

4-6 Wednesday – 210-GD3

Special topics in Computer Science INT3121 20

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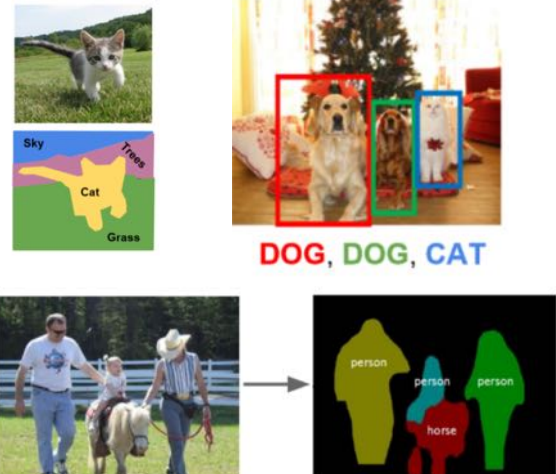
Slide & Code: <https://github.com/chupibk/INT3121-20>

Image Classification with Convolutional Neural Networks

Week 1: Introduction

Why is image classification important?

- Classification is significant in order to understand characteristics of groups
- Image classification is essential in other important tasks of computer vision → the **core task** in CV
 - Semantic/Instance segmentation
 - Object detection
- Large variety of practical applications



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Image Classification: grayscale

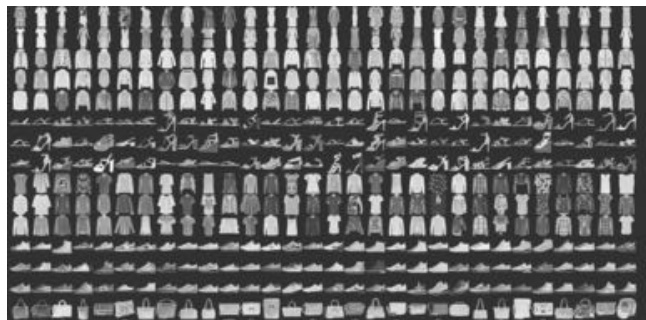
MNIST (LeCun et al., 1998)



10 classes

<http://yann.lecun.com/exdb/mnist/>

Fashion-MNIST (2017)



10 classes

<https://github.com/zalandoresearch/fashion-mnist>

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Eyeglass detection



MeGlass, 2018

<https://github.com/cleardusk/MeGlass>

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Dog breed identification

120 breeds



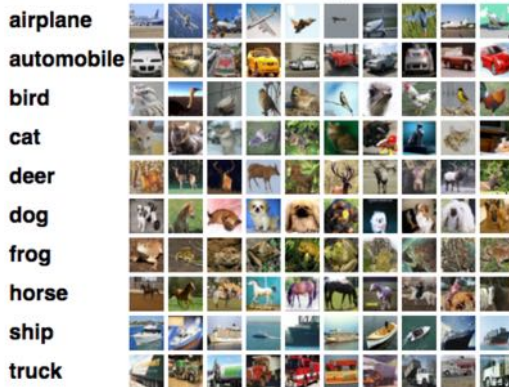
<https://www.kaggle.com/c/dog-breed-identification>

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Image classification: tiny images

CIFAR-10 (Krizhevsky and Hinton, 2009)
32x32 size



CIFAR-100 (Krizhevsky and Hinton, 2009)

Superclass	Classes
aquatic mammals	beaver, dolphin, otter, seal, whale
fish	aquarium fish, flatfish, ray, shark, trout
flowers	orchids, poppies, roses, sunflowers, tulips
food containers	bottles, bowls, cans, cups, plates
fruit and vegetables	apples, mushrooms, oranges, pears, sweet peppers
household electrical devices	clock, computer keyboard, lamp, telephone, television
household furniture	bed, chair, couch, table, wardrobe
insects	bee, beetle, butterfly, caterpillar, cockroach
large carnivores	bear, leopard, lion, tiger, wolf
large man-made outdoor things	bridge, castle, house, road, skyscraper
large natural outdoor scenes	cloud, forest, mountain, plain, sea
large omnivores and herbivores	camel, cattle, chimpanzee, elephant, kangaroo
medium-sized mammals	fox, porcupine, possum, raccoon, skunk
non-insect invertebrates	crab, lobster, snail, spider, worm
people	baby, boy, girl, man, woman
reptiles	crocodile, dinosaur, lizard, snake, turtle
small mammals	hamster, mouse, rabbit, shrew, squirrel
trees	maple, oak, palm, pine, willow
vehicles 1	bicycle, bus, motorcycle, pickup truck, train
vehicles 2	lawn-mower, rocket, streetcar, tank, tractor

