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A Polarimetric Thermal Database for Face Recognition Research

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Face Recognition Overview

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Objective: Develop techniques exploiting multi-spectrum facial signatures for robust cross-spectrum face recognition in challenging scenarios (nighttime, extended range)

Significance:

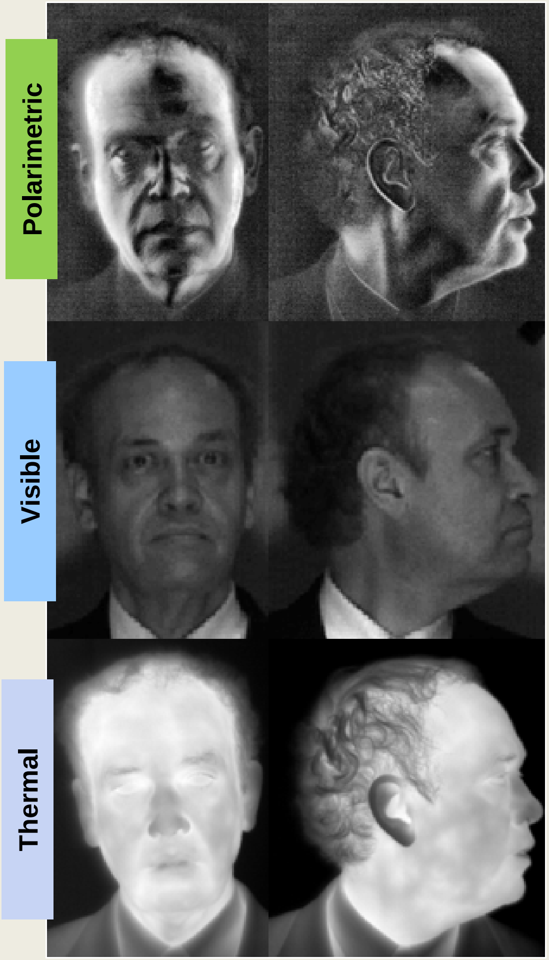
- Enable nighttime face recognition for surveillance and access control applications
- Recognize individuals in infrared images from a visible face watch list or database

Key technical challenges:

- Substantial differences in infrared and visible face signatures due to phenomenology, especially for thermal infrared band
- Limited facial details at distance, non-frontal face poses

Community context:

- Some work on NIR-to-visible and SWIR-to-visible recognition
- Limited work in thermal-to-visible face recognition (West Virginia U, Michigan State U, Karlsruhe Institute of Technology)
- No prior published work on polarimetric thermal based face recognition



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Polarimetric Face Recognition

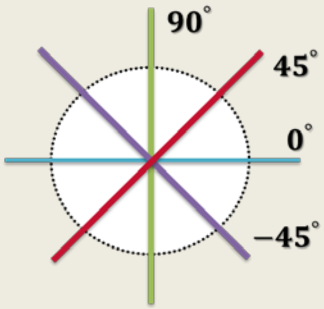
Advantages:

Polarimetric LWIR provides key textural and geometric facial details not present in conventional thermal face signature

Polarimetric characteristics:

- Measures emission intensity at different polarization-states
- Stokes vectors describe preferred polarization-state of captured light
- Degree of Linear Polarization (DoLP) used to approximate amount of linearly polarized light emitting from a source
- Provides information about surface texture and orientation of surface normal with respect to viewing angle

