CEITEC

Central European Institute of Technology

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Data Science Practicum

(Lecture 6, 23.10.)

Denisa Šrámková

NLP

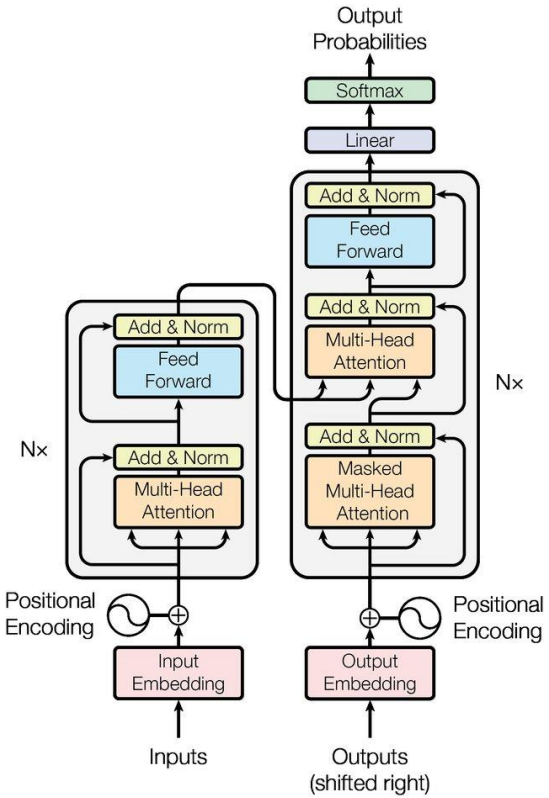
Natural Language Processing

- Transformer architecture - training details
- Text classification - *continuation*
- Hyperparameter optimization
- Text generation

Transformer architecture

Main categories:

1. Encoder only: BERT
2. Decoder-only: GPT-like
3. Encoder-Decoder: BART/T5-like



How are these models pre-trained?

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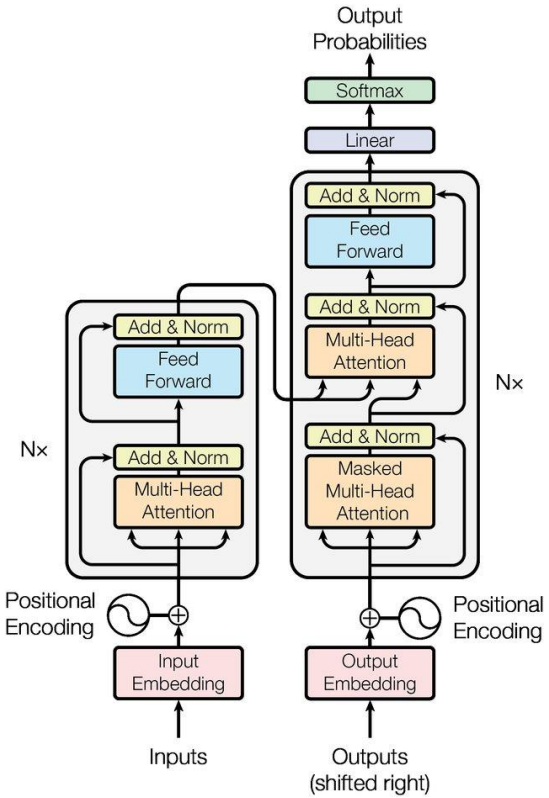

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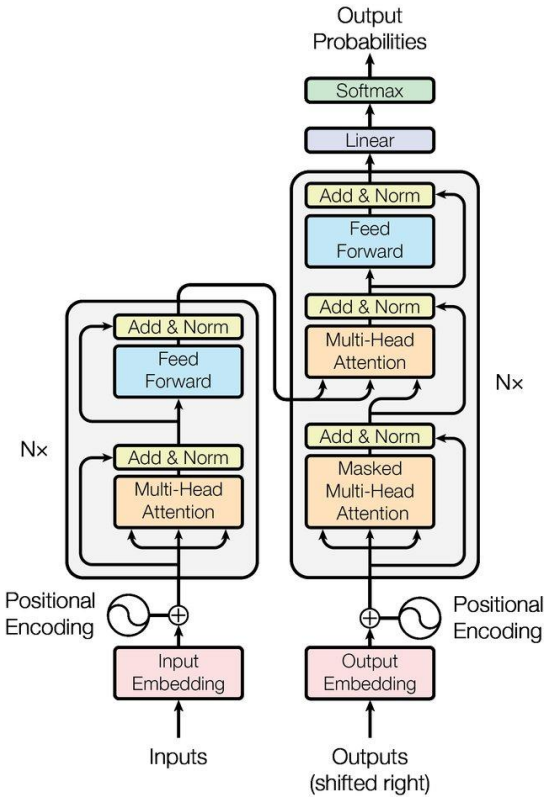

