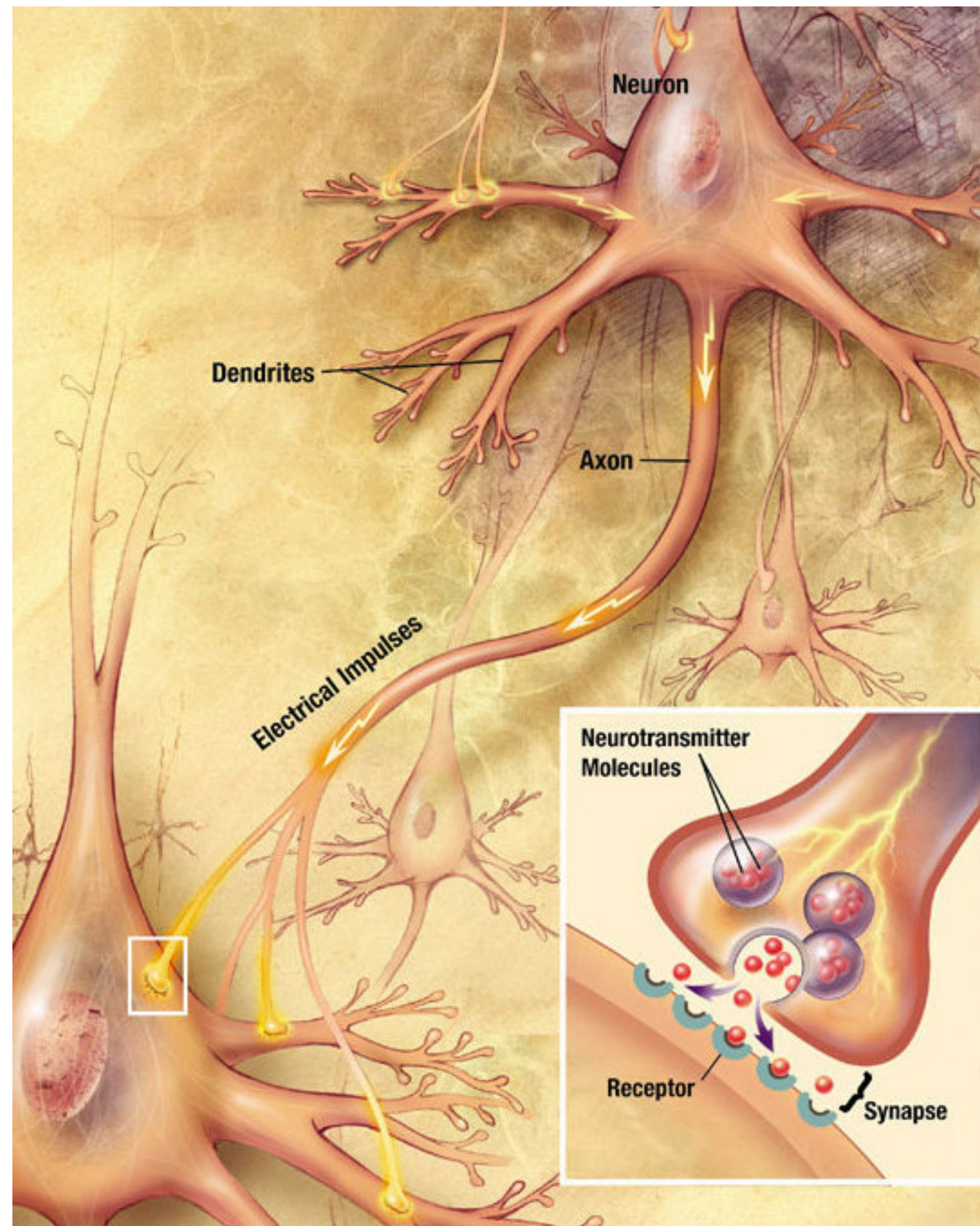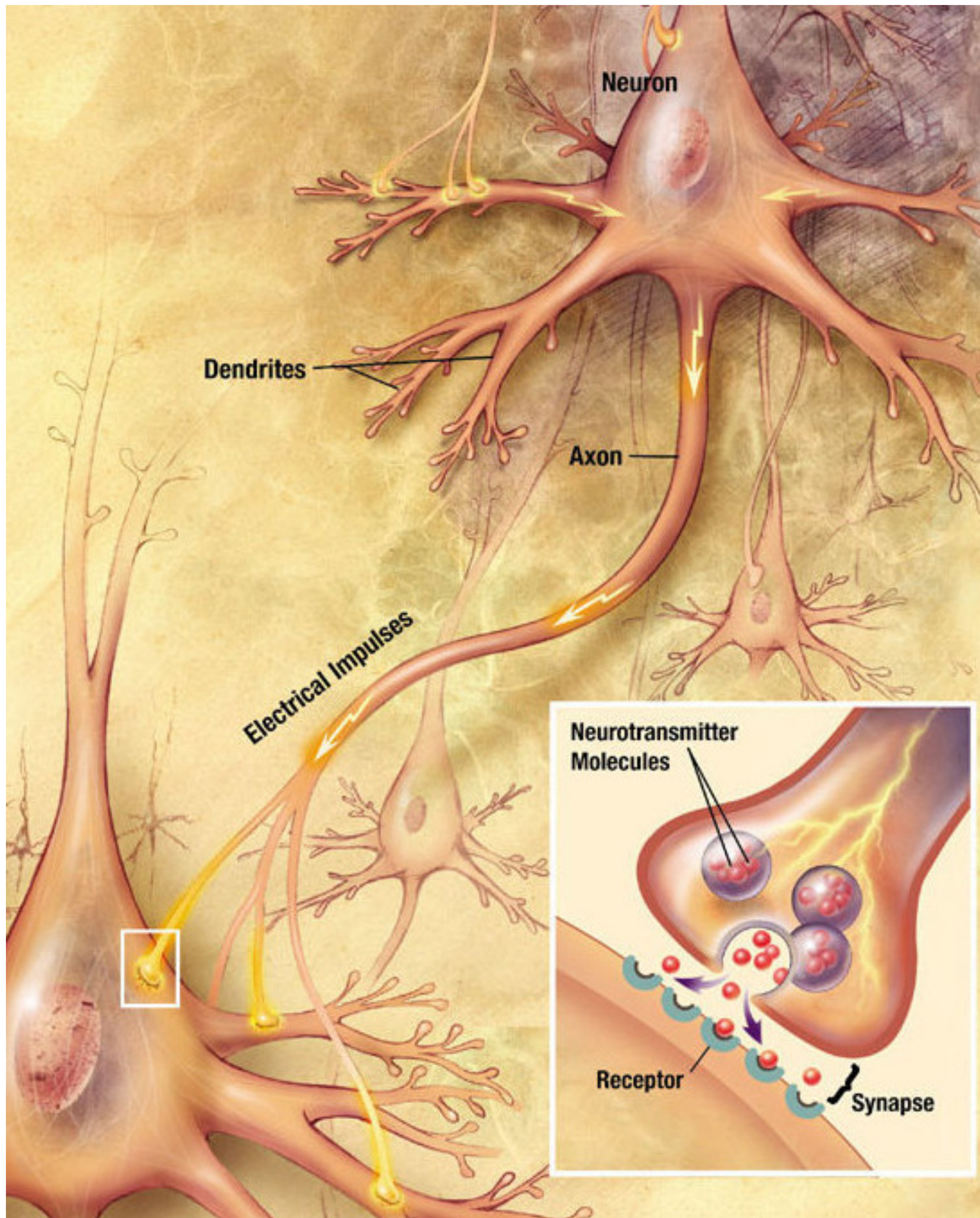# Neural Networks

