Investigation of DNN Model Robustness Using Heterogeneous Datasets

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Objective

- This research aims to investigate some fundamental properties of the deep learning framework for computer vision tasks, including:
  - How to train the network when heterogeneous data (multiple distinct representations of the same source) are concerned?
  - What is the optimal information fusion strategy?
  - What actually happens inside the network when different fusion strategies are applied? (XAI)
  - Implications on devising defenses against adversarial attacks

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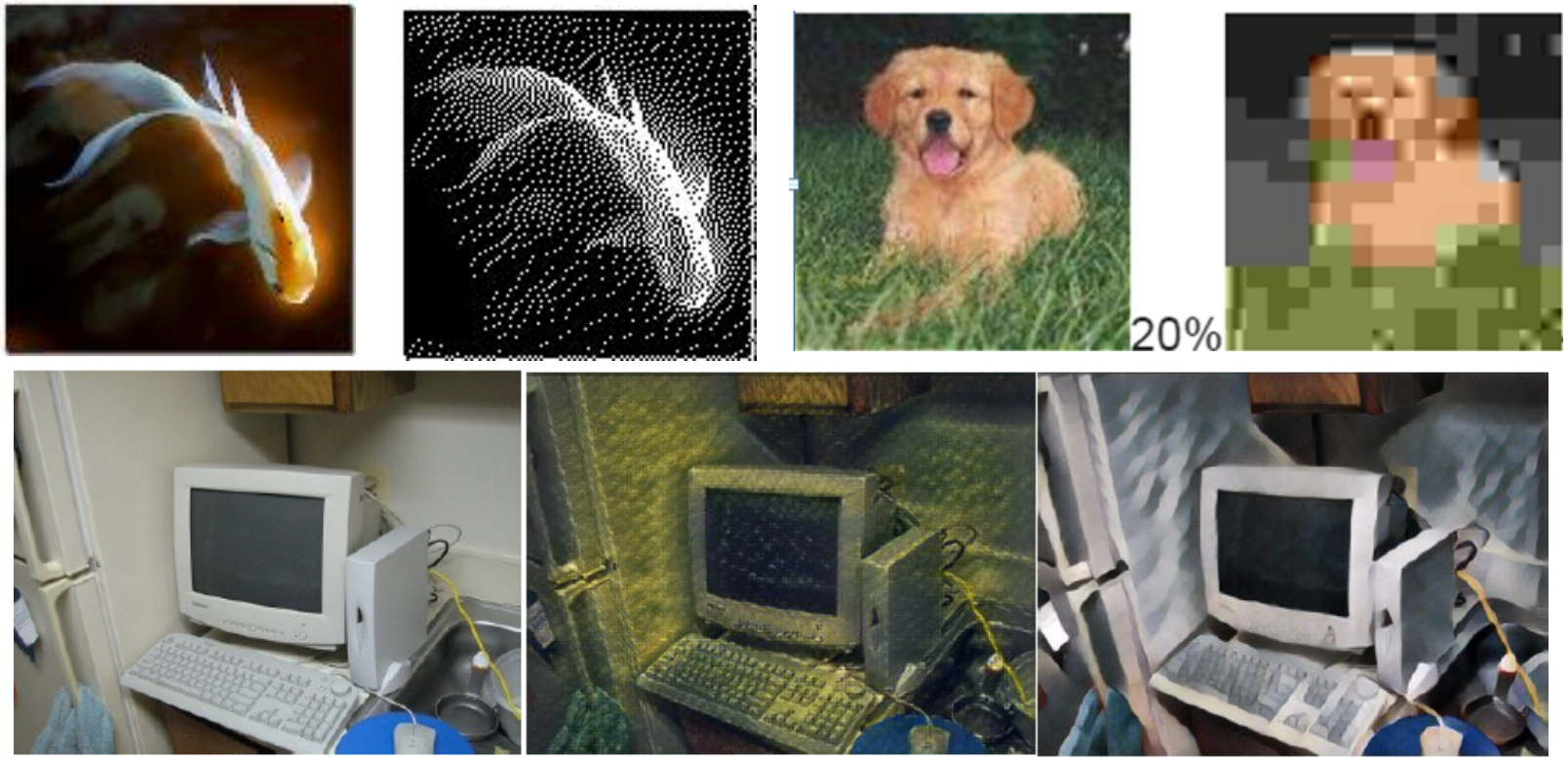
Heterogeneous Data

- Definition: Multiple distinct representations of the same source
- Examples: RGB vs. halftone, original vs. compressed, original vs. stylized image



