# REGULARIZATIONS

Deep Neural Networks
Session 10

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## Agenda

- L-1, L-2
- Dropout
- Early Stopping
- Augmentation

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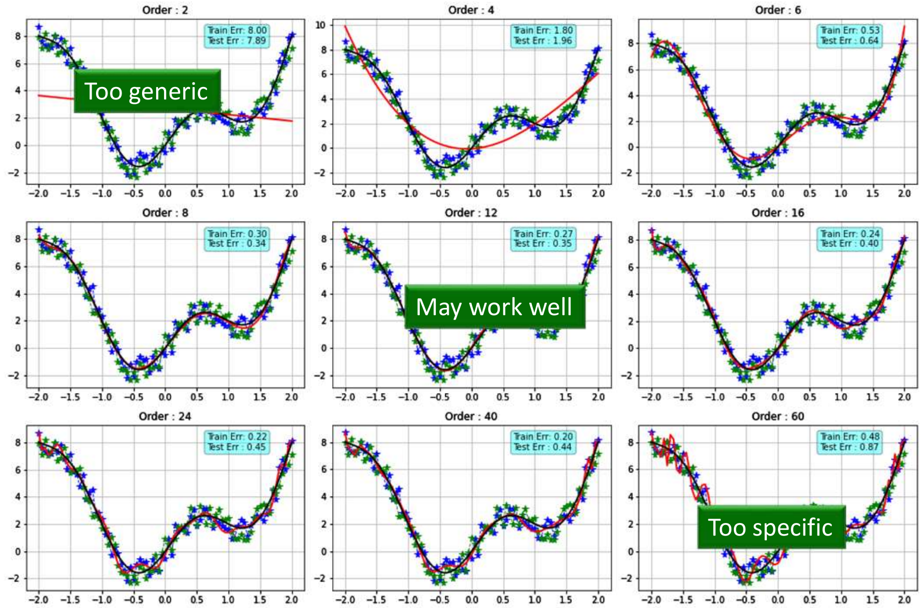
## Under-fitting vs. Over-fitting

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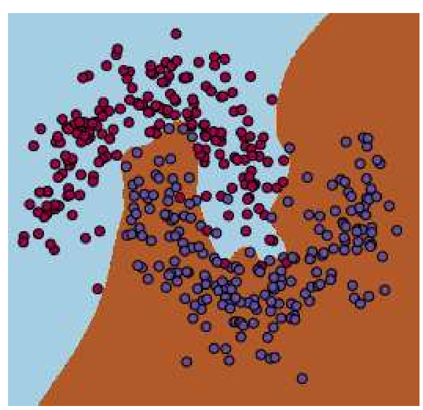
## Regularization

- Regularization helps in avoiding over fitting by penalizing the coefficients
- In deep learning, it actually penalizes the weight matrices of the nodes
- Different Regularization Techniques in Deep Learning
  - L1 regularization
  - L2 regularizations
  - Dropouts
  - Early stopping
  - Data Augmentation



Most Libraries have tunable hyper-parameters!

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## Weights vs. Bias

- For neural networks, we typically choose to use a parameter norm penalty Ω that penalizes only the weights at each layer and leaves the biases un-regularized.
- The biases typically require less data to fit accurately than the weights.
- Fitting the weight will requires observing both (fan_ in and fan_out) layer in a variety of conditions.
- Each bias controls only a single layer.
- This means that we do not induce too much variance by leaving the biases un-regularized.
- Also, regularizing the bias parameters can introduce a significant amount of under fitting.





