

CAS in Applied Data Science Muerren 2024



Géraldine Schaller-Conti

Program of the week

17:00 - 18:30 Tutorial (Geraldine) **Convolutions**

19:00 - 20:00 Dinner at hotel Regina

20:30 - 21:00 Neural Style Transformations (an example on how to use deep ML to create art - Sigve)

Thursday (Geraldine)

08:15 - 09:00 Lecture **Deep Forward Networks – optimization**

09:15 - 10:00 Tutorial **Transfer Learning**

10:00 - 10:30 Coffee break

10:30 - 12:30 Tutorial **Transfer Learning**

12:30 - 17:00 Skiing, work or whatever

17:00 - 18:15 Tutorial and project discussions **Projects**

19:00 - 22:00 Fondue and sledge ride back down to Regina in the dark

Everyone has to be READY OUTSIDE THE HOTEL at 18:45.

The train up departs at 19:00.

Friday (Geraldine)

08:15 - 09:00 Lecture **Convolutional models and generative models**

09:15 - 10:00 Tutorial **Recurrent Neural Networks**

10:00 - 10:30 Coffee break and Check Out

10:30 - 12:00 Tutorial / Discussion Session **Recurrent Neural Networks**

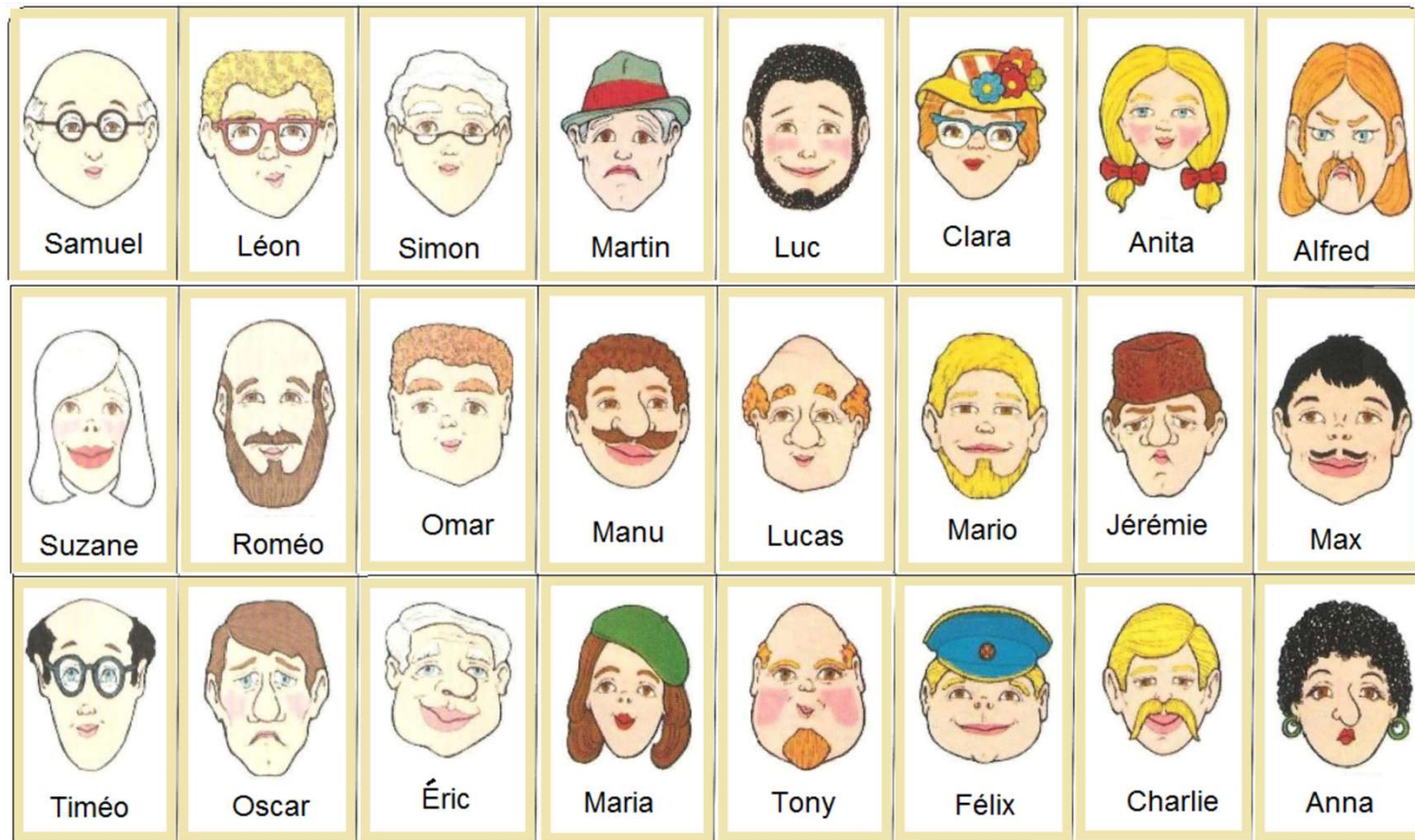
12:00 - 12:30 Wrap up (Sigve)

