Introduction to deep learning 1/?

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Introduction

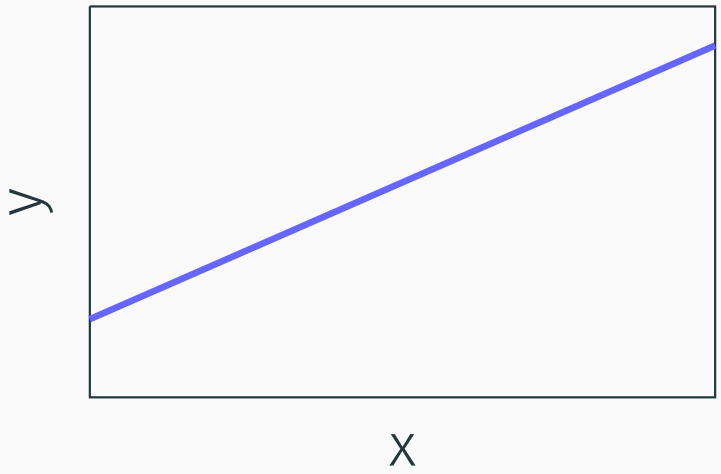
1. Building an artificial neural network (ANN)
2. Training the ANN
3. Transformation to a Convolutional Neural Network (CNN)

Building a neural network: Linear regression

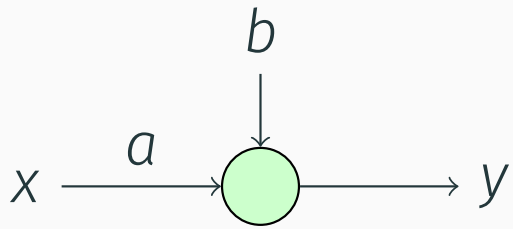
$$y = ax + b$$

Building a neural network: Linear regression

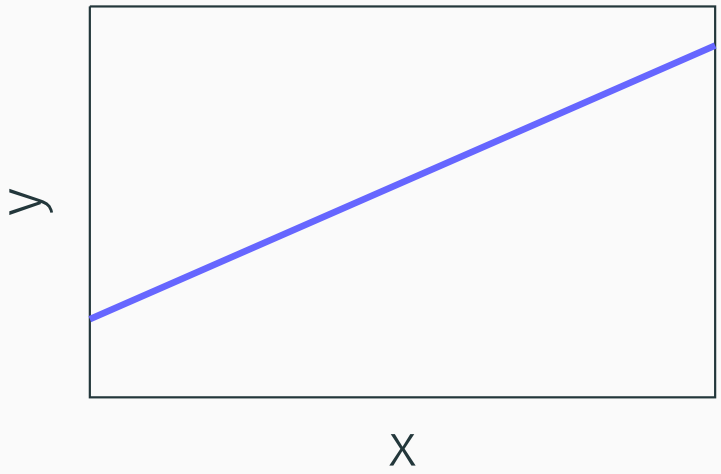
$$y = ax + b$$



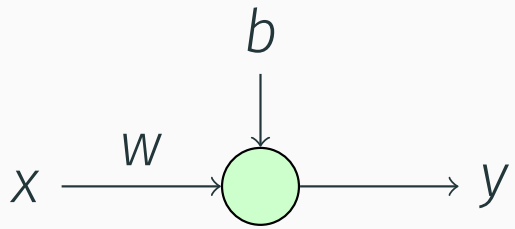
Building a neural network: Linear regression



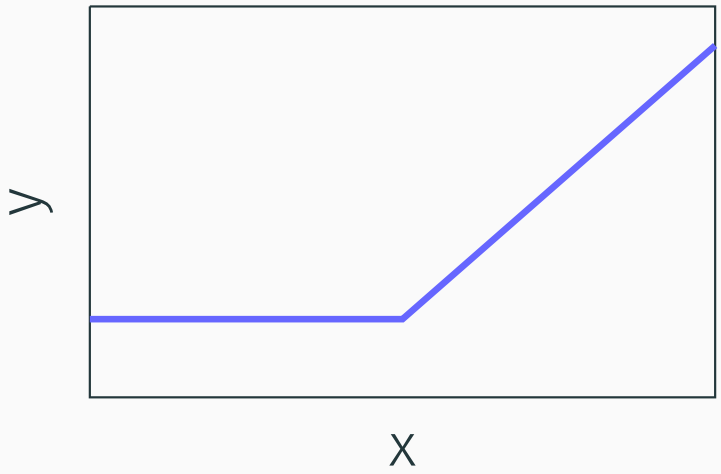
$$y = ax + b$$



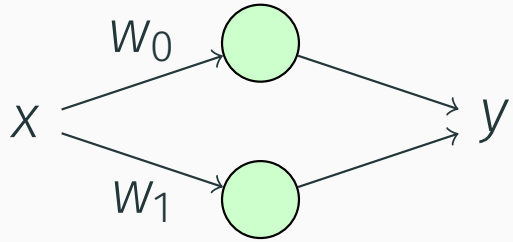
Building a neural network: Artificial neuron



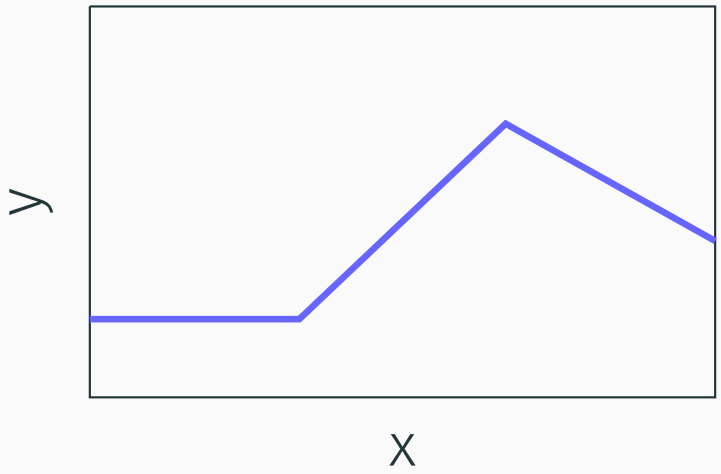
$$y = max(0, wx + b)$$



Building a neural network: Artificial neural network (ANN)



$$y = max(0, w_0 x + b_0) + max(0, w_1 x + b_1)$$



Building a neural network: Universal approximation theorem

”Any relationship that can be described with a polynomial function can be approximated by a neural network with a single hidden layer.”