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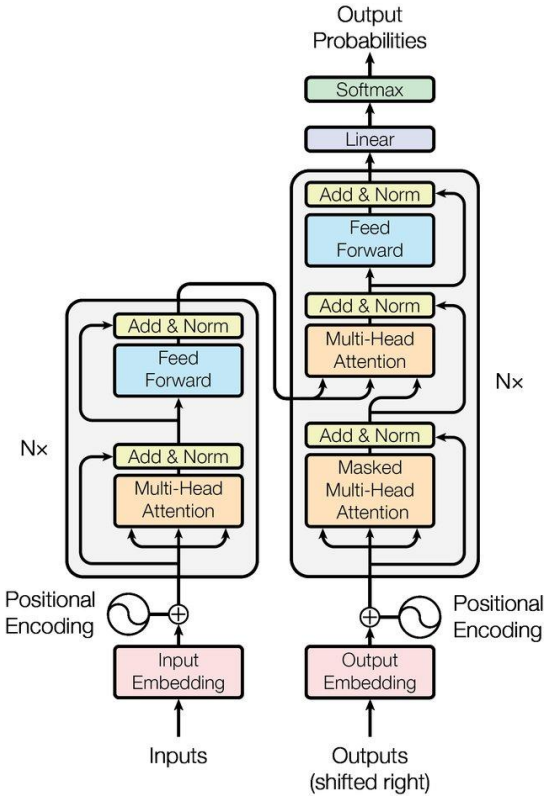

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2. Decoder-only: GPT-like
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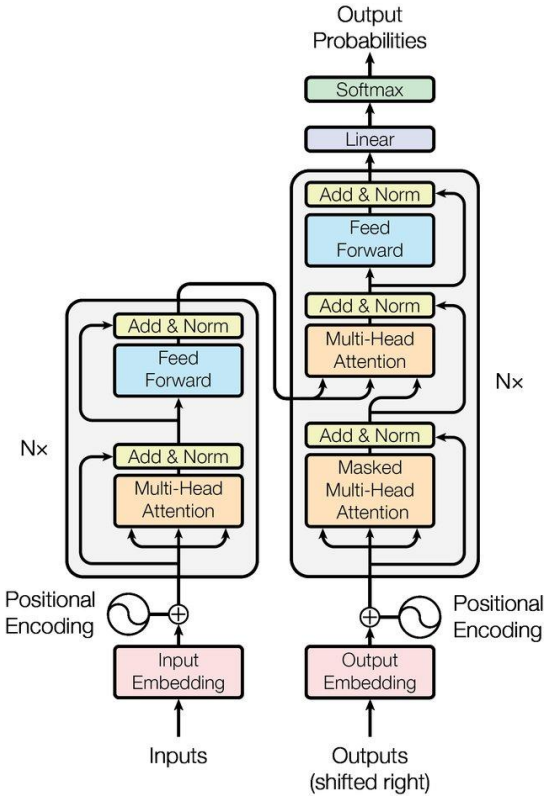

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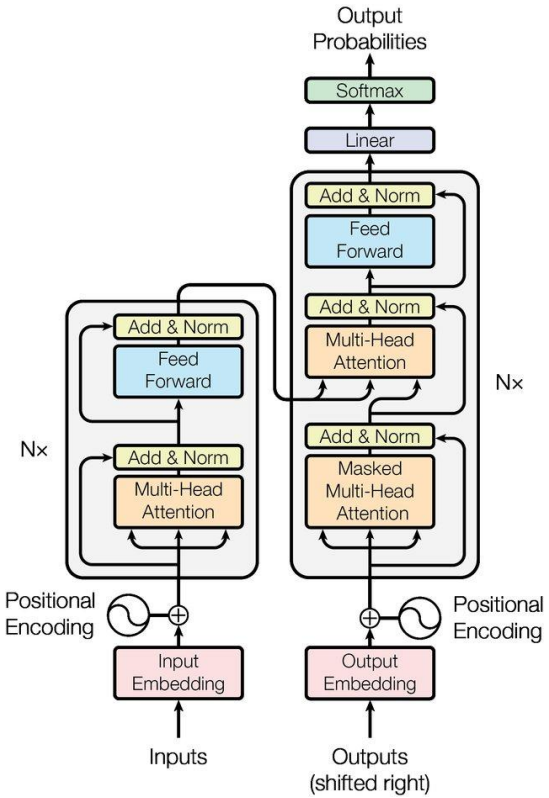
"John didn't" → model → "study."

3. Encoder-Decoder: BART/T5-like



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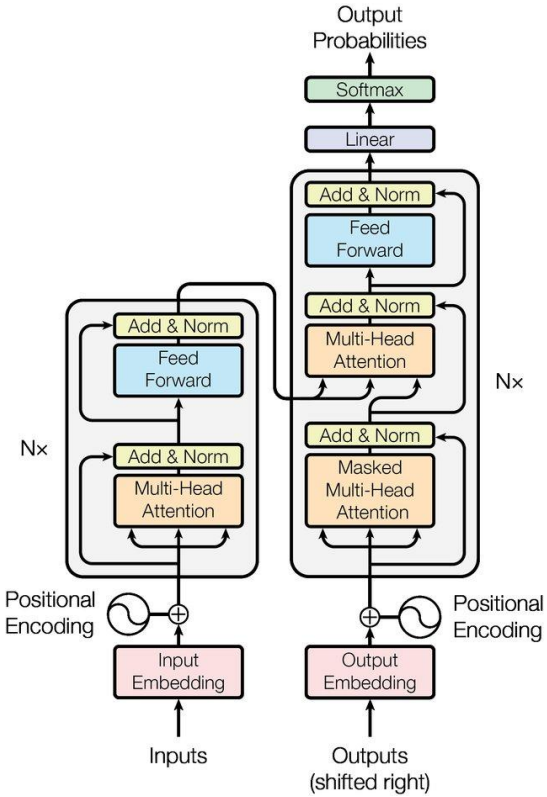
2. Decoder-only: GPT-like
   - predicting next word:

"John didn't" → model → "study."

