Numpy Tutorial

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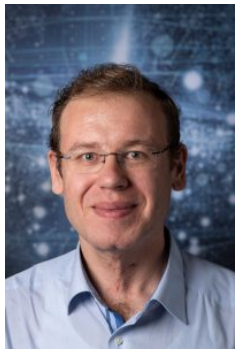
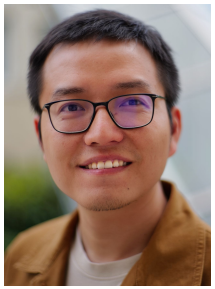
Pattern Recognition Lab, Friedrich-Alexander University of Erlangen-Nürnberg

October 1, 2024

Who are we? - Lab Members



Andreas
Maier



Chang
Liu

Alexander
Barnhill

Zijin
Yang

Leonhard
Rist

Merlin
Nau

Noah
Maul

Mathias
Zinnen

Who are we? - Student Tutors

Lukas
Hüttner

Majid
Sharghi

Mohannad
Barakat

Christian
Wielenberg

Haiting
Huang

Julian
Greil

Thakkar
Rahul
Jayantilal

Mohapatra
Maitreya

Organisation

Contact us ...

- in StudOn
- via the tutors mailing list: `cs5-deep-tutors@lists.fau.de`
- in MS Teams

Important: Don't hesitate to ask questions/give comments!

Online teaching

- Exercise will be completely online
- **Follow the Guide in StudOn**
  - You can also find all information under Organisational_concepts in StudOn homepage
- We will use MS Teams
  - Team activation in IDM required!
  - "General" channel for general questions and comments
  - "Private" channel for each exercise day
  - Direct support during exercise hours can be requested in resp. channel

Important: Feedback and suggestions are most welcome!

Semester plan

- Five exercises:
  0. Python + Numpy Recap and Data Generation
  1. Fully Connected Networks
  2. CNNs and Optimization
  3. Regularization and Recurrent Neural Networks
  4. Image Classification with PyTorch
- Platform: MS Teams

Semester plan

- Five exercises:
  0. Python + Numpy Recap and Data Generation
  1. Fully Connected Networks
  2. CNNs and Optimization
  3. Regularization and Recurrent Neural Networks
  4. Image Classification with PyTorch
- Platform: MS Teams
- Materials available in StudOn
- Each exercise takes 2-4 weeks $\rightarrow$ start early, submit early
- Bonus points for exam up to 10% (6 points). Unittests coverage determines your bonus points.
- Written exam (mock exam available in StudOn)

Submission

- Group submission possible - pairs of two
  → “Finding Group Partners" channel in **MS Teams**
- Personal submission only (max group of 2 people)
- **Required to get the bonus points**
- We prioritize the requests, have a look into our online course guide at StudOn
  → Organisational_concepts/03 – MS Teams
- Mind the deadlines !!!
  → please use the provided script (*dispatch.py*) to prepare your upload
- Upload your code to StudOn
- Explain your code (next week after uploading) (screen sharing)

No Plagiarism!

- One plagiarized case result in no bonus points for all exercises!
- We will check that with plagiarism software!
- Using code generated by ChatGPT can result in substantial overlap with other groups
- If you don't code yourself, you won't learn!

Verteilung - Exercise 4: AlexNet and ResNet in TF / AlexNet and ResNet

90% - 100%	1	#
80% - 90%	2	#
70% - 80%	13	##
60% - 70%	61	##########
50% - 60%	172	##############################
40% - 50%	245	##
30% - 40%	421	##
20% - 30%	314	##
10% - 20%	46	########
0% - 10%	0	.