- Some guy in the 80s, probably

Building a neural network: Universal approximation theorem

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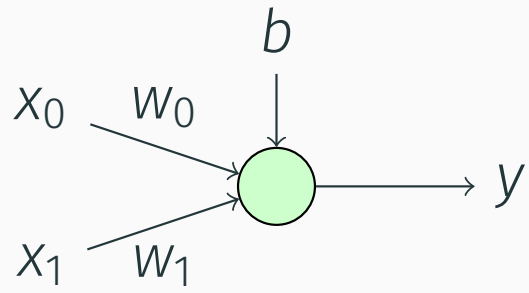
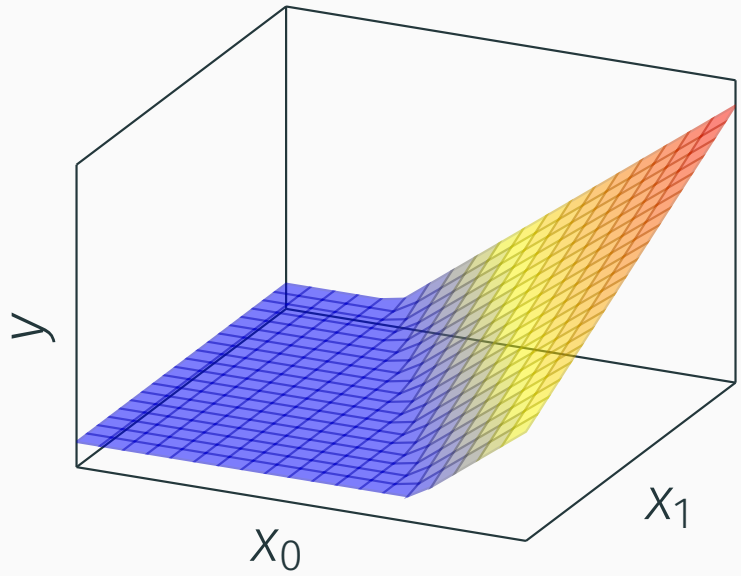
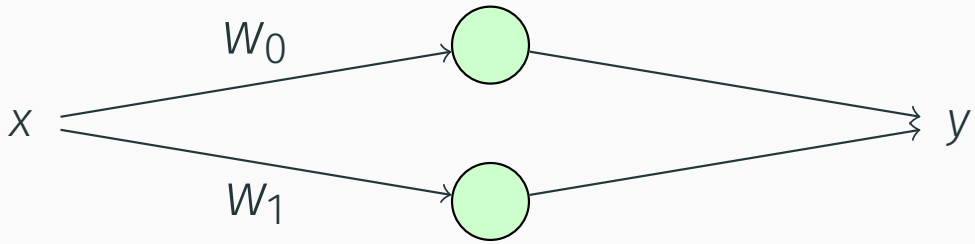
Building a neural network: Increasing dimensionality



$$y = max(0, w_0 x_0 + w_1 x_1 + b)$$

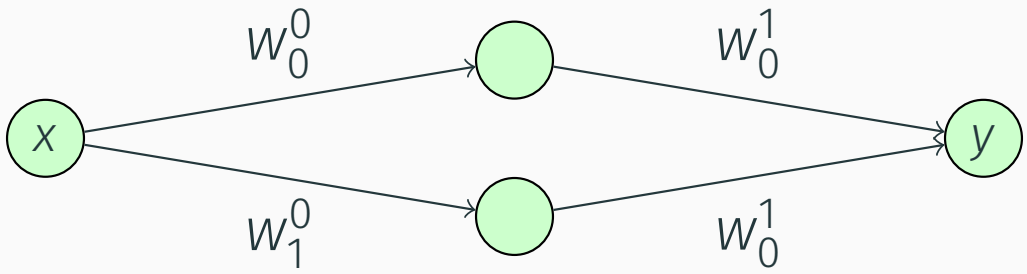


Building a neural network



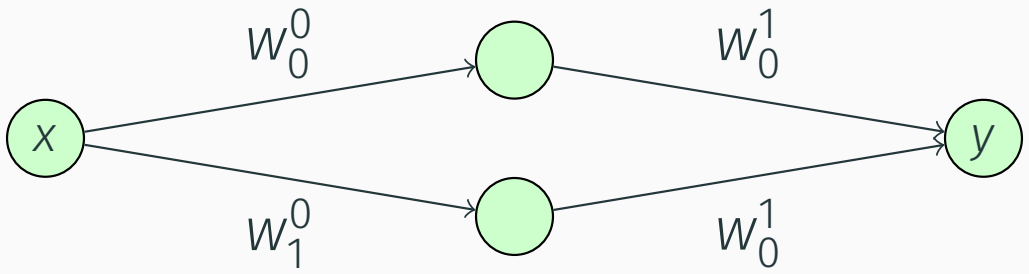
$$y = max(0, w_0 x + b_0) + max(0, w_1 x + b_1)$$

Building a neural network



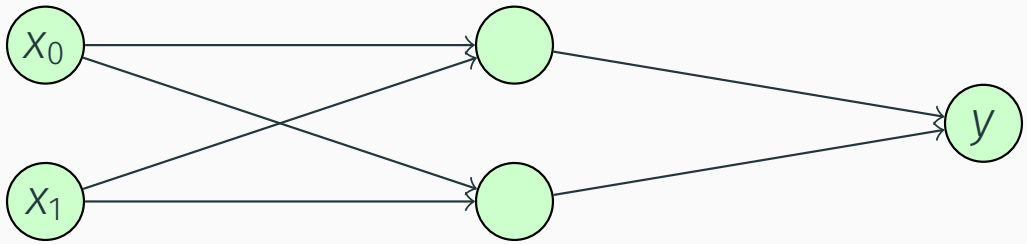
$$y = max(0, w^1_{0,0} * max(0, w^0_{0,0} * x + b_{0,0}) + w^1_{1,0} * max(0, w^0_{0,1} * x + b_{1,0}) + b_1)$$

Building a neural network



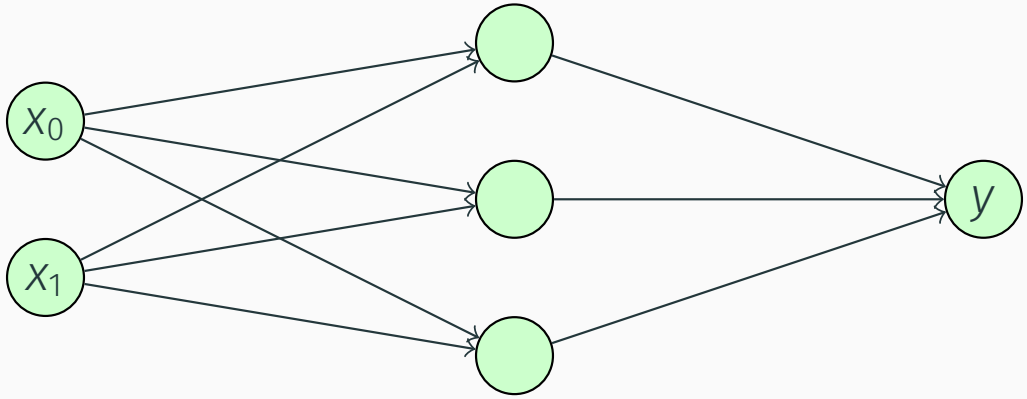
$$y = max(0, w^1_{0,0} * max(0, w^0_{0,0} * x + b_{0,0}) + w^1_{1,0} * max(0, w^0_{0,1} * x + b_{1,0}) + b_1)$$

