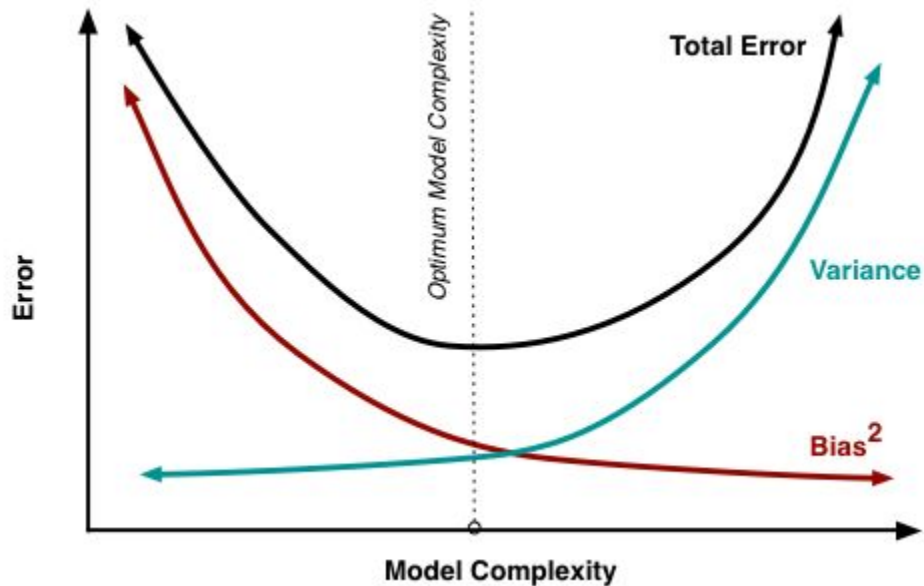


# Visualizing the Bias-Variance Tradeoff

Halldor Thorhallsson & Gursimran Singh

# The Bias-Variance Tradeoff


- A fundamental concept in Machine Learning
  - Bias -  $(E[\hat{f}(x)] - f(x))^2$
  - Variance -  $E[(\hat{f}(x) - E[\hat{f}(x)])^2]$
- Can be difficult to grasp
- Very few interactive visualisations out there that explain this!



# TensorFlow Playground

Tinker With a **Neural Network** Right Here in Your Browser.  
Don't Worry, You Can't Break It. We Promise.

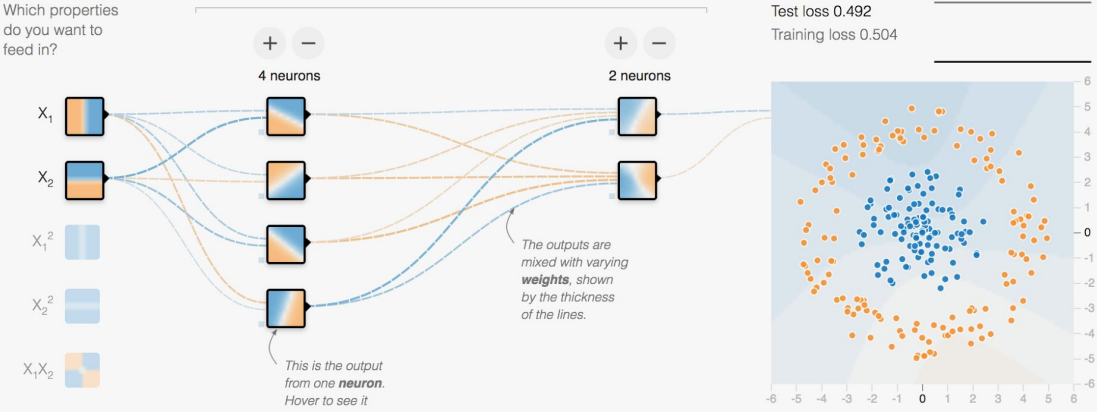
↻ ▶ Epoch 000,000 Learning rate 0.03 Activation Tanh Regularization None Regularization rate 0 Problem type Classification