Machine Learning
CS5824/ECE5424
Bert Huang
Virginia Tech

Outline

- Logistic regression and perceptron as neural networks

- Multi-layered perceptron

- Nonlinearity

Neuron

Dendrites

Axon

Electrical Impulses

Neurotransmitter Molecules

Receptor

Synapse

Neuron

Dendrites

Axon

Electrical Impulses

Neurotransmitter Molecules

Receptor

Synapse

https://en.wikipedia.org/wiki/Neuron#/media/File:Chemical_synapse_schema_cropped.jpg
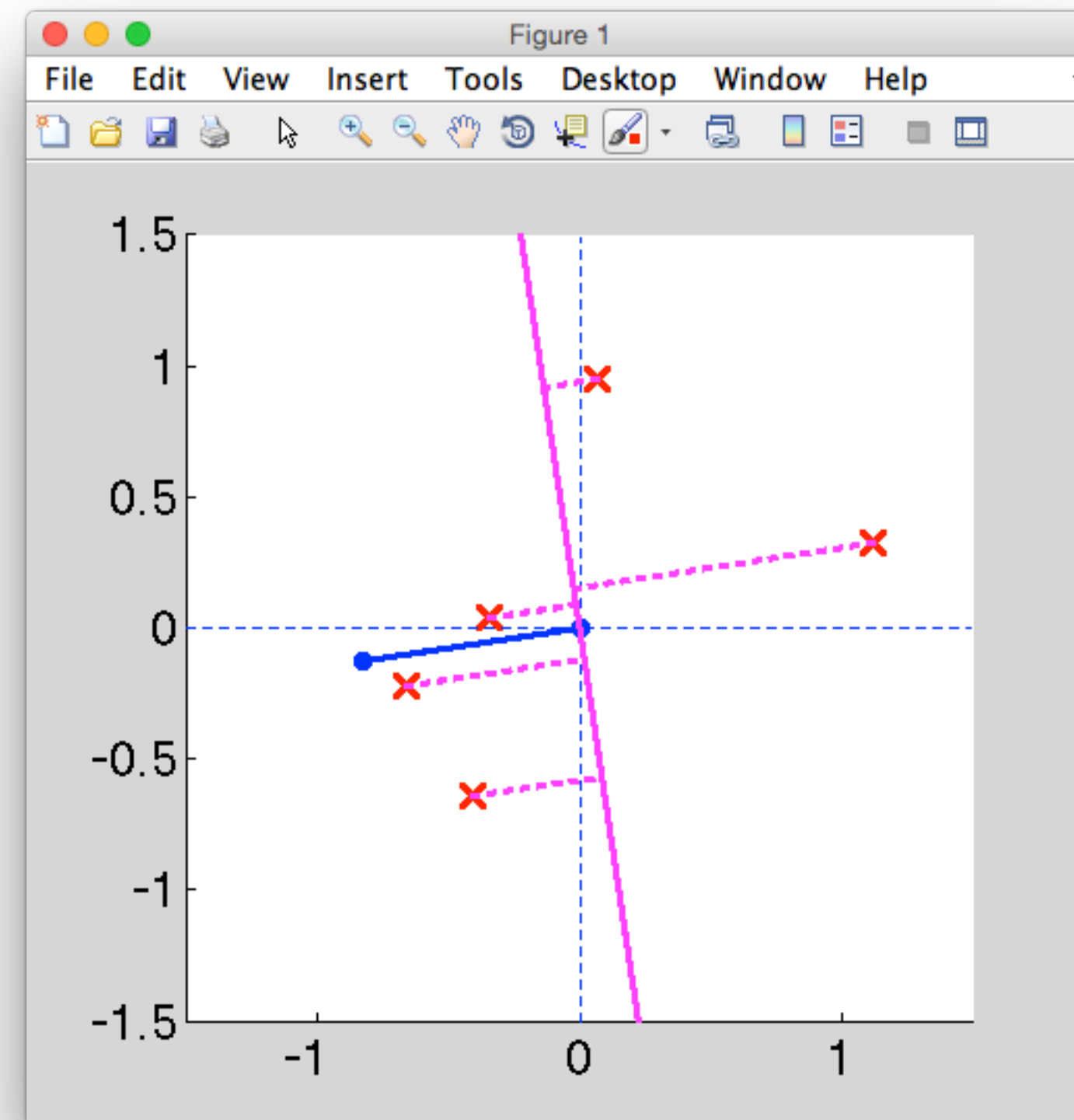
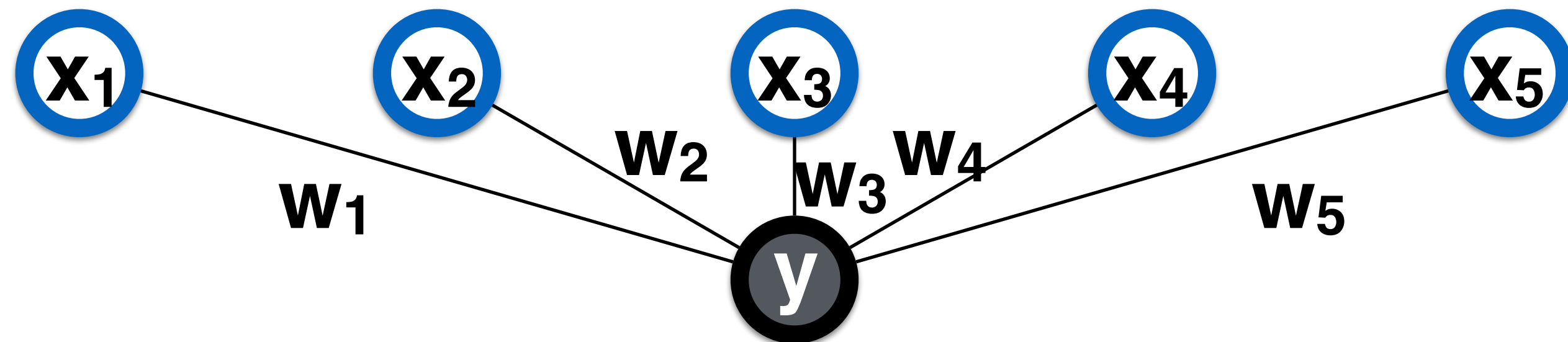