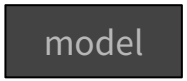
3. Encoder-Decoder: BART/T5-like
   - uses objectives of encoder or decoder models (e.g. T5: replacing random spans of text with single [MASK] token)



Text classification

“New bird species discovered in Philippines Cambridge, England, Aug. 17 (UPI) -- British and Filipino researchers have found a new bird species on a remote island in the northern Philippines, which is a relative to the familiar Moorhen.”

['new',' bird', 'species',' discovered', 'in', 'philippines', 'cambridge', ',' , 'england', ',', 'aug', '.', '17', '(', 'up', '##i', ')', '-', '-', 'british', 'and', 'filipino', 'researchers', 'have', 'found', 'a', 'new', 'bird', 'species', 'on', 'a', 'remote', 'island', 'in', 'the', 'northern', 'philippines', ',', 'which', 'is', 'a', 'relative', 'to', 'the', 'familiar', 'moor', '##hen', '.']



Label: 95.2% Science, 3.2% Business, 1.6% Sport

Text classification

Text classification

Raw input

"New bird species discovered in Philippines Cambridge, England, Aug. 17 (UPI) -- British and Filipino researchers have found a new bird species on a remote island in the northern Philippines, which is a relative to the familiar Moorhen."

Tokenization

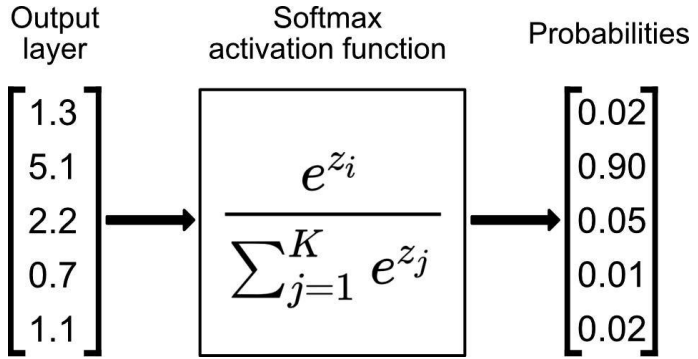
['new', 'bird', 'species', 'discovered', 'in', 'philippines', 'cambridge', ',', 'england', ',', 'aug', '.', '17', '(', 'up', '##i', ')', '-', '-', 'british', 'and', 'filipino', 'researchers', 'have', 'found', 'a', 'new', 'bird', 'species', 'on', 'a', 'remote', 'island', 'in', 'the', 'northern', 'philippines', ',', 'which', 'is', 'a', 'relative', 'to', 'the', 'familiar', 'moor', '##hen', '.']

model

Prediction

Label: 95.2% Science, 3.2% Business, 1.6% Sport

Softmax:



Exercise 1: Text classification

https://github.com/simecek/dspracticum2023/blob/main/lesson06/ds_practicum_ex1_text_classification.ipynb

Hyperparameters

```
training_args = TrainingArguments(
    output_dir='./results',
    num_train_epochs=2,
    per_device_train_batch_size=16,
    evaluation_strategy='epoch',
    learning_rate=5e-5,
    weight_decay=0.0
)

trainer = Trainer(
    model=model,
    args=training_args,
    train_dataset=train_dataset,
    eval_dataset=valid_dataset,
    compute_metrics=compute_metrics
)

trainer.train()
```

