Hands-on Deep Learning for Computer Vision and Biomedicine

Practical Course
Winter Semester 2017/2018

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Learning Goals

- Theory & Practice:
  - Basics, machine learning, deep learning
  - Standard architectures (e.g. convolutional networks)
  - Standard applications (e.g. supervised learning)
  - Advanced architectures, advanced applications
- Deep learning craftsmanship
  - Understanding real data and practical problems, finding solutions
  - Designing architectures, choosing/designing loss functions
  - Designing the training procedures
  - Tuning hyperparameters
  - Evaluating and understanding results, iterating, drawing conclusions
- Practical project experience with real-world open problems
  - The projects are geared towards scientific publications
- Presentation skills

Structure of Practical Course

- Three lectures in the beginning of the semester (Tuesday 2-4pm)
- Practical project
  - Own project for each group
  - 1 or 2 students per group
  - Most projects: Python, NumPy, deep learning frameworks
  - You will get access to computers and GPUs in Garching and remotely
  - Deep learning requires early and regular attention
  - Regular discussions with supervisors (important for progress of learning and project success)
- Final presentations
  - Introduction, Methods, Results, Conclusions
  - 20min presentation + 10min Q&A
  - Groups can learn from each other and discuss
  - Presentation dates will be determined by voting (end of semester)

Next Steps

- 14-19 July: Apply for a place at https://matching.in.tum.de/
- There are many applicants
- Sending info about yourself is crucial to get matched and to get assigned a project with appropriate difficulty
- Email us info until 21 July, e.g.:
  - Your programming skills
  - Some code you wrote in any context
  - Your interests, learning goals
  - Your courses, grades
- If you require project info in advance, contact us
- If you want to propose own projects ideas, they should be discussed with us until 21 July
- Places in the course will be assigned on 26 July

After 26 July

- If you get a place in matching system, you have two options:
  - Either form a group of two and submit project preferences together
  - Or submit your individual project preferences, and whether you have a preference for being assigned a partner, or working on your own, or both is fine
- Projects will be announced, discussed and assigned as soon as possible
- Example of project preferences that a student or group sends us:
  1. Project “C” (most preferred)
  2. Project “T” or “U”
  3. Project “A”
  4. Project “G”
- We will consider your preferences, and also our knowledge about which of your preferred projects match your programming skills

Other Options

- Also consider applying for:
  - Bachelor Thesis
  - Master Thesis
  - Interdisciplinary Project
  - Guided Research

- If you don’t get a place in the practical course:
  - Email us, enter the waiting list
  - Apply in subsequent semesters
  - Apply for Thesis, Interdisciplinary Project, Guided Research

Prerequisites

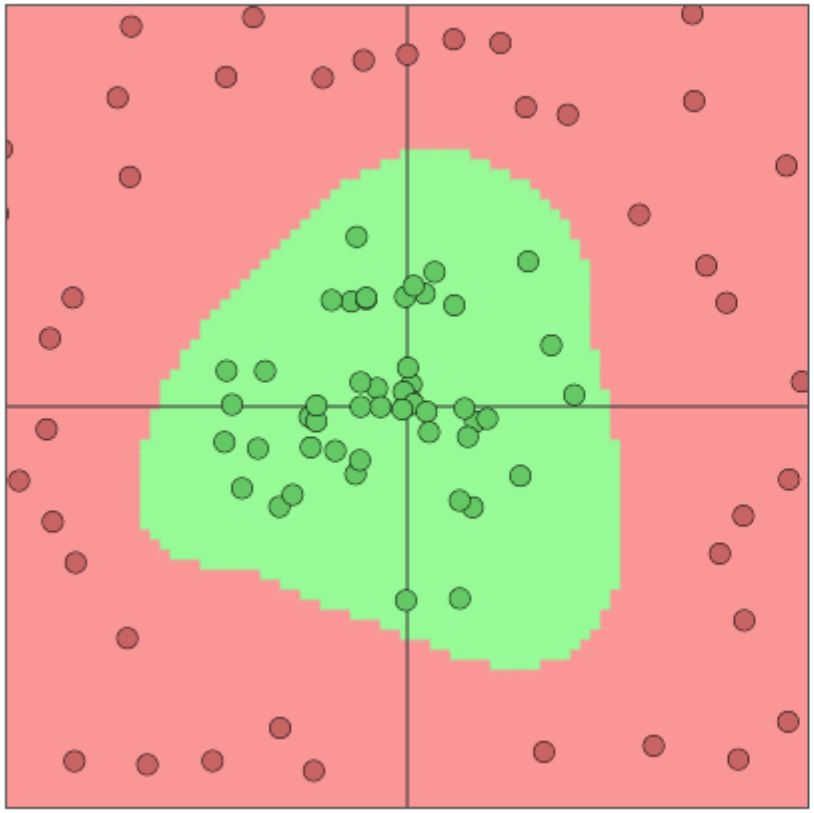
- Good programming skills
  - Python
  - Array programming in NumPy (or Matlab or similar)
- Curiosity
- Time for regular hard work

