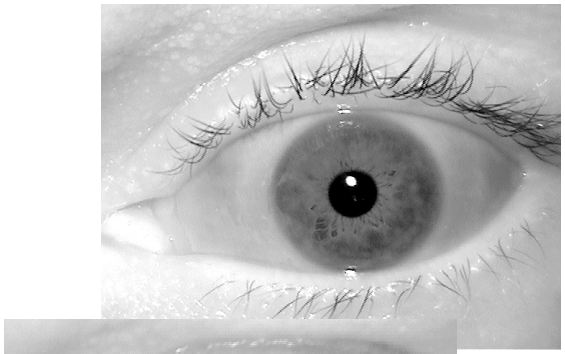
Fractional Hamming distance score

Fragile Bits

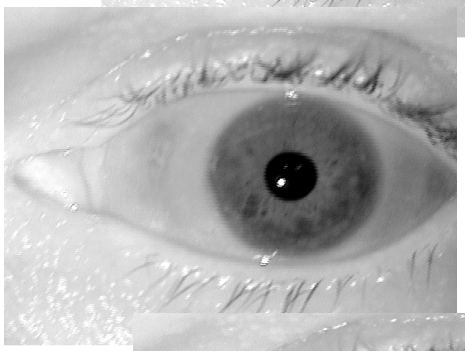
Bolle et al. suggested that "…perhaps not all bits are equally likely to flip, … there are some particularly 'fragile' bits."*

*Ruud M. Bolle et al., "Iris individuality: A partial iris model," in *Int. Conf. on Pattern Recognition*, 2004, II: 927-930.

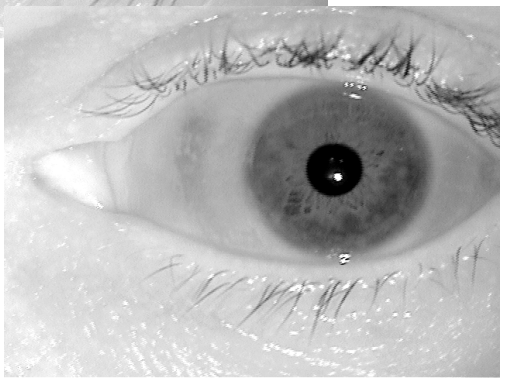
We compared iris codes from multiple aligned images of the same eye.



1101010010...



0101000010...



1101010010...

Comparison for consistency

Data:

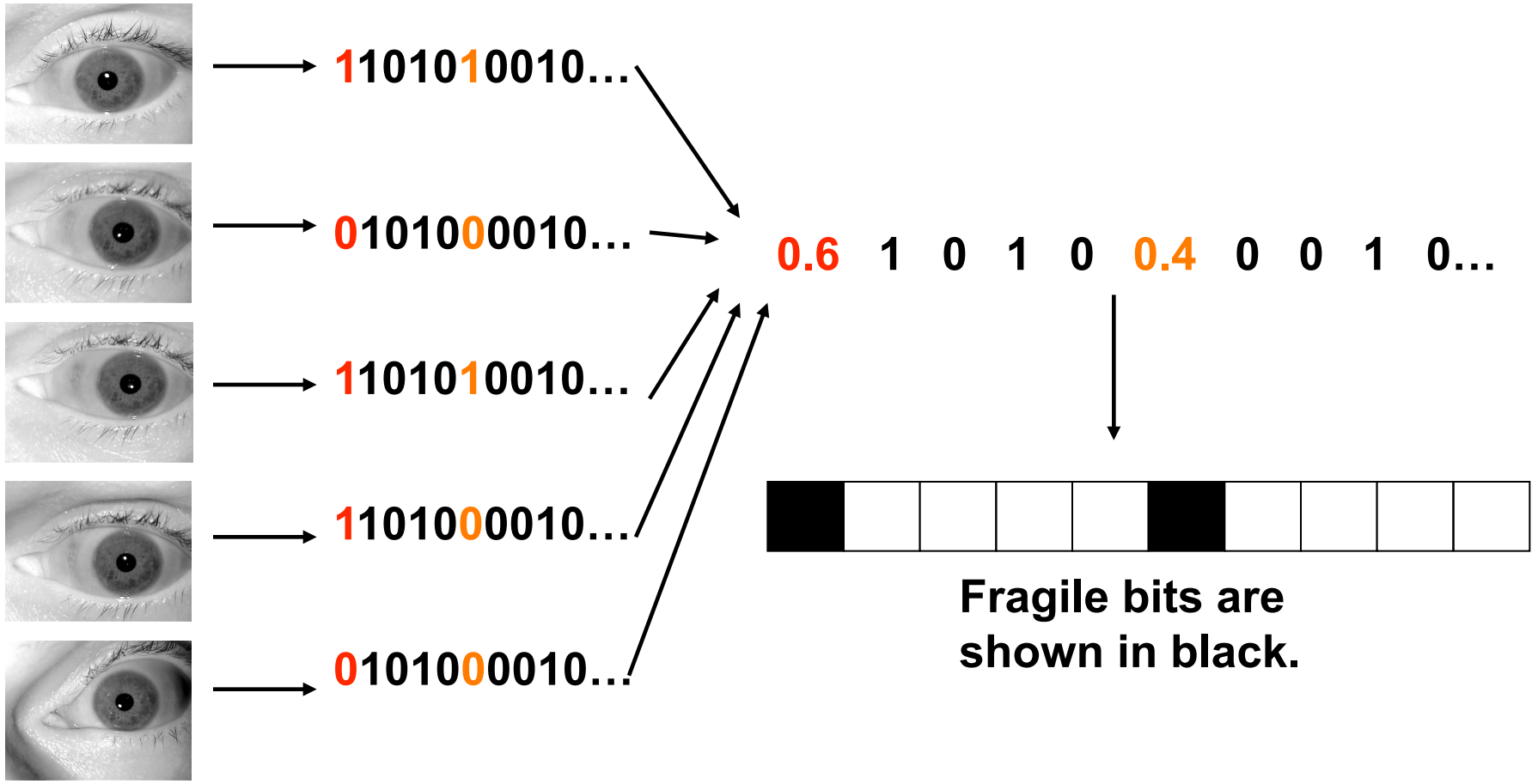
- 1226 images
- 24 subjects
- For each subject, we had between 15 and 118 images of their left eye

