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Imaging-free classification of fast-moving object based on single-pixel detection

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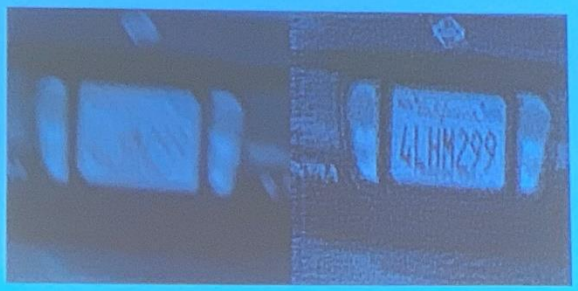
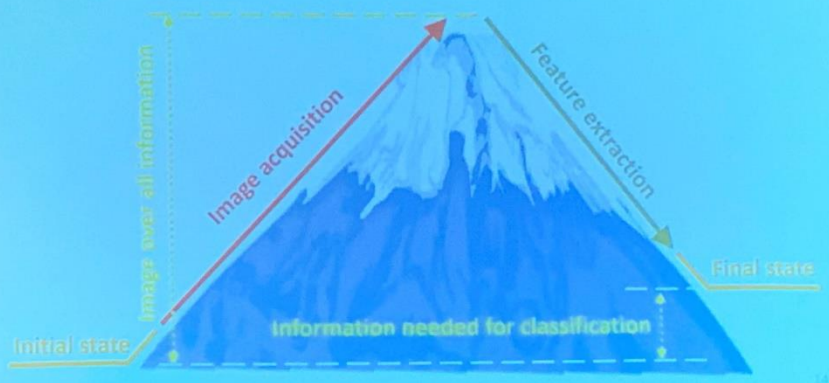
Image Post-processing

- Effectively eliminate motion blur through computation
- Computationally exhausted
- Inapplicable for real-time object classification



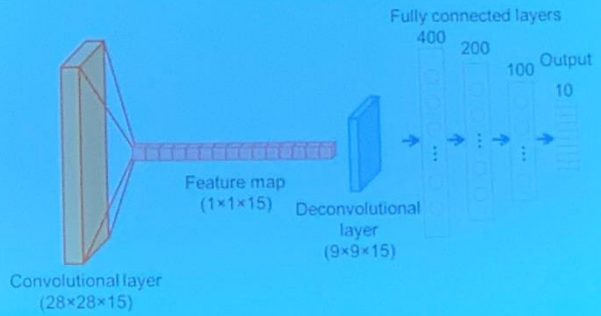
How to Achieve Real-time & Long-duration Fast-moving Object Classification?

- Images involve too much redundancy for object classification



Optoelectronic Hybrid CNN

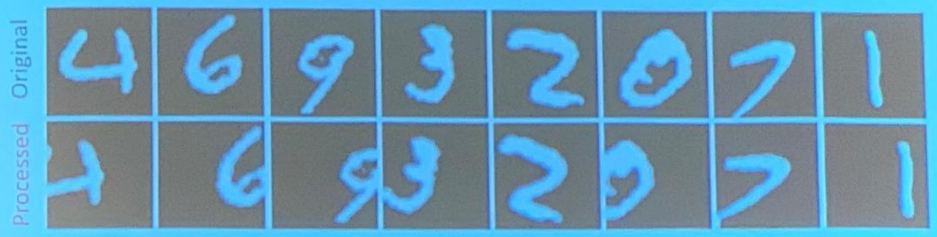
- Convolution implemented in an optical means (in application)
- Goal: Fast-moving handwritten digit classification



Z. Zhang, X. Li, et al., "Image-free classification of fast-moving objects using "learned" structured illumination and single-pixel detection," Opt. Express 28, 13269-13278 (2020)

Training Data Preparation

- Random rotation and lateral shift added to the training / test set
- Reason: adding robustness against object motion



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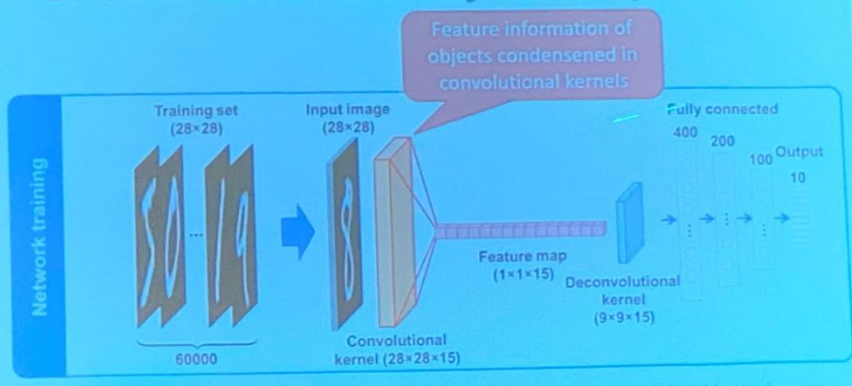
CNN Training