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Image classification: large data

ImageNet (1000 classes) - Deng et al., 2009



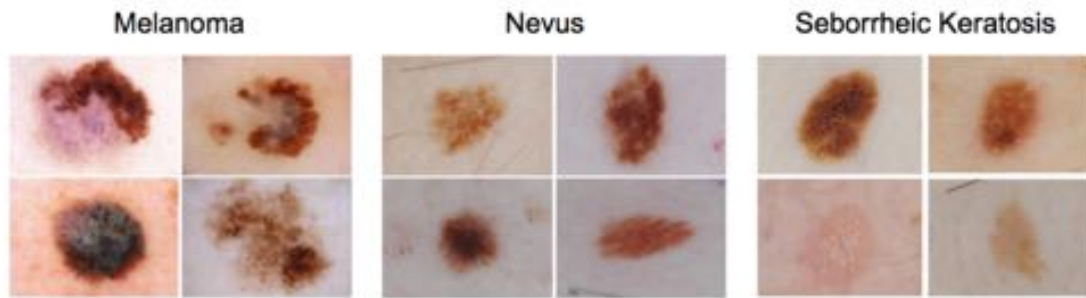
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<http://www.image-net.org/>

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Image classification: medical image

ISIC2017, Skin lesion analysis toward melanoma detection

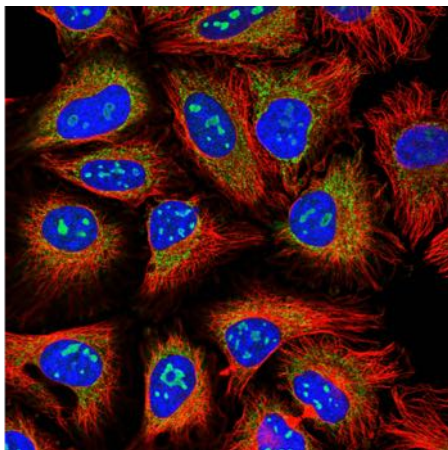


<https://challenge.kitware.com/#phase/5840f53ccad3a51cc66c8dab>

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Human protein atlas image classification



28 classes:

- | | |
|------------------------------|-----------------------------------|
| 0. Nucleoplasm | 14. Microtubules |
| 1. Nuclear membrane | 15. Microtubule ends |
| 2. Nucleoli | 16. Cytokinetic bridge |
| 3. Nucleoli fibrillar center | 17. Mitotic spindle |
| 4. Nuclear speckles | 18. Microtubule organizing center |
| 5. Nuclear bodies | 19. Centrosome |
| 6. Endoplasmic reticulum | 20. Lipid droplets |
| 7. Golgi apparatus | 21. Plasma membrane |
| 8. Peroxisomes | 22. Cell junctions |
| 9. Endosomes | 23. Mitochondria |
| 10. Lysosomes | 24. Aggresome |
| 11. Intermediate filaments | 25. Cytosol |
| 12. Actin filaments | 26. Cytoplasmic bodies |
| 13. Focal adhesion sites | 27. Rods & rings |

<https://www.kaggle.com/c/human-protein-atlas-image-classification/overview>

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Plant seedlings classification

Differentiate a weed from a crop seedling
960 plants, 12 species

1. Black-grass
2. Charlock
3. Cleavers
4. Common Chickweed
5. Common wheat
6. Fat Hen
7. Loose Silky-bent
8. Maize
9. Scentless Mayweed
10. Shepherds Purse
11. Small-flowered Cranesbill
12. Sugar beet



<https://www.kaggle.com/c/plant-seedlings-classification/data>

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PlantDisease classification



38 classes

<https://www.crowdai.org/challenges/1>

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Image classification: satellite images

DeepSat SAT-4, four classes: barren land, trees, grassland, all land → red, green, blue and near infrared bands



<https://www.kaggle.com/crawford/deepsat-sat4>

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And many others...