Software:

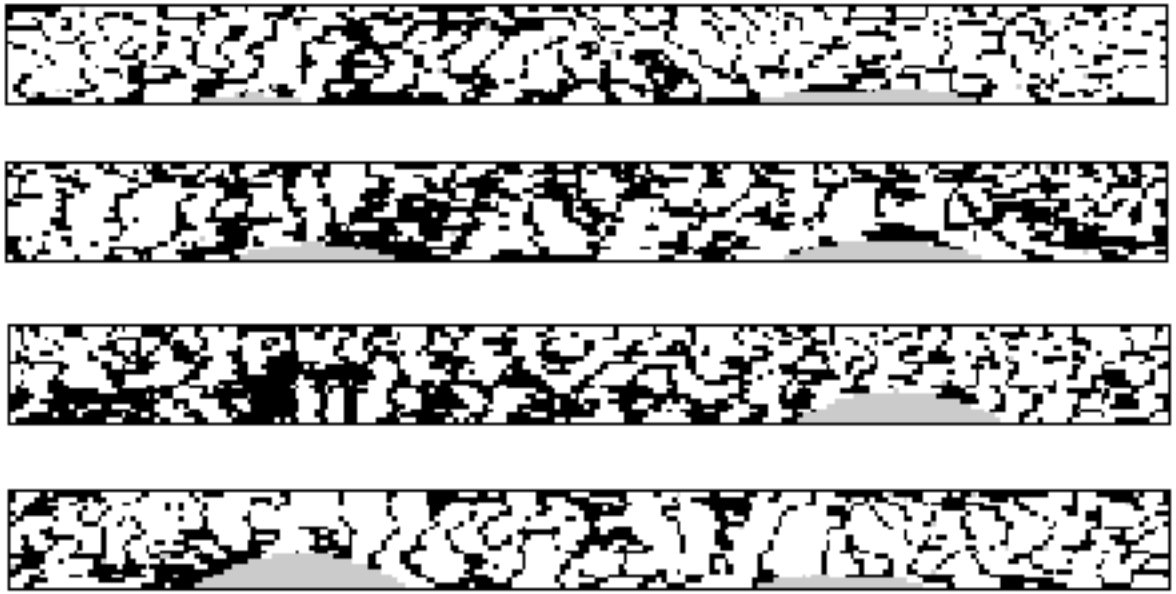
- IrisBEE software with the segmentation improvements by Xiaomei Liu.*

*Xiaomei Liu, Kevin W. Bowyer, and Patrick J. Flynn, "Experiments with an improved iris segmentation algorithm," in *Proc. Fourth IEEE Workshop on Automatic Identification Technologies*, 2005, 118-123.

Once we had multiple iris codes from the same eye, we aligned them, and compared them to find the average value for each bit.



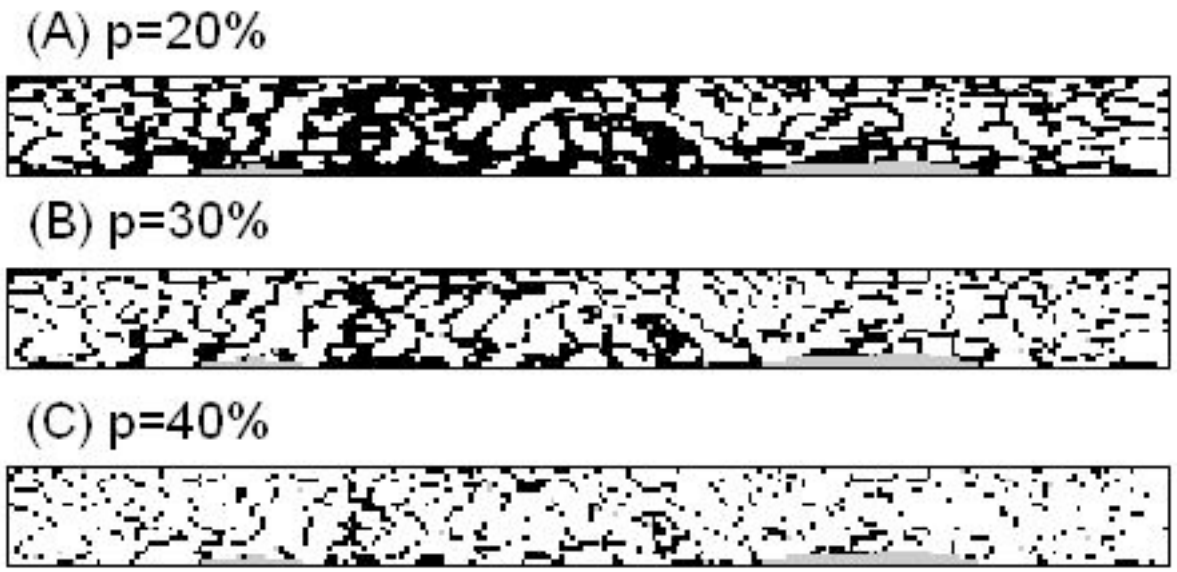
All subjects had fragile regions in their iris codes.



Fragile bits for 4 different subjects.

Bits that flipped in more than 30% of iris codes were marked as fragile. The masked region is the union of masked regions across all images.