Building a neural network



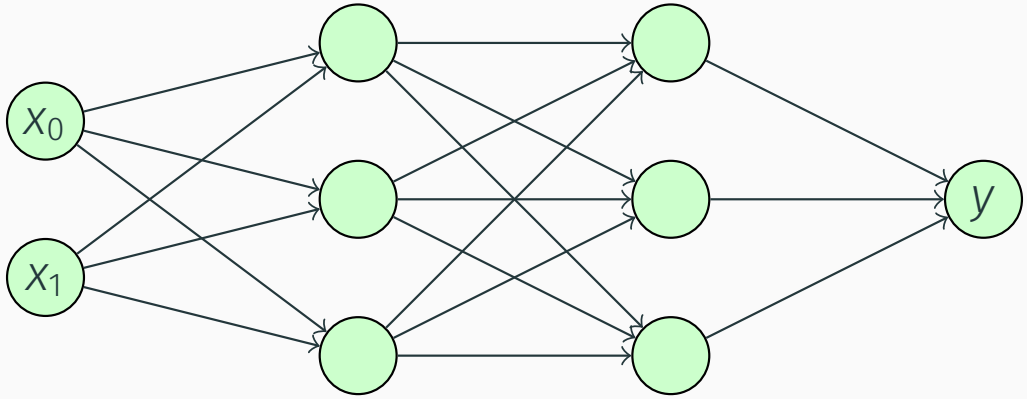
$$y = max(0, w^1_{0,0} * max(0, w^0_{0,0} * x_0 + w^0_{1,0} * x_1 + b_{0,0}) + w^1_{1,0} * max(0, w^0_{0,1} * x_0 + w^0_{1,1} * x_1 + b_{0,1}) + b_1)$$

Building a neural network



$$
\begin{aligned}
y = max(0, & w^1_{0,0} * max(0, w^0_{0,0} * x_0 + w^0_{1,0} * x_1 + b_{0,0}) + \\
& w^1_{1,0} * max(0, w^0_{0,1} * x_0 + w^0_{1,1} * x_1 + b_{0,1}) + \\
& w^1_{2,0} * max(0, w^0_{0,2} * x_0 + w^0_{1,2} * x_1 + b_{0,2}) + \\
& b_1)
\end{aligned}
$$

Building a neural network

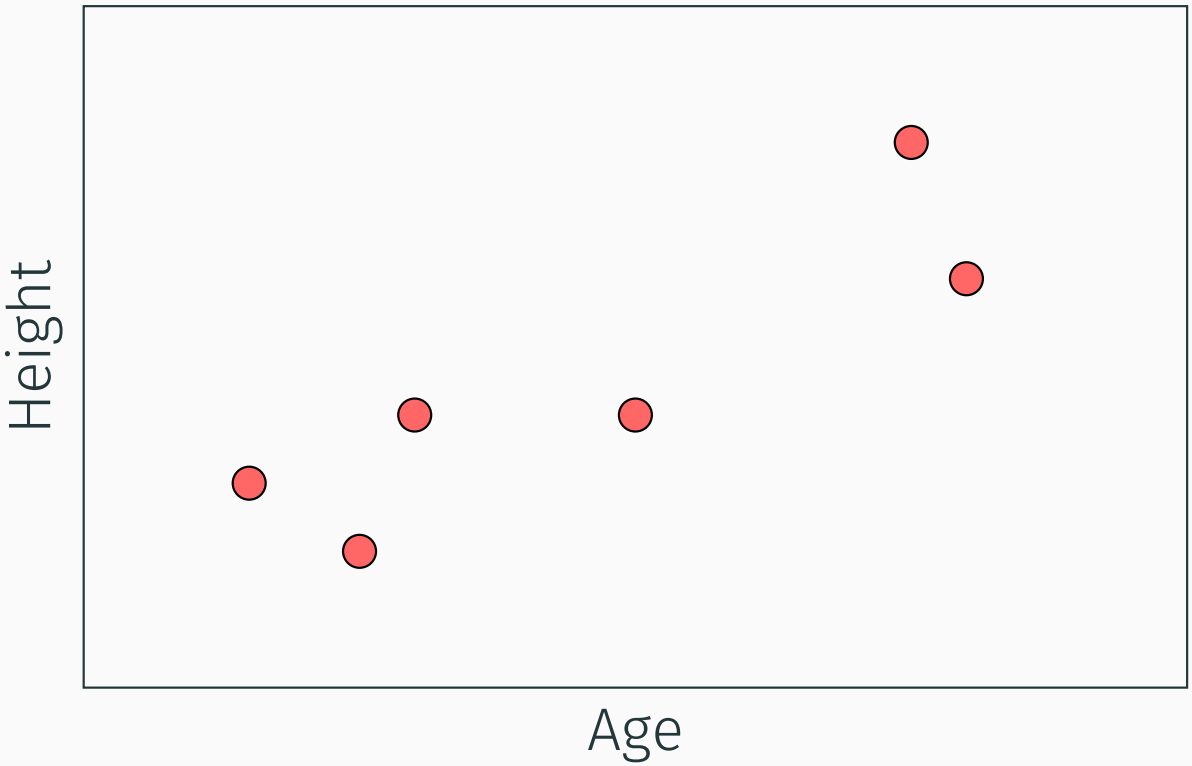


$$
\begin{aligned}
y = max(0, & w^2_{0,0} * max(0, w^1_{0,0} * max(0, w^0_{0,0} * x_0 + w^0_{1,0} * x_1 + b_{0,0}) + \\
& w^1_{1,0} * max(0, w^0_{0,1} * x_0 + w^+_{1,1} * w_1 + b_{0,1}) + \\
& w^1_{2,0} * max(0, w^0_{0,2} * x_0 + w^+_{1,2} * w_1 + b_{0,2}) + \\
& b_{1,0}) + \\
& w^2_{1,0} * max(0, w^1_{0,1} * max(0, w^0_{0,0} * x_0 + w^0_{1,0} * x_1 + b_{0,0}) + \\
& w^1_{1,1} * max(0, w^0_{0,1} * x_0 + w^+_{1,1} * w_1 + b_{0,1}) + \\
& w^1_{2,1} * max(0, w^0_{0,2} * x_0 + w^+_{1,2} * w_1 + b_{0,2}) + \\
& b_{1,1}) + \\
& w^2_{2,0} * max(0, w^1_{0,2} * max(0, w^0_{0,0} * x_0 + w^0_{1,0} * x_1 + b_{0,0}) + \\
& w^1_{1,2} * max(0, w^0_{0,1} * x_0 + w^+_{1,1} * w_1 + b_{0,1}) + \\
& w^1_{2,2} * max(0, w^0_{0,2} * x_0 + w^+_{1,2} * w_1 + b_{0,2}) + \\
& b_{1,2}) + \\
& b_2)
\end{aligned}
$$