https://en.wikipedia.org/wiki/Neuron#/media/File:GFPneuron.png
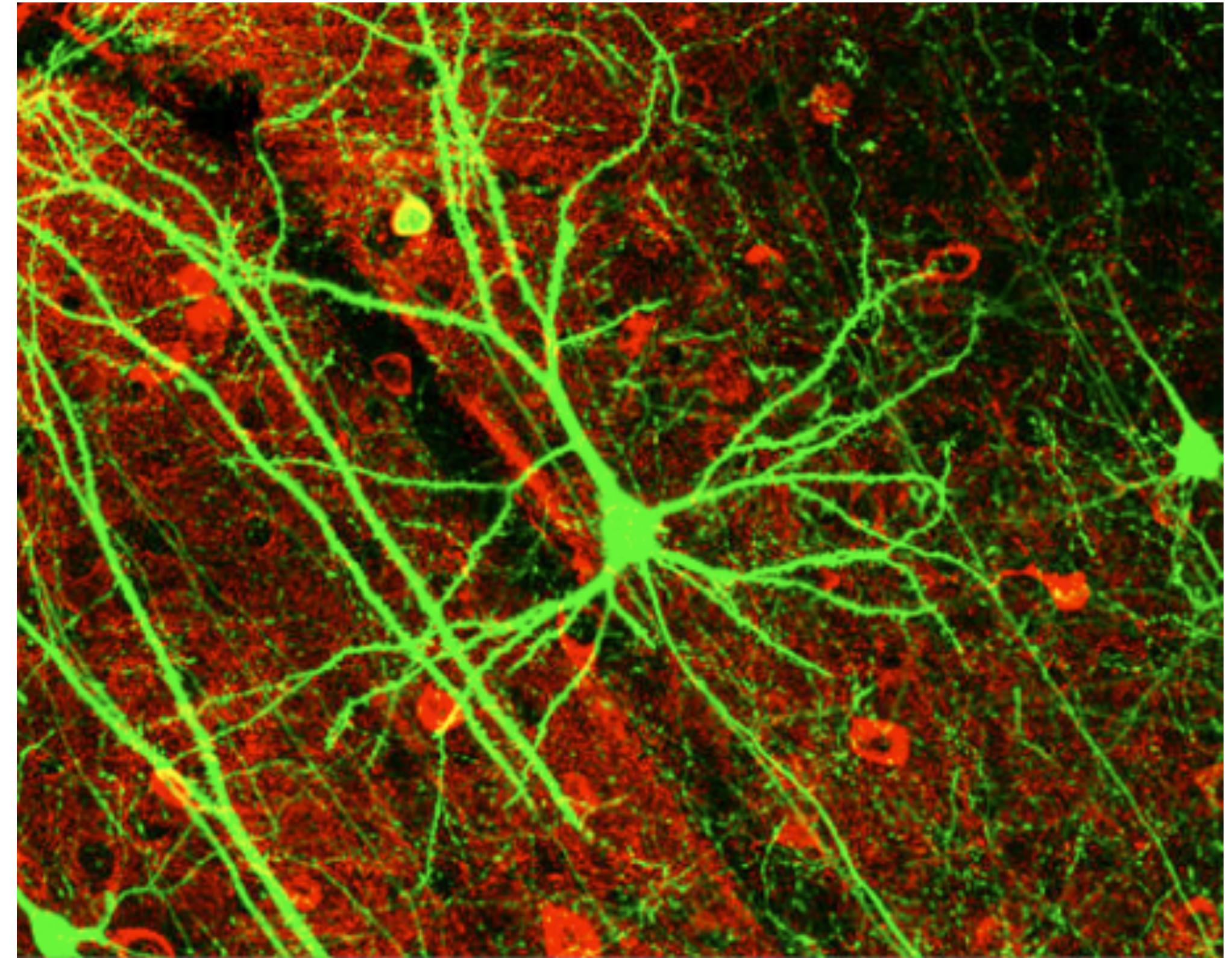
Parameterizing p(y|x)

$$p(y|x) := f$$

$$f : \mathbb{R}^d \to [0, 1]$$

$$f(x) := \frac{1}{1 + \exp(-w^\top x)}$$

x_1 x_2 x_3 x_4 x_5

w_1 w_2 w_3 w_4 w_5
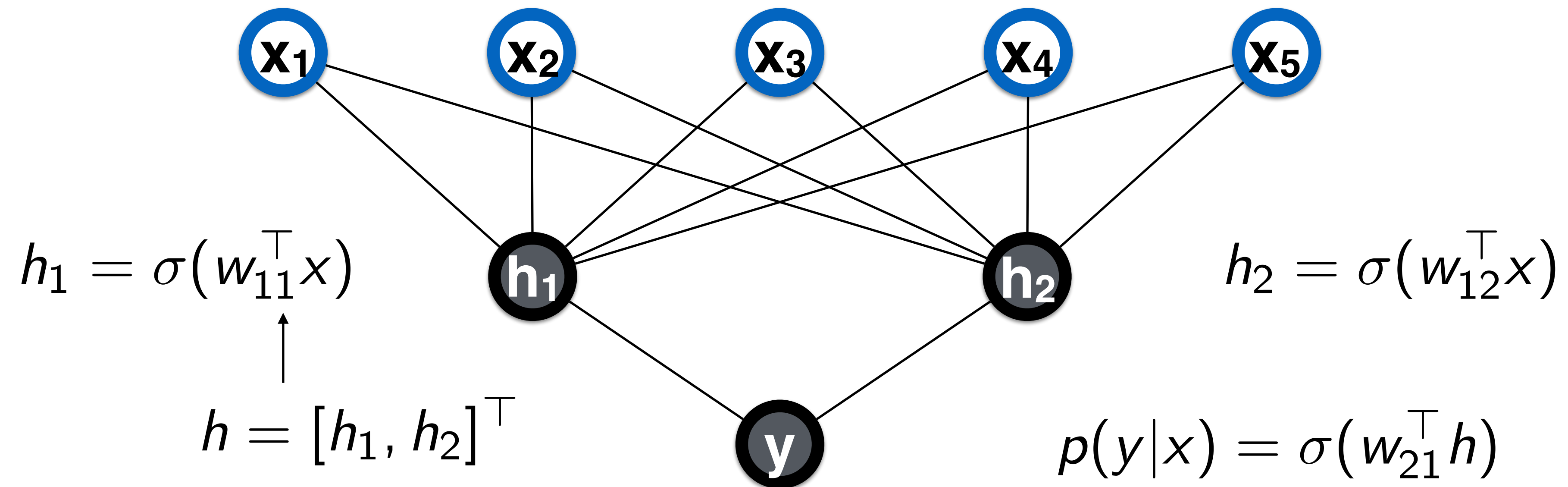
y
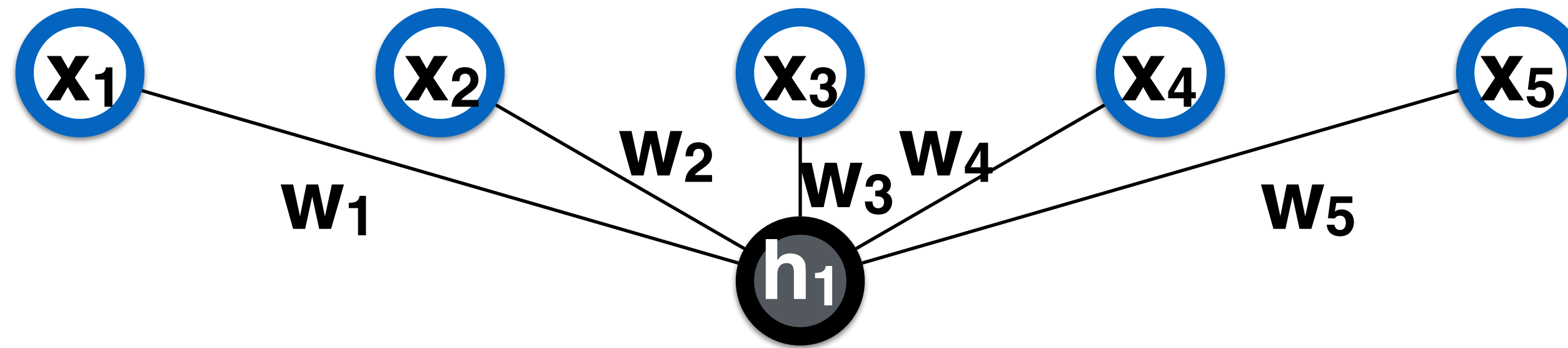
Multi-Layered Perceptron