12:30 End

About me 😊

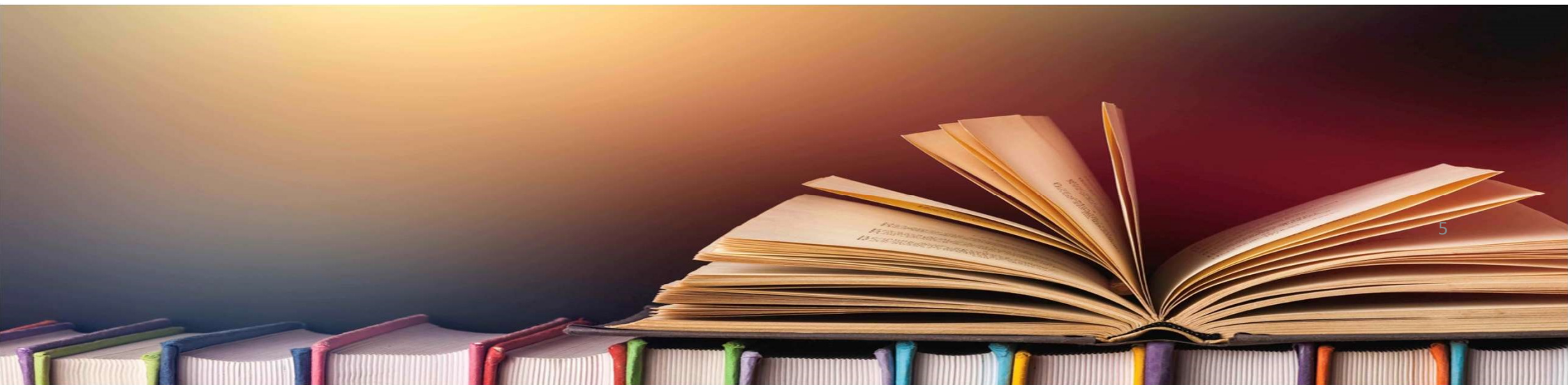


About you ☺



Bibliography

- Deep Learning book (Goodfellow, Bengio, Courville)
- Machine Learning @ Stanford (Prof Andrew Ng)
- Hands-On Machine Learning with Scikit-Learn & Tensorflow (Aurélien Géron)



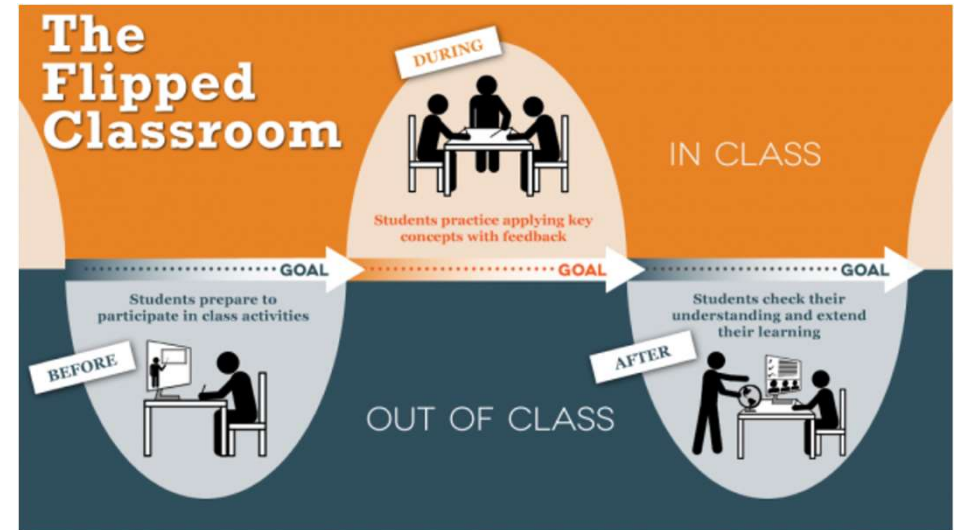
Teaching method

Inverted classroom based

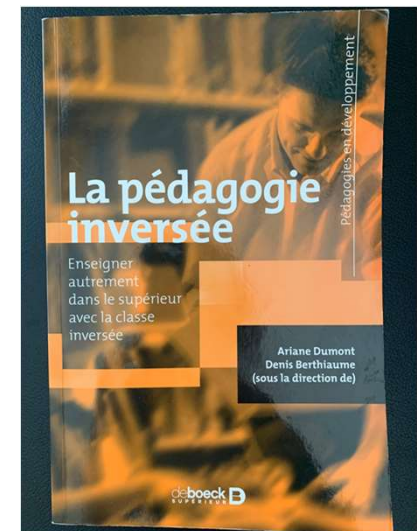
- Introduction lectures
- Real content you learn yourself with the **notebooks**. *Either to put in practice your knowledge or to learn ahead of another lecture*

Why

- Supposed to be better
- More fun
- Learning by doing



To give back sense to being present (Marcel Lebrun)