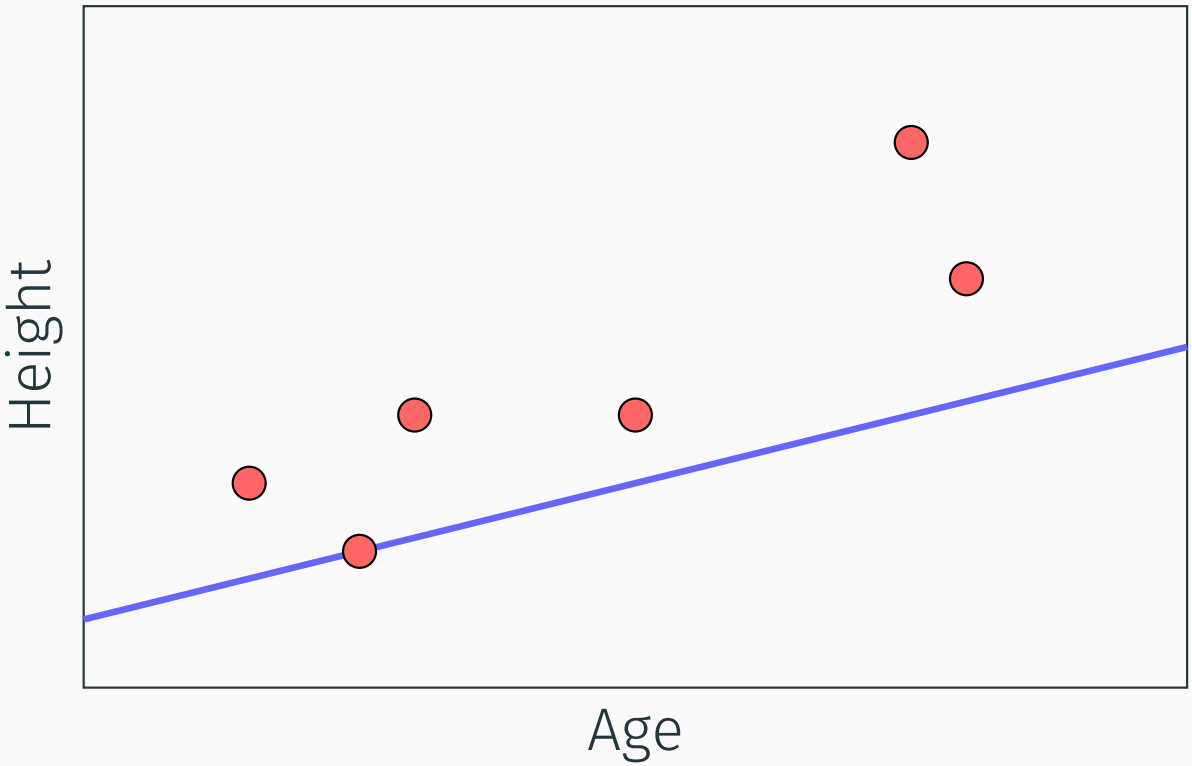
Building a neural network: Summary

- Artificial neurons are (linear) weighted sums wrapped in non-linear activation functions
- Multiple artificial neurons stacked together in a layerwise fashion comprise an artificial neural network
- Artificial neural networks allow us to model arbitrarily complex relationships between inputs and outputs