- Automatic feature extraction through CNN training



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CNN in Imaging-free Application

1) Illuminating the target object with the convolutional kernels
2) Collecting the intensity of light with a single-pixel detector
3) Feeding the collected light intensity to the feature map of CNN

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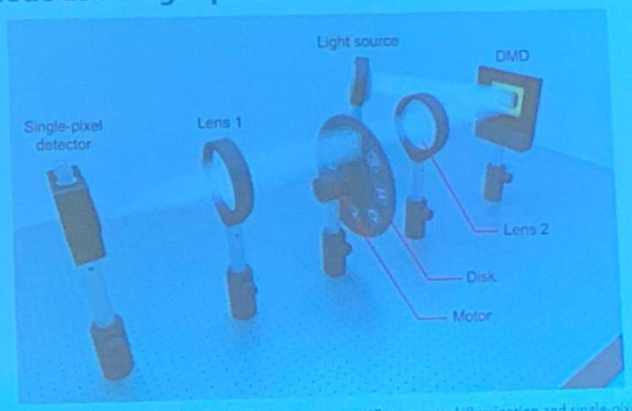
Experimental Setup

- Digital micro-mirror device (DMD) as a high-speed projector
- Photodiode as a single-pixel detector



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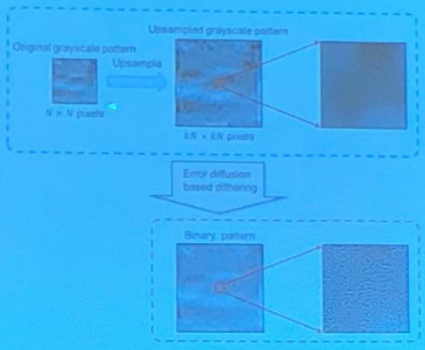
Pattern Binarization for High-speed Spatial Light Modulation

- DMD can only generate binary patterns at a high speed (~22.7 kHz)
- Method: Upsample and dither



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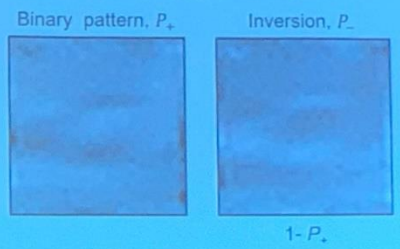
Differential Measurement for SNR Improvement

- Pattern illuminated followed by its inversion
- Subtraction of the two single-pixel measurements as an effective measurement
- Total pattern number doubled (15 -> 30)



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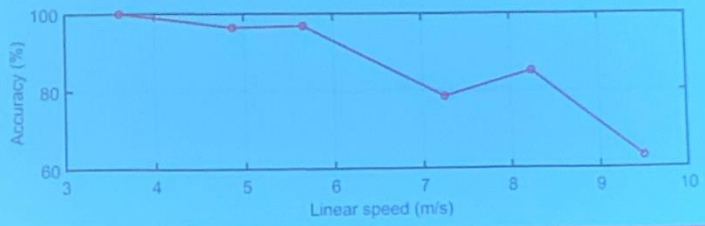
Moving Handwritten Digits Classification Results

Results

Motor voltage (V)	Angular speed (rad/s)	Linear speed (m/s)	Rotation speed (rpm)	Accuracy (%)
1.5	24.05	3.61	229.2	100
2	32.49	4.87	310.2	96.43
2.5	37.74	5.66	360.6	96.88
3	48.34	7.25	462.0	78.57
3.5	54.94	8.24	525.0	85.11
4	63.31	9.50	604.8	62.96



DMD refreshing rate	FOV	Temporal res.	Data throughput
17,850 Hz	45 mm × 45 mm	1.68 ms (data acq.) 1.43 ms (computation)	0.95 Mb/s

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Summary

1. A imaging-free fast-moving object classification method based on a hybrid CNN proposed
2. Applicable for real-time and long-duration classification
3. High-speed spatial light modulation and single-pixel detection allowing feature information to be acquired directly
4. Potentially applicable for hidden moving object classification at invisible wavebands