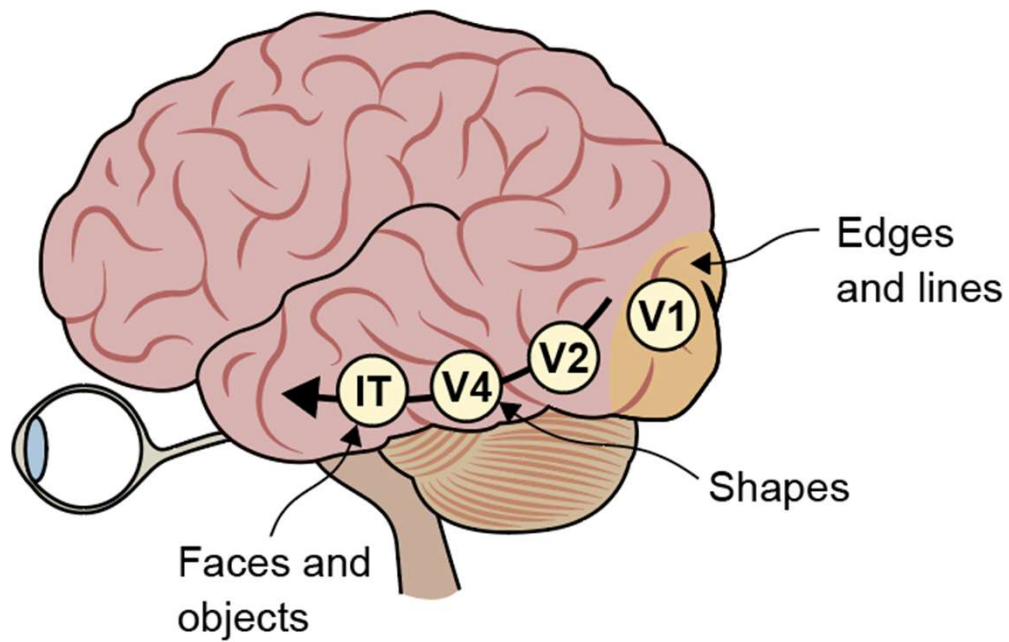
Tutorial IV : Convolutions

Introduction

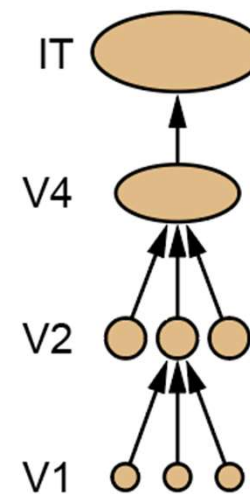
- **Goal** : basics to perform image recognition
- **Program** : inverted classroom style
 - Theory
 - Overview to get the big picture of the Notebook
 - Work alone (30 minutes)
 - Work in groups of 4 (30 minutes)
- **Technical** : Google Colab, Pytorch

Theory

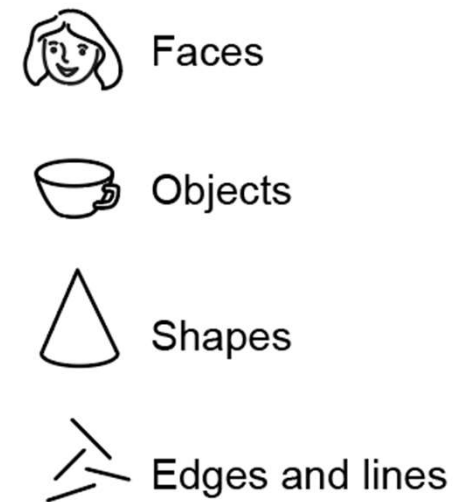
Human vision



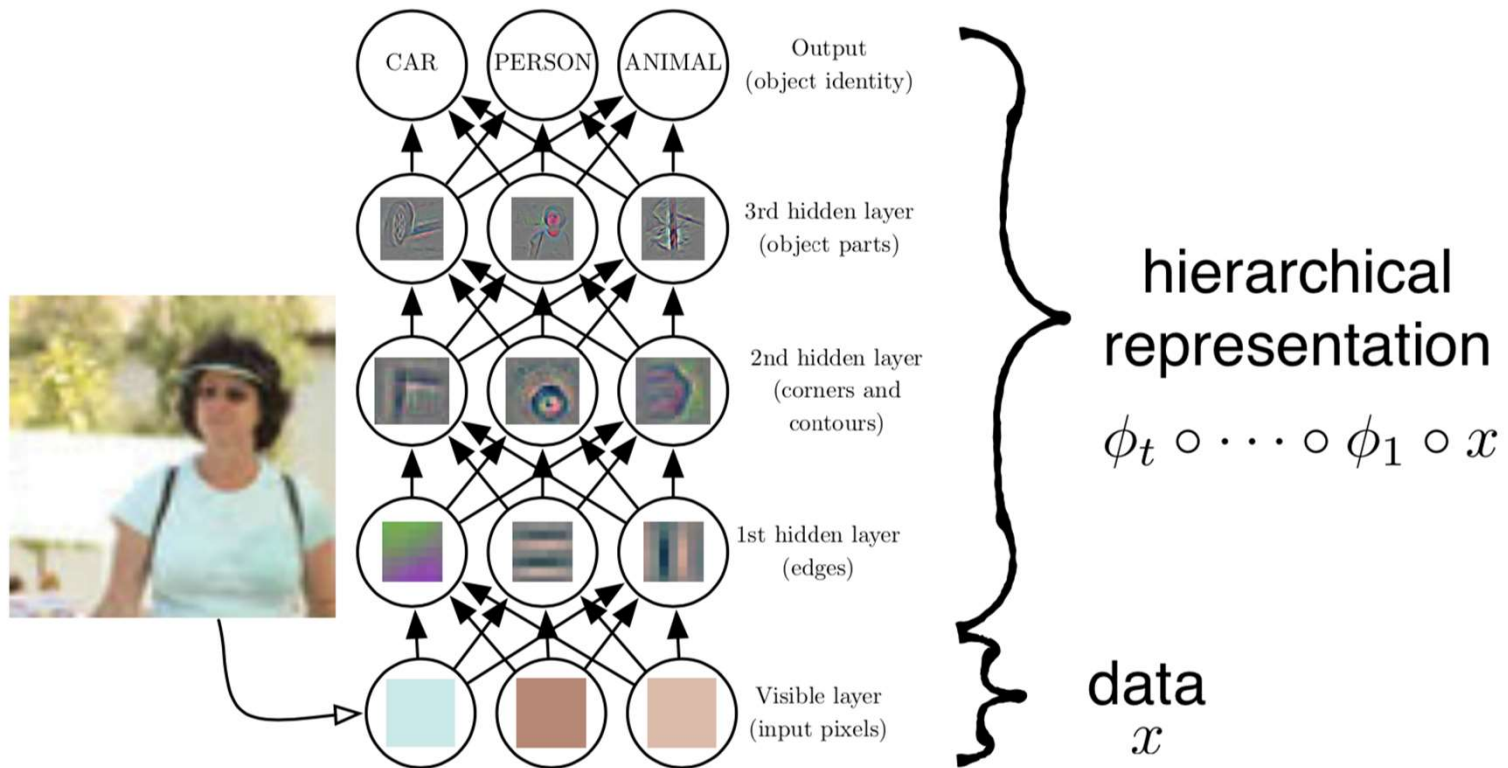
Receptive fields size



Features



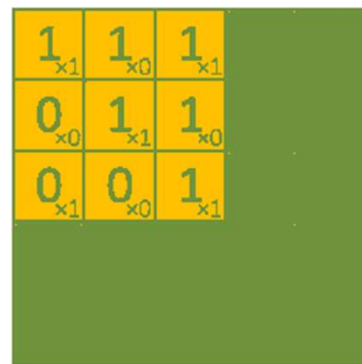
Computer vision



Kernel (filter)