Coping with Hybrid Input

- Devise and train deep neural networks for the recognition of different representation of images.
  - Original vs. Low-Resolution Images
  - Original vs. Compressed Images
  - Original (intensity-based) vs. Halftone Images (density-based)

Training with Heterogeneous Data

- Hybrid training: train the model with both data sets simultaneously (data augmentation perspective)
- Feature concatenation: train the network with two branches and merge the extracted features (feature fusion perspective)
- The Order of Training: investigate the effect of continual learning by training the model with a pre-arranged order (incremental learning perspective)
- Finding: hybrid training yields better performance consistently

Training Results - Resolution and Compression Ratio

Original vs. down-sampled images

Training	Evaluation	Accuracy
Original	Original	0.61
	4x	0.17
	9x	0.08
4x down-sampled	Original	0.02
	4x	0.57
	9x	0.34
9x down-sampled	Original	0.01
	4x	0.28
	9x	0.51
Hybrid - Original + 4x down-sampled	Original	0.62
	4x	0.60
	9x	0.35
Hybrid - Original + 9x down-sampled	Original	0.57
	4x	0.47
	9x	0.53

Original vs. compressed images

Training	Evaluation	Accuracy
Original	Original	0.61
	60% compressed	0.36
	80% compressed	0.03
60% compressed	Original	0.47
	60% compressed	0.52
	80% compressed	0.05
80% compressed	Original	0.17
	60% compressed	0.24
	80% compressed	0.32
Hybrid - Original + 60% compressed	Original	0.58
	60% compressed	0.53
	80% compressed	0.09
Hybrid - Original + 80% compressed	Original	0.53
	60% compressed	0.48
	80% compressed	0.39

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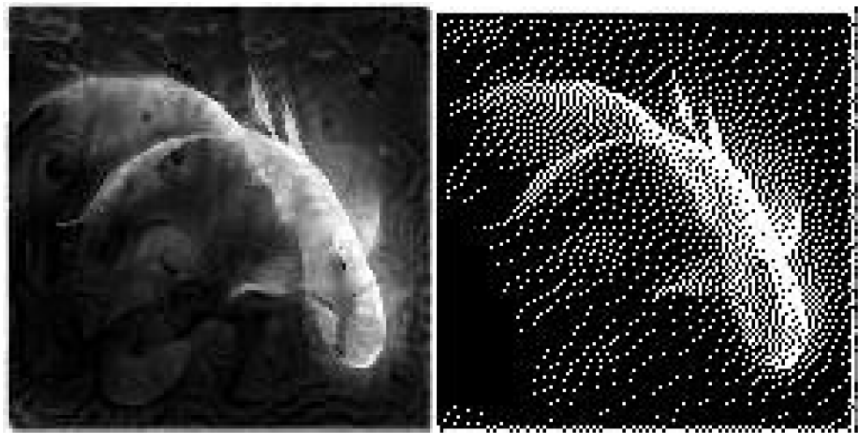
Training Results - Original vs. Halftone Images



Training	Evaluation	Accuracy	
		Top-1	Top-5
Grayscale	Grayscale	0.61	0.77
	FS Halftone	0.01	0.03
Floyd-Steinberg (FS) Halftone	Grayscale	0.42	0.64
	FS Halftone	0.61	0.80
Feature Concatenation	Grayscale	0.45	0.69
	FS Halftone	0.48	0.71
Hybrid Training	Grayscale	0.66	0.85
	FS Halftone	0.59	0.82

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Training Results – Order and Hybrid Training

The Effect of Training Order

Training Order	Evaluation	Accuracy
4x then Original	Original	0.60
	4x	0.22
	9x	0.07
Original then 4x	Original	0.02*
	4x	0.55
	9x	0.36
9x then Original	Original	0.56
	4x	0.29
	9x	0.11
Original then 9x	Original	0.01*
	4x	0.27
	9x	0.51

*:catastrophic forgetting

Hybrid Training

Training	Evaluation	Accuracy
Hybrid	Original	0.59
	4x	0.57
	9x	0.54
	60% compressed	0.55
	80% compressed	0.40

Summary

- Strong dependence of classifier performance on training data
- Compressed and down-sampled images maintain the overall structure but remove detailed textures, resulting in poor performance (consistent with ICLR 2019 paper)
- Similar results observed in halftone representation, color-depth reduced images obtained with mean-shift segmentation or bilateral filtering.
- Remedy: increase shape bias by adding heterogeneous data sets to the training samples.
- Order of training is crucial in hybrid training.
- Cannot augment endlessly, when to stop?

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