**DATA**  
Which dataset do you want to use?  
  
Ratio of training to test data: 50%  
Noise: 0  
Batch size: 10

**FEATURES**  
Which properties do you want to feed in?  
 $X_1$   
 $X_2$   
 $X_1^2$   
 $X_2^2$   
 $X_1 X_2$

**2 HIDDEN LAYERS**  
+ - 4 neurons  
+ - 2 neurons

**OUTPUT**  
Test loss 0.492  
Training loss 0.504



*This is the output from one neuron. Hover to see it larger.*

*The outputs are mixed with varying weights, shown by the thickness of the lines.*

# Demo!

[Demo KNN Link](#)

[Demo Linear Models Link](#)

# VAD Analysis

## What

- Multiple samples  $(X^{(1)}, y^{(1)}), (X^{(2)}, y^{(2)}), \dots (X^{(n)}, y^{(n)})$ ,
- Predictions  $y_{\text{hat}}^1, y_{\text{hat}}^2 \dots y_{\text{hat}}^n$
- **Derived:** Residuals  $\rightarrow y^{(i)} - y_{\text{hat}}^i$

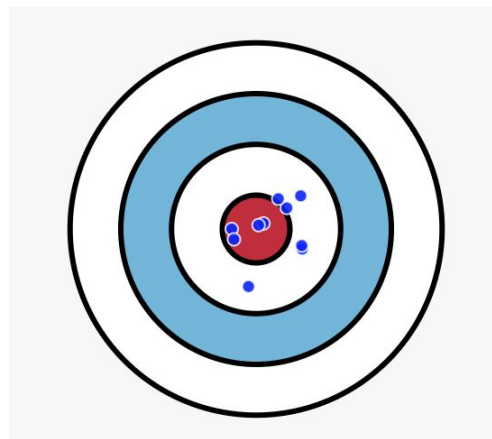
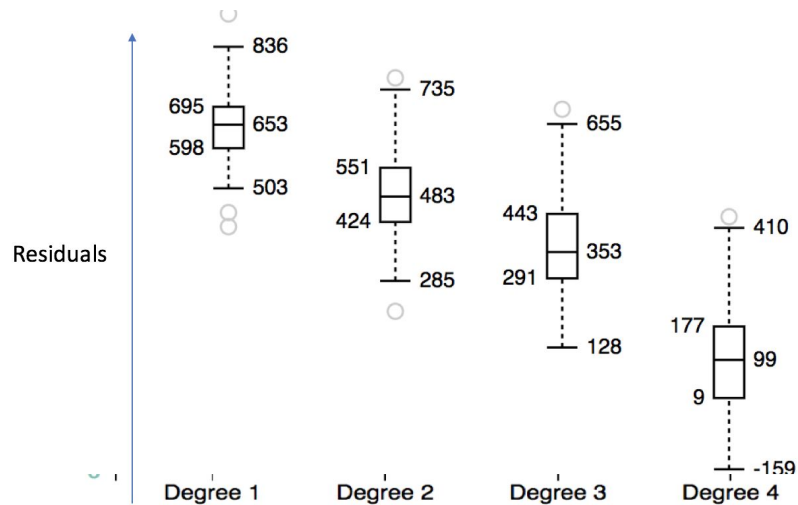
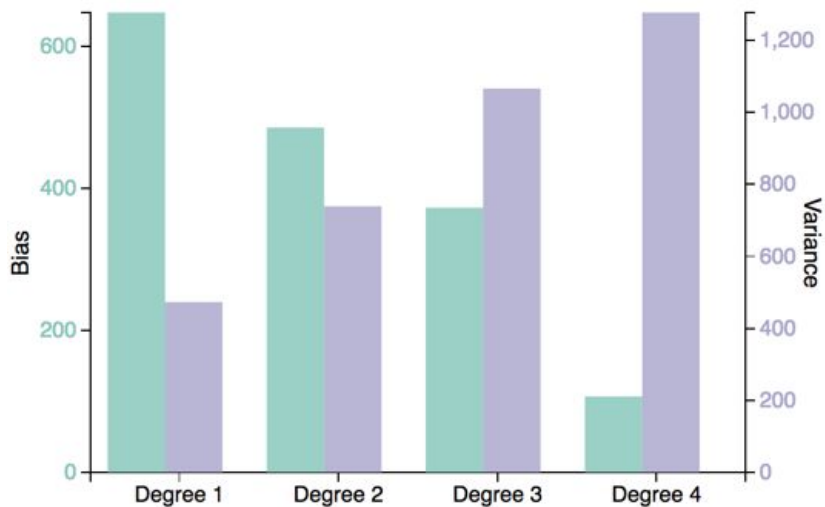
## Why