AI Categories - image classification		
21 Competitions		
	Recursion Cellular Image Classification CellSignal: Deciphering biological signal from experimental noise in cellular images Released - 1 month to go - % research, biology, classification, image data	\$13,000 638 teams
	Catscout's Image Classification Challenge Catscout's excellent photos Featured - 2 years ago - % multiclass classification	\$25,000 627 teams
	Human Protein Atlas Image Classification Classify subcellular protein patterns in human cells Featured - 1 month ago - % classification, image data	\$37,000 2,369 teams
	iMaterialist Challenge (Fashion) at FGVC5 Image classification of fashion products Released - 1 year ago	\$2,900 212 teams
	iMaterialist Challenge (Furniture) at FGVC5 Image Classification of Furniture & Home Goods Released - 1 year ago	\$2,900 428 teams
	Digit Recognizer Learn to recognize seven fundamentals with the famous MNIST data Testing Started - Ongoing - % tabular data, image data, multiclass classification, object identification	Knowledge 2,860 teams
	Kuzushiji Recognition Opening the door to a thousand years of Japanese culture Featured - 3 months to go - % history, image data, multiclass classification, japan	\$15,000 124 teams
	APTOS 2019 Blindness Detection Direct diabetic retinopathy to stop blindness before it's too late Featured - 1 week to go - % health-care, medicine, image data, multiclass classification...	\$10,000 2,870 teams
	IWildCam 2019 - FGVC6 Categorize animals in the wild Featured - 3 months ago - % image data, multiclass classification	Kudex 338 teams

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	Inclusive Images Challenge Diversify test image classifiers across new geographic distributions Released - 9 months ago - % image data, multiclass classification	\$25,000 660 teams
	dstl Satellite Imagery Feature Detection Can you train an eye in the sky? Featured - 2 years ago - % image data, multiclass classification, object segmentation	\$100,000 419 teams
	Leaf Classification Predict seven leaflets, one plantlet at a time Featured - 2 years ago - % image data, multiclass classification, object segmentation	Knowledge 1,098 teams
	National Data Science Bowl Predict seven leaflets, one plantlet at a time Featured - 4 years ago - % neuroscience, image data, multiclass classification	\$75,000 1,043 teams
	Data Science Bowl 2017 Can you improve lung cancer detection? Featured - 2 years ago - % healthcare, image data, binary classification	\$1,000,000 1,972 teams
	Plant Seedlings Classification Determine the species of a seedling from an image Featured - 1 year ago - % image data, multiclass classification	Kudex 634 teams
	Diabetic Retinopathy Detection Identify signs of diabetic retinopathy in eye images Featured - 4 years ago - % ophthalmology, health sciences, image data, binary classification	\$100,000 661 teams
	Dog Breed Identification Determine the breed of a dog in an image Featured - 1 year ago - % animals, image data, multiclass classification, object identification	Kudex 1,285 teams
	Dogs vs. Cats Redux: Kernels Edition Distinguish images of dogs from cats Featured - 2 years ago - % animals, image data, binary classification, object identification	Knowledge 1,214 teams
	Starai/C-CORE Iceberg Classifier Challenge Ship or nothing, can you decide from space? Featured - 2 years ago - % weather, shipping, image data, binary classification	\$50,000 3,341 teams
	The Nature Conservancy Fisheries Monitoring Which coastal treatment will be most effective? Featured - 2 years ago - % fishing, image data, multiclass classification, object detection	\$100,000 2,293 teams
	Intel & MobileODT Cervical Cancer Screening Which cancer treatment will be most effective? Featured - 2 years ago - % healthcare, image data, multiclass classification, object identification	\$100,000 848 teams

