LECTURER: Nghia Duong-Trung

NEURAL NETS AND DEEP LEARNING

TOPIC OUTLINE

UNIT 3

OVERTRAINING AVOIDANCE

- Course book: DLBDSNNDL01_Neural Nets and Deep Learning, provided by IU, myStudies
- Reading list DLBDSNNDL01, provided by IU, myStudies
- This slide is a summarization of important contents in the course book.
- Additional teaching materials:

https://github.com/duongtrung/IU-DLBDSNNDL01_Neural_Nets_and_Deep_Learning

DISCLAIMER

- This is the modified version of the IU slides.
- I used it for my lectures at IU only.

STUDY GOALS

- understand the concept of overtraining a machine learning model.
- distinguish between different regularization techniques.
- describe common regularization strategies, such as early stopping, l1 and l2 regularization, dropout, and weight pruning.
- analyze the effects of regularization techniques in improving the performance of a machine learning model.

EXPLAIN SIMPLY

- What is overtraining and why is it important?
- How can we to differentiate between various regularization techniques?
- How do the regularization strategies work and what are their effects?

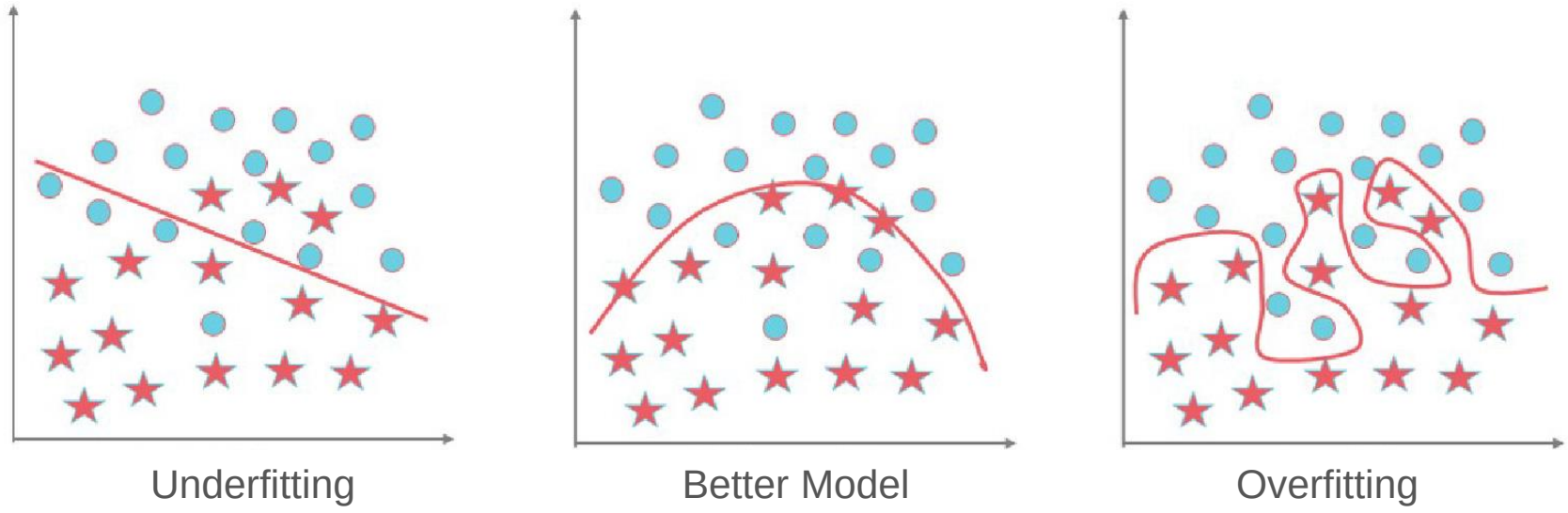
DEFINITION

Overfitting ...

- happens when a model predicts **training** examples with high accuracy but
- performs **poorly** with previously unseen data

Underfitting ...