Hyperparameters

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trainer.train()
```

TrainingArguments

class transformers.TrainingArguments <source>

(output_dir: str, overwrite_output_dir: bool = False, do_train: bool = False, do_eval: bool = False, do_predict: bool = False, evaluation_strategy: typing.Union[transformers.trainer_utils.IntervalStrategy, str] = 'no', prediction_loss_only: bool = False, per_device_train_batch_size: int = 8, per_device_eval_batch_size: int = 8, per_gpu_train_batch_size: typing.Optional[int] = None, per_gpu_eval_batch_size: typing.Optional[int] = None, gradient_accumulation_steps: int = 1, eval_accumulation_steps: typing.Optional[int] = None, eval_delay: typing.Optional[float] = 0, learning_rate: float = 5e-05, weight_decay: float = 0.0, adam_beta1: float = 0.9, adam_beta2: float = 0.999, adam_epsilon: float = 1e-08, max_grad_norm: float = 1.0, num_train_epochs: float = 3.0, max_steps: int = -1, lr_scheduler_type: typing.Union[transformers.trainer_utils.SchedulerType, str] = 'linear', warmup_ratio: float = 0.0, warmup_steps: int = 0, log_level: typing.Optional[str] = 'passive', log_level_replica: typing.Optional[str] = 'warning', log_on_each_node: bool = True, logging_dir: typing.Optional[str] = None, logging_strategy: typing.Union[transformers.trainer_utils.IntervalStrategy, str] = 'steps', logging_first_step: bool = False, logging_steps: float = 500, logging_nan_inf_filter: bool = True, save_strategy: