CAMEL: Camera Adaptation with Embedded Machine Learning Based Feedback Control

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Driving Applications: Reconfigurable Imaging (ReImagine)

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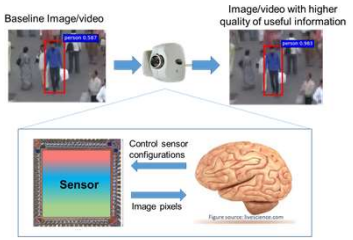
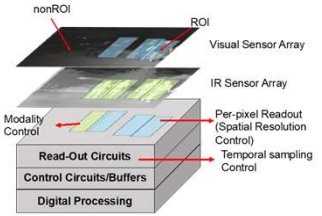
Smart Surveillance

Aerial Surveillance

High Speed Object Tracking

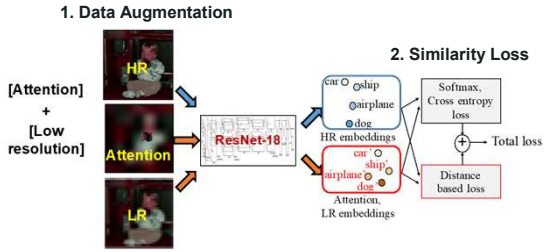
Objective: A Camera that delivers higher quality of useful content





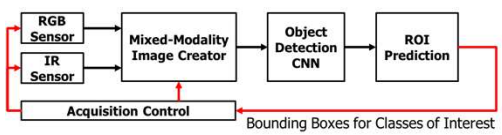
Innovation: An adaptive camera model that uses embedded deep learning algorithms to dynamically control sensor parameters (Spatial/Temporal Resolution, Modality)

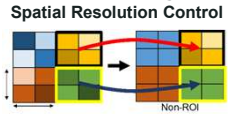
Training of DNNs

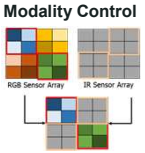


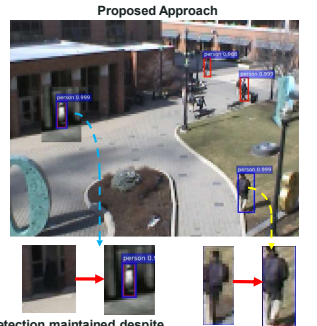
- Task accuracy can degrade for mixed parameter (spatial + modality + temporal) input
- DNNs are retrained with data augmentation and novel loss functions to ensure robust performance for mixed parameter input
- Training process can be adapted to any user-defined task e.g. Facial Recognition

Adaptive Camera with Spatial + Modality Control





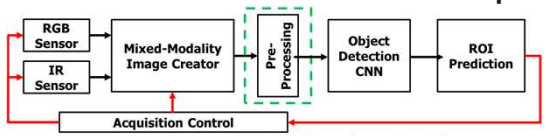


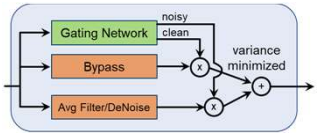


Approach	Tracking Accuracy (MOTA)	Object Detection Accuracy (mAP)	Bandwidth (Mbits/s)
Baseline	0.528	0.467	61.93
Spatial Res. only	0.544	0.467	19.88
Proposed (Spatial + modality)	0.650	0.500	17.50

- Higher tracking performance is delivered under 3x lower bandwidth
- Losses in tracking accuracy/object detection accuracy due to illumination variances within the scene are recovered through modality control

Noise in the Pipeline



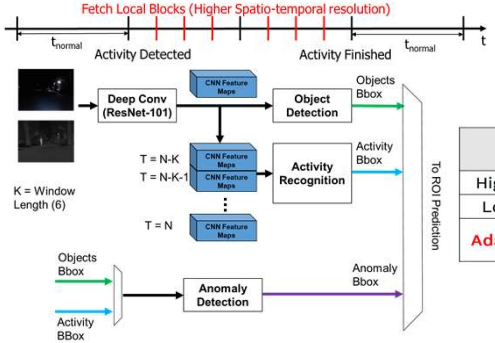


- Adaptive camera with feedback is highly sensitive to noise in the input as false negatives are increased
- Noise-robust network can enhance the tolerance to noise and recover the accuracy degradation.
- Noise – robust adaptive camera uses mixture of pre-processing techniques

MOTA – Multiple Object Tracking Accuracy

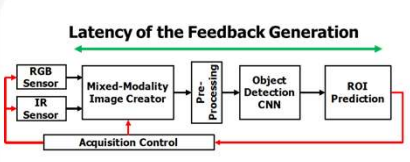
Network	Feedback	Feedback + σ=0.15
Non-Robust (Data augmentation only)	0.527	0.345
Noise-Robust	0.527	0.451

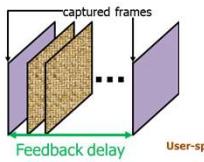
Adaptive Camera with Spatiotemporal Control

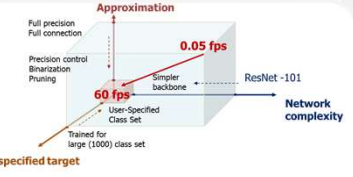


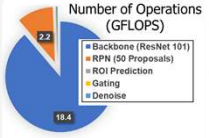
Cases	Bandwidth (MB/s)	Normalized Accuracy*
High frame rate(240 fps)	15,840	1
Low frame rate(30 fps)	1,980	0.95
AdaptiveSpatioTemporal	576 (27X lower)	1

Latency of the Feedback Generation









Platform	Conv Backbone	Latency (s)	Frame Rate (fps)	AP (Person)	MOTA
GTX1080 [300W]	ResNet-101	0.128	7.8	0.43	0.54
mGPU [5W]	ResNet-101	21	0.04	0.43	0.05
	SSD MobileNet v1, Class-based Training+Pruning	0.099	10.1	0.27	0.35

- Latency between acquisition of frame and generation of feedback degrades the tracking accuracy
- Hardware/Software innovations are needed to speed up DNN inference

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