Multi-Layered Perceptron

raw data

x_1 x_2 x_3 x_4 x_5

pixel values

representation

h_1

h_2

shapes

shadows

round

y

prediction

faces

Multi-Layered Perceptron

$h_1 = \sigma(w_{11}^\top x)$

$h_2 = \sigma(w_{12}^\top x)$

$h = [h_1, h_2]^\top$
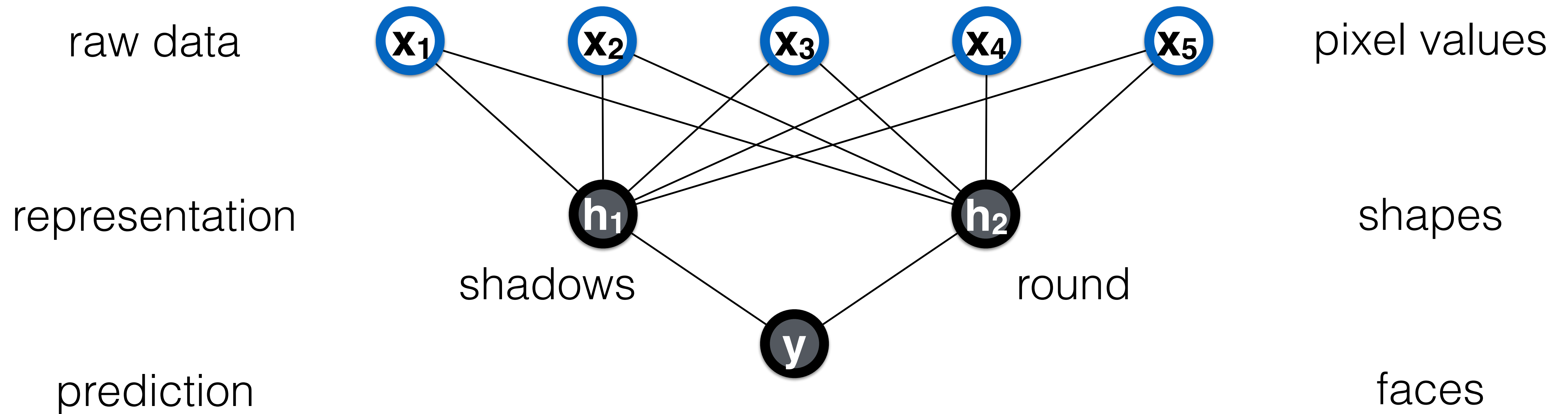
$p(y|x) = \sigma(w_{21}^\top h)$
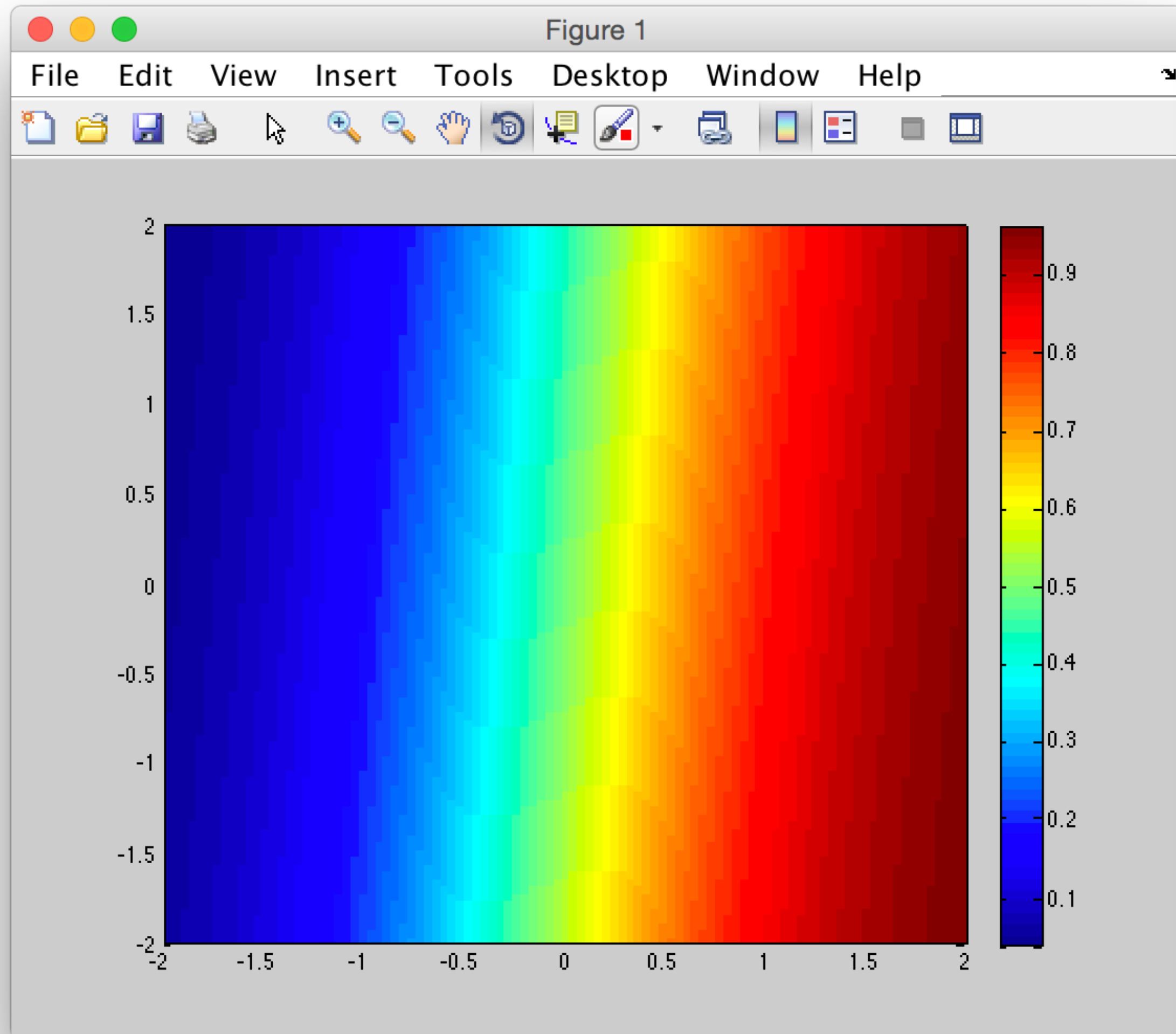