Training a neural network: Loss functions

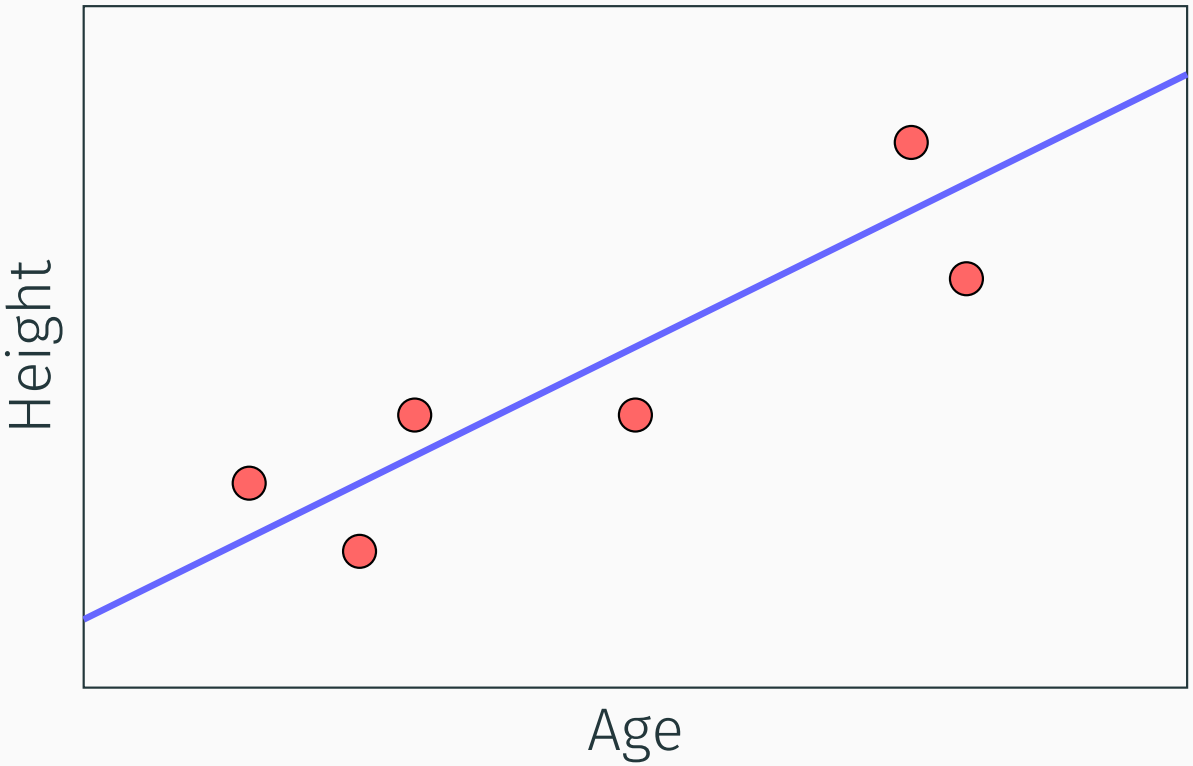


Training a neural network: Loss functions



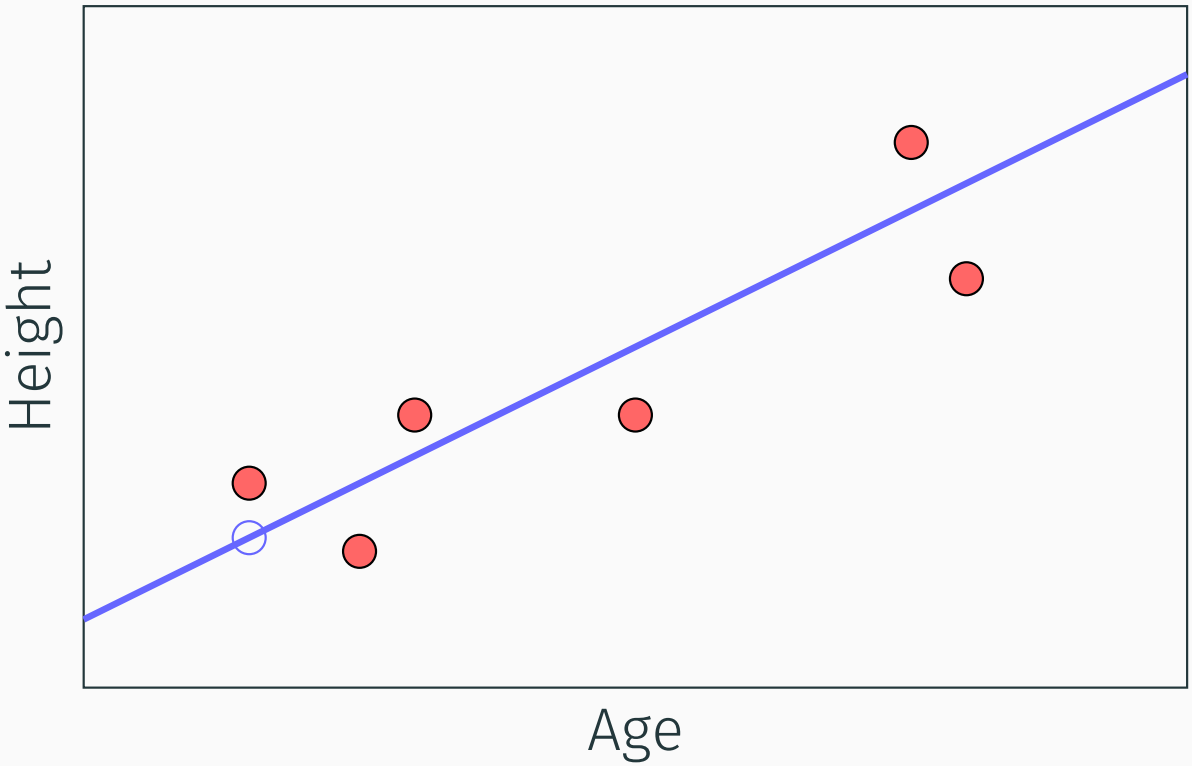
$$\hat{y} = 0.4x + 0.1$$

Training a neural network: Loss functions



$$\hat{y} = 0.9x + 0.1$$

Training a neural network: Loss functions



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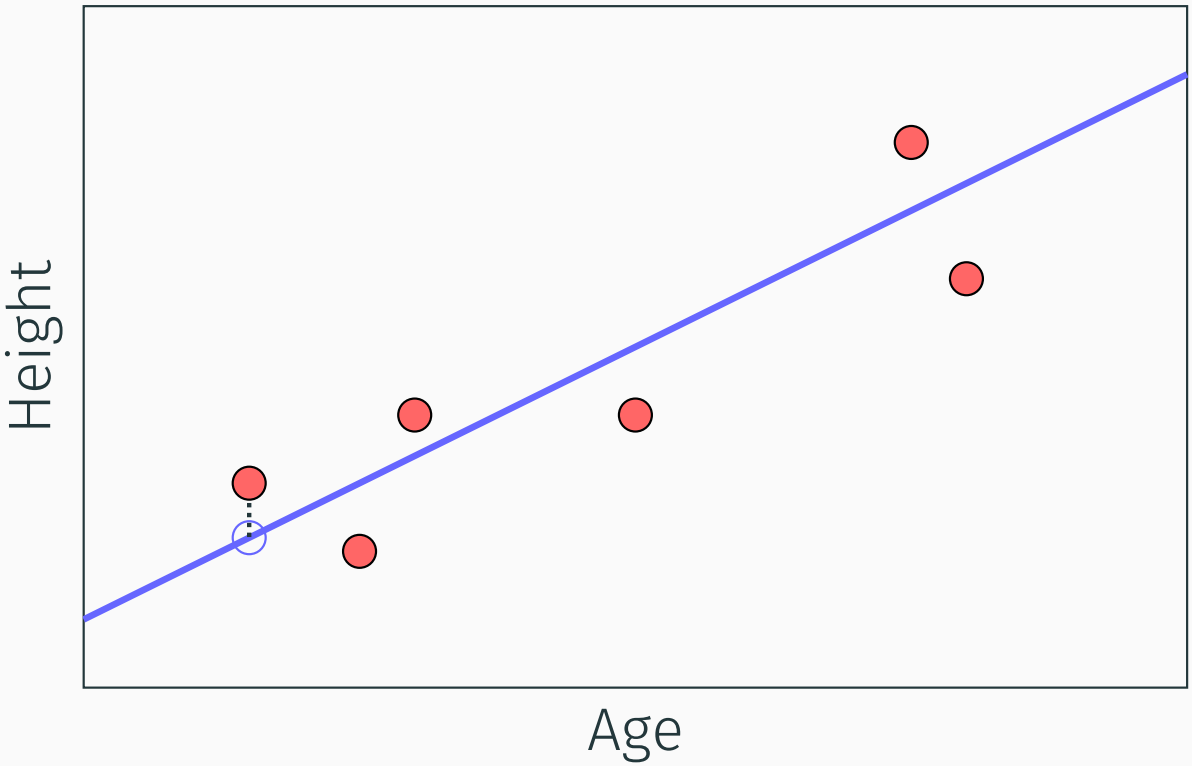

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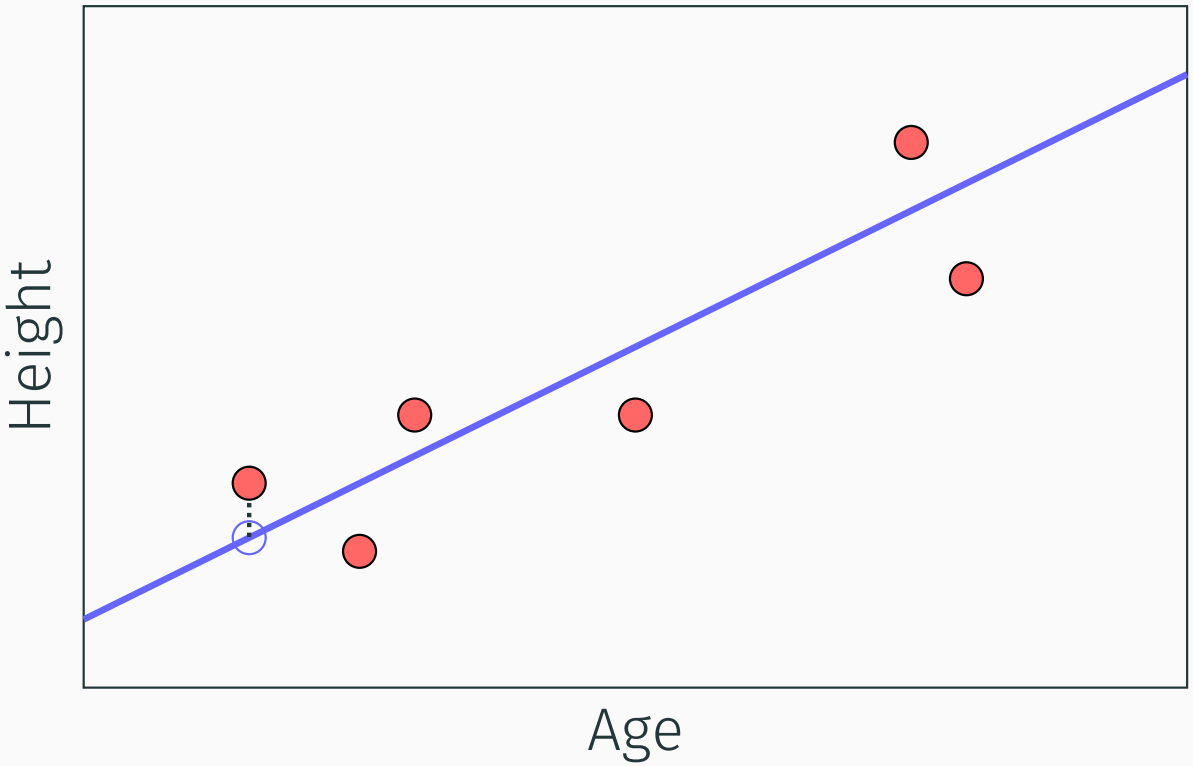
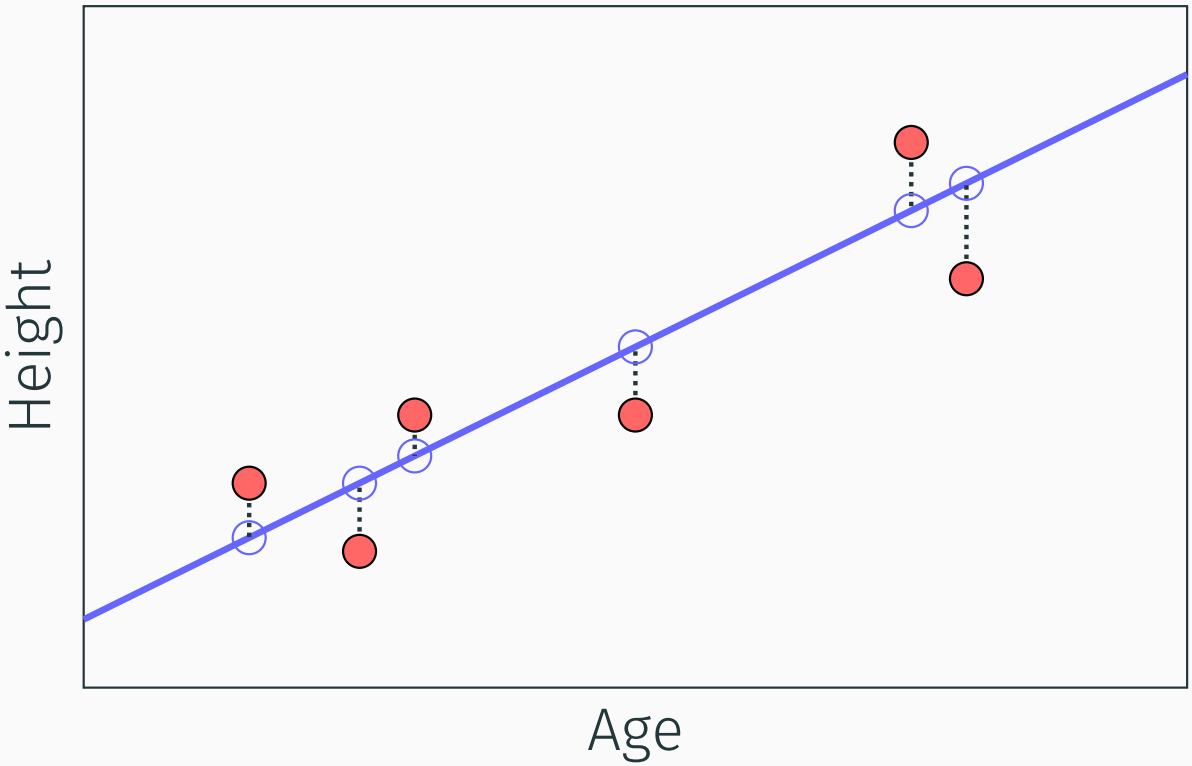
Training a neural network: Loss functions