typing.Union[transformers.trainer_utils.IntervalStrategy, str] = 'steps', save_steps: float = 500, save_total_limit: typing.Optional[int] = None, save_safetensors: typing.Optional[bool] = False, save_on_each_node: bool = False, no_cuda: bool = False, use_cpu: bool = False, use_mps_device: bool = False, seed: int = 42, data_seed: typing.Optional[int] = None, jit_mode_eval: bool = False, use_ipex: bool = False, bf16: bool = False, fp16: bool = False, fp16_opt_level: str = 'O1', half_precision_backend: str = 'auto', bf16_full_eval: bool = False, fp16_full_eval: bool = False, tf32: typing.Optional[bool] = None, local_rank: int = -1, ddp_backend: typing.Optional[str] = None, tpu_num_cores: typing.Optional[int] = None, tpu_metrics_debug: bool = False, debug: typing.Union[str, typing.List[transformers.debug_utils.DebugOption]] = '', dataloader_drop_last: bool = False, eval_steps: typing.Optional[float] = None, dataloader_num_workers:

https://huggingface.co/docs/transformers/v4.34.1/en/main_classes/trainer#transformers.TrainingArguments

Hyperparameters

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trainer = Trainer(
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trainer.train()
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- learning rate
- dropout
- weight decay
- warmup

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Learning rate

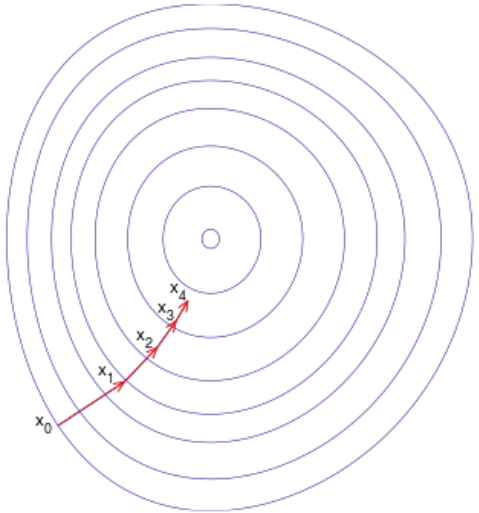
Derivative of Error with respect to weight