Gruppierte Übereinstimmungen (90% - 100%)

[redacted]	[redacted]	97,23%

Exercise Setup

First part:

Build a neural network from scratch using test based development

- Implementation task is defined by **description** and **unit tests**
- No skeletons
- Every function and structure is built as a layer
  $\rightarrow$ As a class in its own file
  $\rightarrow$ Mandatory functions **__init__()**, **forward()**, **backward()**
- Unit tests help to expose bugs and errors
  $\rightarrow$ Tested and debugged with python3

Second part:

Build some common neural networks with PyTorch

- Some functionality provided
- No exhaustive unit tests

PyTorch

Schedule

Date	Event
21.10.2024	Handout all exercises
08.11.2024	Deadline Ex.0
22.11.2024	Deadline Ex.1
13.12.2024	Deadline Ex.2
19.01.2025	Deadline Ex.3
09.02.2025	Deadline Ex.4

A detailed time table could be found in StudOn with lecture suggestions

$\rightarrow$ Organisational_concepts/05 – Time table

- These deadlines are for code uploading. You have until the end of next week of each deadline to present your code

Bonus Points System

- Exercises contribute to max. 10% of bonus for the final exam
- Unittest coverage corresponds to bonus points
  → Each exercise consists of several TestCases
  → TestCases subdivide the bonus points
  → Each TestCase consist of several unittests
  → **All** unittests of one TestCase must pass to get the respective bonus
- The percentages correlate to effort and difficulty → but also the small bonuses add up
- The unittest files can compute the points for you → have a look in the description
- Be aware, some TestCases depend on others
  → It's impossible to test a neural network without having its layers first
- You only get the bonus if you submit in time! **Mind the deadlines!**

Bonus Points - Ex0

- Ex0 (1% in exam = 0.6 point from 60 points)
  - (10%) TestCircle
  - (10%) TestSpectrum
  - (10%) TestChecker
  - (70%) TestGen
- Percentage next to Ex0 represents the bonus points in the exam (here 1%)
- E.g., TestCircle contributes with 10% to the 1% (resulting in 0.1% for the exam)
- TestGen seems important with 70% and hence causes the most effort
- TestGen contains also more unittests than the others.

Bonus Points Distribution

- Ex1 (1.5% in exam = 0.9 point from 60 points)
  - (45%) TestFullyConnected1
  - (5%) TestReLU
  - (10%) TestSoftMax
  - (10%) TestCrossEntropy
  - (5%) TestOptimizers1
  - (25%) TestNeuralNetwork1 [1]
- Ex2 (3% in exam = 1.8 point from 60 points)
  - (45%) TestConv [2,3,4]
  - (15%) TestPooling [3]
  - (2%) TestFlatten
  - (5%) TestInitialization
  - (8%) TestOptimizers2 [0]
  - (2%) TestFullyConnected2 [0]
  - (23%) TestNeuralNetwork2 [0, 1]

Bonus Points Distribution

- Ex0 (1% in exam = 0.6 point from 60 points)
- Ex1 (1.5% in exam = 0.9 point from 60 points)
- Ex2 (3% in exam = 1.8 point from 60 points)
- Ex3 (3% in exam = 1.8 point from 60 points)
  - (2.5%) TestSigmoid
  - (2.5%) TestTanH
  - (5%) TestConstraints [2, 5]
  - (5%) TestDropout
  - (25%) TestBatchNorm [2, 3, 4, 6]
  - (40%) TestRNN [2, 4, 6]
  - (20%) TestNeuralNetwork3 [0, 1]
- Ex4 (1.5% in exam = 0.9 point from 60 points)
  - All Tests + Leaderboard f1 mean 0.6

Bonus Points Table

```
OK
..........
----------------------------------------------------------------------
Ran 10 tests in 6.853s

OK
========================== Statistics ==============================
| Pos   | Test            | Result   | Percent in Exercise   | Percent in Exam   |
|-------|-----------------|----------|-----------------------|-------------------|
| 0     | TestCheckers    | OK       | 10 / 10 (%)           | 0.100 / 10 (%)    |
| 1     | TestCircle      | OK       | 10 / 10 (%)           | 0.100 / 10 (%)    |
| 2     | TestSpectrum    | OK       | 10 / 10 (%)           | 0.100 / 10 (%)    |
| 3     | TestGen         | OK       | 70 / 70 (%)           | 0.700 / 10 (%)    |
|       |                 |          |                       |                   |
| Ex0   | Total Achieved  |          | 100 / 100 (%)         | 1.000 / 10 (%)    |
```

Example of bonus table for ex0. Tutors will assign your bonus points base on this table. See Description.pdf how to run this table.