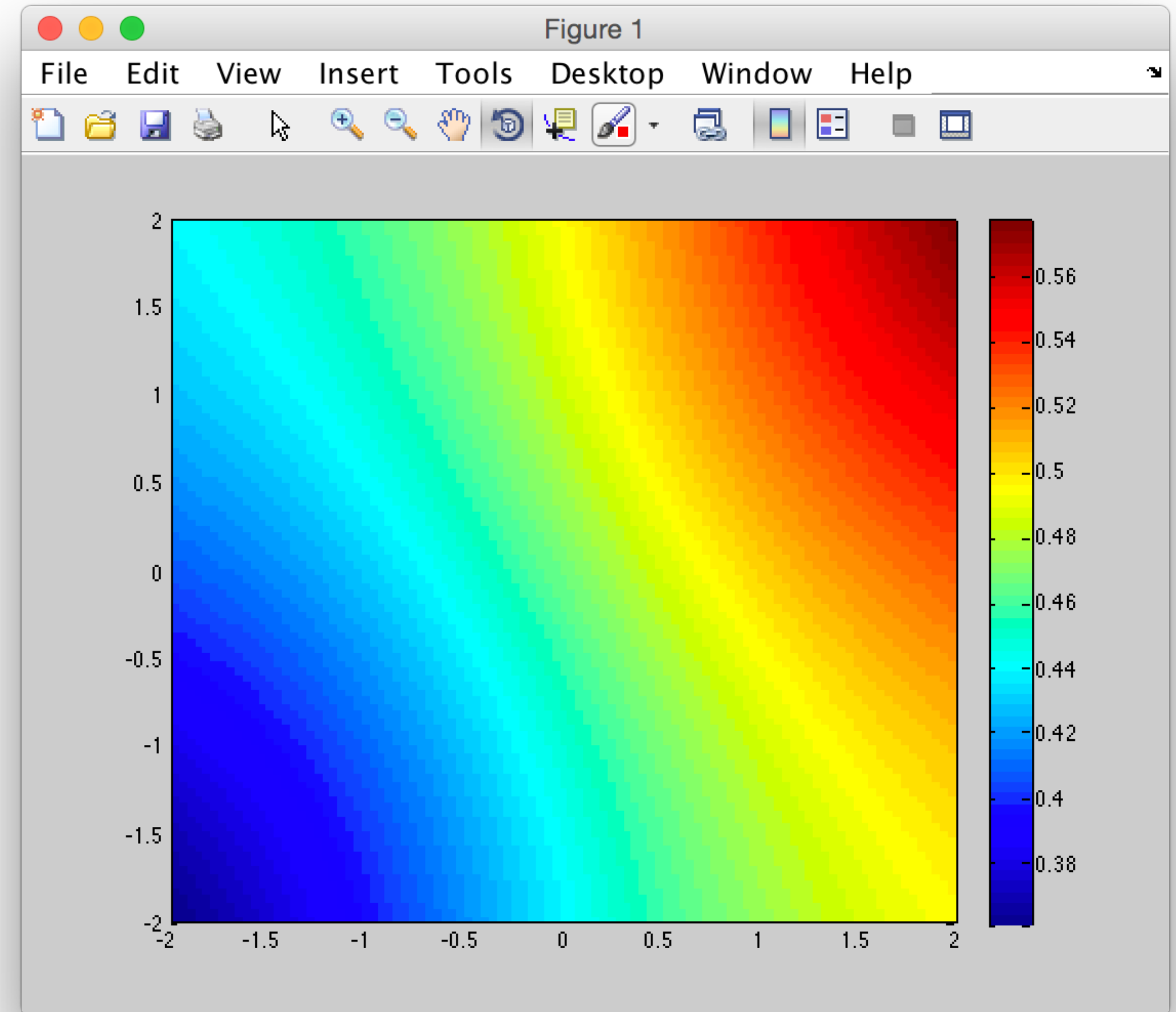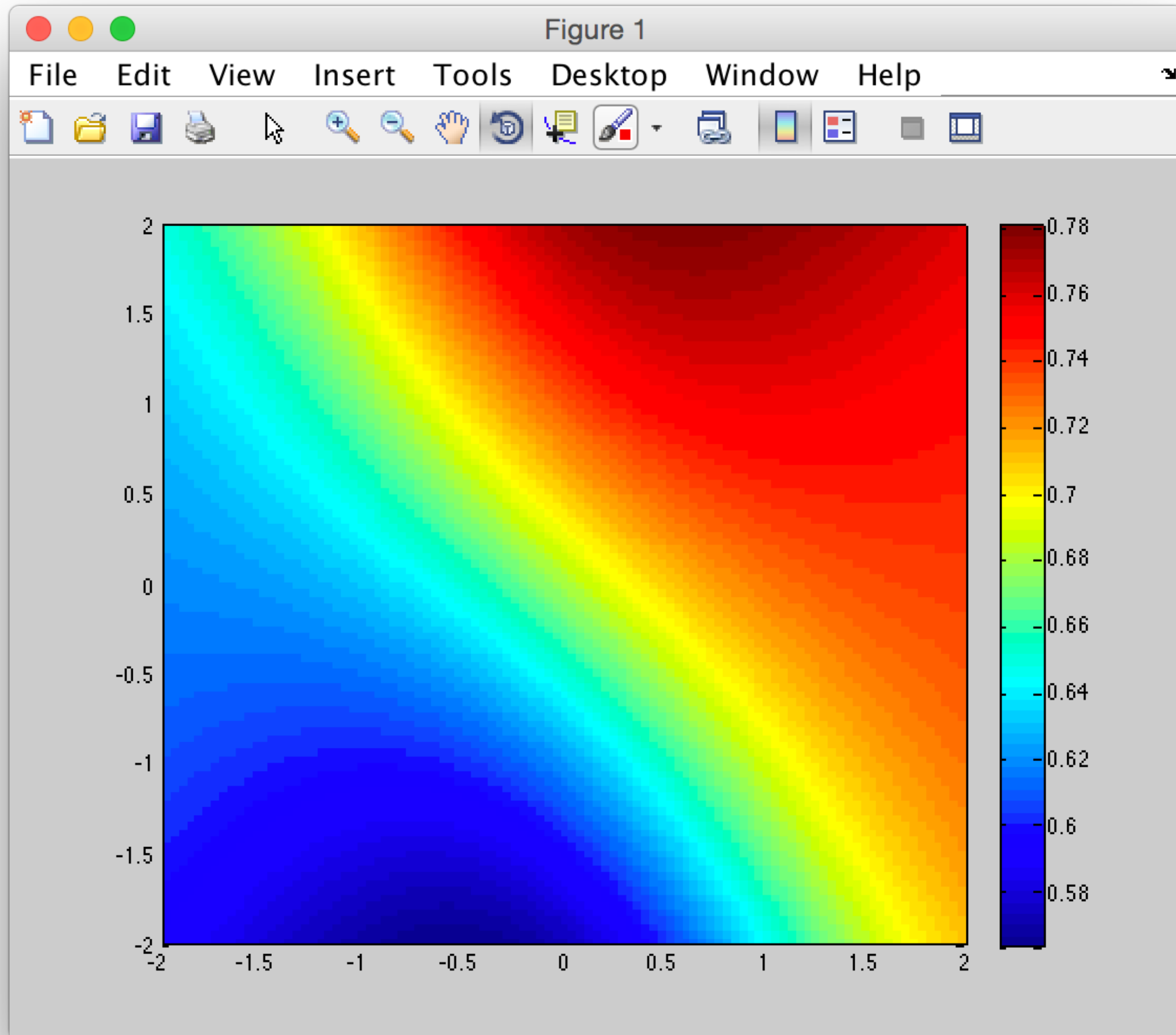
$$p(y|x) = \sigma\left(w_{21}^\top \left[\sigma(w_{11}^\top x), \sigma(w_{12}^\top x)\right]^\top\right)$$