$$\hat{y} = 0.9x + 0.1$$

$$error_i = |\hat{y} - y|$$

Training a neural network: Loss functions

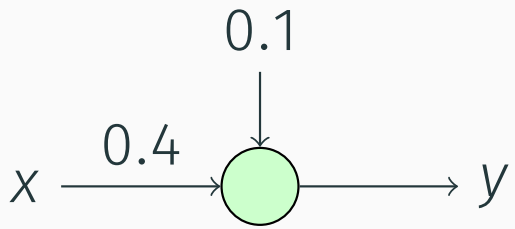


$$\hat{y} = 0.9x + 0.1$$

$$error_i = |\hat{y} - y|$$

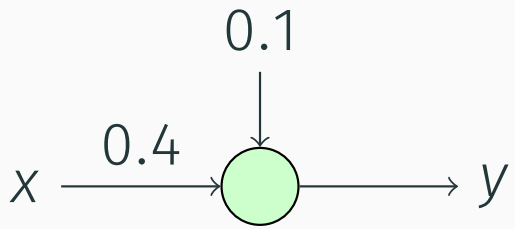
$$mse = \frac{1}{n}\sum_{i<n}(\hat{y}_i - y_i)^2$$

Training a neural network: Gradient descent



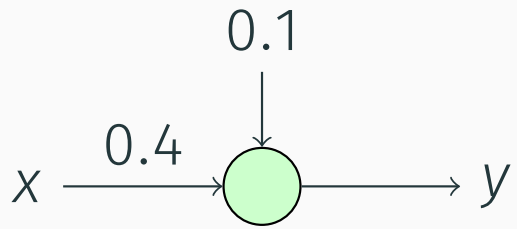
$$y = 0.4x + 0.1 \qquad loss = (y - \hat{y})^2$$

Training a neural network: Gradient descent



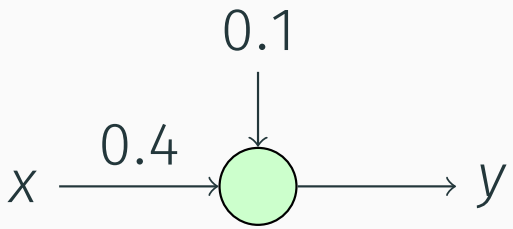
$$0.16 = 0.4 * 0.15 + 0.1 \qquad 0.019 = (0.3 - 0.16)^2$$

Training a neural network: Gradient descent



$$(0.3 - (0.4 * 0.15 + 0.1))^2 = 0.019$$

Training a neural network: Gradient descent

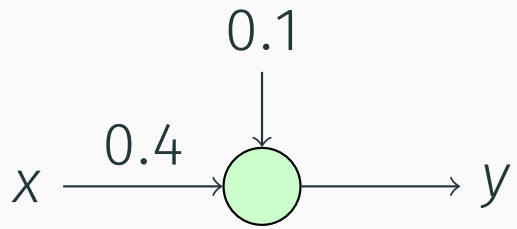


$$\underset{\uparrow}{(0.3} - (\underset{\uparrow}{\underbrace{0.4 \overset{\downarrow}{*} 0.15 \overset{\downarrow}{+} 0.1}_{\hat{y}}}))^2 = 0.019$$

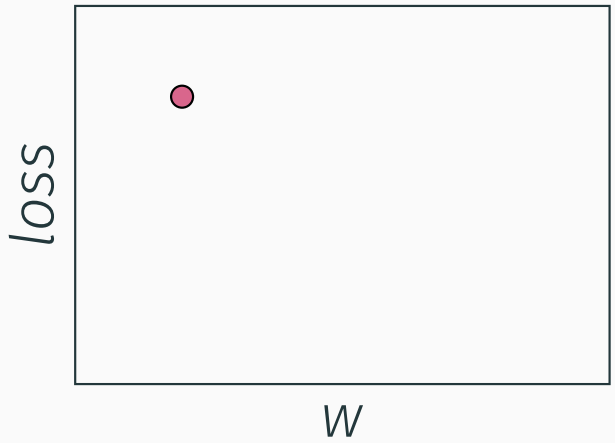
w x b loss

y

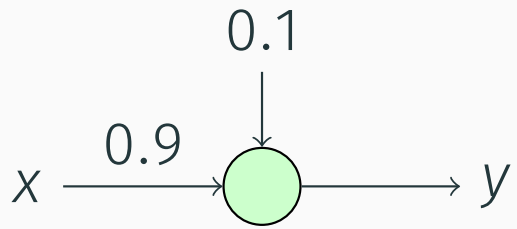
Training a neural network: Gradient descent



