Deep Learning DM873
Exam notes

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IMADA

June 26, 2019

Contents

Part I

Formal course description

Aim

Machine learning has become a part in our everydays life, from simple product recommendations to personal electronic assistant to self-driving cars. More recently, through the advent of potent hardware and cheap computational power, “Deep Learning” has become a popular and powerful tool for learning from complex, large-scale data. In this course, we will discuss the fundamentals of deep learning and its application to various different fields. We will learn about the power but also the limitations of these deep neural networks. At the end of the course, the students will have significant familiarity with the subject and will be able to apply the learned techniques to a broad range of different fields.

The course builds partly on the knowledge acquired in the course DM555 but can be taken by any Computer Science or Computational BioMedicine Master student.

In relation to the competence profile of the degree it is the explicit focus of the course to:

- giving the competence to plan and execute a deep learning task by means of deep neural networks.
- providing knowledge on the different types of deep learning approaches including their advantages and disadvantages.
- transfer learned methods to new fields of applications.
- challenges the student with real-life datasets and problem-solving skills

Statement of aims

- The learning objectives of the course is that the student demonstrates the ability to:
- Describe the principles of deep neural networks in a scientific and precise language and notation
- Analyze the various types of neural networks, the different layers and their interplay
- Describe the feasibility of deep learning approaches to concrete problems
- Understand the theoretical mathematical foundations of the field
- Apply deep learning frameworks for solving concrete problems

Pensum

- All lecture slides are relevant for the exams.
- All readings noted in the lecture list are relevant for the exam.
- Ian Goodfellow, Yoshua Bengio, Aaron Courville - The Deep Learning Book
- Gareth James, Daniela Witten, Trevor Hastie - Robert Tibshirani An Introduction to Statistical Learning (ISL)

Part II

Exam topics

Exam Form

The exam will last about 15-20 minutes. At the beginning, one topic from the list below will be drawn randomly. For each topic the examinee should be prepared to make a short presentation of 5 minutes. It is allowed to bring one page of hand-written notes (DIN A4 or US-Letter, one-sided) for each of the topics. The examinee will have 2 minutes to briefly study the notes for the drawn topic before the presentation. The notes may be consulted during the presentation if needed but it will negatively influence the evaluation of the examinee's performance. During the presentation, only the blackboard can be used (you cannot use overhead transparencies, for instance).

After the short presentation, additional question about the presentation's topic but also about other topics in the curriculum will be asked.

Below is the list of possible topics and some suggested content. The listed content are only suggestions and is not necessarily complete nor must everything be covered in the short presentation. It is the responsibility of the examinee to gather and select among all relevant information for each topic from the course material. On the course website you can find suggested readings for each of these topics.

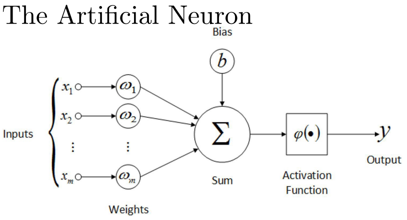
Feed-Forward Networks

introduction

A feed foreward is the oldest and simplest network we have, it only supports feeding information in one direction (forward) eg we can't have loops.

Function Principle

The Artificial Neuron



Network build up Layers of neurons,

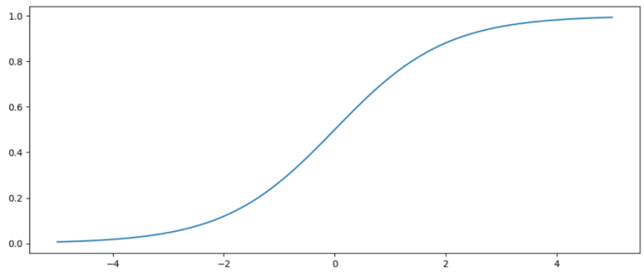
Output Units

Sigmoid

The sigmoid function is a binary type of output unit, which also means it can only product of a binary variable,and can only predict the Bernoulli distribution. it is of the form

$$\sigma(x) = \frac{1}{1 + exp(-x)} \tag{1}$$

The activation function for the sigmoid looks like the following.



Softmax

The softmax function is a more powerful output that is able to handle Multinoulli distribution/categorical results.
The softmax consists of two layers, first in linear layer followed by the softmax function.

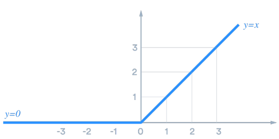
$$Softmax(z)_i = \frac{e^z i}{\Sigma_j e^z j} \tag{2}$$

The output vector of the softmax layer contains values in the interval [1,0] which represent the probability, the sum of all value in the output vector must always equal 1.

Hidden Units

ReLU - Rectified linear unit

$$f(x) = max(0, x) \tag{3}$$



Architecture design

Size and dept.

Backpropagation

introduction

This is the way the network calculates the gradient, This is then used to adjust the weights so the network can reach a minima in the learning function.

Function Principle

Make example

Computational Graphs

Mini batches

We split the dataset into smaller batches and run one iteration of the Backpropagation function once per mini batch.

Regularization

introduction

Our problem is that our network needs to preform good on not just our training data but also new data.

Over/Underfitting & Model Capacity

Overfitting got this.

Data augmentation

We can augment data by injection noise, rotating the images a few degrees, blur,

Adversarial training

Early stopping

We can obtain a model with better validation set error (and thus better test error) by returning to the parameter setting at the point of time with the lowest validation set error, and at the same time reduce the chance of over fitting.(if we are limited in data set)

Bagging (Bootstrap Aggregating)

Dropout

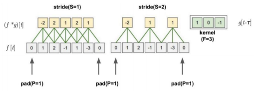
Convolutional Neural Networks

introduction

The base principle for convolution is that we multiply with a matrix.

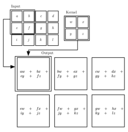
Function Principle

We have a kernal that we multiply over our input.



1d. case

2d. case



Pooling

Max pooling. makes our network more resistant to shifting of pixels.

- Max pooling
- Average
- L2 norm
- Weighted average.

Initialization of the kernels

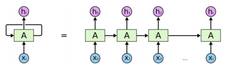
- Random initialization
- bluring filters.
- edge detection.
- sharpen

Recurrent Neural Networks

introduction

Recurrent Neural Networks are a family of neural networks for processing sequential data
Speech Recognition, etc.

Function Principle



Problems with long term memory

It should be able to handle large gabs inbetween information but in practice this fails in practice.
Eg it can maybe understand "i'm hungry" but it has issues understanding the connection over larger paragraphs. here LSTM offer a solution.

Long Short Term Memory

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Optimization for Neural Networks

introduction

Problems

Initial point Finding a good initial staring point, as this is often required for finding the global minima. else we risk getting stuck in a local minima which would mean our solution would not be optimal.

Cliffs and explosion Gradients

Momentum

Momentum method accelerates learning, when:

- Facing high curvature
- Small but consistent gradients
- Noisy gradients

Parameter Initialization

Only property known with certainty: Initial parameters must be chosen to break symmetry

- If two hidden units have the same inputs and same activation function then they must have different initial parameters
- Usually best to initialize each unit to compute a different function
- This motivates use random initialization of parameters

Adaptive Learning

Change the learning rate according to the gradient which one to use it up to the designer of the network, but the most pupolar ones are

- SGD,
- SGD with momentum,
- RMSProp,
- RMSProp with momentum,
- AdaDelta
- Adam

Batch Normalization

Pre-training

Local minima

Autoencoders and GANs

introduction

Autoencoders

Variational Autoencoders

GANs

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