Stokes Vector



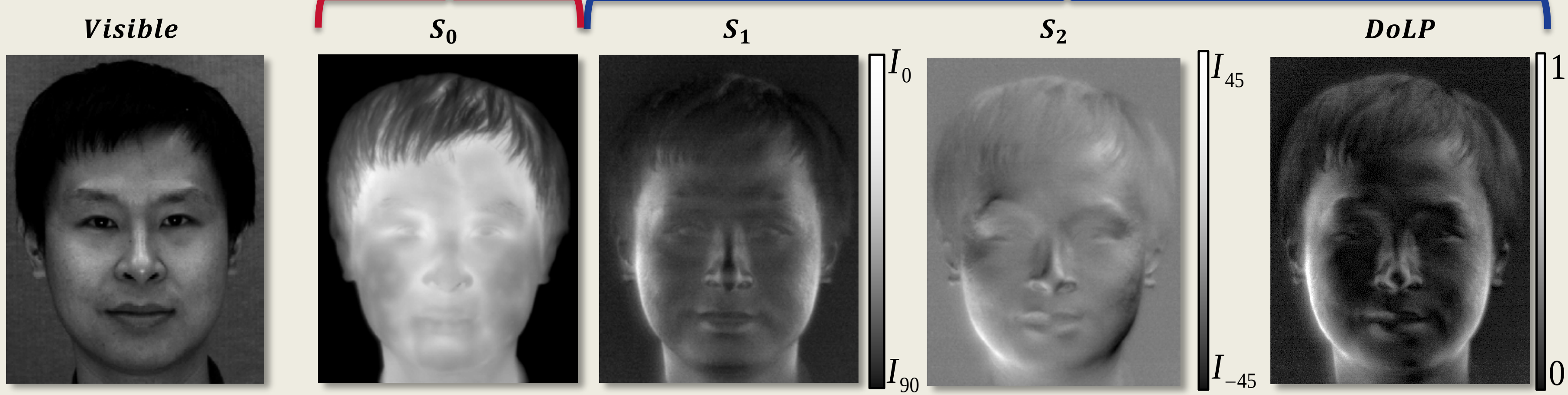
$$S_0 = I_0 + I_{90}$$

$$S_1 = I_0 - I_{90}$$

$$S_2 = I_{45} - I_{-45}$$

$$DoLP = \frac{\sqrt{S_1^2 + S_2^2}}{S_0}$$

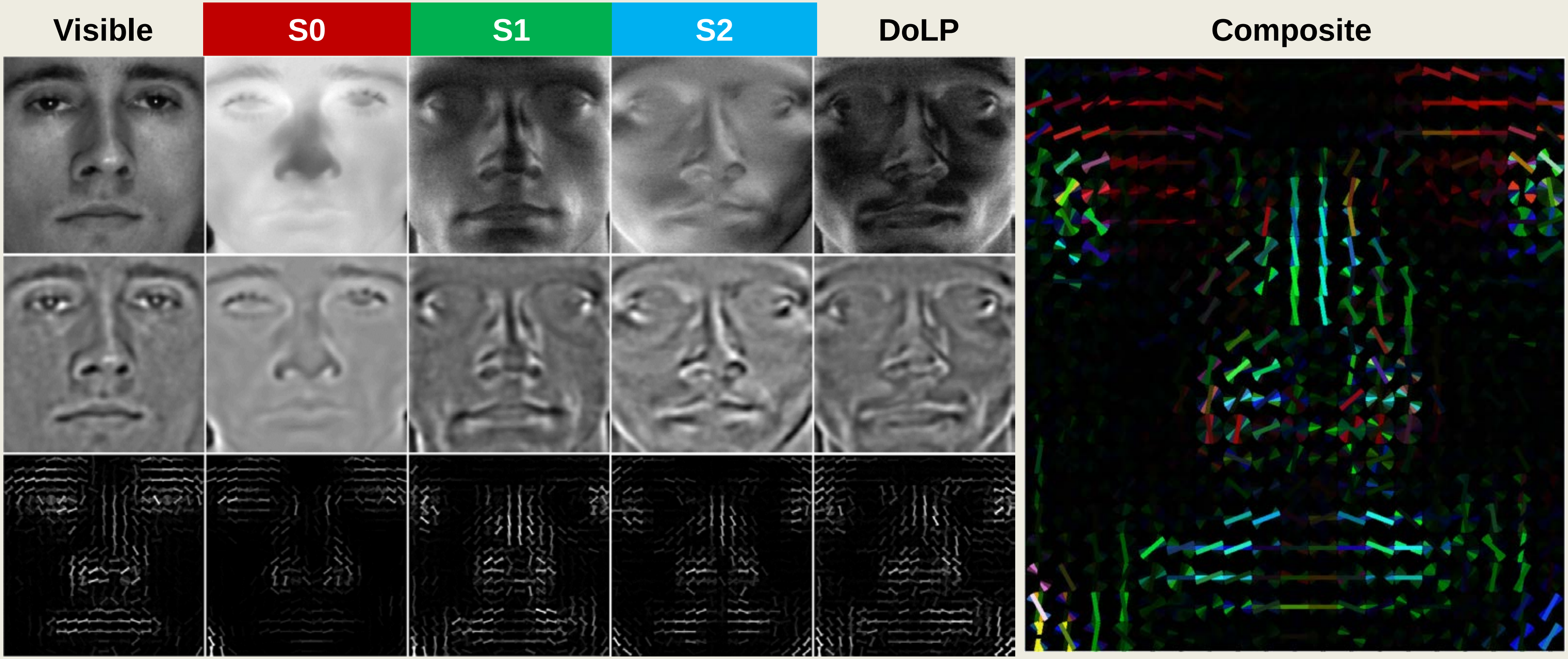
Conventional Thermal **Polarimetric Images**



