Extending the Imaging Volume of an Iris Recognition System

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Expanded Image Volume
Understanding Imaging Volume

- Field of view: Field dependent aberrations
- Depth: Defocus aberrations
Problem statement

• Identify a user from 18” to 28” without refocusing
  – Extend the depth of field
  – Cannot reduce F/# or aperture diameter
Impact of Defocus

- Modulation drops at higher spatial frequencies
- Loss of information
- Phase reversal at some spatial frequencies
Traditional Approach: Higher F/#

Reducing aperture size

- Decreases MTF variation with defocus  BUT …
- Loss of resolution
- Loss in SNR
Wavefront Coded Iris Recognition System

- Computational imaging
- Application specific optical element
Wavefront Coded Imaging

OPTICS

Aspherical element

COMPUTATION

Processing Filter

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Low F/# **AND** Extended Depth of Field

Traditional Imaging

Wavefront Coded Imaging
Explaining Wavefront Coded Imaging

Traditional

Wavefront Coded

After Processing
MTF with Defocus

Traditional system (no Wavefront Coding)
Modulation with Wavefront Coding

Wavefront Coded system

MTF

Normalized spatial frequency

28"

24.5"

20"

23"

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Comparing MTFs
Traditional and Wavefront Coded PSFs

No Aberrations

Traditional Imaging

Wavefront Coded before Signal Processing

Wavefront Coded after Signal Processing

With Aberrations

PSF footprint varies considerably with defocus

PSF has bigger footprint but stays invariant

PSF footprint as compact as best focus PSF

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Further reading

Applied Optics
February 2005 Issue
Wavefront Coded surface designed for Computer Security Application

Surface shape, 40.0 microns peak to valley
IHOS MTF after Processing

- Notice frequencies within *inner* circle restored to within -5 dB

- Frequencies within the *outer* circle have nulls or drop below -48 dB in parts
Authentic Scores - Traditional system

![Graph showing the relationship between distance and score for the traditional system. The graph plots the hamming distance score against distance in inches. The data points are scattered, indicating variability in the system's performance at different distances. The graph highlights the traditional system's score at various distances, with a notable trend suggesting performance degradation with increased distance.]
Authentic Scores – Wavefront Coded system
SNR vs. Detection

Hypothetical iris recognition algorithm

- Inadequate SNR
- Trade-off with performance loss
- Trade-off without performance loss
What increases SNR?

- Active illumination with high irradiance incident on the subject
- Wavelengths where the iris contrast is highest
- Large aperture diameters
- High sensor responsivity at operating wavelengths
- Detectors with high full-well depth (large dynamic range)
- Detectors with low read noise
Other Applications

- Miniature cameras (cell-phone camera)
- Automobile cameras
- Infrared imaging
- Microscopy
- Single lens systems
- Improved opto-mechanical tolerances
Summary

- Wavefront Coded imaging
  - Optics preserves “information”
  - Post-processing adapts “information” for application
  - Infrared to Ultraviolet
  - Space telescopes to miniature cameras
- Excess-SNR traded for imaging volume
- 3X Depth of Field Increase
- Applied Optics March 2005
  - Special Issue on Biometric Recognition System
Thank You

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