- Used to **detect features** (vertical/horizontal filter,...)
- Different kernels to create different feature maps → learn to see various patterns and details in images

1	0	1
0	1	0
1	0	1



Image

4		

how well the pattern in the kernel matches the content in that part of the image

= Feature map

Convolved
Feature

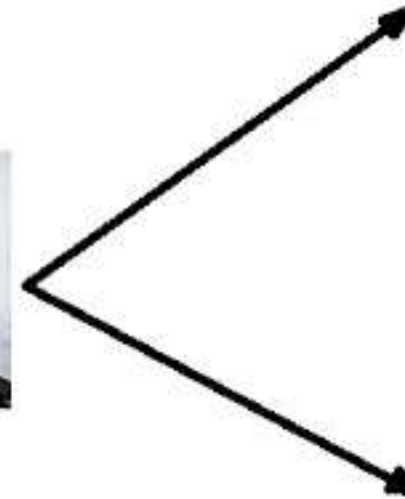
Kernel example

1	0	-1
1	0	-1
1	0	-1

Vertical

1	1	1
0	0	0
-1	-1	-1

Horizontal



Vertical edges

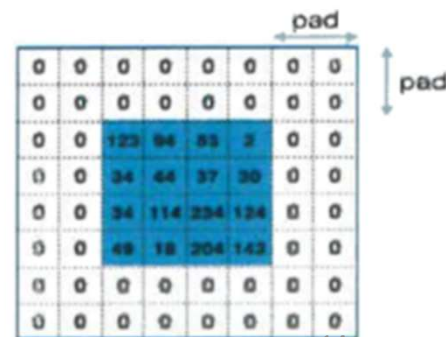
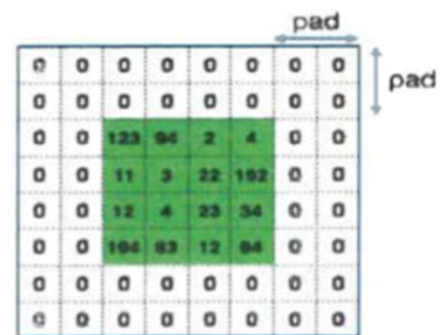
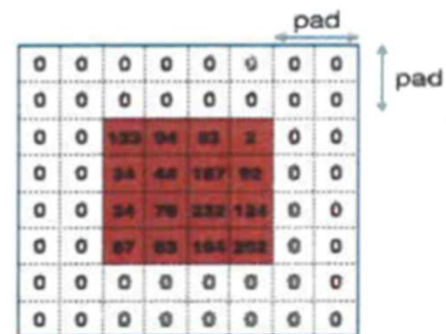
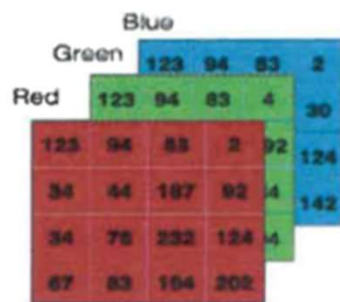