- happens when the model cannot capture substantial **relationships** between input features and target output
- results in **high** error rates



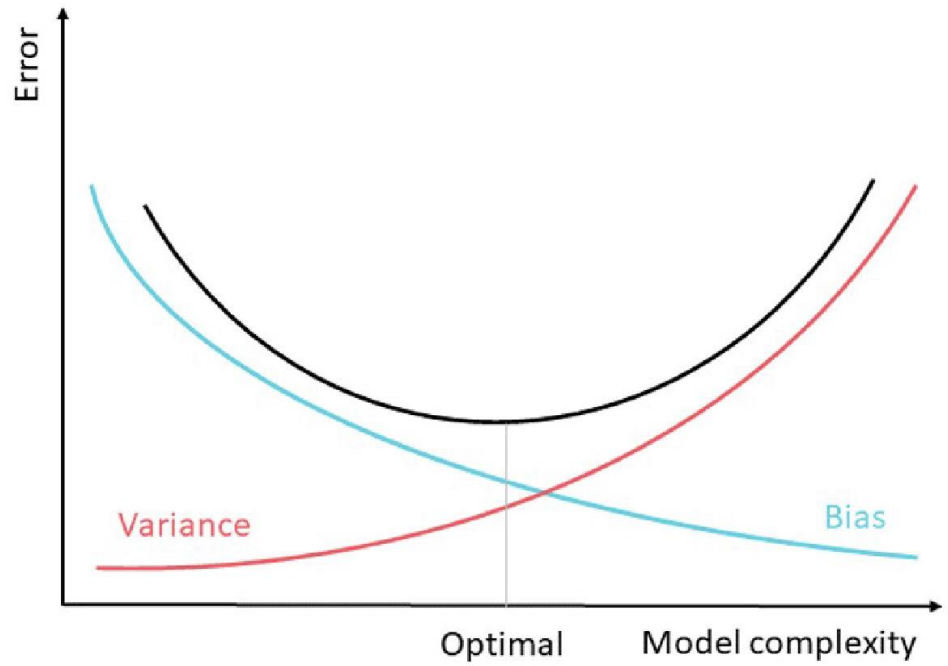
Source of the text and the image: Zöller (2023)

Bias ...

- denotes an error related to the model's tendency to consistently make **incorrect** predictions
- occurs when wrong **assumptions** are made for the input data.
- can lead to **underfitting** of the model.

Variance ...

- expresses the error related to the excessive **sensitivity** of the model on the training data.
- is a result of representing **minor** input variations.
- occurs more often when the model is far too **complex**, thus leading to an **overtrained** model.