Bonus Points - Dependencies

- [0] requires its predecessor (e.g. TestOptimizers1 requires TestOptimizers1)
- [1] requires all tests of current exercise
- [2] requires TestOptimizers1
- [3] requires TestFlatten
- [4] requires TestInitialization
- [5] requires TestOptimizers2
- [6] requires TestFullyConnected1

Bonus Points - Recommendation

Our recommmendation:

Do them all! Why?

1. You do not get confused by dependencies (it's easier to keep an overview if you do them all)

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4. We will cover content for the exam - thus highly relevant!

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4. We will cover content for the exam - thus highly relevant!
5. Perform way better in the exam

Bonus Points - Recommendation (cont.)

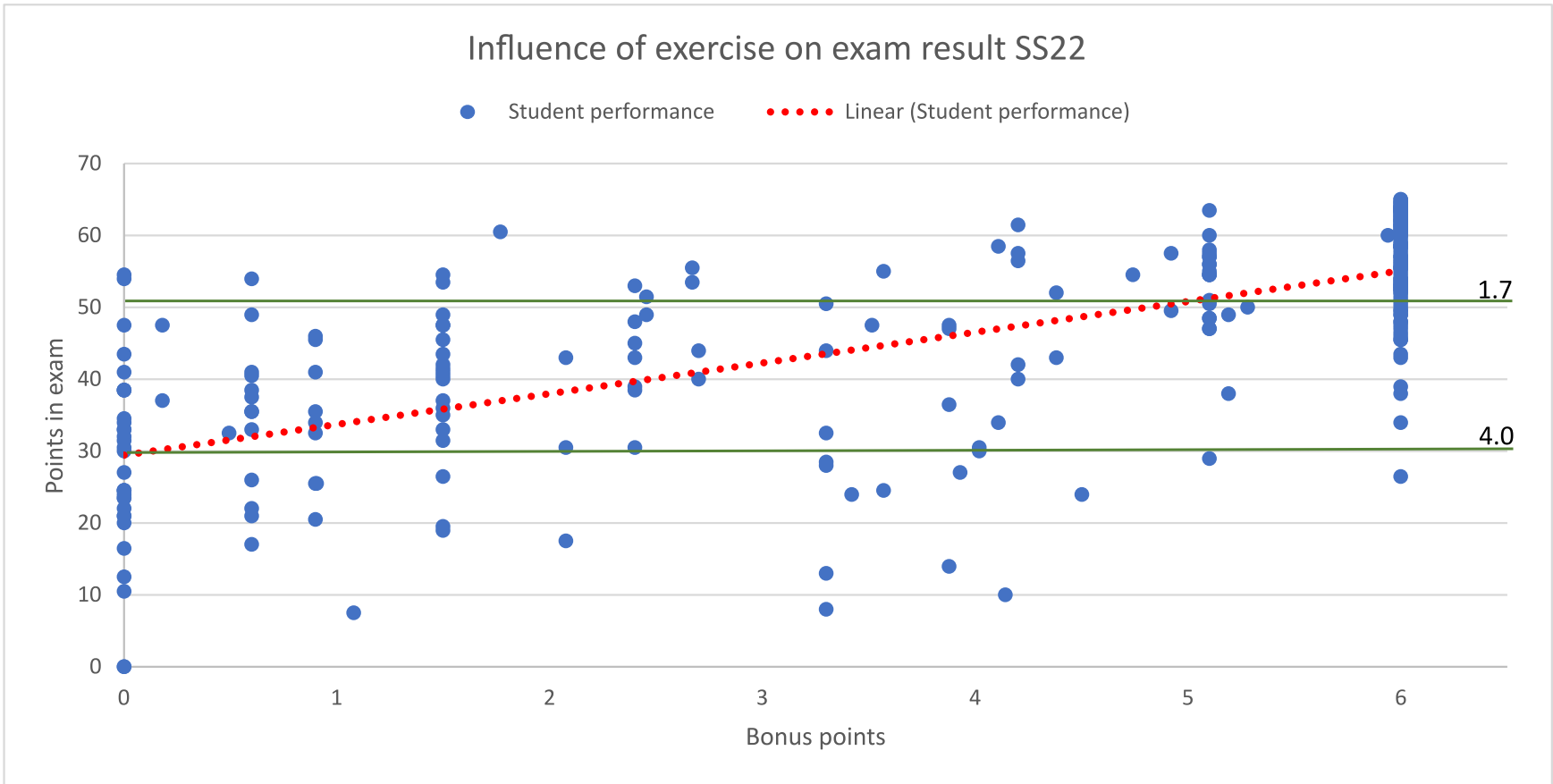

Figure: performance of 267 students from SS22. Students who completed all exercises perform much better than students who haven't completed the exercises

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SCHOOL OF ENGINEERING

Python Overview

About Python...

- Programming language with good readability
- Interpreted scripting language
  $\rightarrow$ Relies on the call of libraries written in lower-level programming languages
  $\rightarrow$ Basic programming semantics exist but are very inefficient