Horizontal edges

Padding, Stride, Dilation



=



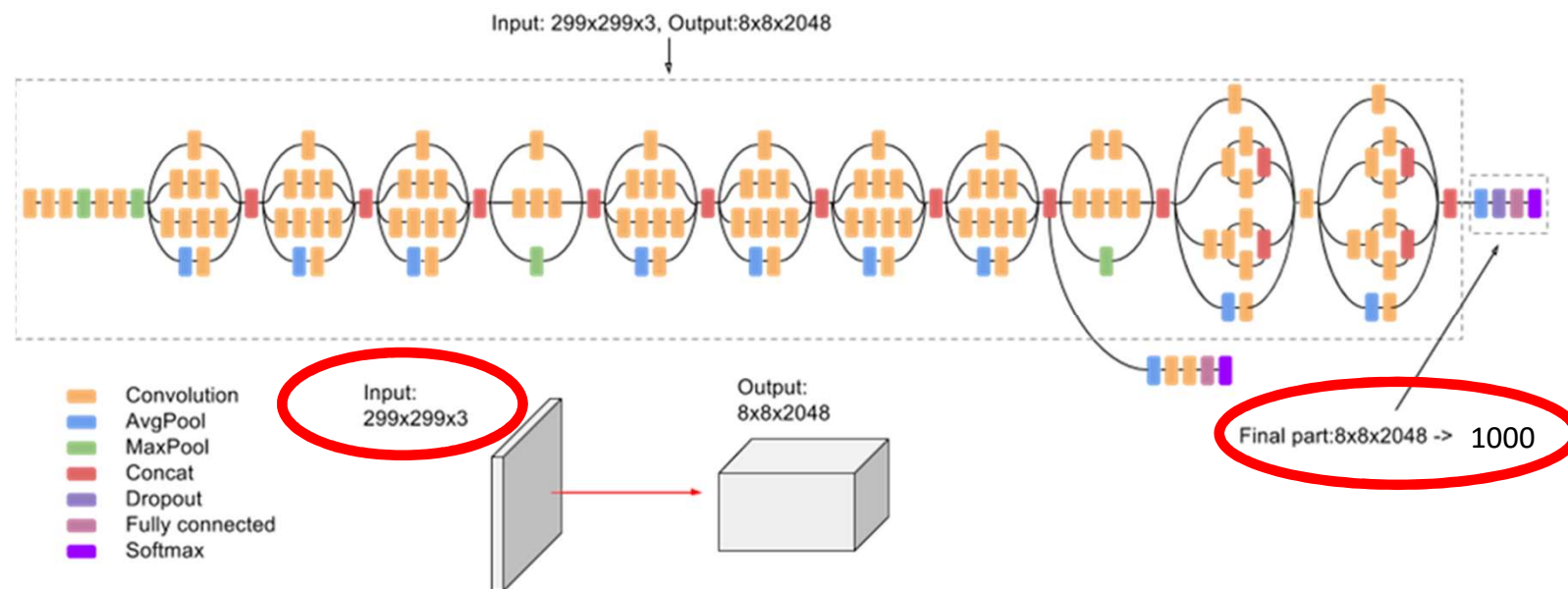
1	2	3
4	5	6
7	8	9



1		2		3				
		4		5		6		
				7		8		9

Inception V3 model

- Deep learning model based on Convolutional Neural Networks
- Used for image classification
- Released in year 2015
- It has 42 layers

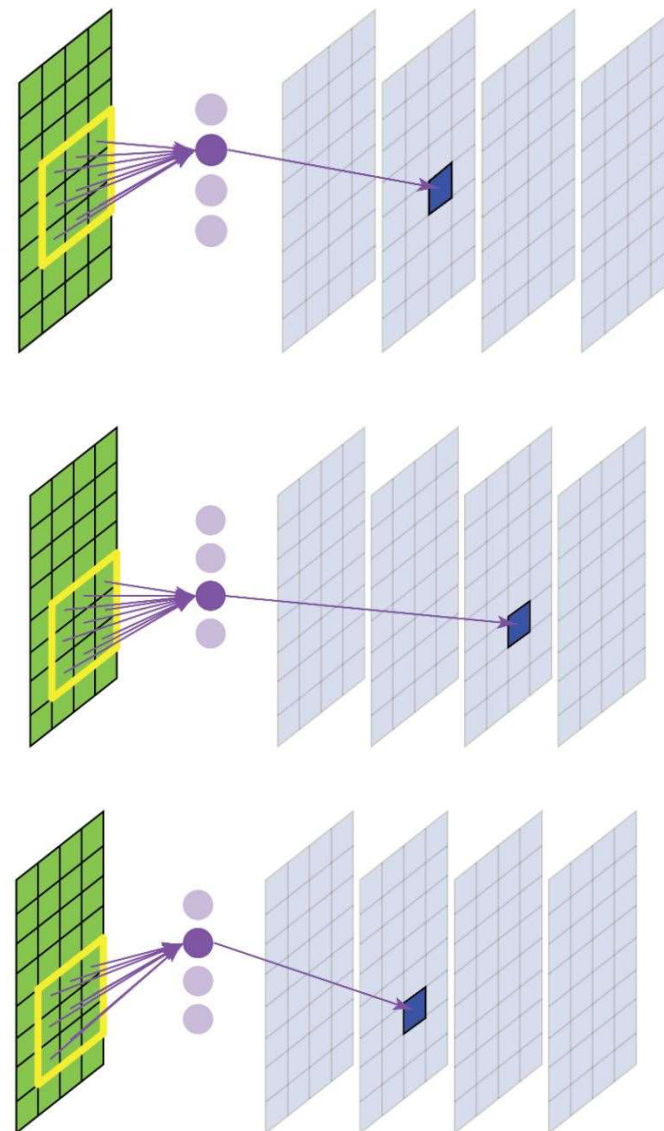
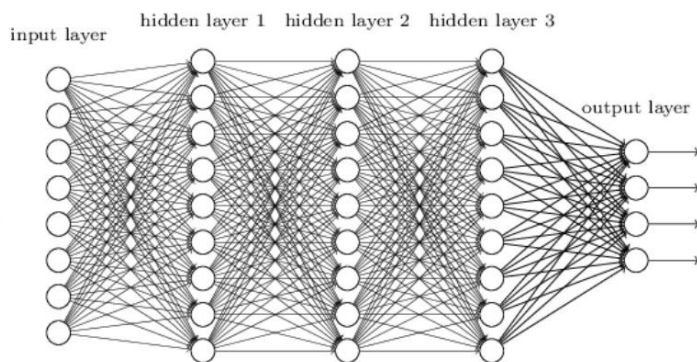
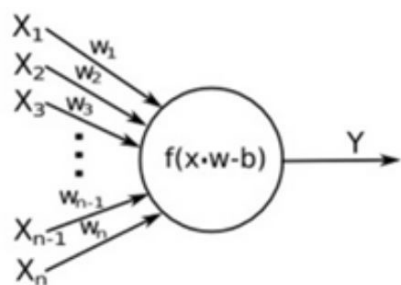


Overview of the notebook

Tutorial IV (1)

- 1) Load necessary **libraries** (common libraries and personal modules)
- 2) Images
- 3) **Convolutions**

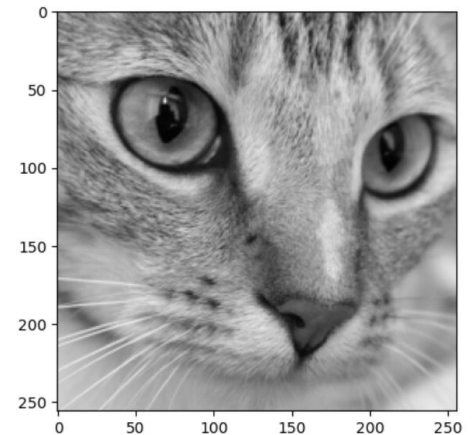
Perceptron



Tutorial IV (2)