Old weight

$$^{*}W_x = W_x - a\left(\frac{\partial Error}{\partial W_x}\right)$$

New weight

Learning rate



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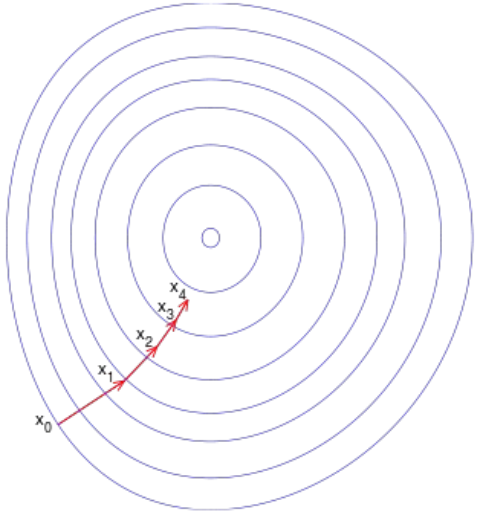

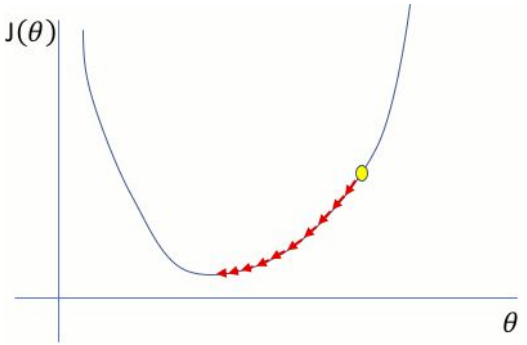

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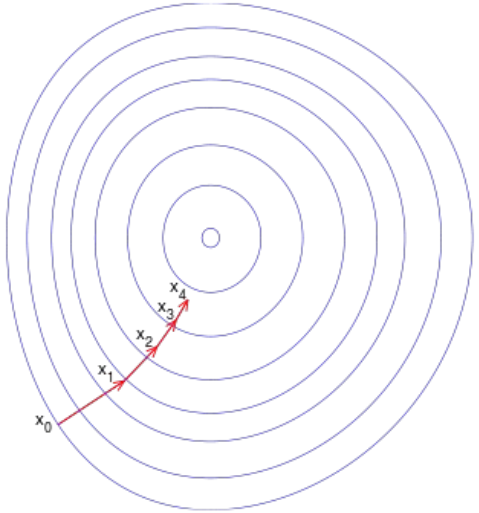

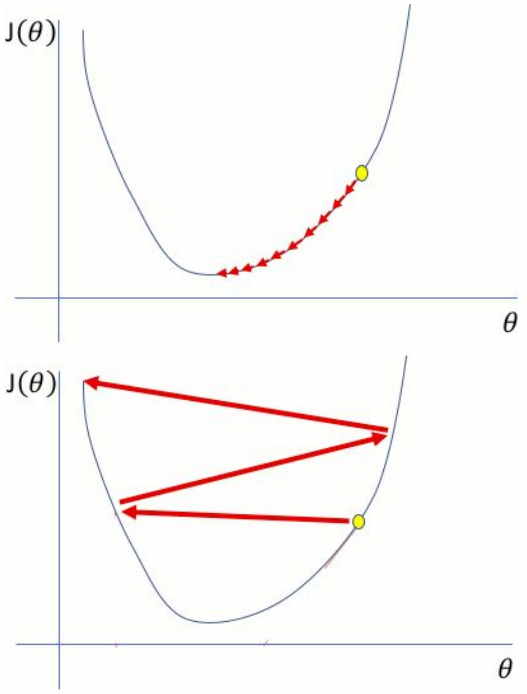

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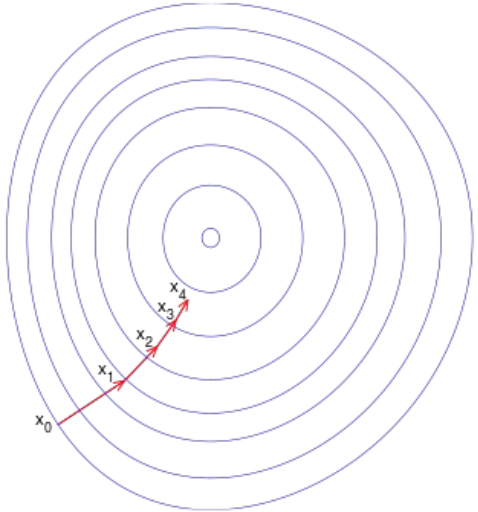
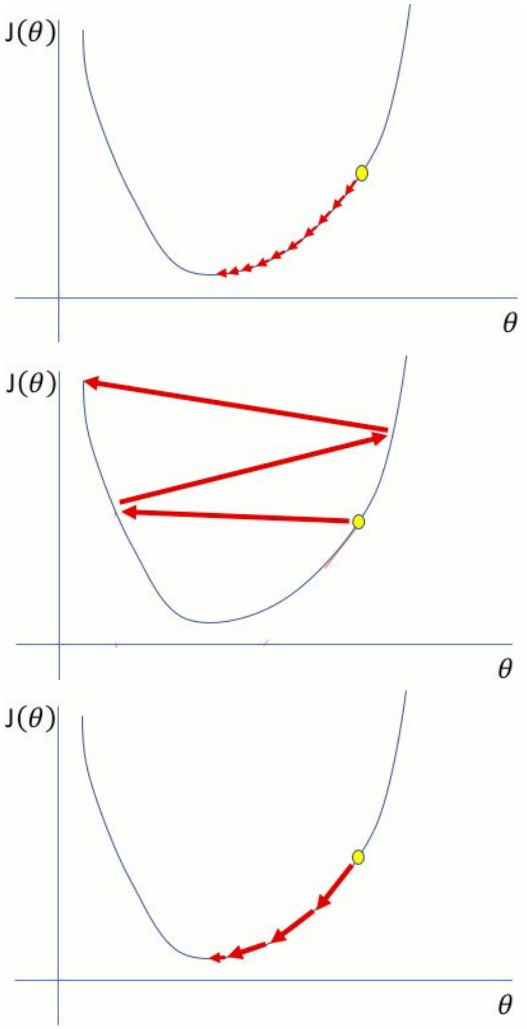
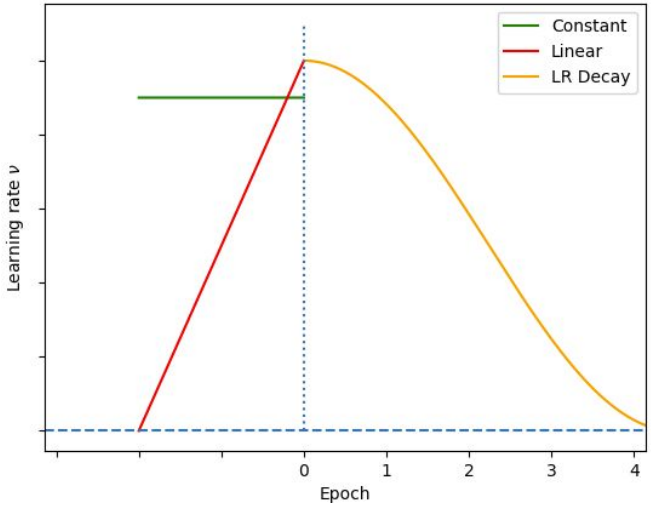




Warmup

So far our learning rate has been constant, but it doesn't have to be.



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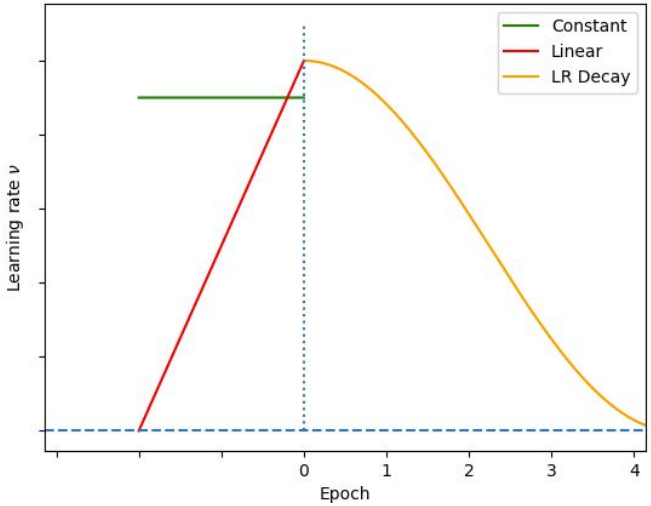


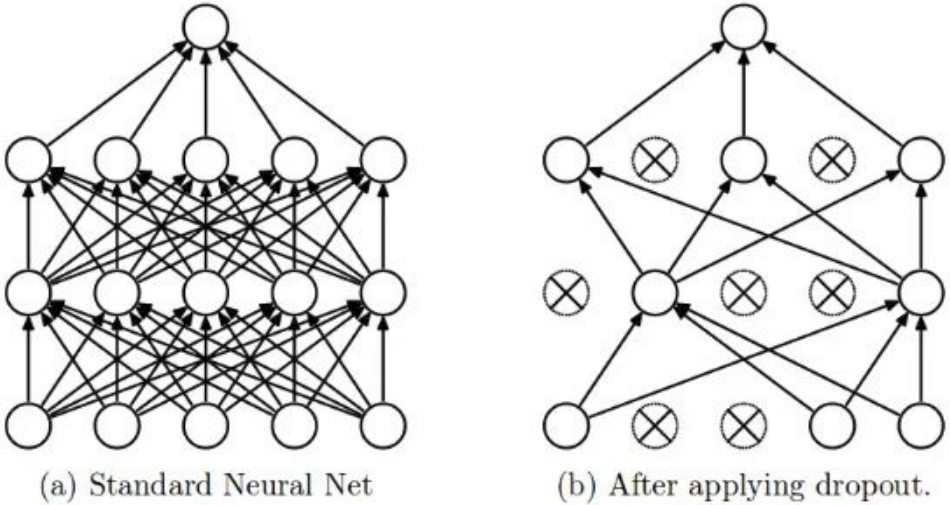
Regularization techniques

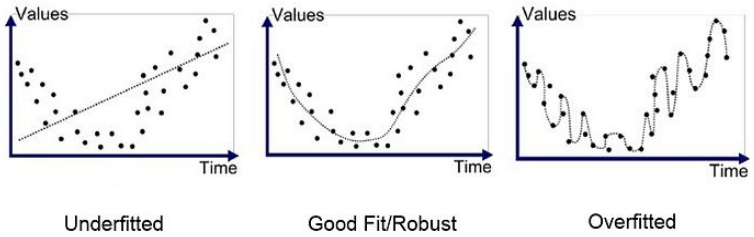
Generalization = ability to cope with new unseen instances

Regularization = methods improving generalization

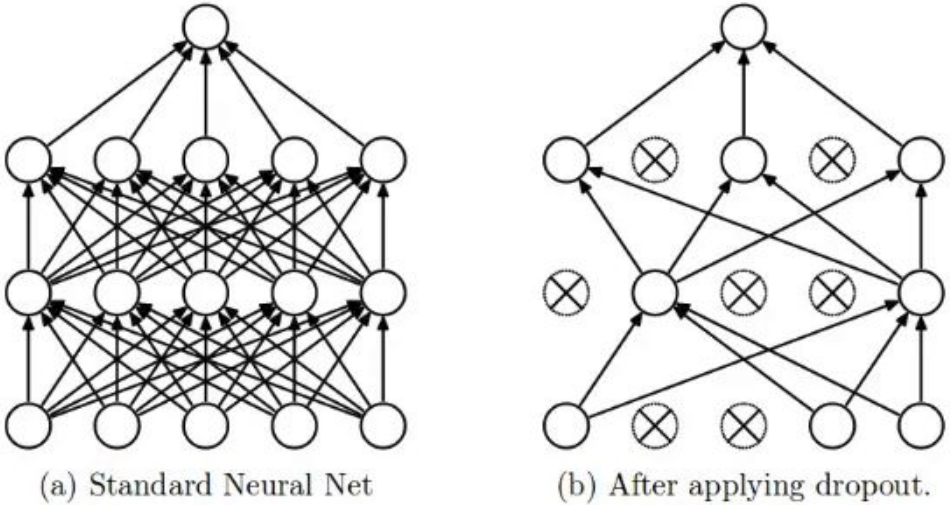
- **Dropout**
- **Weight decay**
- Early stopping
- Ensemble methods
- …

Dropout


(a) Standard Neural Net
(b) After applying dropout.


Values
Time
Values
Time
Values
Time
Underfitted
Good Fit/Robust
Overfitted

Dropout


(a) Standard Neural Net
(b) After applying dropout.
Present with probability p
w
(a) At training time
Always present
pw
(b) At test time

Weight decay

Gradient descent: $w_{ji}^{(t+1)} = w_{ji}^{(t)} + \Delta w_{ji}^{(t)}$