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Problem statement

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Definition of Image classification problem

- Image classification is a discriminant function of mapping images to symbols
- Single-output classification:
 - An image I is mapped to one symbol $c_i \in S = \{c_1, c_2, \dots, c_L\}$ and $|S| \geq 2$
 - If the target symbol set has two elements ($|S| = 2$), we call, “binary classification”
 - If $|S| > 2$, we call “multi-class classification”
- Multi-output classification:
 - An image I is mapped to multiple symbols, a vector of symbol $v = \{c_{s1}, c_{s2}, \dots, c_{sm}\}$ where $c_{si} \in S_i = \{c_1^i, \dots, c_{L_i}^i\}$

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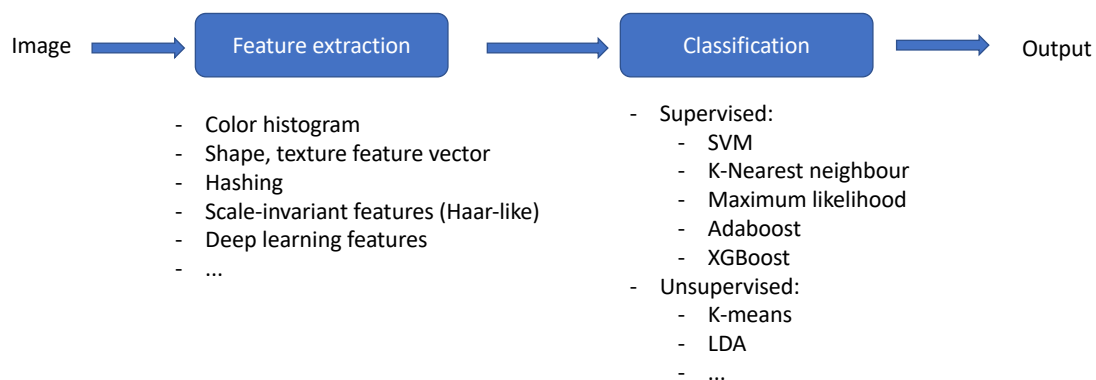
Approaches

A (very) brief history

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Classical approaches: pipeline



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Modern approaches: end-to-end

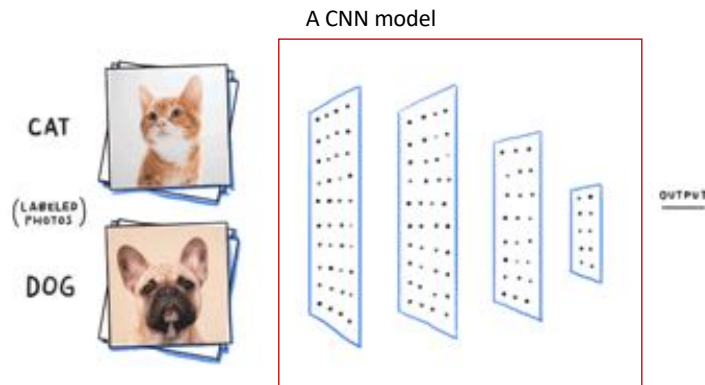


Image credit: <https://becominghuman.ai/building-an-image-classifier-using-deep-learning-in-python-totally-from-a-beginners-perspective-be8dbaf22dd8>

Arise of CNNs

“Transformers: Generation 1” (1984~)

- Kunihiko Fukushima [1980]: Neocognitron
 - a self-organizing artificial network of simple and complex cells that could recognize patterns and was unaffected by position shifts
- Yann Lecun [1989~]: LeNet-5
 - A backprop style learning algorithm to Fukushima’s CNN
 - MNIST dataset (1998)
- Pascal VOC project [2006]: annual competition from 2006-2012
 - 20 object categories
- ImageNet benchmark [2009]: Large scale visual recognition competition (ILSVRC)
 - Over a million images, 1000 of object classes
 - AlexNet [2012] -> breakthrough moments for CNNs
 - 2010-2011: ILSVRC error rate hovered around 26%
 - AlexNet, LeNet-5: 16.4%
 - Current state-of-the-art: 13.6%