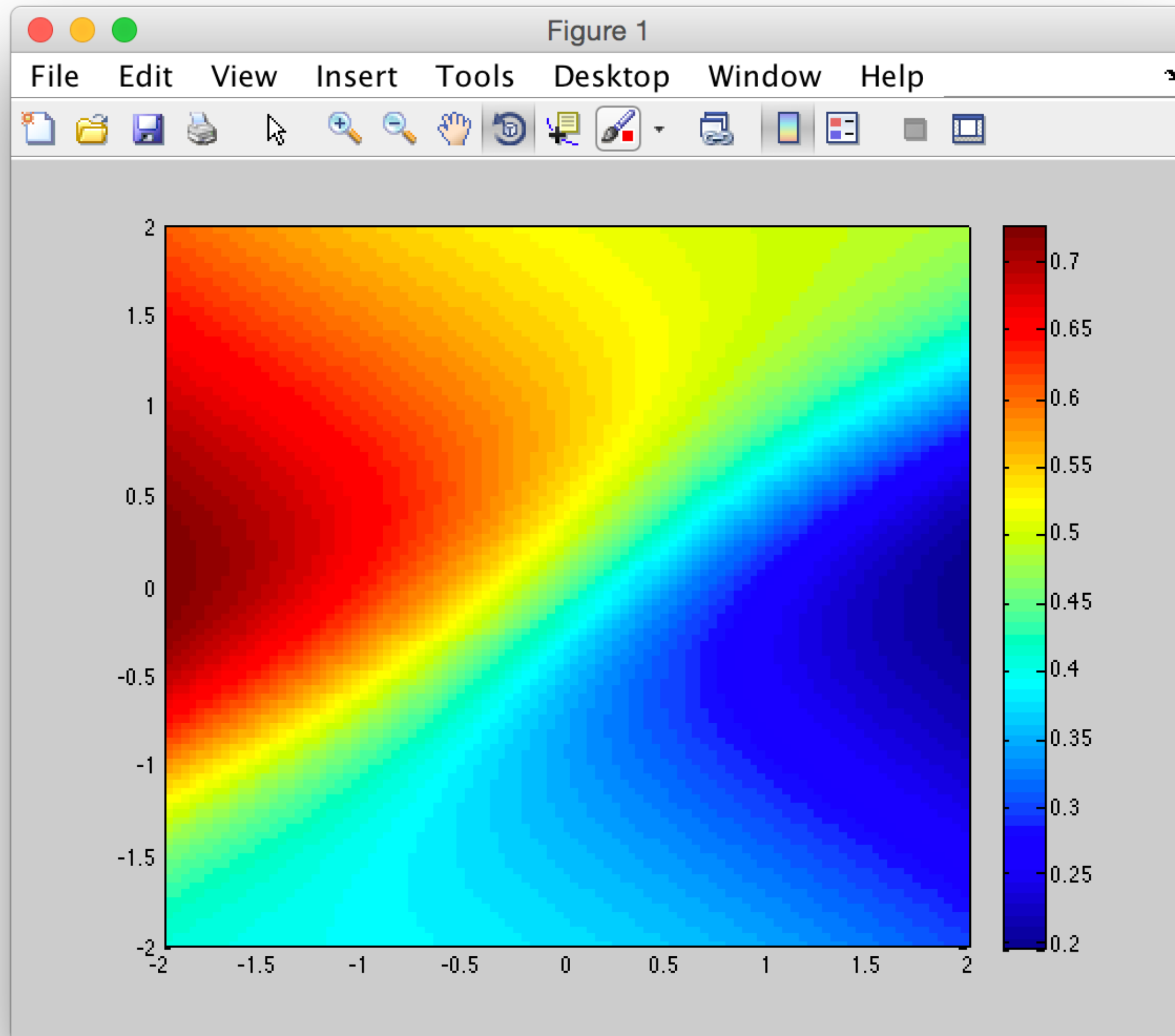
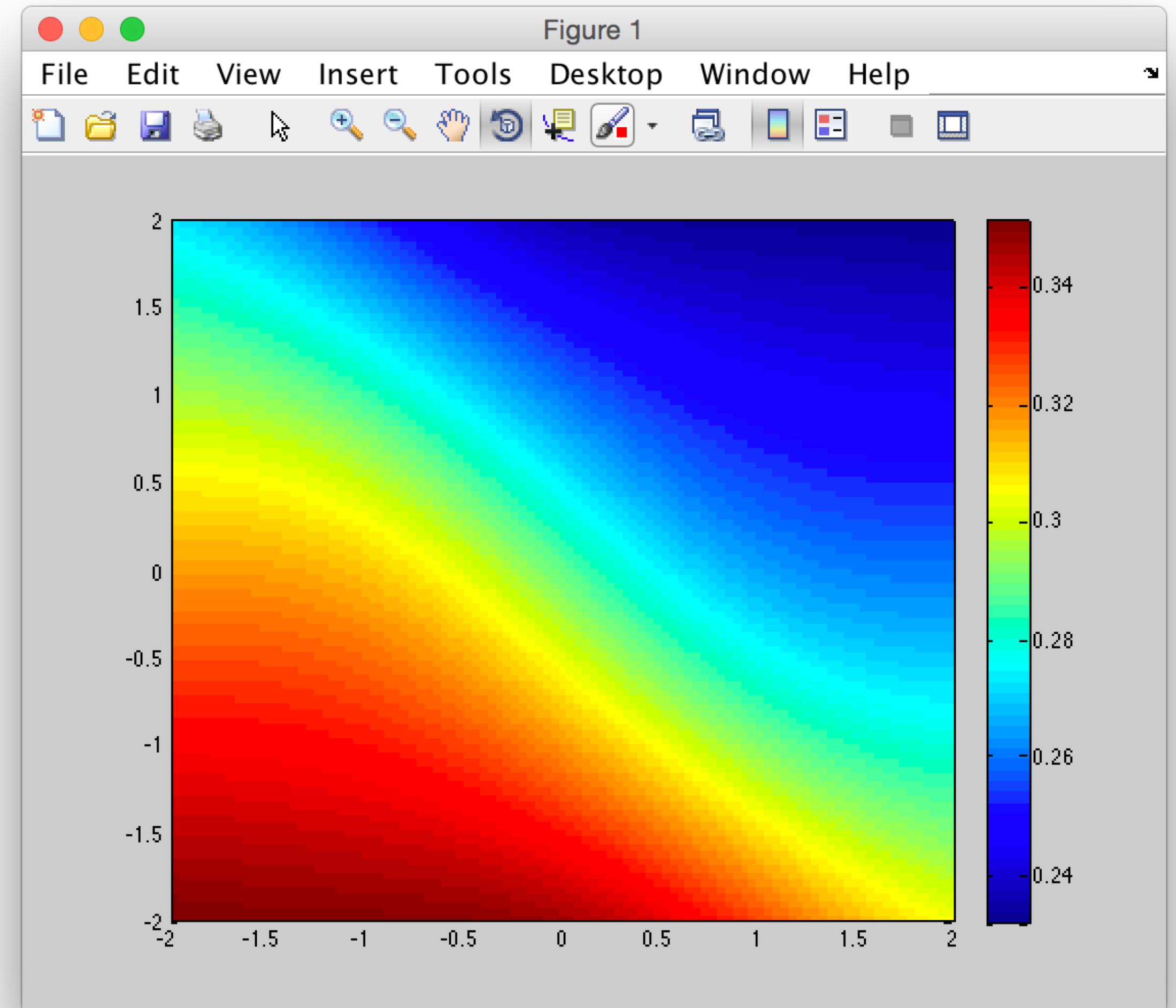# Decision Surface: Logistic Regression
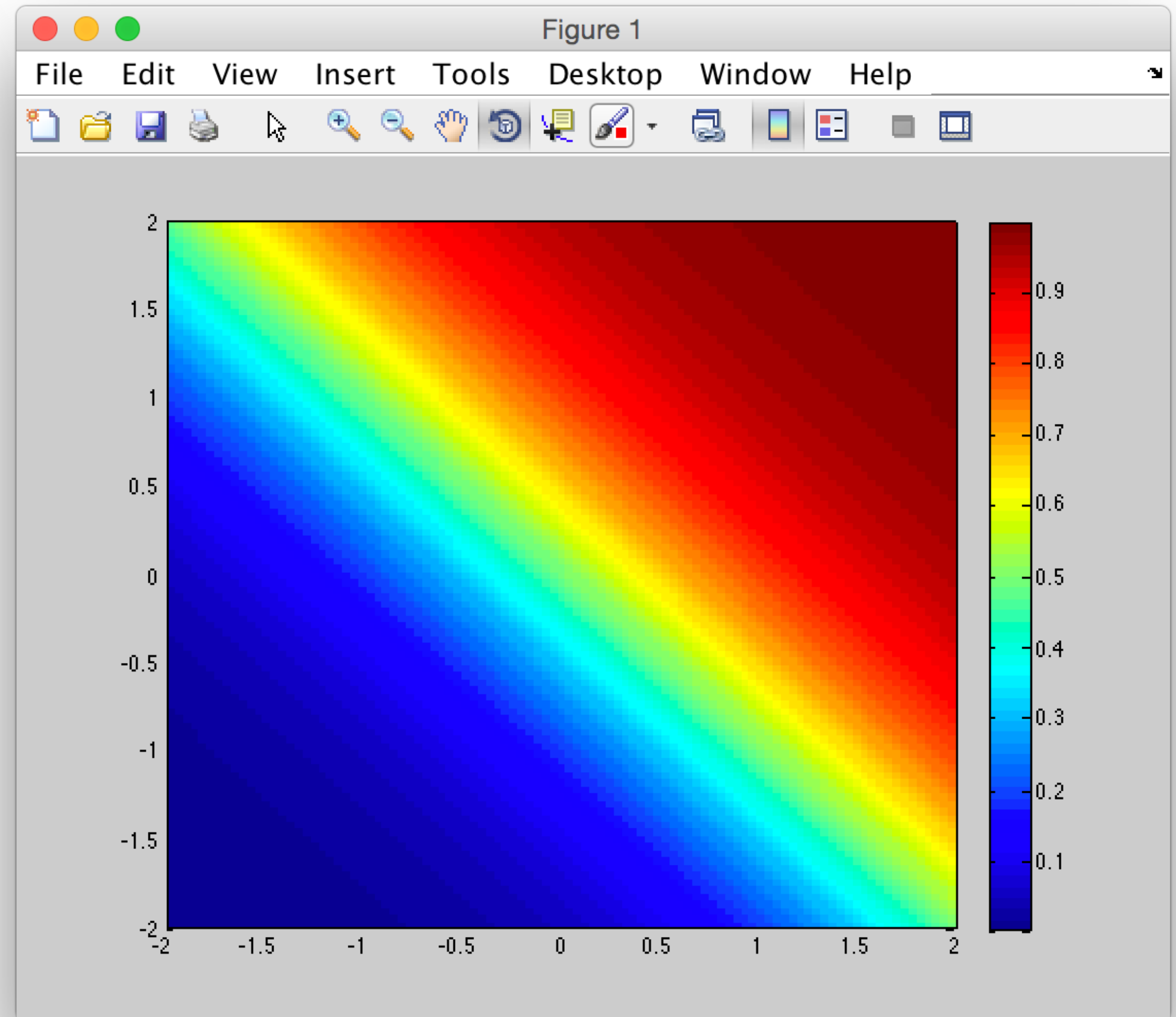
Decision Surface: 2-Layer, 2 Hidden Units