$$\Delta w_{ji}^{(t)} = -\varepsilon(t) \cdot \frac{\partial E}{\partial w_{ji}}(\vec{w}^{(t)})$$

Weight decay: $w_{ji}^{(t+1)} = (1 - \zeta)(w_{ji}^{(t)} + \Delta w_{ji}^{(t)})$

Weight decay

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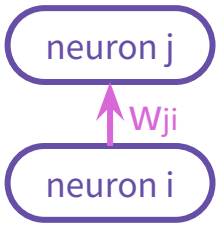


Weight decay

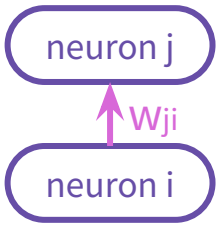
Gradient descent: $w_{ji}^{(t+1)} = w_{ji}^{(t)} + \Delta w_{ji}^{(t)}$ update of weight w_{ji} at time step t+1

$$\Delta w_{ji}^{(t)} = -\varepsilon(t) \cdot \frac{\partial E}{\partial w_{ji}}(\vec{w}^{(t)})$$

learning rate

computed from backpropagation

Weight decay: $w_{ji}^{(t+1)} = (1 - \zeta)(w_{ji}^{(t)} + \Delta w_{ji}^{(t)})$



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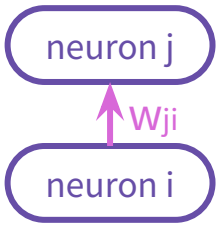
Weight decay: $w_{ji}^{(t+1)} = (1-\zeta)(w_{ji}^{(t)} + \Delta w_{ji}^{(t)})$

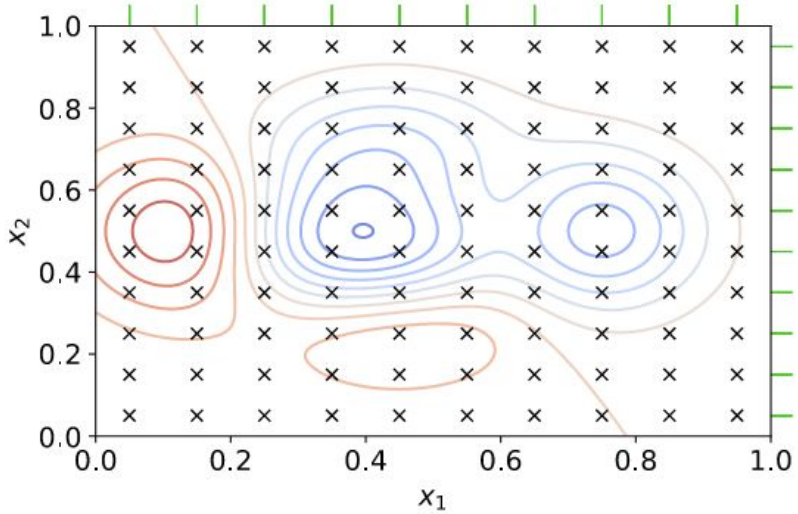


Hyperparameter optimization: Approaches

How can we choose the best values for our hyperparameters?

Hyperparameter optimization: Approaches

Grid search/ parameter sweep(/ exhaustive brute force search):



Hyperparameter optimization: Approaches

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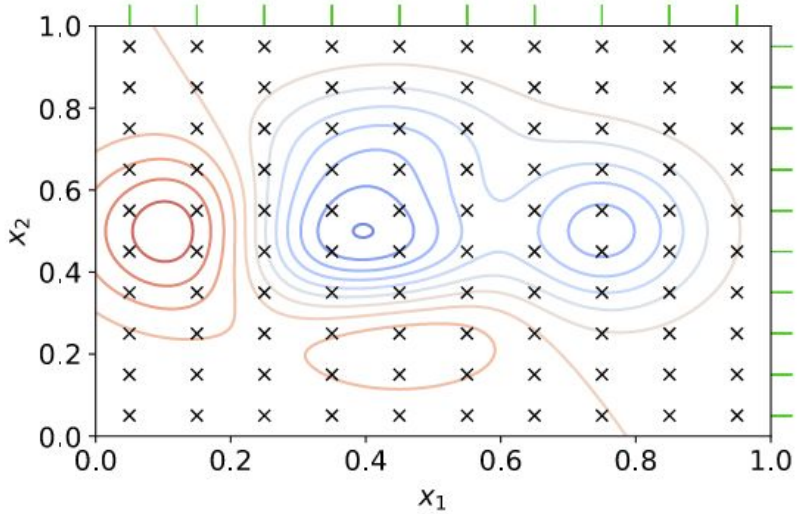

Implementation?

Hyperparameter optimization: Approaches

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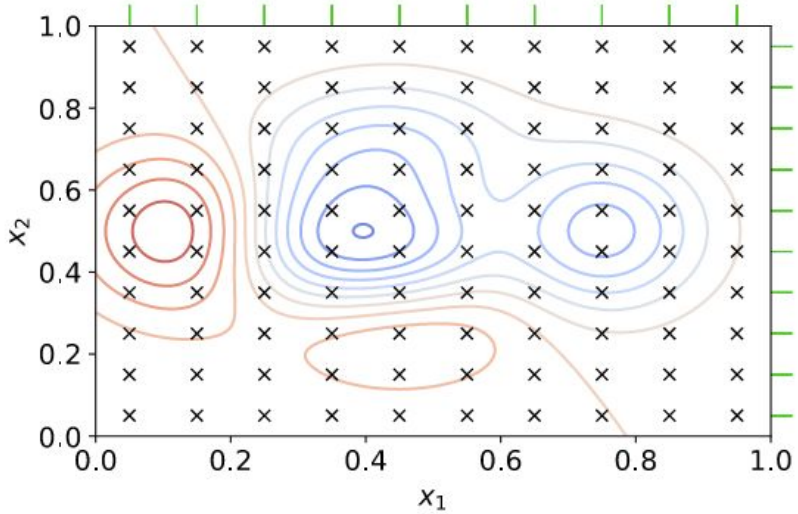


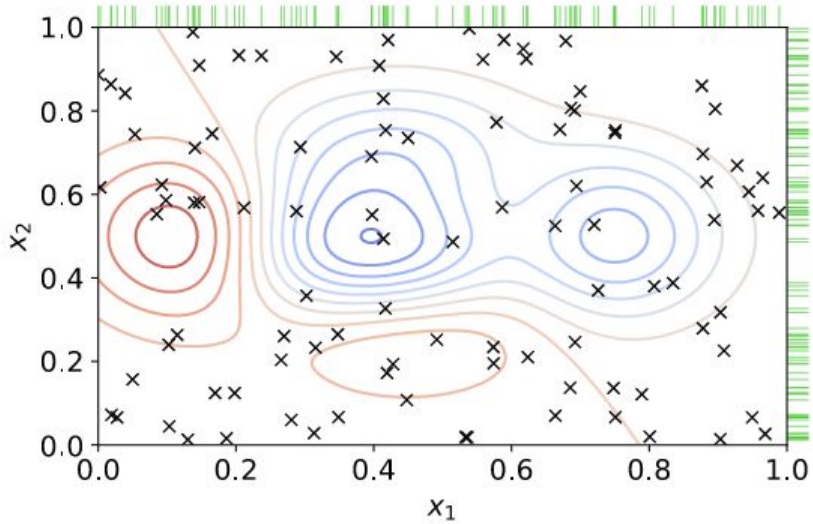
Implementation?