- Huge amount of libraries for all sorts of applications

About Numpy...

- Essential python package
- Central object: Numpy array
  $\rightarrow$ Acts like a matrix/vector
  $\rightarrow$ Enables all sorts of mathematical operations
  $\rightarrow$ Optimised for speed
- A cheat sheet with handy functions for this exercise can be found in the StudOn group

About Scipy...

- Python package closely linked to numpy
- Provides additional functionality
  $\rightarrow$ Signal processing
  $\rightarrow$ Statistical operations

Recommendations

Package Manager (not needed in CIPs)

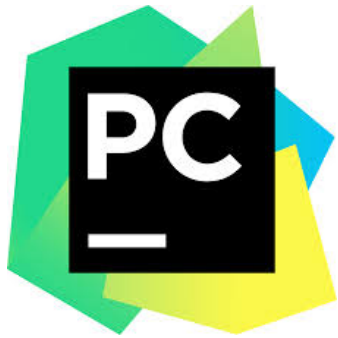
We recommend **Anaconda** (Windows)

- Open source
- One click installation
- Also installs python
- Easy handling of virtual environments

IDE

We recommend **PyCharm**

- Open source
- Easy package handling
- Debugging possibilities
- Free licenses for professional version for students



One alternative: Visual Studio Code with Live Share Plugin (allows remote pair programming)

Version Control

We recommend using GitLab!

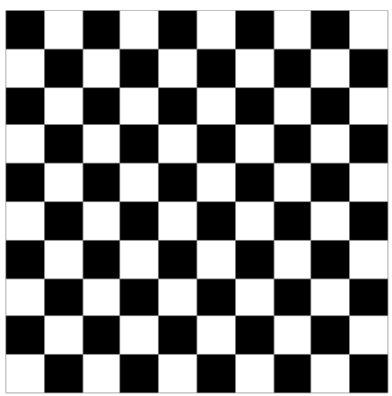
- Please use the university's gitlab server: https://gitlab.cs.fau.de/
- Perfect for co-working
- Compare your code with old versions
- Please use **private projects**! You can add your study partner as additional developer.