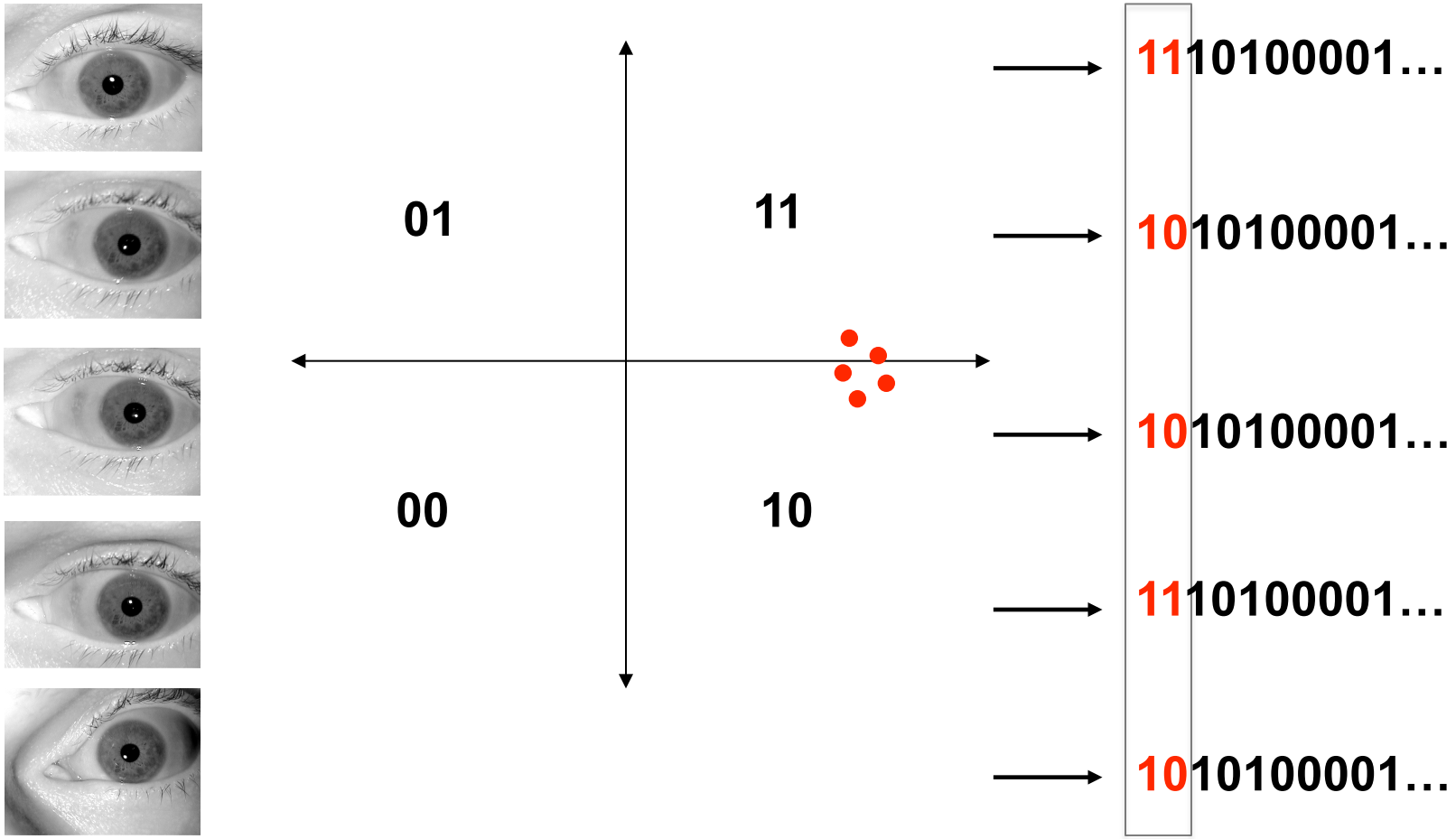
The number of fragile bits depends on the threshold used.



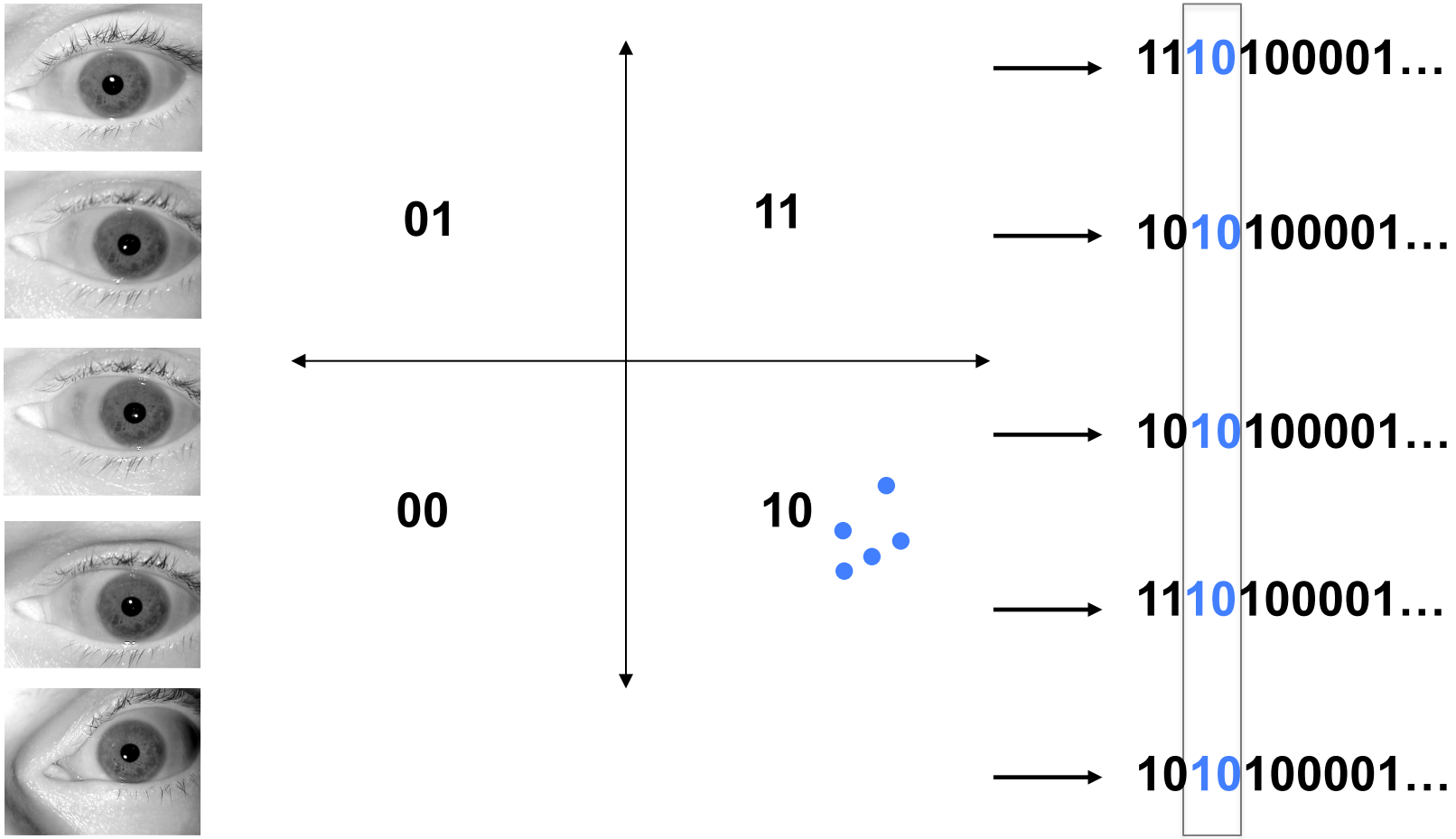
There are more bits that flip in at least 20% of iris codes than there are that flip in at least 40% of iris codes.