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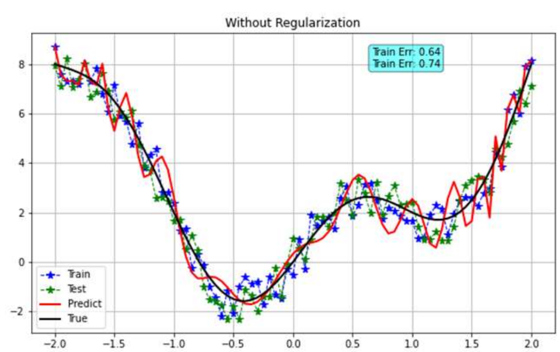
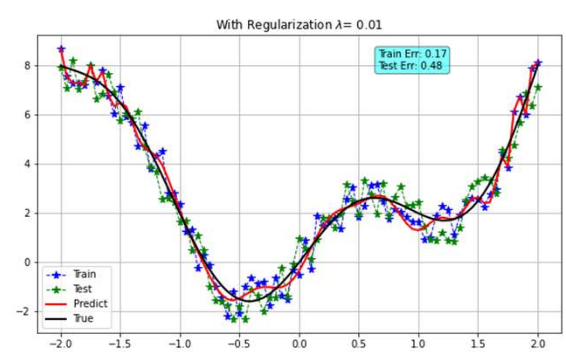
## Effect of L2 Regularization



## Theory – Logistic Regression – L1 & L2

- Idea is to minimize Cost Function
  - J (W, b) = $\frac{1}{m}$ * Σ ℓ (a, y)
  - = - $\frac{1}{m}$ {y * log(a) + (1-y) * log(1-a)}

- A term is added to Cost function $\frac{\lambda}{2*m} . \|W\|_2^2$

  J (W, b) = $\frac{1}{m}$ * Σ ℓ (a, y) + $\frac{\lambda}{2*m} . \|W\|_2^2$





## Theory – Logistic Regression – L1 & L2

- J (W, b) = $\frac{1}{m}$ * Σ ℓ (a, y) + $\frac{\lambda}{2*m} . \|W\|_2^2 + \cancel{\frac{\lambda}{2*m} . b^2}$
  - This is referred as L2 regularization
  - **Regularization hyperparameter λ**: It is another parameter we tune…

- $\|W\|_2^2 = \sum_{j=1}^{n} w_j^2 = W^T$ .W

- Here, we are using Euclidean Norm or L2 Norm

- Compared to W, bias b has fewer dimensions, hence, it is generally not considered

- If you add for b, ($\frac{\lambda}{2*m}$ .$b^2$)… that's ok too
  - Although its effect will be minimal,
  - Better to leave it alone.

## Theory – Logistic Regression – L1 & L2

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- Sometimes L1 too is used
- J (W, b) = $\frac{1}{m}$ * ( Σ ℓ (a, y) ) + $\frac{\lambda}{2*m}$ . $\|W\|_1$
- Differentation of $\frac{\lambda}{2*m}$ . $\|W\|_1$ = $\frac{\lambda}{2*m}$ sign(W)
  - Will be infinitely small and will have smaller impact on gradient descent

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## Neural Network – $Frobenius$ Norm

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- In neural network, we have different layers with different weights
- So we look at its cumulative effect over all layers
- Hence the Cost function
  - J (W, b) = J ($W^{[1]}$, $b^{[1]}$, $W^{[2]}$, $b^{[2]}$, $W^{[3]}$, $b^{[3]}$ ...)
  - J (W, b) = $\frac{1}{m}$ * ( Σ ℓ (a, y) ) + $\frac{\lambda}{2*m}$ . $\sum_{l=1}^{L} \sum (w_{i,j})^2$
  - J (W, b) = $\frac{1}{m}$ * Σ{y * log(a) + (1-y) * log(1-a)} + $\frac{\lambda}{2*m}$ . $\sum_{l=1}^{L} \|W^{[l]}\|^2$
  - Where $\|W^{[l]}\|^2_F = \sum_{i=1}^{n[l-1]} \sum_{j=1}^{n[l]} \left(w_{ij}^{[l]}\right)^2$
    - W is $(n^{[l-1]}, n^{[l]})$ dimensional matrix
- It is called $Frobenius\ norm$ of a matrix
- Also the $Frobenius\ norm$ defined as the square root of the sum of the absolute squares of its elements

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## Frobenius Norm of a Vector

- $||A||_F = \sqrt{\Sigma(a_{ij})^2}$

i.e.