Composite Features

Exploiting Polarization-state information for face recognition

- ❑ Stokes images contain complementary information about facial features
- ❑ Should be able to provides more information for cross-spectrum matching



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Multi-Spectrum Face Dataset

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Collected multi-condition & multi-range polarimetric-thermal, conventional LWIR and visible face database

- First-of-its kind polarimetric face database
- Ranges: 2.5 m, 5 m, 7.5 m
- Conditions: baseline, expressions
- 60-subjects
- **Distributable to partners in government, industry and academia to facilitate research**
  - Database release agreement
  - Contact Sean (shuowen.hu.civ@mail.mil) and Matthew (matthew.d.thielke.civ@mail.mil)

Polarimetric LWIR

- (Polaris Sensor Technologies)
- 640x480; 10.6° x 7.9° FOV
- 7.5-11.1 μm
- Cooled

FLIR SC660 LWIR

- 640x480
- 24° x18° FOV
- 7.5-13 μm
- Uncooled

Visible x4 (grayscale and color)

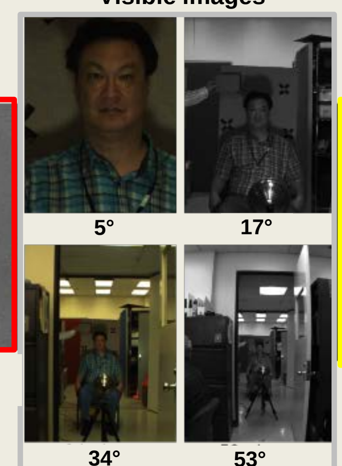
- 658x492, 5°, 17°, 34°, 53° FOV
- 400-920nm