- Pre-processing of the image

- Gray-scale, cropping, float conversion, normalization
- Add dimensions (batch, channel, height, width) (in `get_convolved`)
- Convert Numpy to pytorch (in `get_convolved`)



- Define the convolution

- Forward model (`class Model`)
- Apply 4 convolutions one after each other (inside `class Model`, call `conv_2d` function)

- Define the filter

- Identity filter
- Convert to `np.array` (in `get_convolved`)
- Add dimensions
- Convert Numpy to pytorch

```
flt_mtx = [  
    [ 0, 0, 0, 0, 0,],  
    [ 0, 0, 0, 0, 0,],  
    [ 0, 0, 1, 0, 0,],  
    [ 0, 0, 0, 0, 0,],  
    [ 0, 0, 0, 0, 0,],  
] # identity transformation
```


Tutorial IV (3)

- Use it ! (`ims_convolved = get_convolved(img_raw, flt_mtx)`)
 - You get back 5 figures

- Exercise :

1. experiment with different filters and understand what they do, e.g.:

- identity transformation
- identity transformation with positive non-unit values
- identity transformation with negative unit value
- identity transformation off center
- blurring with box filter
- edge detection with + and - bands
- try whatever you like

2. experiment with convolution parameters:

- padding = 1, 2, 3
- stride = 2
- dilation = 2

0	0	0	0	0
0	0	0	0	0
0	0	30	0	0
0	0	0	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	-1	0	0
0	0	0	0	0
0	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

0	-1	1	0	0
0	-1	1	0	0
0	-1	1	0	0
0	-1	1	0	0
0	-1	1	0	0

Tutorial IV (4)

filter type	effect
gaussian	blurring
first derivative of gaussian	detection of edges
second derivative of gaussian	detection of peaks

- **Most common filters**

- Define 1D functions
- Create 2D filters by repeating the 1D filters along axis 0 (`np.tile`)
- Multiply by `transpose()` to get the horizontal dimension (filter size does not change)
- Use them ! (`ims_convolved = get_convolved(img_raw, flt_mtx)`)

4) Homework (leave it for now)

Tutorial IV (5)

5) Load a pretrained model (inception V3) from torchhub

6) Test the model

- Preprocessing of the image (cropping, shuffle sizes, totensor, normalize adds batch size) → [1,3,299,299]
- Deactivate the gradient (eval mode)
- Get the logits (1000 values), then the probabilities (applying softmax)
- Print out the 5 most probable classes
- Do the same with 100 classes

Tutorial V : Transfer Learning

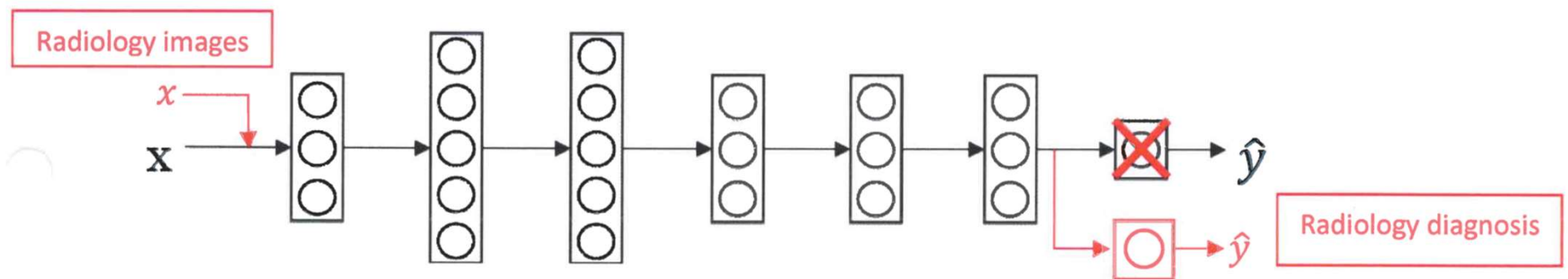
Introduction

- **Goal** : use the Inception model to classify images of different nature, learn how to save a model
- **Program** : inverted classroom style
 - Theory
 - Overview to get the big picture of the notebook
 - Work alone ()
 - Work in groups of 4 (45 minutes, then 2 minute presentation)
- **Technical** : Google Colab, Pytorch