ImageNet leading board

Rank	Method	Top 1 Accuracy	Top 5 Accuracy	Number of params	Extra Training Data	Paper Title	Year	Paper	Code
1	FixResNeXt-101 32x4d	86.6%	98.0%	829M	✓	Fixing the train-test resolution discrepancy	2019	Paper	Code
2	ResNeXt-101 32x4d	85.4%	97.6%	829M	✓	Exploring the Limits of Weakly Supervised Pretraining	2018	Paper	Code
3	ResNeXt-101 32x3d	85.1%	97.5%	466M	✓	Exploring the Limits of Weakly Supervised Pretraining	2018	Paper	Code
4	EfficientNet-B7	84.4%	97.1%	66M	×	EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks	2019	Paper	Code
5	GPPE	84.3%	97%	557M	×	GPPE: Efficient Training of Giant Neural Networks using Pipeline Parallelism	2018	Paper	Code
6	ResNeXt-101 32x4d	84.2%	97.2%	194M	✓	Exploring the Limits of Weakly Supervised Pretraining	2018	Paper	Code
7	EfficientNet-B6	84.0%	96.9%	43M	×	EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks	2019	Paper	Code
8	AmoebaNet-A	83.9%	96.6%	469M	×	Regularized Evolution for Image Classifier Architecture Search	2018	Paper	Code
9	FixPNASNet-5	83.7%	96.8%	85.1M	×	Fixing the train-test resolution discrepancy	2019	Paper	Code
10	MultiGrain PNASNet @ 500px	83.6%	96.7%	86M	×	MultiGrain: a unified image embedding for classes and instances	2019	Paper	Code
11	EfficientNet-B5	83.3%	96.7%	30M	×	EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks	2019	Paper	Code
12	MultiGrain SENet154 @ 400px	83.0%	96.5%	86M	×	MultiGrain: a unified image embedding for classes and instances	2019	Paper	Code
13	Oct-ResNeXt-101 + SE	82.9%	96.3%	67M	×	Drop an Octave: Reducing Spatial Redundancy in Convolutional Neural Networks with Octave Convolution	2019	Paper	Code
14	PNASNet-5	82.9%	96.2%	85.1M	×	Progressive Neural Architecture Search	2017	Paper	Code
15	NASNet-A/B	82.7%	96.2%	89M	×	Learning Transferable Architectures for Scalable Image Recognition	2017	Paper	Code
16	SENet-154	82.7%	96.2%	146M	×	Squeeze-and-Excitation Networks	2017	Paper	Code
17	EfficientNet-B4	82.6%	96.3%	19M	×	EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks	2019	Paper	Code
18	FixResNeXt-99 B101n	82.5%	96.6%	25.6M	✓	Fixing the train-test resolution discrepancy	2019	Paper	Code
19	DPN-131	81.45%	95.84	80M	×	Dual Path Networks	2017	Paper	Code
20	PolyNet	81.3%	95.8%	92M	×	PolyNet: A Pursuit of Structural Diversity in Very Deep Networks	2016	Paper	Code
21	DPN-g8	81.1%	95.6%	×	×	Dual Path Networks	2017	Paper	Code
22	EfficientNet-B3	81.1%	95.5%	12M	×	EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks	2019	Paper	Code
23	ResNeXt-101 64x4	80.9%	95.6%	83.6M	×	Aggregated Residual Transformations for Deep Neural Networks	2016	Paper	Code
24	DPN-g4	80.7%	95.3%	×	×	Dual Path Networks	2017	Paper	Code
25	Inception-ResNet V2	80.1%	95.1%	55.8M	×	Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning	2016	Paper	Code
26	RandomPre-V5	80.1%	94.8%	×	×	Exploring Randomly Wired Neural Networks for Image Recognition	2019	Paper	Code
27	ScaleNet-152	79.94%	94.82%	×	×	Data-Driven Neuron Allocation for Scale Aggregation Networks	2019	Paper	Code
28	ResNet-200	79.9%	95.2%	×	×	Identity Mappings in Deep Residual Networks	2016	Paper	Code
29	Modified Aligned Xception	79.81%	94.83%	×	×	Encoder-Decoder with Abrupt Separable Convolution for Semantic Image Segmentation	2018	Paper	Code
30	SKNet-101	79.81%	×	×	×	Selective Kernel Networks	2019	Paper	Code