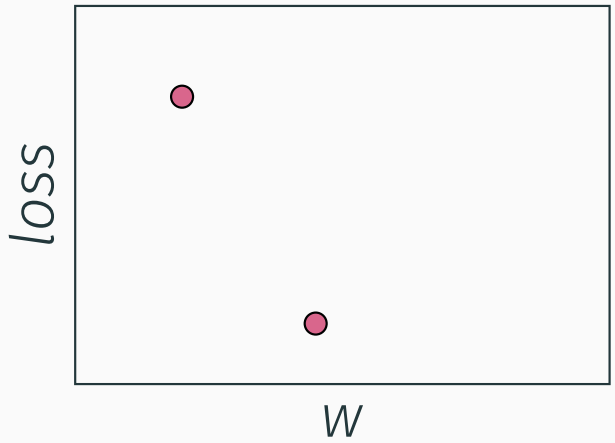
$$(0.3 - (0.4 * 0.15 + 0.1))^2 = 0.019$$



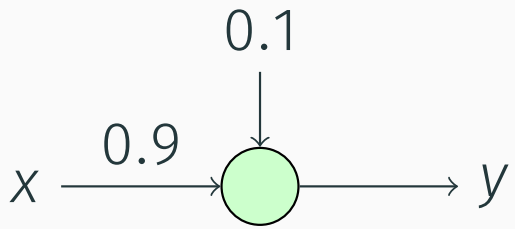
Training a neural network: Gradient descent



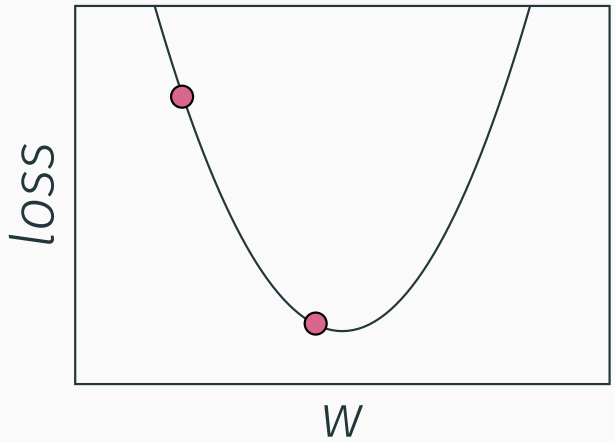
$$(0.3 - (0.9 * 0.15 + 0.1))^2 = 0.004$$



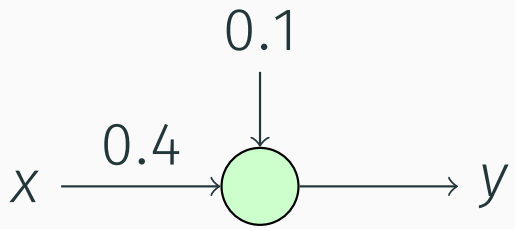
Training a neural network: Gradient descent



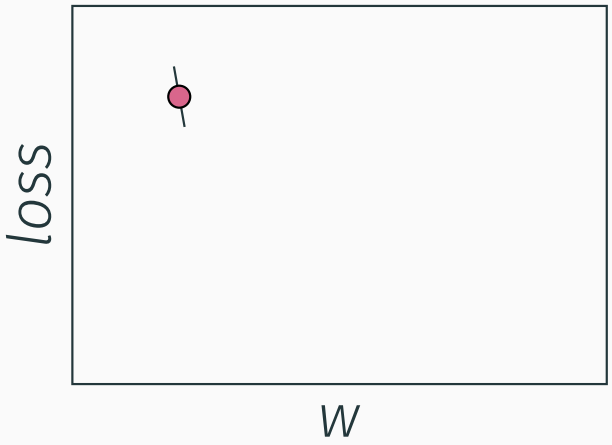
$$(0.3 - (0.9 * 0.15 + 0.1))^2 = 0.004$$