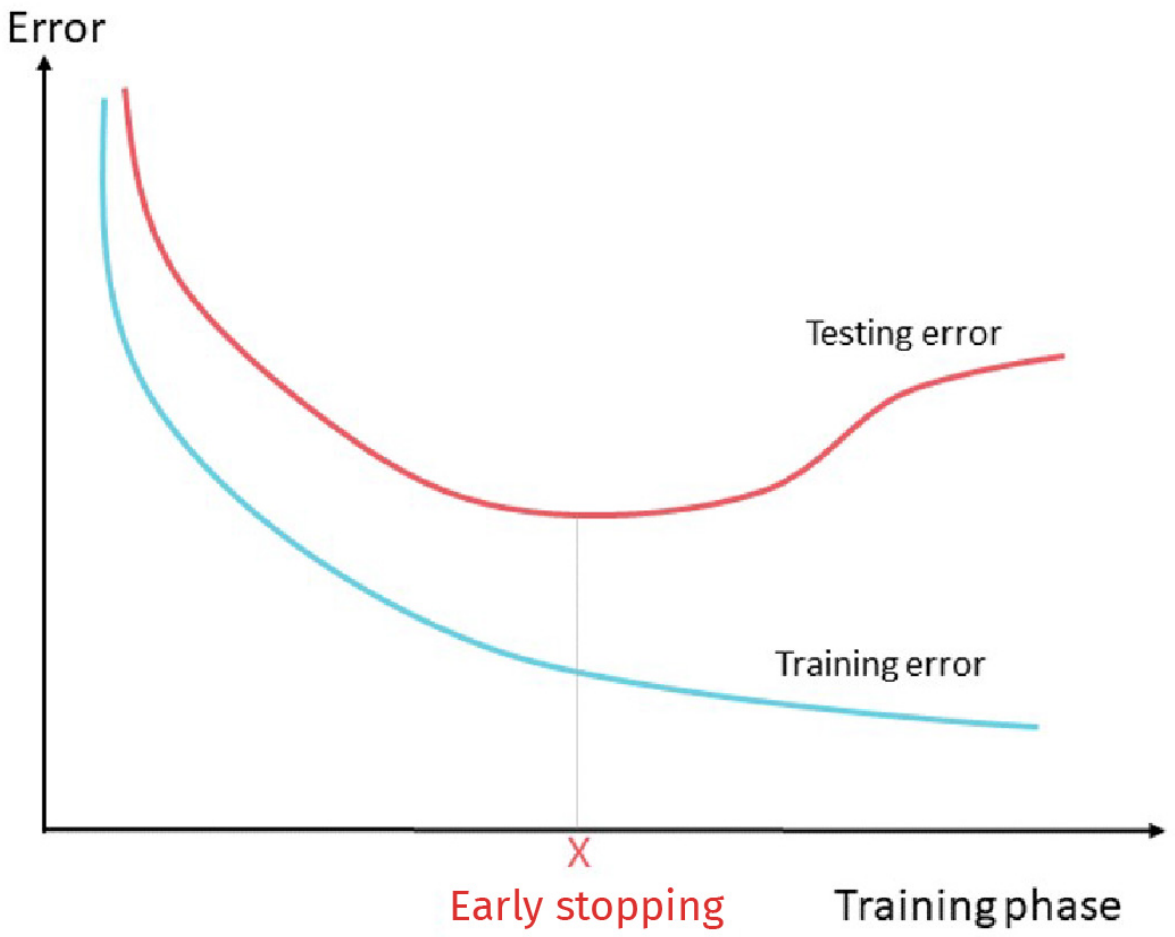


Bias Variance Trade-off

Source of the text and the image: Zöller (2023)

Early stopping ...

- is a regularization technique used to **avoid overtraining,**
- **stops** the training process when the validation error reaches a minimum and starts to increase.
- is a **simple** and **effective** technique to improve model robustness.



Early Stopping Regularization

Source of the text and the image: Zöller (2023)

L1 and L2 Regularizations ...

- are used to prevent overfitting in machine learning models.
- add penalty term to the loss function during training to control the model complexity.
- aim to reduce the test error while not increasing the training error.
- improve the robustness by reducing the influence of irrelevant or noisy features.
- help in finding a balance between model complexity and model performance.
- can be combined to yield better results, as in the case of elastic net regularization.
- are important to control the weights and preventing them from becoming too large.
- are widely used.

Source of the text: Zöller (2023)

Comparison between L1 and L2 Regularization

Aspect	L1 Regularization	L2 Regularization
Mathematical representation	$L_1(X, y, W) = f(X, y, W) + \lambda \cdot \sum_{i=1}^{n} \lvert w_i \rvert$	$L_2(X, y, W) = f(X, y, W) + \lambda \cdot \sum_{i=1}^{n} \lvert w_i^2 \rvert$
Penalty Term	Absolute values of weights	Squared values of weights
Encourages	Sparsity (many weights to exactly zero)	Small weights (all weights are small but not exactly zero)
Simplicity and Interpretability	Simpler, more interpretable models	Models with more complex weight patterns
Strengths	Reduces model complexity by setting some weights to zero, useful when many features are irrelevant	Effective for complex data patterns, provides a full range of weights
Weaknesses	struggle with complex data patterns, can lead to underfitting	Does not provide feature selection, may still have many small weights

Source of the text: Zöller (2023)

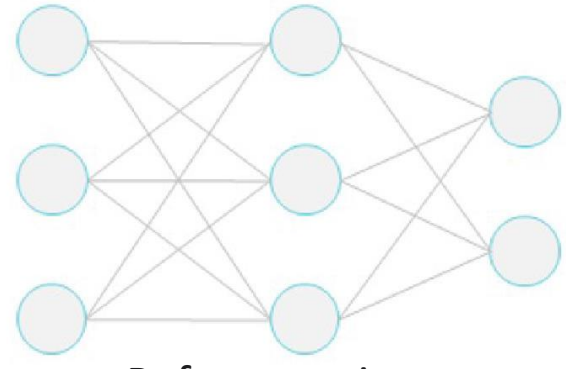
Dropout ...