Where do fragile bits come from?

Fragile bits come from the quantization of the filter response.



The best bits come from filter responses far from the axes.



We are *not* saying that particular parts of the iris are fragile.

Instead, bit fragility occurs when the *combination* of iris texture an filter produces a result with (1) a small magnitude, or (2) a phase response close to the quantization boundary.

When we use a different filter, we get a different fragile bit pattern.

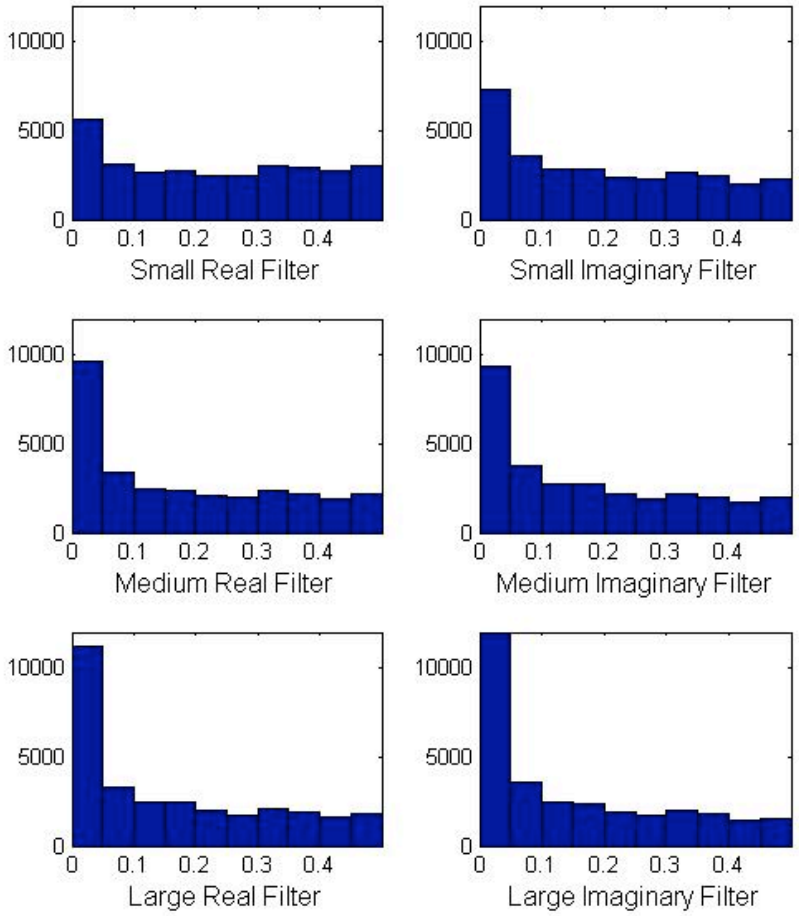
Fragile bit pattern created using a filter from OSIRIS.

Fragile bit pattern created using a filter from IrisBEE.

Larger filters produce fewer fragile bits.

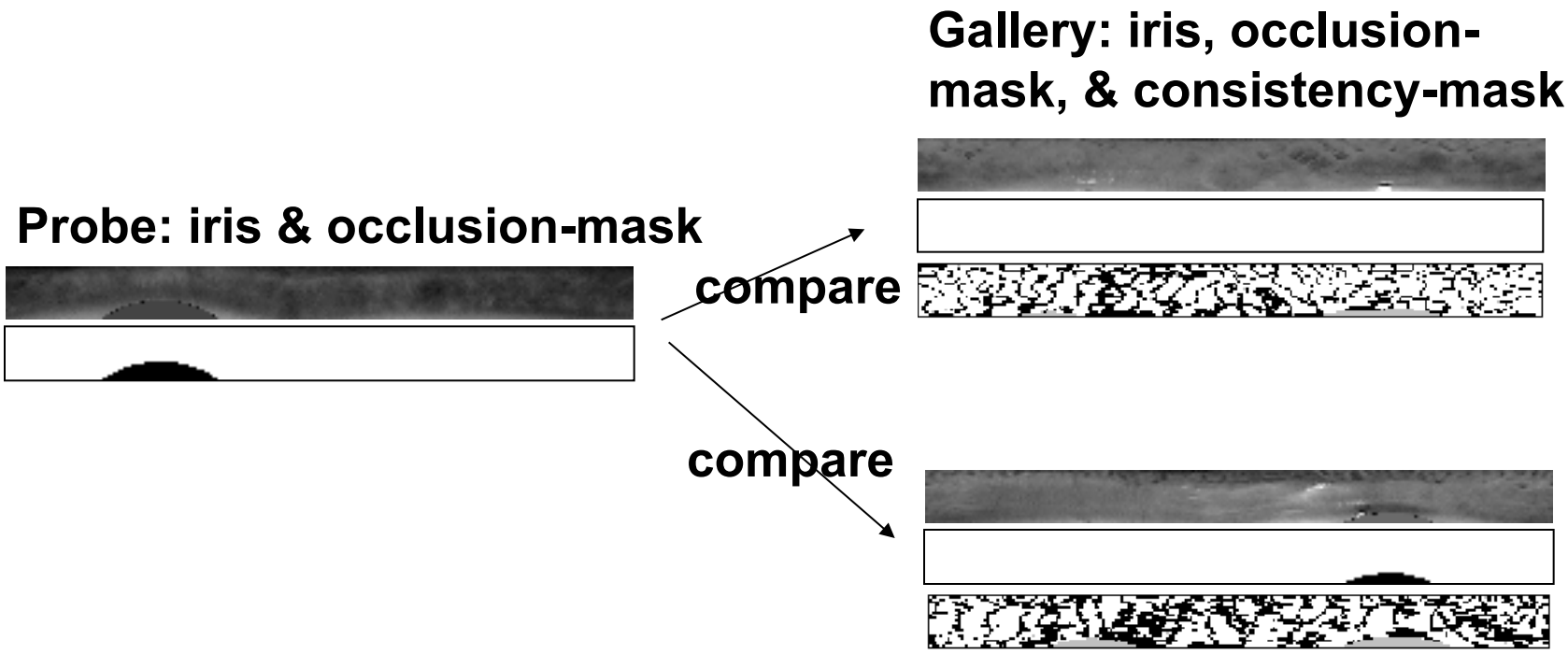
OSIRIS came with three different sizes of 2D Gabor filters.
We graphed the consistency of bits created by each filter.