Sample Imagery at 5 m

Polarimetric LWIR Image

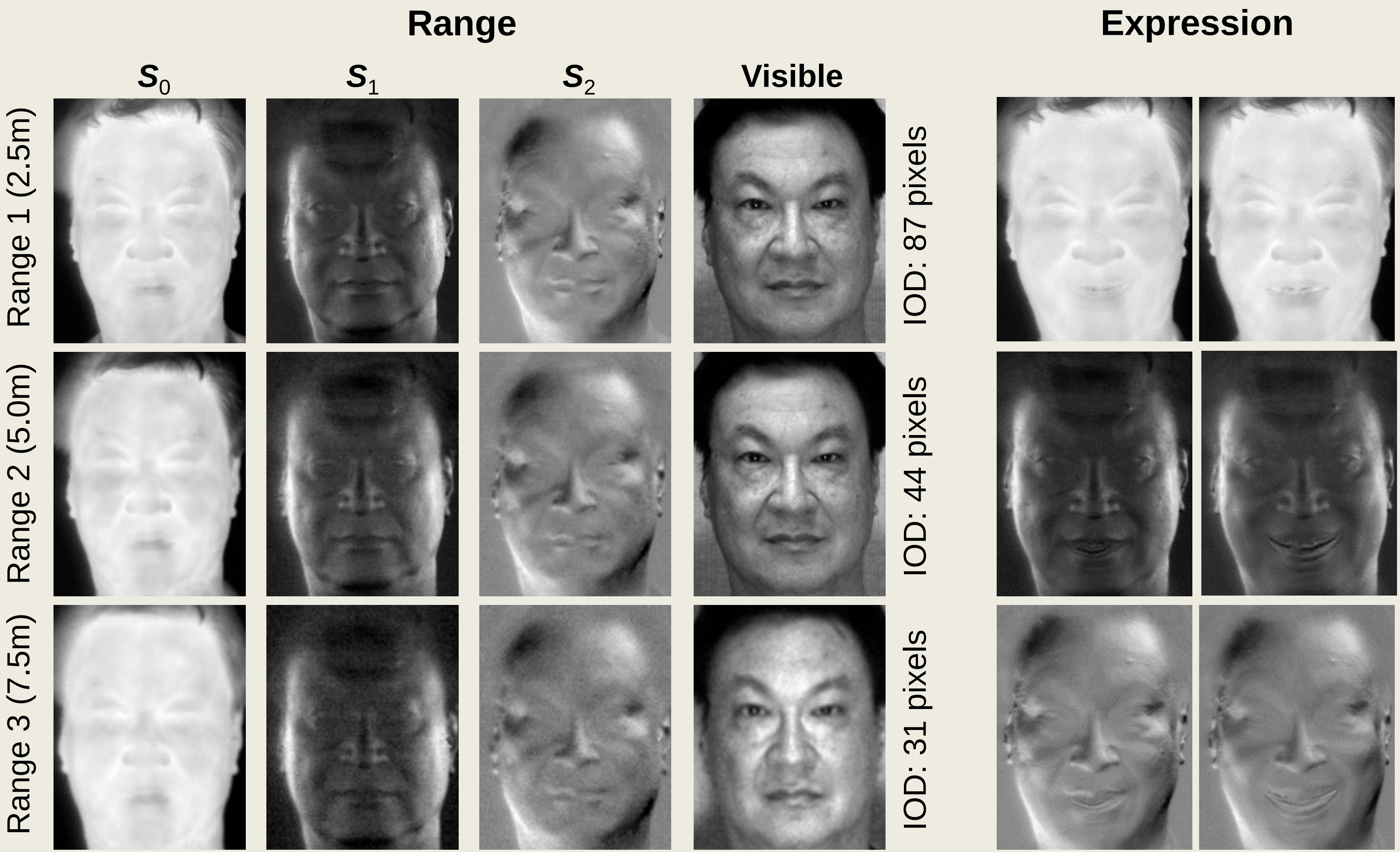
Degree of Linear Polarization (DoLP)