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} = \sqrt{(1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2)}$$



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## Updates to weights

- Earlier
  - $\partial W^{[l]}$ = X . $\partial z$
  - And $W^{[l]}$=$W^{[l]}$- α . $\partial W^{[l]}$
  - For Regularization we add an extra term at the end
  - $\partial W^{[l]}$ = X . $\partial z$ + $\frac{\lambda}{m}$ . $W^{[l]}$
  - $W^{[l]}$ = $W^{[l]}$ - α .[X . $\partial z$ + $\frac{\lambda}{m}$ . $W^{[l]}$]
  - $W^{[l]}$= (1 - $\frac{\alpha . \lambda}{m}$). $W^{[l]}$ - α . X . $\partial z$

Mathematically, we can show that it is still a valid definition of $\partial W^{[l]}$

Weight Decay



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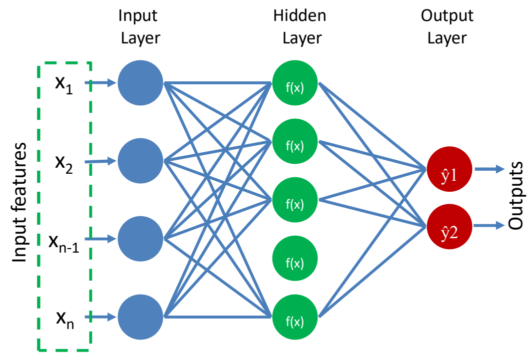
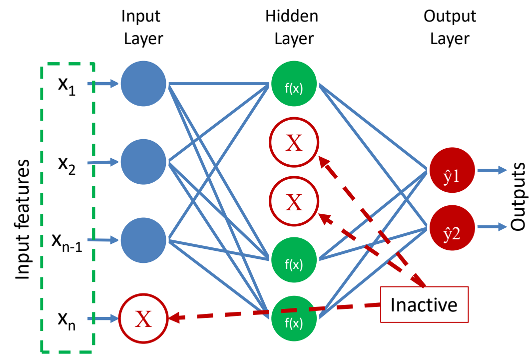
## Regularization : Dropout

- Original




- With Dropout



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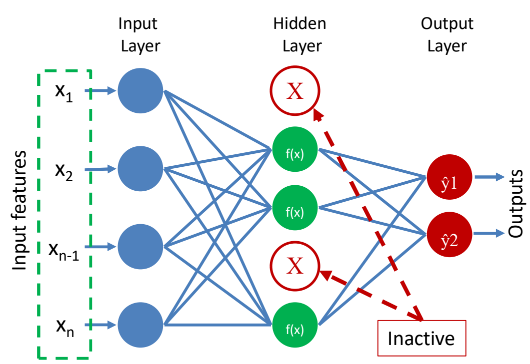
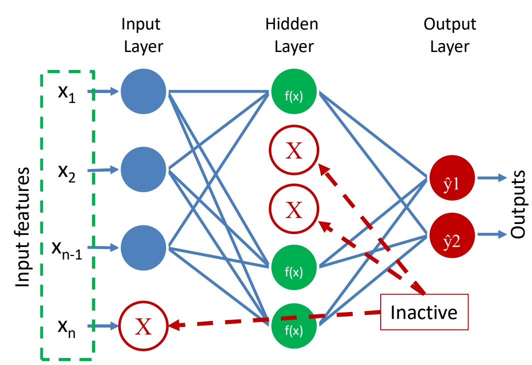
## Regularization : Dropout

- Iteration 1




- Iteration 2



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## 15 Regularization : Early Stopping

- How long to train the model?
- Duration of training ➔ under – fit or over – fit
- Train the model to the point where it performance on test set is best!
- Very simple and very effective