<https://paperswithcode.com/sota/image-classification-on-imagenet>

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In this class

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Objectives

- To introduce modern approaches to important topics in Computer Science
- To help students build a ready-to-deploy image classification applications

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Credits & activities

- Credits: 3
- Activity hours:
 - Class – theory: 21
 - Class – practice: 0
 - Self-study: 24
- Prerequisites:
 - INT2203 Data structures and Algorithms
 - INT1101 Statistics

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Schedule

Week	Content	Class hour	Self-study hour
1	Introduction Image classification problem and its applications A toy problem with CIFAR10	2	1
2	CNN model architectures and visualization	2	1
3	Training and tuning parameters Automatic parameter learning	2	1
4	Data augmentation Data generator	2	2-6
5	Transfer learning	2	2-6
6	Multi-output image classification	2	2-6
7	Building a training dataset How to write a report	1	2-6
8, 9, 10, 11	Seminar: Bag of tricks with CNN (as mid-term tests)	1	2-6
12, 13, 14	Final project presentations	1-3	2-6
15	Class summarization	1	open

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Mid-term tests

- Check state-of-the-art methods for each dataset
- Either:
 - Survey what to do to boost the performance
 - Apply SOTA in one dataset to another dataset and analyze the performance

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Final projects

- Build a new dataset
- Create a model
- Train
- Find a nice set of hyper-parameters
- Report & present
- Extra point: implement UI applications

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Assessment

- Attendance: 10%
- Seminars: 40%
 - Report + presentation
- Final projects: 50%
 - Report + presentation
- Plagiarism and Cheating: immediately 0 mark!

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Libraries used in class

- Python + Keras
 - For image processing: OpenCV, imgaug
- However, for final projects or mid-term tests, any is okay
 - PyTorch
 - Torch
 - Tensorflow
- Make sure to report [what you actually contributed](#)

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References

- Google scholar
- Google
- Kaggle
- [http://rodrigob.github.io/are we there yet/build/classification data sets results.html](http://rodrigob.github.io/are_we_there_yet/build/classification_data_sets_results.html)
- <https://paperswithcode.com/task/image-classification>

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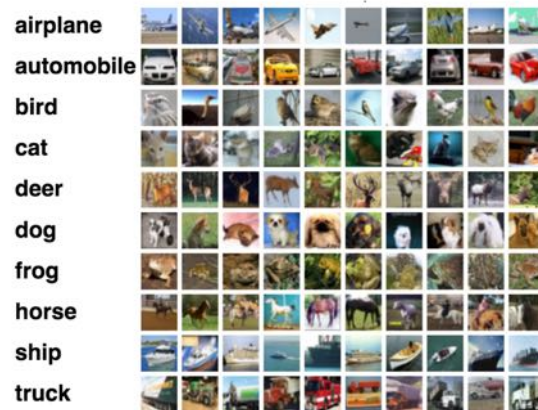
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Toy problem CIFAR10

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<https://www.cs.toronto.edu/~kriz/cifar.html>



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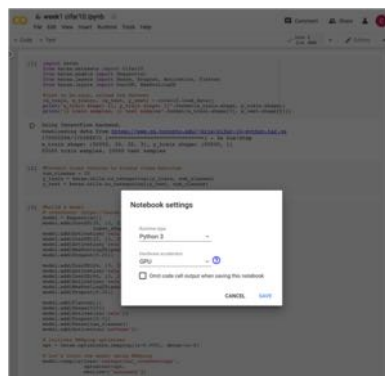
Environments

- Anaconda
- Tensorflow
- Keras
- Python3
- OpenCV 3
- Jupyter Notebook

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Note: Run with GPU of Google Colab



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