Visible images



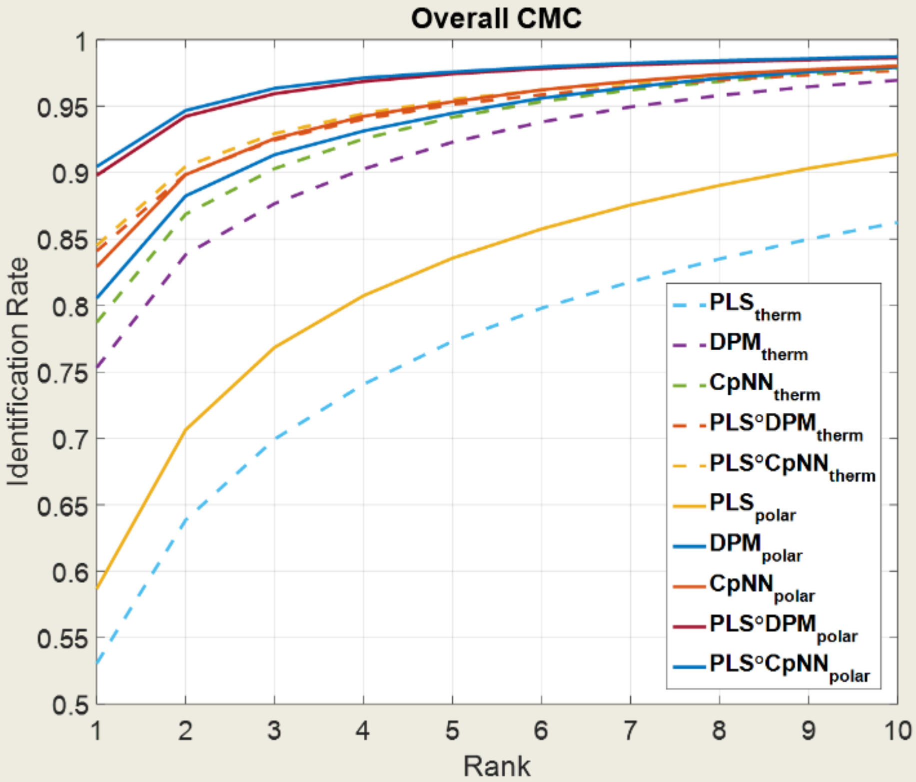
Conventional LWIR Image

Dataset Conditions



Performance Benchmark

- Five techniques are used to assess ***cross-spectrum*** face recognition performance: partial least squares (PLS), deep perceptual mapping (DPM), coupled neural networks (CpNN), DPM followed by PLS (PLS◦DPM), and CpNN followed by PLS (PLS◦CpNN)
- Evaluated conventional thermal-to-visible face recognition performance (dashed lines), and polarimetric thermal-to-visible face recognition (solid lines) on a dataset of 60 subjects (25 for training, 35 for testing)



❖ Performance achieved on Range1-3 baseline data + Range 1 expressions:
- 84.5% for thermal-to-visible using PLS◦CpNN
- 90.5% for polarimetric thermal-to-visible using PLS◦CpNN

❖ Polarimetric thermal imagery provides additional facial details compared to conventional thermal imagery, improving recognition performance