X-axis is percent of times a bit flipped for the given filter.
Y-axis is frequency.

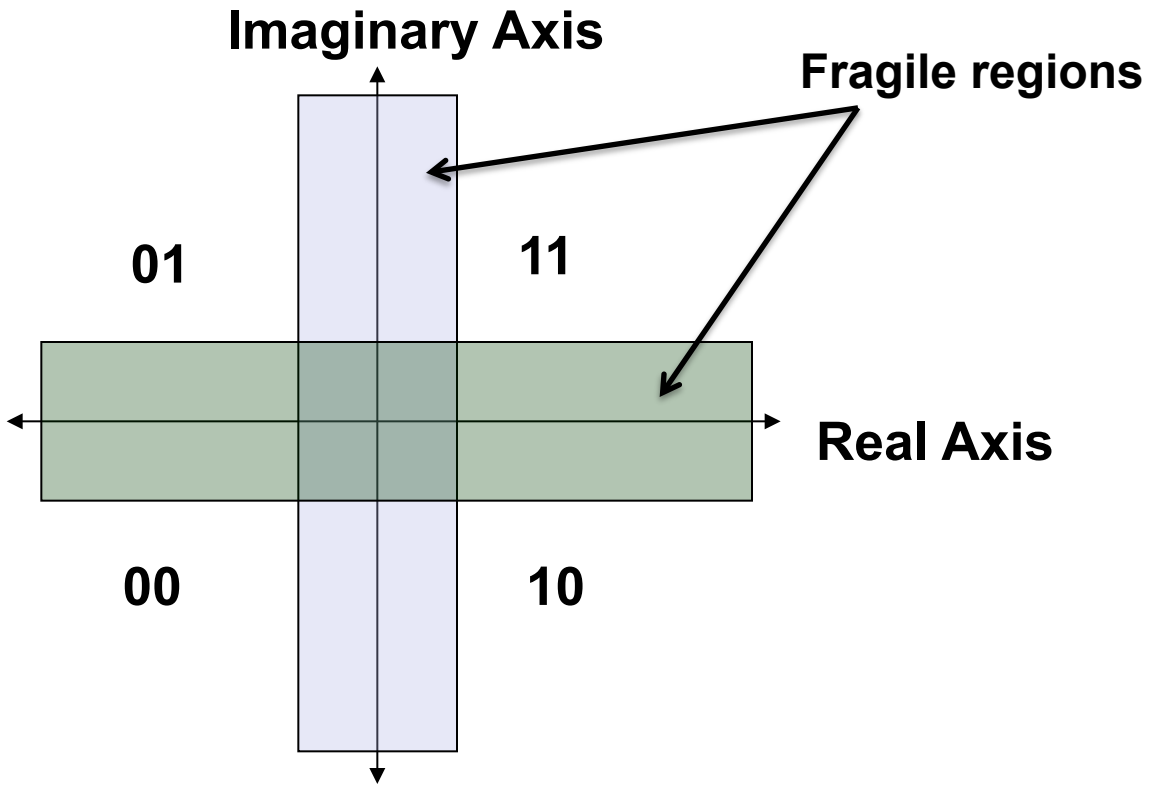


Can we mask fragile bits?

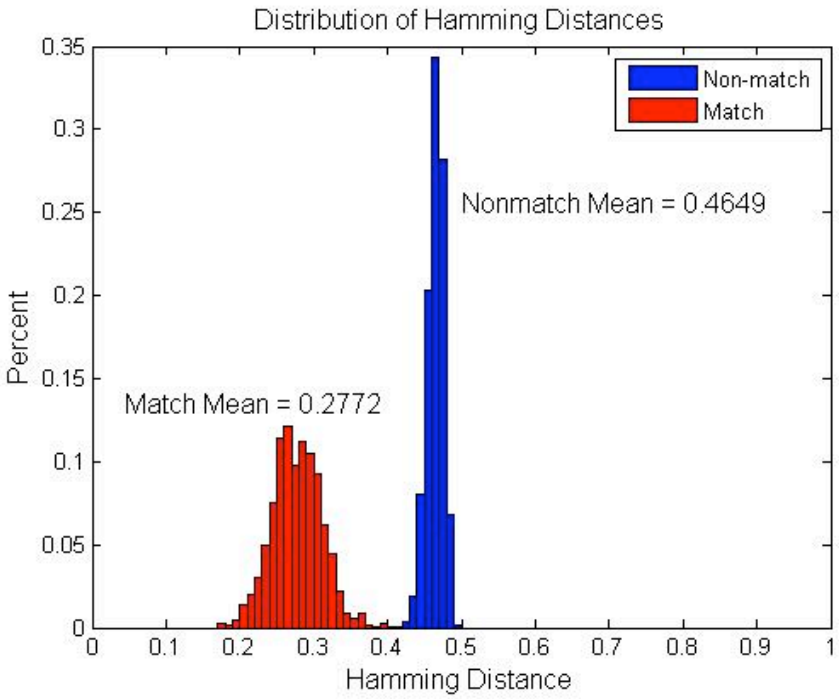
Theoretically, we could create a mask for each subject, and use it to mask fragile bits during matching.