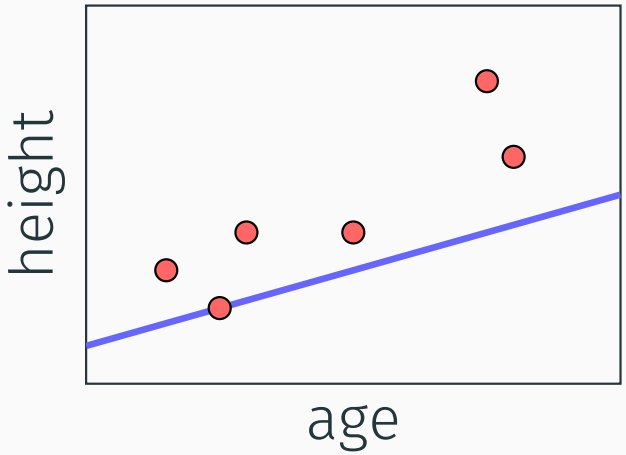


Training a neural network: Gradient descent

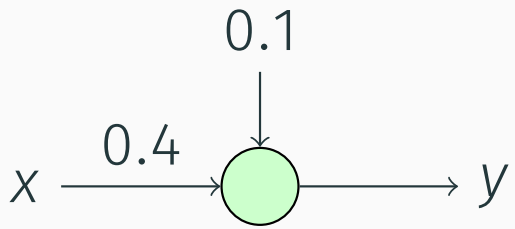


$$(0.3 - (0.4 * 0.15 + 0.1))^2 = 0.019$$

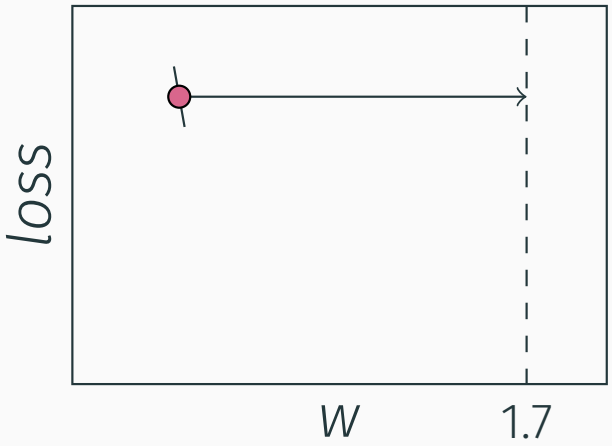


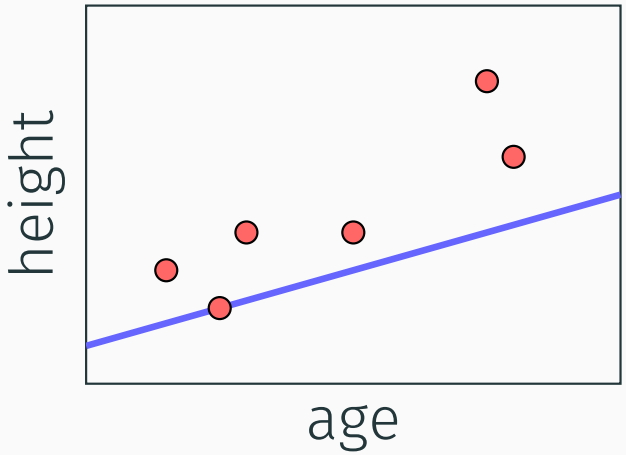


Training a neural network: Gradient descent

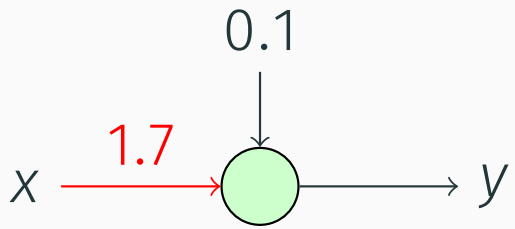


$$(0.3 - (0.4 * 0.15 + 0.1))^2 = 0.019$$

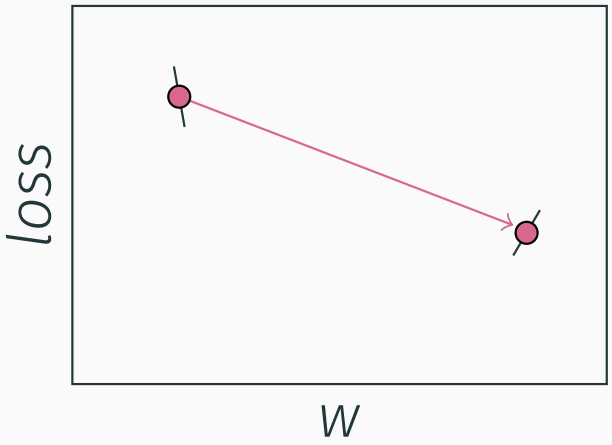


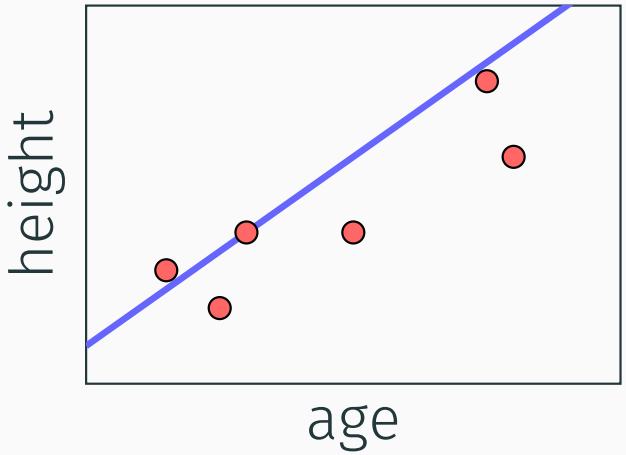


Training a neural network: Gradient descent

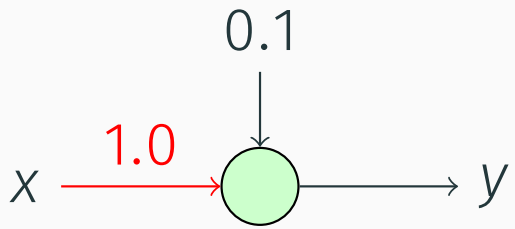


$$(0.3 - (1.7 * 0.15 + 0.1))^2 = 0.003$$

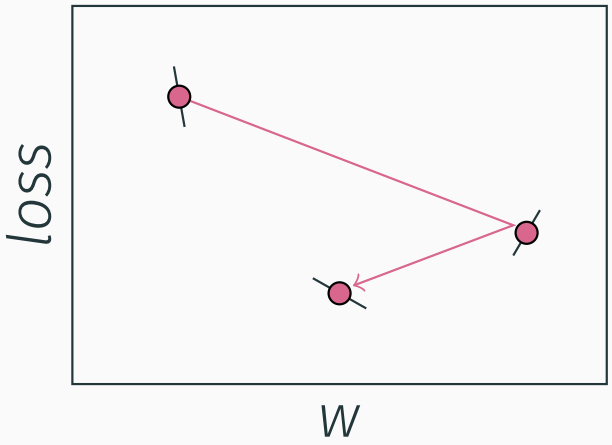


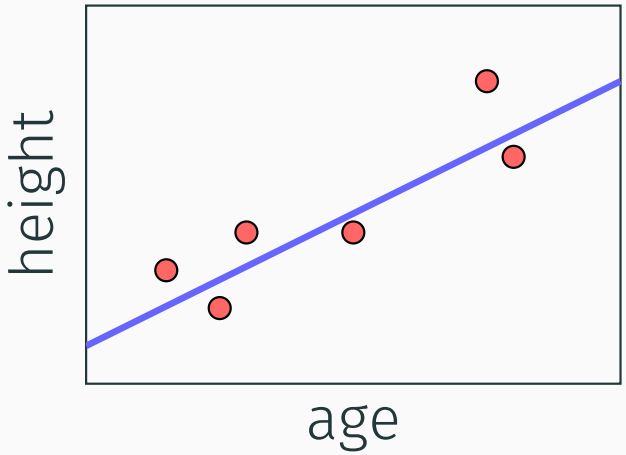


Training a neural network: Gradient descent

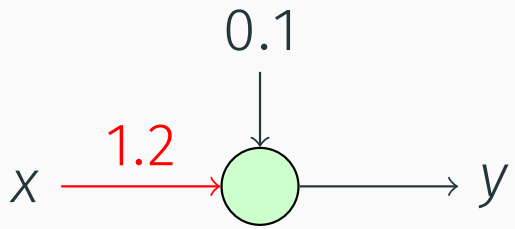


$$(0.3 - (1.0 * 0.15 + 0.1))^2 = 0.002$$

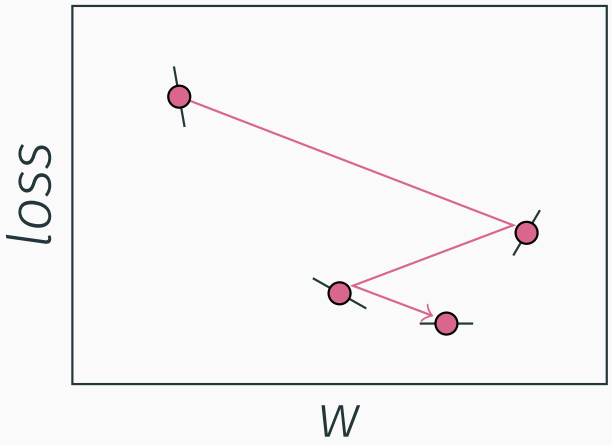


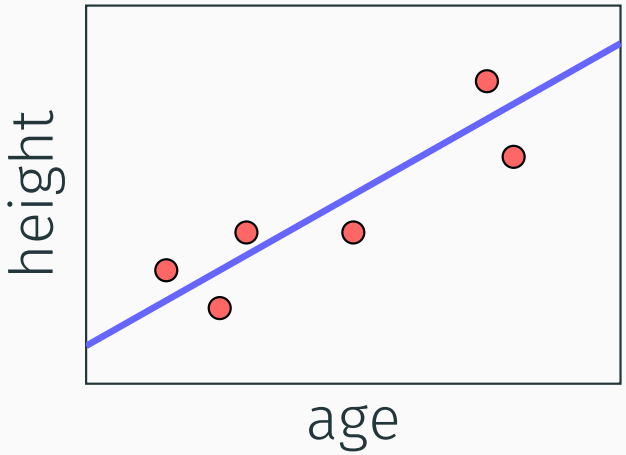


Training a neural network: Gradient descent



$$(0.3 - (1.2 * 0.15 + 0.1))^2 = 0.000$$





Training a neural network: Summary

- The loss function is a mathematical formalization of what we want the model to learn
- Calculating the gradient allows us to see how we can update the parameters of the model to decrease the loss
- Using gradient descent we can update the parameters sequentially until we have the perfect model with zero loss