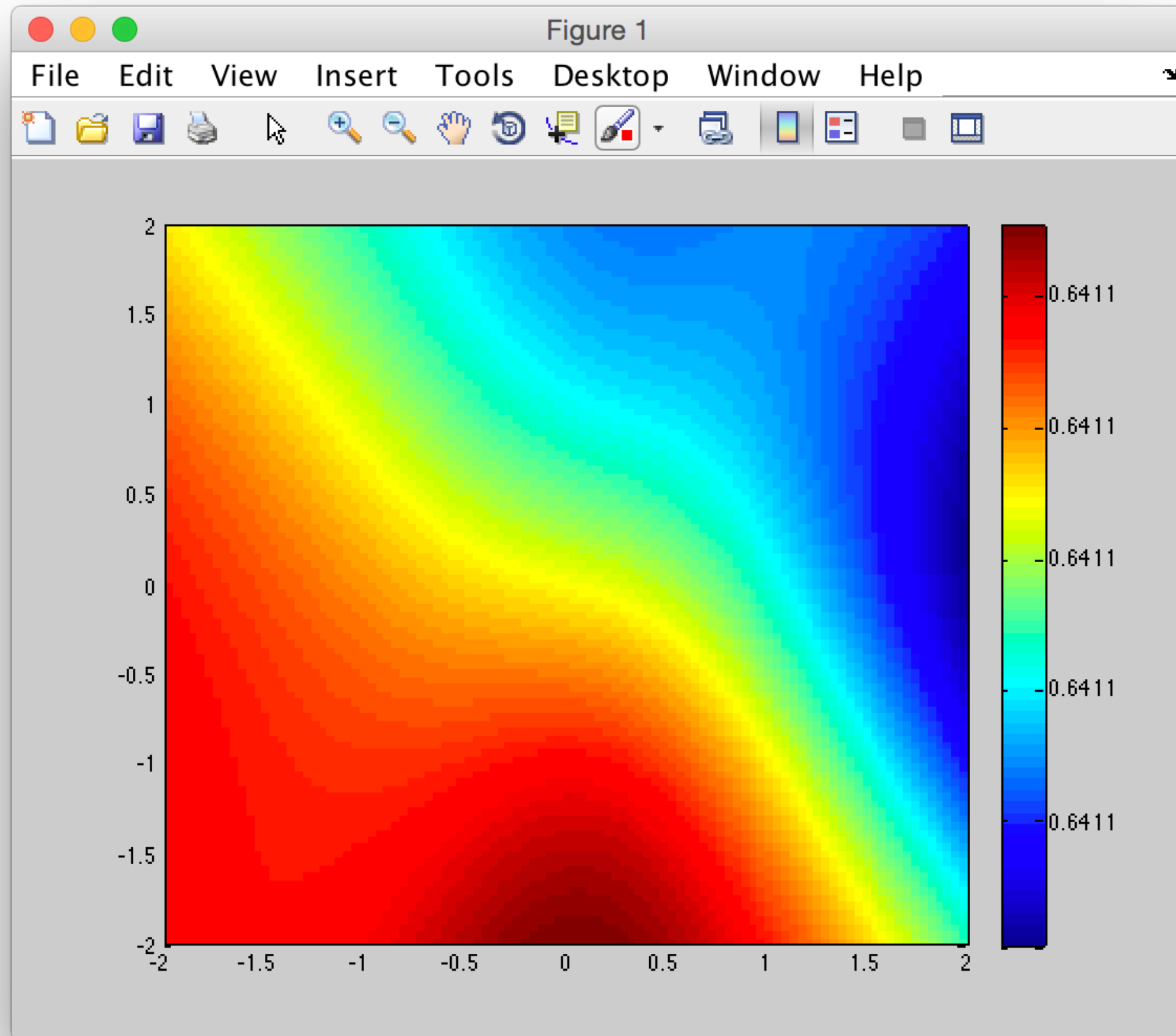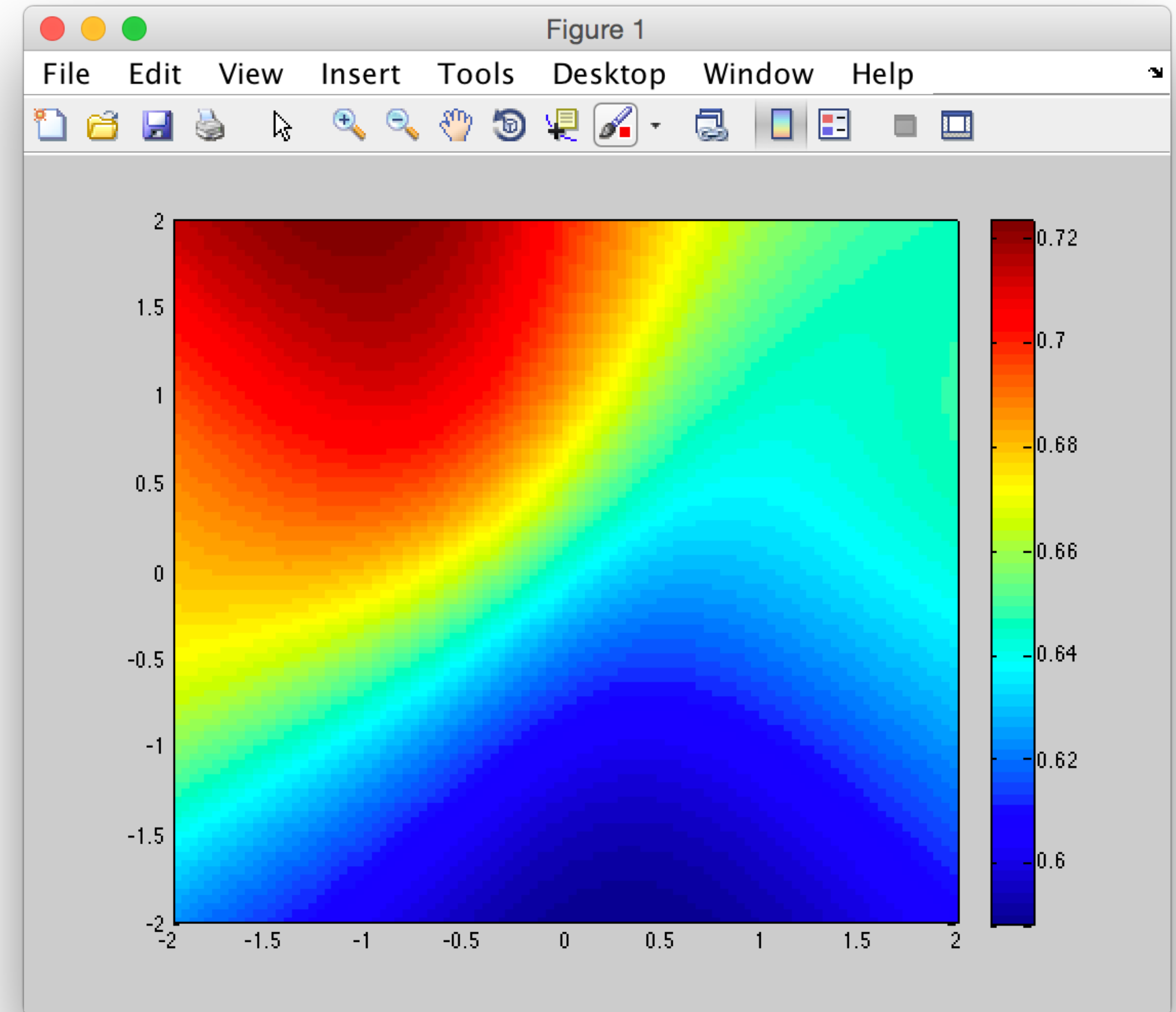# Decision Surface: 2-Layer, More Hidden Units

3 hidden units

10 hidden units

Decision Surface: More Layers, More Hidden Units

10 layers, 5 hidden units per layer

4 layers, 10 hidden units each layer

Training

- Back propagation:

  - Compute hidden unit activations: **forward propagation**

  - Compute gradient at output layer: error

  - Propagate error back one layer at a time

- Chain rule via dynamic programming