Theory

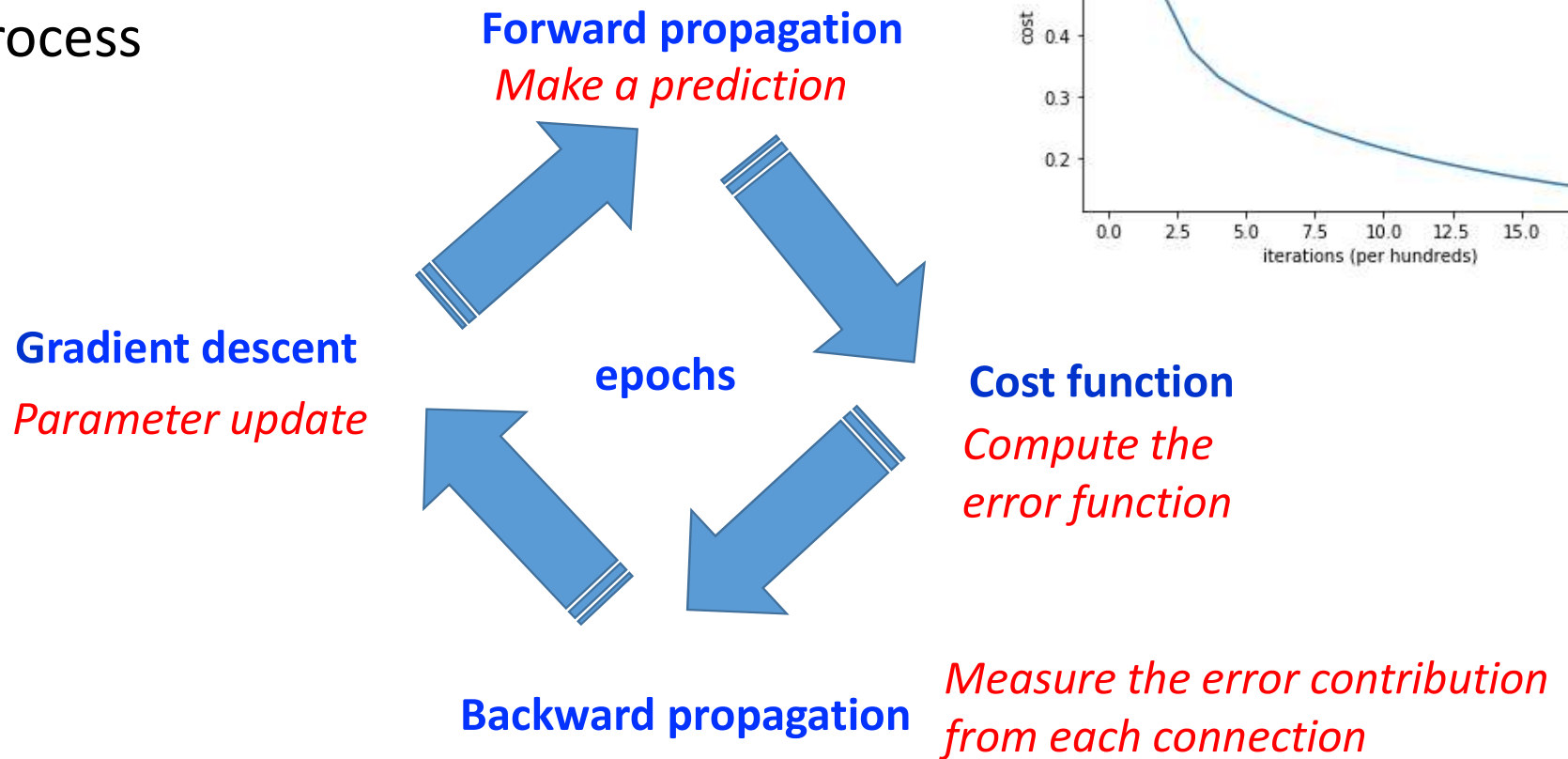
Transfer Learning

- Try to find an existing neural network that accomplishes a **similar task** to the one you are trying to tackle
- reuse the lower layers of this network
 - Output layer should usually be replaced
- **Speeds up** training and requires much fewer training data