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Performance Benchmark

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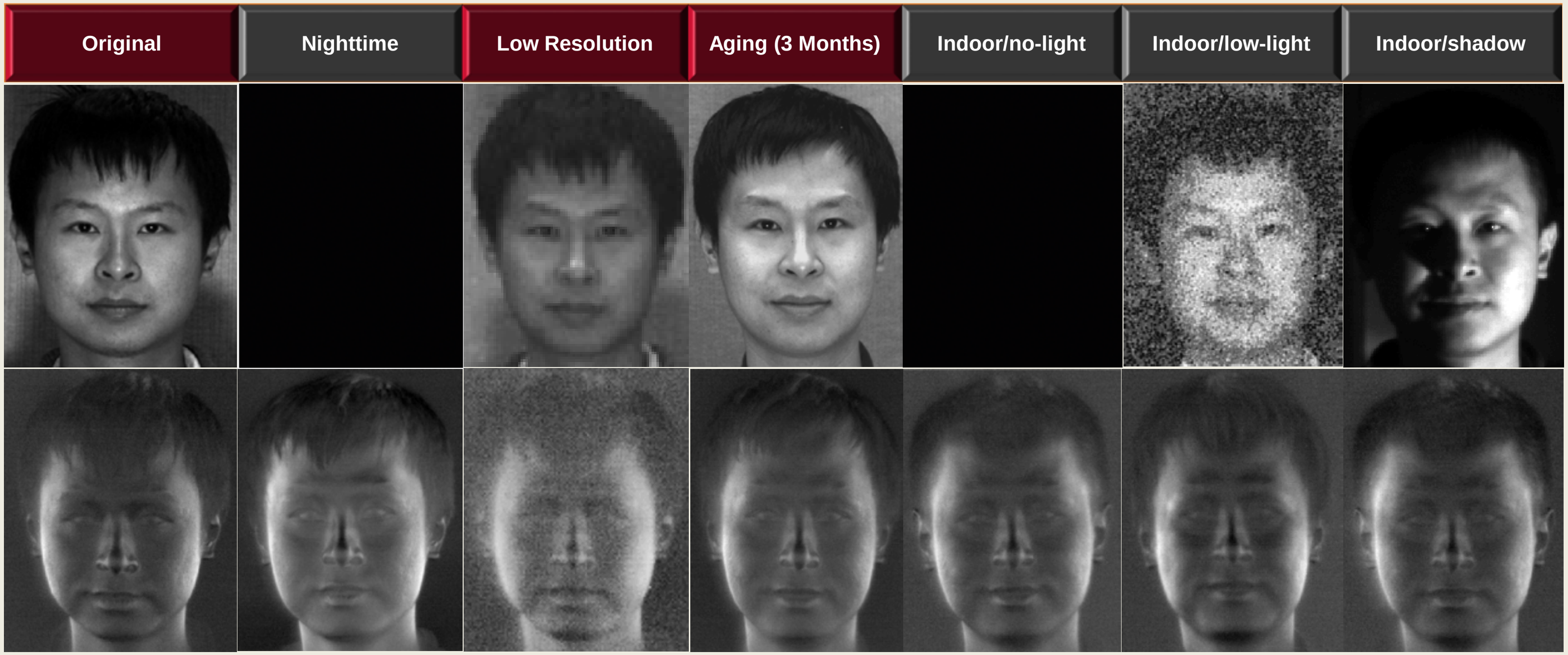
Scenario	Probe	PLS	DPM	CpNN	PLS◦DPM	PLS◦CpNN
	Rank-1 Identification Rate					
Overall	*Polar*	0.5867	0.8054	0.8290	0.8979	0.9045
	Therm	0.5305	0.7531	0.7872	0.8409	0.8452
Expressions	*Polar*	0.5658	0.8324	0.8597	0.9565	0.9559
	Therm	0.6276	0.7887	0.8213	0.8898	0.8907
Range 1 Baseline	*Polar*	0.7410	0.9092	0.9207	0.9646	0.9646
	Therm	0.6211	0.8778	0.9102	0.9417	0.9388
Range 2 Baseline	*Polar*	0.5570	0.8229	0.8489	0.9105	0.9187
	Therm	0.5197	0.7532	0.7904	0.8578	0.8586
Range 3 Baseline	*Polar*	0.3396	0.6033	0.6253	0.6445	0.6739
	Therm	0.3448	0.5219	0.5588	0.5768	0.6014

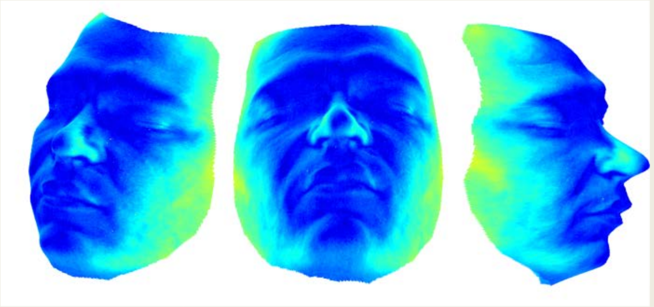
- Cross-spectrum feature mapping with DPM or CpNN combined with PLS significantly outperforms discriminative classifier alone
- More benefit from exploiting polarimetric information under more challenging conditions (e.g. long distance, expressions)

Polarimetric-Thermal Advantages



3D Face Surface Reconstruction

- Potentially provide pose-invariance through frontalization
- Combine Stokes images by Fresnel relations to extract surface normals (θ,φ) at each pixel, integrate surface normals to generate 3D surface
- Challenge: π ambiguity in azimuth angle φ



Conclusion

- Polarization state information captures geometric and textural details unavailable in conventional thermal imagery
- First database containing polarimetric thermal facial imagery to be made available to academia and industry to facility multi-spectrum face recognition research