- To understand the **bias-variance** tradeoff

## How

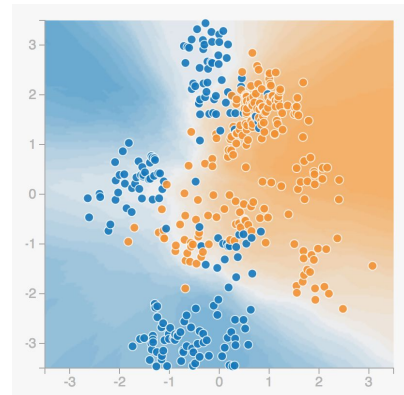
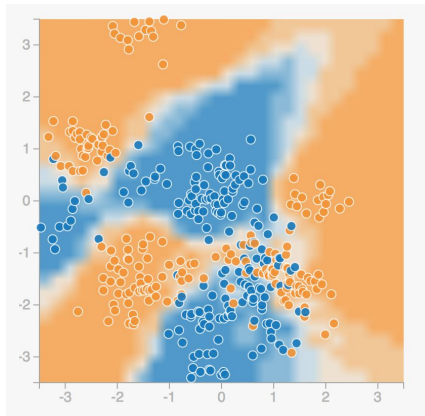
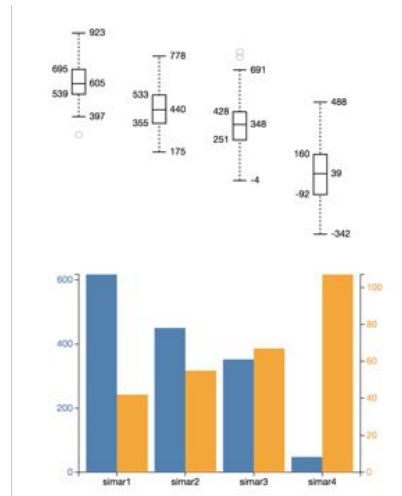
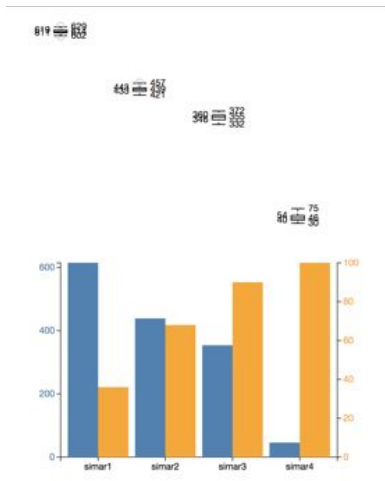
- Bar plot shows bias and variance exactly
- Box plot shows distribution of residuals  $(y^{(1)} - y_{\text{hat}}^1)$
- Dart board shows bias intuitively

# VAD Analysis - How



# Challenges

- Polynomial regression
  - Hard to show bias and variance in the same plot.
  - Future work - show the distribution in the scatter plot.
- KNN
  - Changing parameters is a bit laggy for heatmap
  - What is high/low bias and variance?