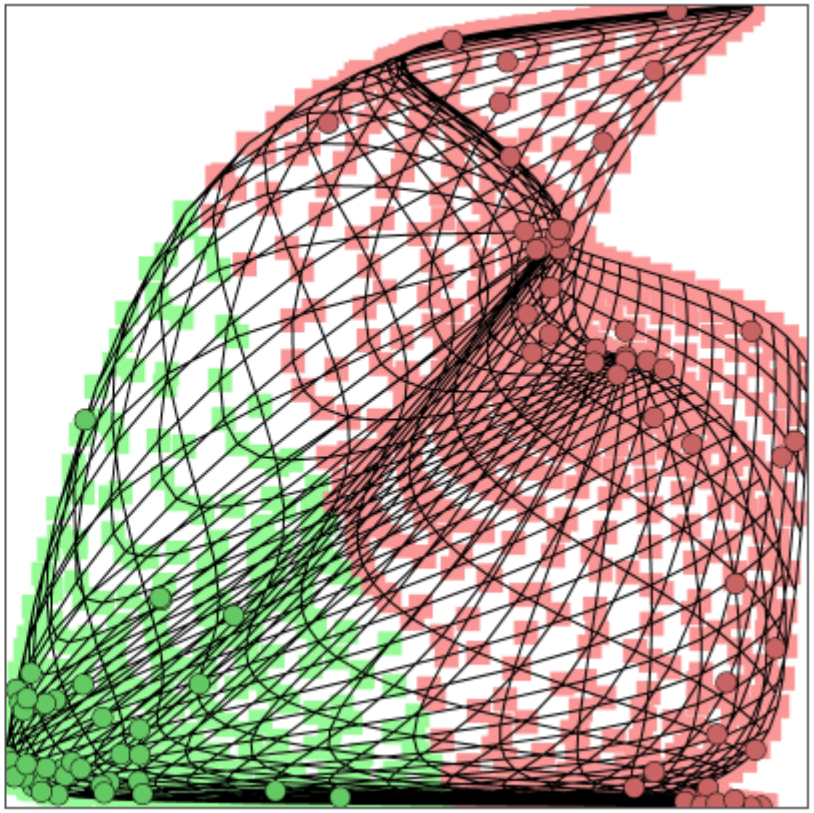
- Prior knowledge (deep learning, computer vision, biomedicine) is **not** required
  - You will learn from your supervisors
- But good programming skills are important

Literature

- Christopher M. Bishop: “Pattern Recognition and Machine Learning”, Springer, 2006.
- http://www.deeplearningbook.org/
- http://neuralnetworksanddeeplearning.com/
- NumPy: Advanced Array Indexing
  https://docs.scipy.org/doc/numpy/reference/arrays.indexing.html