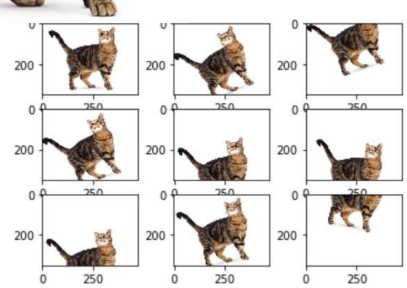
How:
- Train the model and monitor performance
- Save weight every time the  performance improves
- Stop training if performance has not improved for N epochs
- It's the last parameter to tune
  - Repeated early stopping may lead to over-fitting the validation set
  - Example : K-fold



## 16 Regularization : Data Augmentation

- Where limited data is available for training the model (when is it not!)
- Very effective in image identification
- Most libraries have Image Generators (parameter driven)
  - Horizontal and Vertical Shift
  - Horizontal and Vertical Flip
  - Random Rotation
  - Random Brightness / Contrast
  - Random Zoom
  - Random Noise

https://towardsdatascience.com/image-augmentation-for-deep-learning-histogram-equalization-a71387f609b2



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## Reflect…

- What is the purpose of dropout in deep neural networks?
  - A) To add noise to the input data
  - B) To randomly drop neurons during training to prevent overfitting
  - C) To increase the learning rate
  - D) To increase the model complexity
- Answer: B
- What is the primary purpose of regularization in deep neural networks?
  - A) To increase computational efficiency
  - B) To prevent overfitting
  - C) To speed up convergence during training
  - D) To increase the model's capacity
- Answer: B) To prevent overfitting
- Which type of regularization adds a penalty term to the loss function based on the absolute values of the weights?
  - A) L1 Regularization
  - B) L2 Regularization
  - C) Dropout
  - D) Batch Normalization
- Answer: A) L1 Regularization
- How does dropout regularization work?
  - A) It penalizes large weights in the network
  - B) It introduces noise to the input data during training
  - C) It randomly removes neurons during training
  - D) It normalizes the input features
- Answer: C) It randomly removes neurons during training

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## Reflect…

- Which regularization technique is commonly applied to prevent exploding gradients during training?
  - A) Dropout
  - B) Batch Normalization
  - C) L2 Regularization
  - D) Data Augmentation
- Answer: B) Batch Normalization
- What is the role of early stopping as a form of regularization?
- Answer Choices:
  - A) To speed up the training process
  - B) To prevent the model from fitting the training data too closely
  - C) To add noise to the input data
  - D) To stop the training process when the model performance on a validation set plateaus or degrades
- Answer: D) To stop the training process when the model performance on a validation set plateaus or degrades
- Which regularization method penalizes the squared values of the weights in the network?
  - A) Dropout
  - B) L1 Regularization
  - C) L2 Regularization
  - D) Batch Normalization
- Answer: C) L2 Regularization
- What is the trade-off associated with increasing the strength of regularization in a deep neural network?
  - A) Increased risk of overfitting
  - B) Increased risk of underfitting
  - C) Slower convergence during training
  - D) Improved model generalization
- Answer: B) Increased risk of underfitting

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## Reflect…

- In the context of regularization, what does the term "lambda" typically represent?
  - A) Learning rate
  - B) Regularization strength
  - C) Number of hidden layers
  - D) Batch size
- Answer: B) Regularization strength
- Which regularization technique is particularly useful for handling sequences and time-series data in deep learning?
  - A) L1 Regularization
  - B) Data Augmentation
  - C) Recurrent Dropout
  - D) Batch Normalization
- Correct Answer: C) Recurrent Dropout

- What is the purpose of data augmentation as a regularization technique?
  - A) To add noise to the input data
  - B) To increase the model's capacity
  - C) To generate more training samples by applying random transformations to the existing data
  - D) To decrease the learning rate during training
- Answer: C) To generate more training samples by applying random transformations to the existing data



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## Next Session…

- Vanishing Gradients
- Exploding Gradients
- Gradient Check

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