Thanks!  
Q&A



# VAD Analysis ()

## What

- True distribution  $f(x)$
- Training sampled data from  $f(x) \rightarrow X^{(i)}, y^{(i)}$
- Testing/ Generalization sample  $\rightarrow X_g^{(i)}, y_g^{(i)}$
- Predictions  $y_{\text{hat}}$

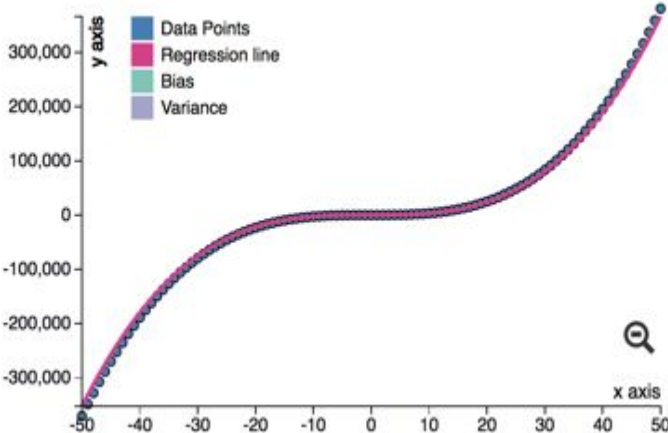
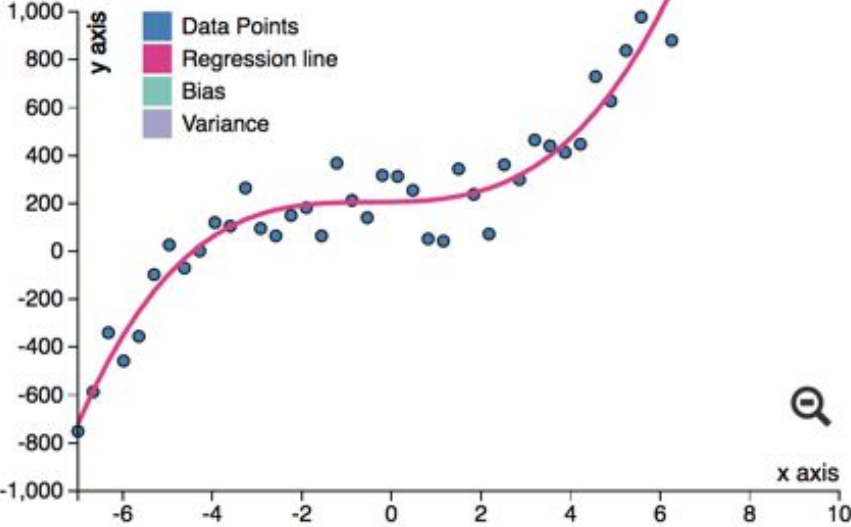
## Why

- To understand how close  $y_{\text{hat}}$  is to  $y^{(i)}$  and  $y_g^{(i)}$

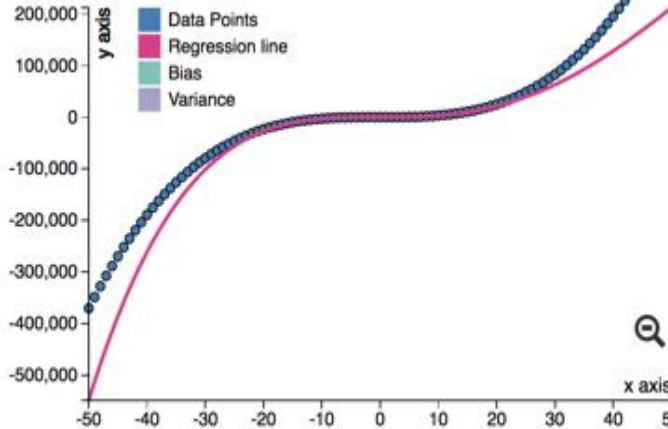
## How

- Scatter plot
- Navigation to view generalization samples

# Scatter plot



Degree 3 fit



Degree 4 fit

# Challenge - Scaling of bias and variance