```
lr_values = [0.003, 0.0003, 0.0003]
epoch_values = [2, 4, 8]

for lr in lr_values:
  for epochs in epoch_values:
    train_model(lr_values, epoch_values)
```

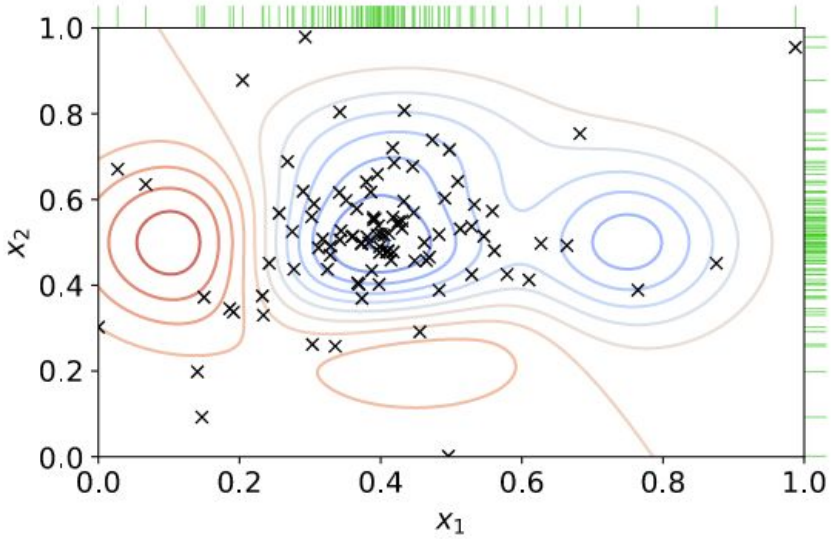
Hyperparameter optimization: Approaches

Random search:



Hyperparameter optimization: Approaches

Bayesian optimization:

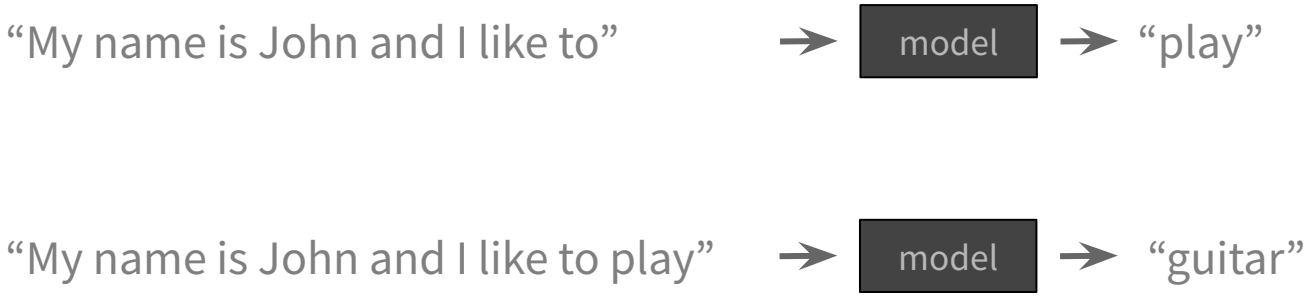


https://github.com/bayesian-optimization/BayesianOptimization

Exercise 2: Genomic benchmarks

https://github.com/simecek/dspracticum2023/blob/main/lesson06/ds_practicum_exercise2_genomic_benchmarks.ipynb

Text generation



Exercise 3: Text generation

https://github.com/simecek/dspracticum2023/blob/main/lesson06/ds_practicum_exercise3_text_generation.ipynb

Homework

1) Try to increase the performance of the model from Exercise 1 and report your best results (e.g. you can apply some hyperparameter optimization)
   - if you are not successful report what approaches you have tried and all of your results