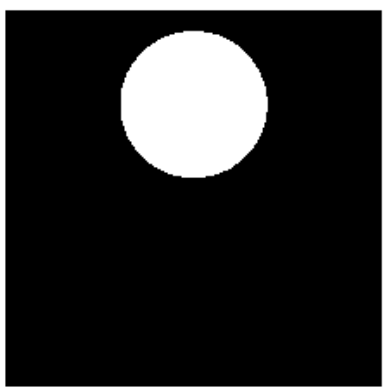
Today's Exercise

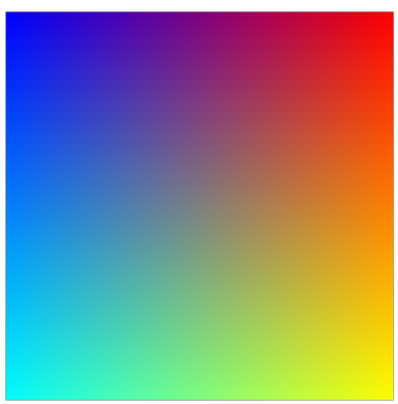
1st Task

Use basic numpy functions to create

- A binary checkerboard pattern
- A binary circle
- An RGB color spectrum







2nd Task

Often it is not possible or desired to train your neural network on the whole data set at once. $\rightarrow$ Divide your data into smaller portions.
Use numpy to implement an image generator class which also enables data augmentation.

- The generator yields so called batches (subsets of the training data) in an iterative manner.
- Batch in this context means a set of images, which are returned at once (by calling "next").
- These batches of images must be returned together with their corresponding labels.
- It returns batches until no training samples are left. One pass through the whole data set is also known as one epoch.

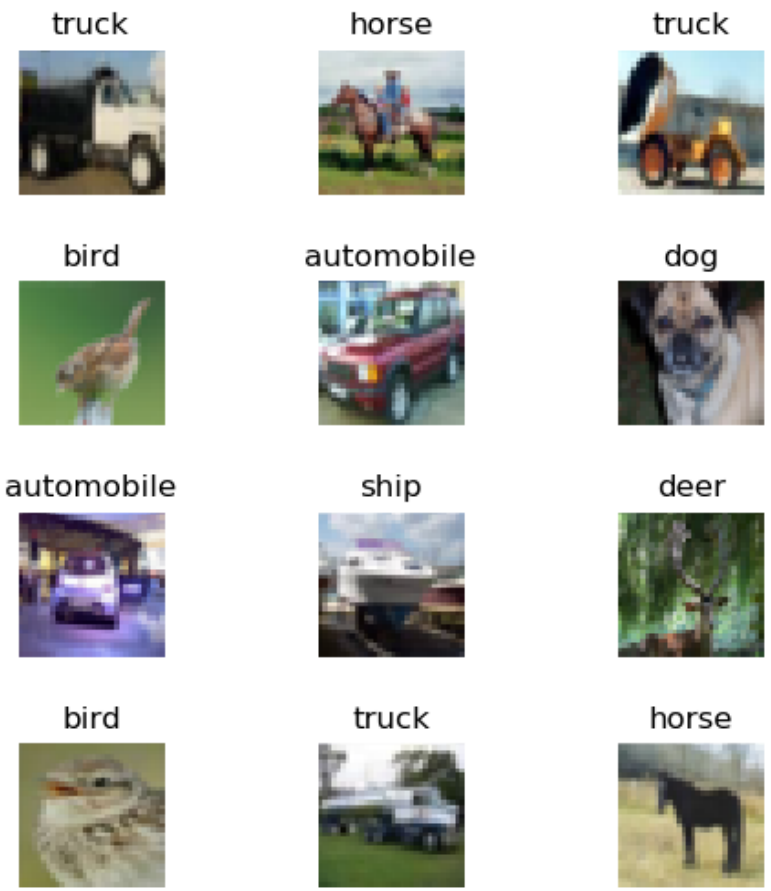


Figure: Example image generator output.

Get Started

- Open the IDE of your choice
- If you want to use PyCharm in the CIP:
  type **module load pycharm-community** into the console and open it by typing **pycharm**
- Follow the instructions of the exercise sheet
- Implement the tasks

Thanks for listening.

Any questions?