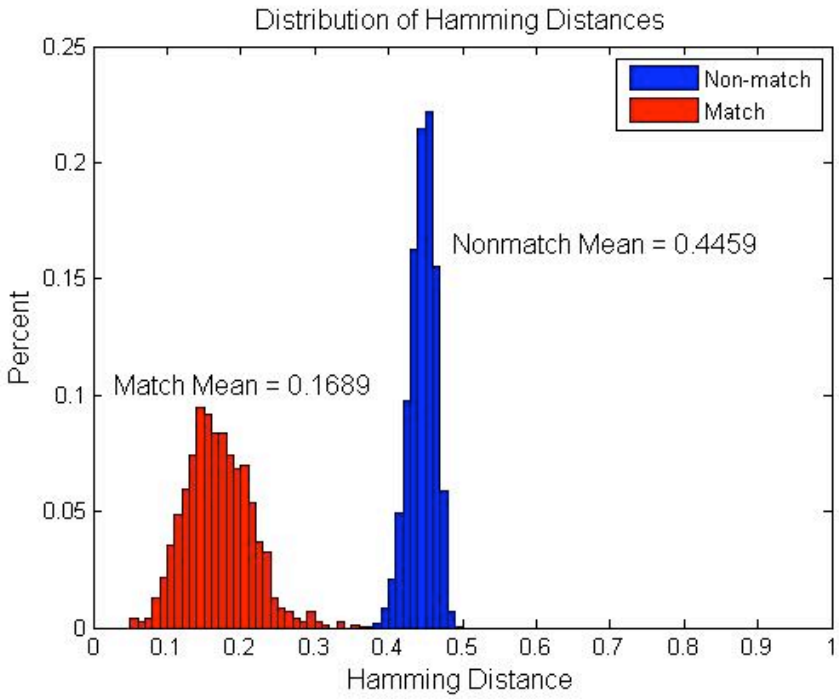
Experimentally, we tried a simpler technique to approximate masking fragile bits.



Masking bits close to the axes of the complex plane improved performance.



All numbers included.



Bits from complex numbers close to the axes omitted from calculations.

How many fragile bits should we mask?

- Daugman suggested masking 25% of bits closest to the axes.
- Barzegar et al. found that 35% works best on CASIA v3 iris images.*

*N. Barzegar and M.S. Moin, "A New User Dependent Iris Recognition System Based on an Area Preserving Pointwise Level Set Segmentation Approach," *EURASIP Journal on Advances in Signal Processing*, 2009.

How many fragile bits should we mask?

- Tanya Peters masked 40 to 50% of bits with good success using my set of low-occlusion, high-quality images.
- On larger data sets, both Tanya and I have found that less masking is better (5 to 10%).*

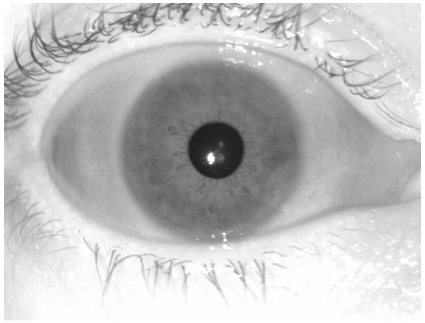
*Hollingsworth, Bowyer, and Flynn, Improved Iris Recognition Through Fusion of Hamming Distance and Fragile Bit Distance, submitted.

How many fragile bits should we mask?

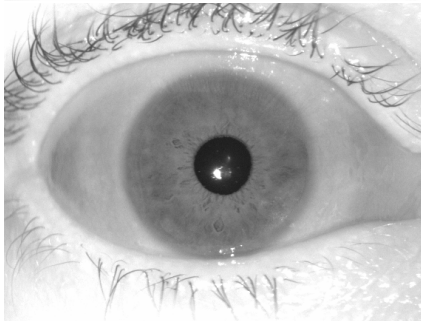
- **Trade-off: Masking more bits reduces amount of good information, but the bits left are theoretically of higher quality.**
- **Speculation: You can mask more fragile bits when you have data of higher quality or with less occlusion.**
- **However, Tanya tried experiments masking different amounts depending on quality level, and did not get any clear results, so this is still an open question.**

What else could we do with fragile bits?

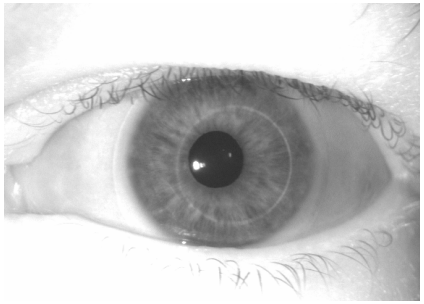
Fragile Bit Masks



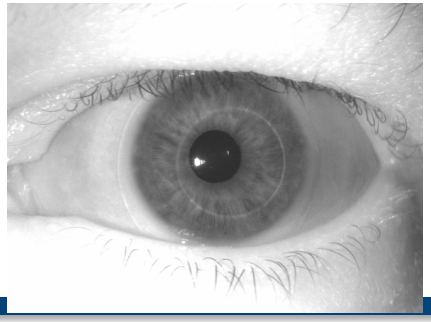
Subject 2463 Image 1910 2400 fragile bits



Subject 2463 Image 1912 2396 fragile bits



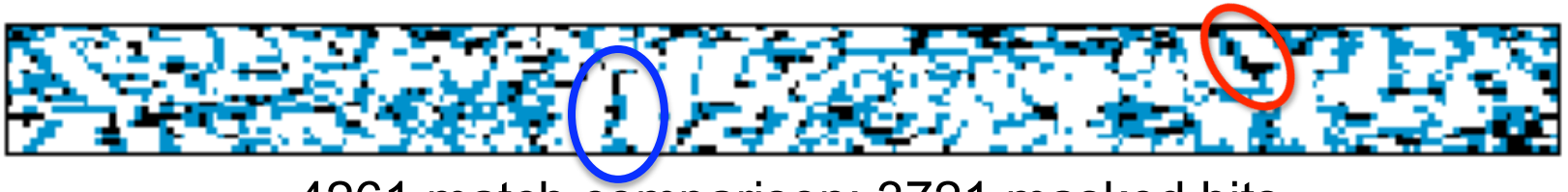
Subject 4261 Image 1032 2389 fragile bits



Subject 4261 Image 1034 2400 fragile bits

Comparisons Between Pairs of Masks

2463 match comparison: 3631 masked bits



4261 match comparison: 3721 masked bits

Nonmatch comparison: 4202 masked bits

Nonmatch comparison: 4247 masked bits

Fragile Bit Distance (FBD)

Measures how well two fragile bit patterns align.