- is used to combat overtraining by randomly dropping out a set of neurons.
- prevents random patterns that don't help map input data to target output.
- is used in neural networks to prevent overfitting and improve generalization.
- randomly removes neurons during training, forcing the network to be less dependent on specific neurons.
- creates a unique network at each step, leading to an ensemble of networks.
- helps the network become more robust and resilient to input variations.
- improves the robustness, making it less affected by minor changes in the input.

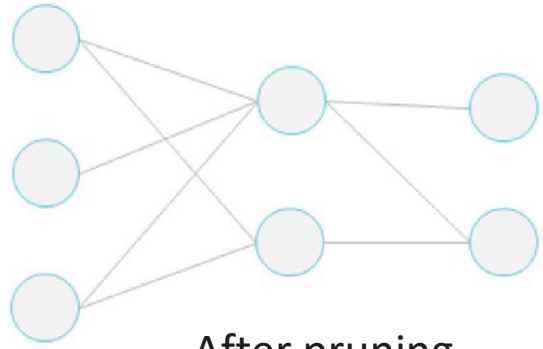
Source of the text: Zöller (2023)

Weight pruning ...

- removes **individual weights** in a neural network.
- aims to decrease the **number of parameters** in the network while keeping the architecture intact.
- can be done based on certain **criteria**, such as magnitude or importance of the weights.
- reduces the computational **cost** of the network.
- is to minimize the impact on the **accuracy** or performance of the network.



Before pruning



After pruning

Source of the text and the image: Zöller (2023)

REVIEW STUDY GOALS

- understand the concept of overtraining a machine learning model.
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SESSION 3

OVERTRAINING AVOIDANCE

TRANSFER TASK
PRESENTATION OF THE RESULTS

Please present your results.

The results will be discussed in plenary.

Task:

Look up the codes in Session 3 on the course’s Github repository.

Task:

In the domain of image classification, neural networks can be used to accurately classify images into various categories. However, overfitting is a common challenge in training these models. Name and briefly explain the common techniques to solve this problem

1. Which of the following statements is the best description for overtraining? Select one.
   a) Overtraining occurs when the accuracy of prediction for a machine learning model on the training data starts to decrease .
   b) Overtraining occurs when the model is too simplistic to learn and discover meaningful underlying patterns in the data it observes..
   c) Overtraining is a problematic issue only for those neural networks that have a large number of hidden layers..
   d) Overtraining occurs when a machine learning model predicts training examples with high accuracy but performs poorly with previously unseen data.

2. Which of the following statements is true about L1 and L2 regularization techniques? Select one
   a) L1 and L2 regularization techniques aim to lower the over-complexity of the model and develop simpler models that promote generalization.
   b) When several models explain the training data, L1 and L2 regularization techniques favor more complex models as they can better address the practical challenges of neural networks.
   c) The cost that is added when using the L1 regularization technique is proportional to the square of values of the weight coefficients.
   d) L2 regularization occurs when the added cost is a fraction of the absolute value of the weight coefficients.

3. Which of the following statements is true about dropout as a regularization technique? Select one
   a) Dropout is a regularization technique which empowers a set of neurons to have very strong connections, thus ignoring the rest of neurons and their weak connections.
   b) Dropout helps with overfitting because it allows neurons to adapt well only with their neighbors thus forcing them to be as impactful as possible.
   c) Dropout helps with overfitting by ensuring that the neural network learns to not depend only on a particular set of neurons, thus becoming more robust.
   d) Dropout is an effective generalization technique only if the neurons are dropped out according to well-defined rules, but shows poor performance if neurons are dropped out at random.

LIST OF SOURCES

Text

Zöller, T. (2023). Neural Nets and Deep Learning Course Book. IU International University of Applied Sciences.

Images

Zöller (2023)