Nonlinear Coordinate Transformation

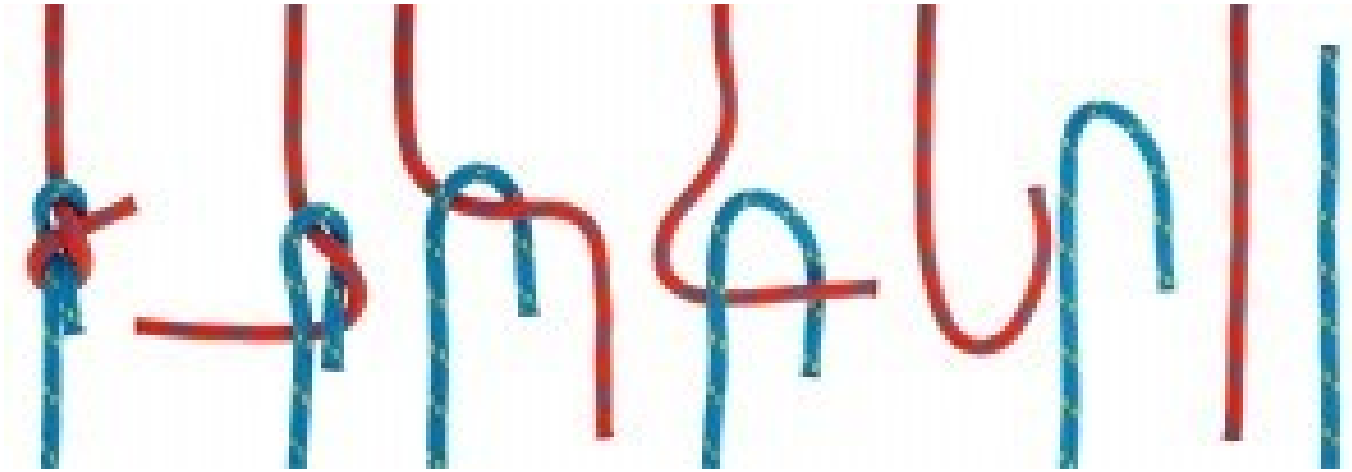




http://cs.stanford.edu/people/karpathy/convnetjs/

Dimensionality may change! (Here: 2D to 2D)

Deep Neural Network: Sequence of Many Simple Nonlinear Coordinate Transformations that "disentangle" the data (by transforming the entire coordinate system)



Data is sparse (almost lower-dimensional)

Linear separation of red and blue classes

Fully-Connected Layer a.k.a. Dense Layer

$x^{(0)}$ is input feature vector for neural network (one sample).

$x^{(L)}$ is output vector of neural network with L layers.

Layer number l has:

- Inputs (usually $x^{(l-1)}$, i.e. outputs of layer number $l-1$)
- Weight matrix $W^{(l)}$, bias vector $b^{(l)}$ - both trained (e.g. with stochastic gradient descent) such that network output $x^{(L)}$ for the training samples minimizes some objective (loss)
- Nonlinearity s_l (fixed in advance, for example $\mathrm{ReLU}(z) \coloneqq \max\{0, z\}$)
- Output $x^{(l)}$ of layer l

Transformation from $x^{(l-1)}$ to $x^{(l)}$ performed by layer l:

$$x^{(l)} = s_l\left(W^{(l)}x^{(l-1)} + b^{(l)}\right)$$

One Layer: Graphical Representation

$$W^{(l)} = \begin{pmatrix} 0 & 0.1 & -1 \\ -0.2 & 0 & 1 \end{pmatrix}$$

$$x^{(l-1)} = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$$

$$b^{(l)} = \begin{pmatrix} 0 \\ 1.2 \end{pmatrix}$$

$$W^{(l)}x^{(l-1)} + b^{(l)} =$$

$$= \begin{pmatrix} 0 \cdot 1 + 0.1 \cdot 2 - 1 \cdot 3 + 0 \\ -0.2 \cdot 1 + 0 \cdot 2 + 1 \cdot 3 + 1.2 \end{pmatrix}$$

$$= \begin{pmatrix} -2.8 \\ 4 \end{pmatrix}$$