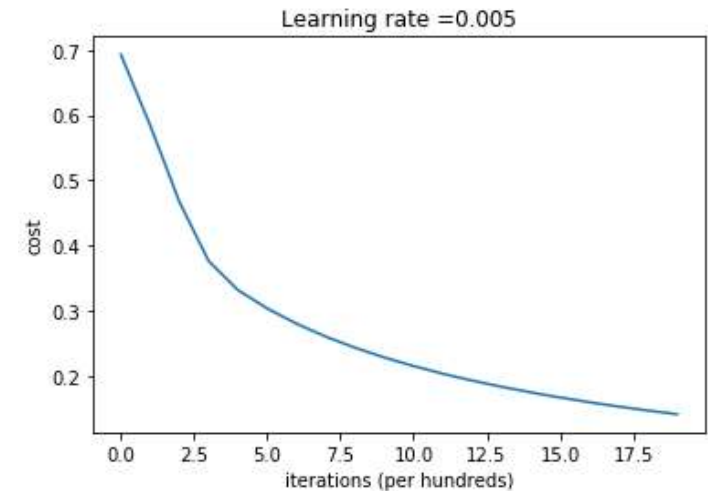


Training Loop

- *Iterative* process

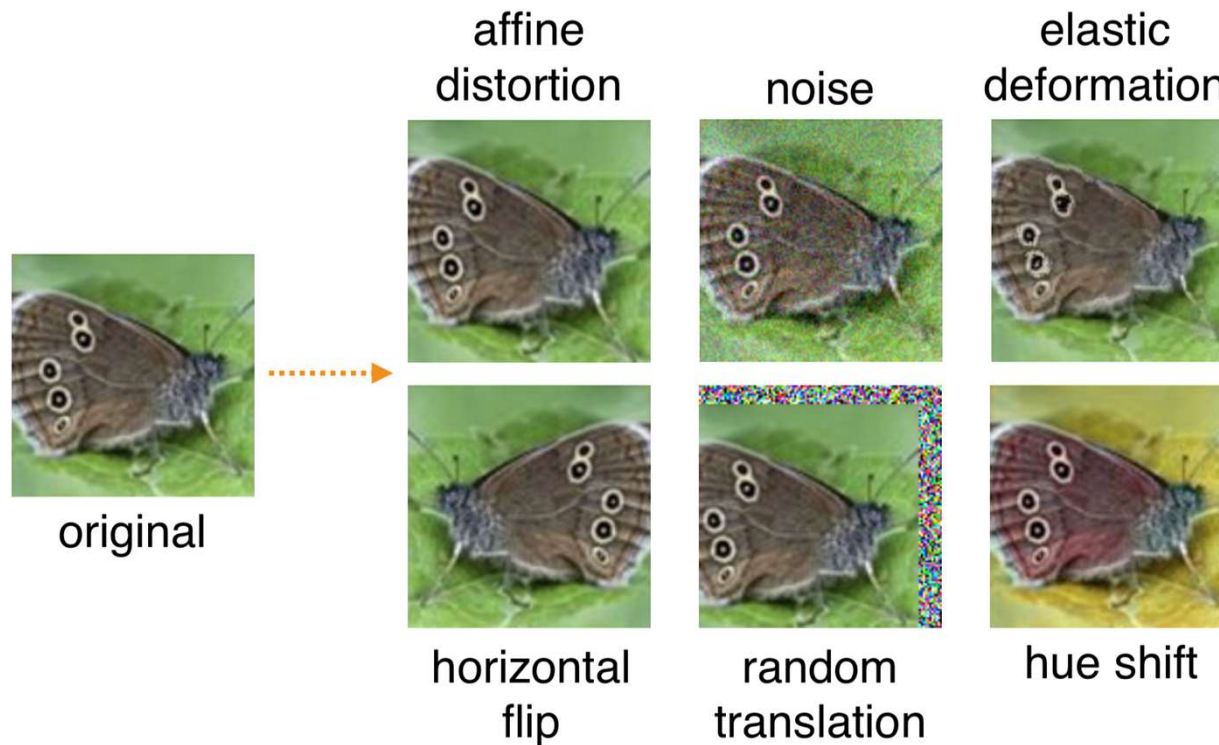


Learning curve



Dataset Augmentation

- Apply **realistic transformations** to data to create new synthetic samples, with same label



Overview of the notebook

Tutorial V (1)

1) Load necessary **libraries** (common libraries and personal modules)

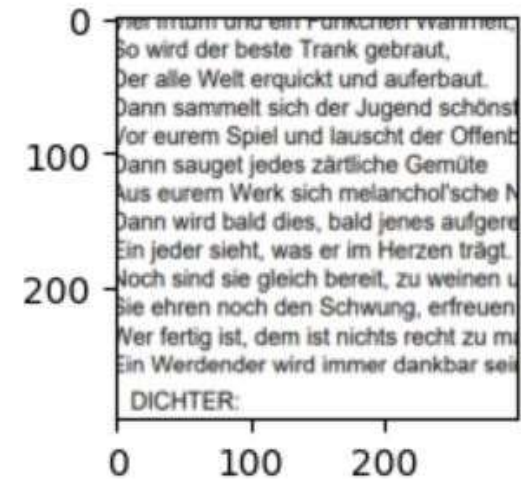
2) Transfer Learning

- Load the **inception model** (**base_model**)
- Build **new model** using the **base_model** (**model**)
 - Define a head function (in_features, n_classes=2) : use of sigmoid
- **Optimization** : define the loss function (**criterion**) and the optimizer
- **Helper functions** to get the prediction (**get_predictions**) and to compute the batch accuracy (**calculate_accuracy_batch**)

Tutorial V (2)

3) Dataset

- Images :
 - Get them from ML3 folder
 - Preprocessing using `transforms.Compose (resize, tensor, normalize)`
 - Shape `[3,299,299]`
 - Transform to numpy array for display (`im_numpy`)
- Labels
- Split dataset into train/test samples
 - `Torch.utils.data.random_split`
 - `Train_test_split` with `stratify` enabled from scikit-learn
- Create data loaders for training/val (beware shuffle param)
- Example : batch of 10 images, plot them, print logits and output classes (`res`)



Tutorial V (3)

4) Training

- **Train_model** function
 - Contains the loop on **epochs**
 - Calls the **train** and **validate** functions (beware the params)
 - Save **history** (loss, accuracy) and model for a given epoch
- **Train function** : reset gradients, compute logits and loss, compute gradients (backward prop), update parameters, calculate accuracy of the batch (helper functions), returns train loss and train accuracy
- **Validate function**: structure BUT (no optimizer, no backward, no update of the params), returns test loss and test accuracy
- **Plot_history** function
- Run it ! **history = train_model(...)** using 70 epochs

Tutorial V (4)

5) Load trained variables from checkpoint

- Choose epochs values
- Load corresponding models
- Call validate function to get the validation loss and validation accuracy (see how it evolves)

6) Save final model for inference

7) Inference :

- Load the model, eval() mode
- Get an image, preprocess (convert to tensor, add batch dimension)
- Get the logits and associated class

Tutorial V (4)

8) Improve the results : data augmentation

- Load images from **ML3** folder
- Preprocess (**resize**, **Randomcrop**, **tensor**, **normalize**)
- Convert to Numpy for plotting purposes (**im_numpy**)
- The rest of the code is similar to previous code

9) Exercise (groups of 4) (35 min), 2min presentation

Tutorial VI : Transfer Learning

Introduction

- **Goal** : use Recurrent Neural Networks to predict and generate text sequence
- **Program** : inverted classroom style
 - Theory
 - Overview to get the big picture of the notebook
 - Work alone
 - Work in groups of 4
- **Technical** : Google Colab, Pytorch

Theory

Overview of the notebook

Tutorial VI (1)

1) Load necessary **libraries** (common libraries and personal modules)

2) Text data

- Read the data (**rnn.txt**), print the first 100 words

3) Build the **dataset**

- 2 dictionaries : word → id (**dictionary**) and id → word (**reverse_dictionary**)
 - Build_dictionaries function
- Vocabulary size = 493 (0=most common word)
- Helper functions to get sequences of int or words (**text_to_ints**, **ints_to_text**)
- Print example : first 100 words (or int), length of input data=2118 (words_as_int)

Tutorial VI (2)

4) Data streaming

- Create dataset using **WordDataSet** class to create blocks of text
 - Block length = $n_input + 1 = 3 + 1 = 4$
- Create **DataLoader** with **batch size=50**, **preprocess** data (separate input and target sequences, **stack** data and convert Numpy → **tensors**, put them to **GPU**)
 - Length of dataset = Number of blocks in sequence = $\text{Total length} / \text{Block length} = 2118 / 4 = 529$
- Example : print the 50 samples that are in the 1st batch

Back-up slides

- https://www.tensorflow.org/api_docs/python/tf/keras/applications