Each iris template contains

- **an iris code *i*,**
- **an occlusion mask *m*,**
- **and a fragility mask *f*.**

Unmasked bits = 1,
Masked bits = 0.

Fragile Bit Distance (FBD)

The FBD expresses the fraction of unoccluded bits masked for fragility.

The FBD between two iris templates A and B is:

$$FBD = \frac{\left\| m_A \cap m_B \cap \overline{f_A \cap f_B} \right\|}{\left\| m_A \cap m_B \right\|}$$

Expected FBD

Each iris code:
25% fragile, 75% consistent.

In a nonmatch comparison:
(75%)(75%) = 56.25% consistent in both iris codes,
i.e. 43.75% fragile (FBD = 0.4375).

Expected FBD

Each iris code:
25% fragile, 75% consistent.

In a nonmatch comparison:
(75%)(75%) = 56.25% consistent in both iris codes,
i.e. 43.75% fragile (FBD = 0.4375).

In a match comparison:
between 25% and 43.75% fragile

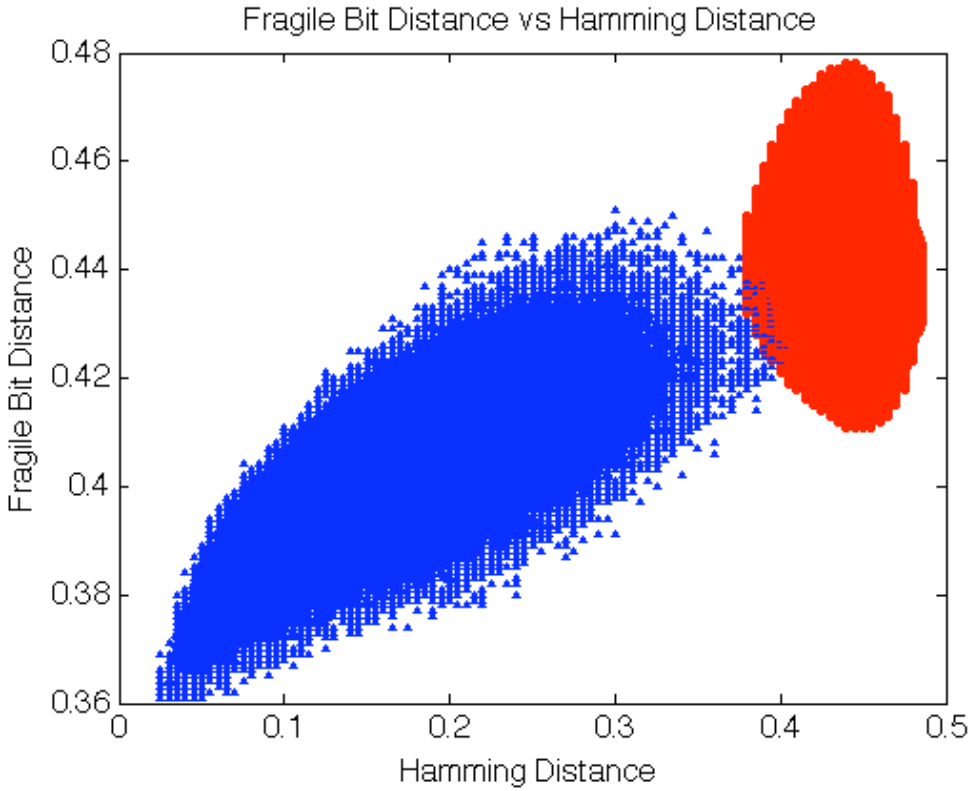
Data:

- 19891 images
- 686 subjects (1372 eyes)
- LG 4000 camera

FBD for matches and nonmatches

	Average Impostor FBD (std dev)	Average Genuine FBD (std dev)
Theoretical Value	0.4375	Between 0.25 & 0.4375
Measured Value	0.4397 (0.0097)	0.4047 (0.0149)

Joint distribution of HD and FBD



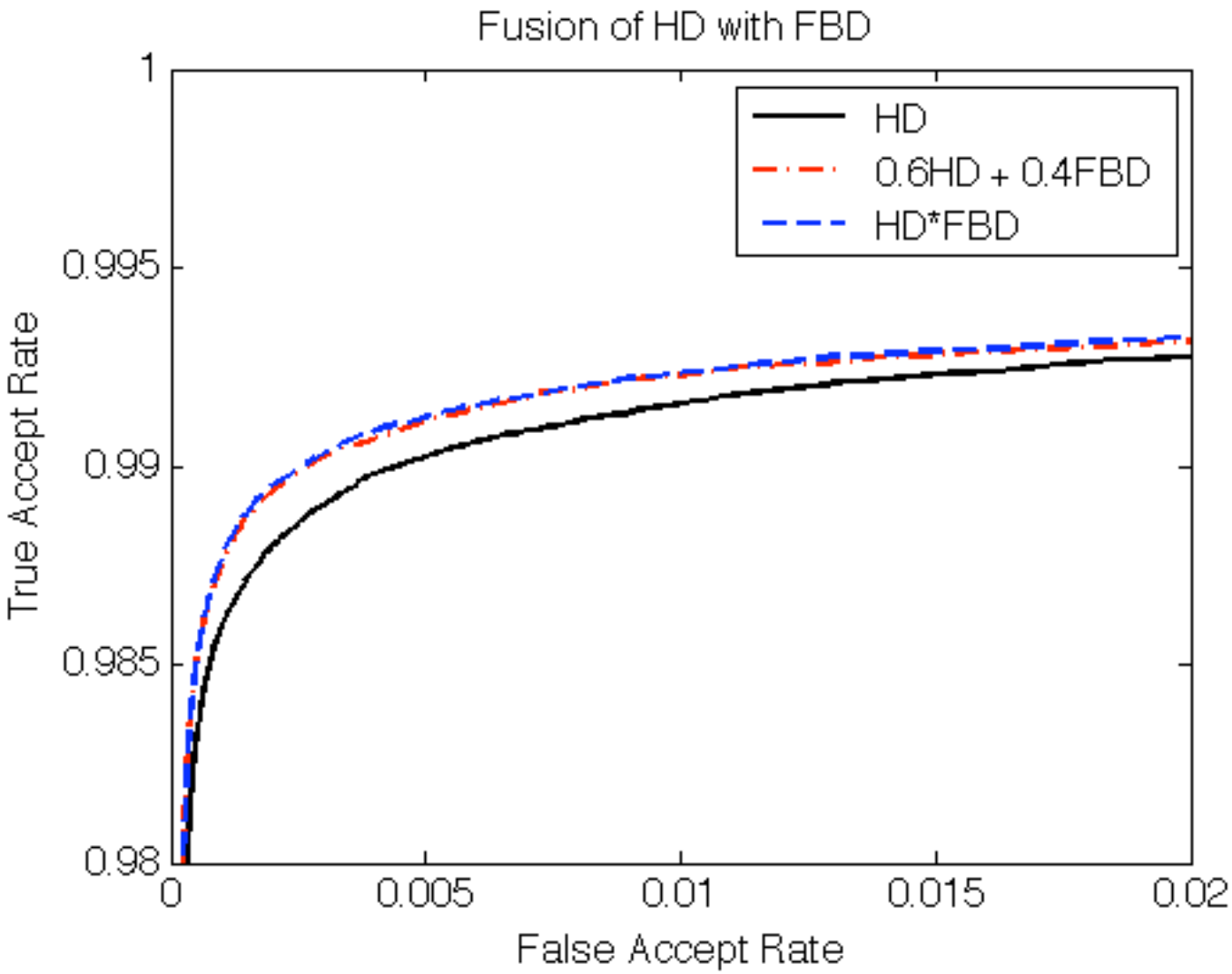
- FBD is less powerful than HD.
- Fusion is better than either alone.
- Fusion methods tried:
  - Multiplication
  - Weighted Average

FBD is less powerful than HD, but we can combine the two features and do better than HD alone.

Method	Equal Error Rate (EER)
HD (baseline)	8.70×10^{-3}
0.4HD + 0.6FBD	8.02×10^{-3}
HD x FBD	7.99×10^{-3}

The EER decreased by 8%.

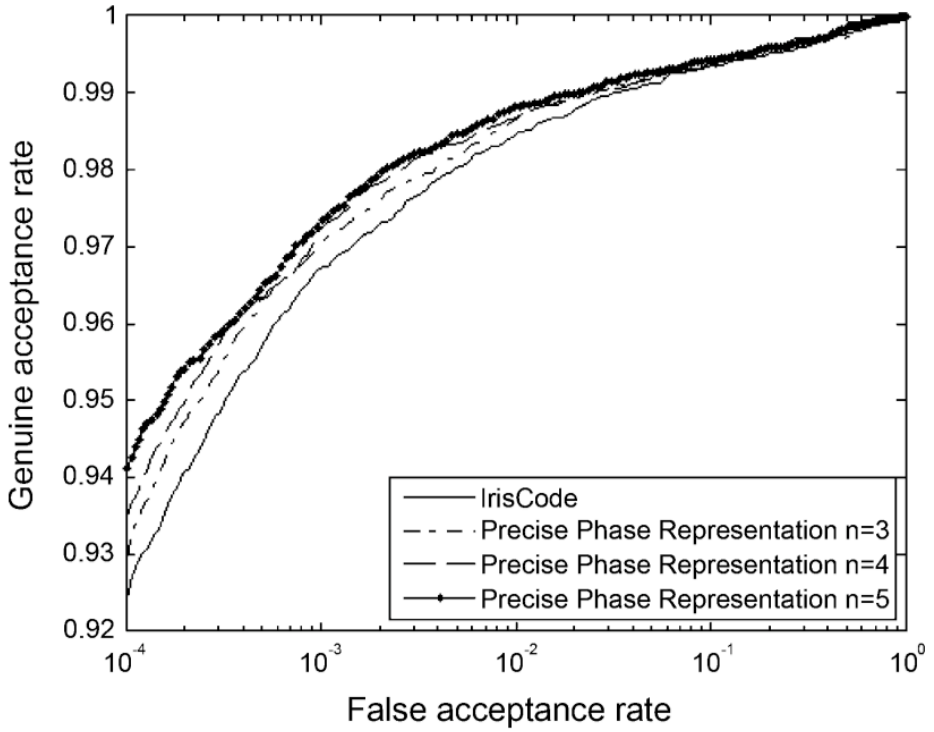
What Else can be done with Fragile Bits?



Related Work

Kong et al. divided the complex plane into six or eight bins and found an improvement in the ROC curve.

A. Kong, D. Zhang, and M. Kamel, “An Analysis of IrisCode,” *IEEE Transactions on Image Processing*, vol. 19, Feb. 2010, pp. 522-532.



Conclusions

- Fragile bits exist.
- Fragile bits come from the quantization of the filter response.
- Fragile bits are a result of the *combination* of iris texture and filter.
- Masking fragile bits improves performance.
  - Commercial systems already mask fragile bits.

- FBD measures how two fragile bit patterns differ.
  - Low FBDs -> Genuine Comparisons.
  - High FBDs -> Impostor Comparisons.
- To compute FBD, the system must save fragile and occlusion bits separately (costs space and time).
- Fusion of FBD and HD improves EER by 8%.

Questions?