Neural Networks
Declan Groves
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks

Neural Networks

Declan Groves

June 30 2016

Outline

What is a Neural Network?

Gradient Descent

Backprop

Activations

How to train your pet network

Convolutional Neural Networks

1 What is a Neural Network?

2 Gradient Descent

3 Backprop

4 Activations

5 How to train your pet network

6 Convolutional Neural Networks

Overview

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- Hypest ML
- Good at unstructured problems
- Suboptimal at structured problems

History

- Around since the 1950s
- Resurgence in 1970s
- Resurgence in late 2000s

A graphical linear model

Neural Networks

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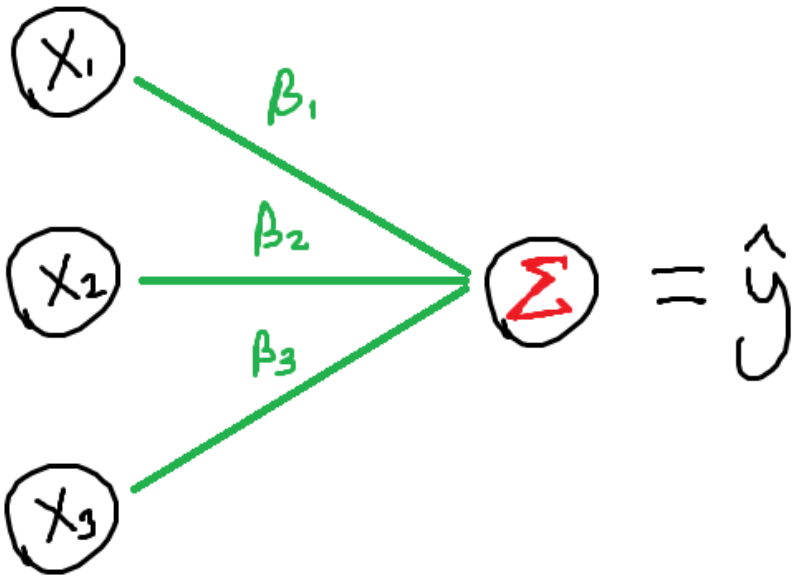

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Gradient Descent

Backprop

Activations

How to train your pet network

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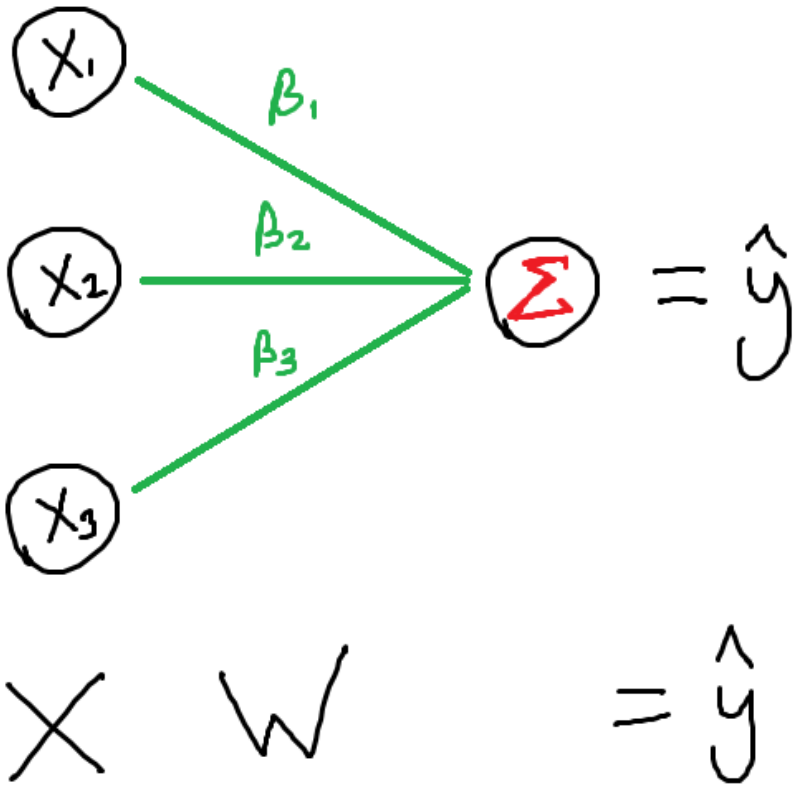

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Gradient Descent

Backprop

Activations

How to train your pet network

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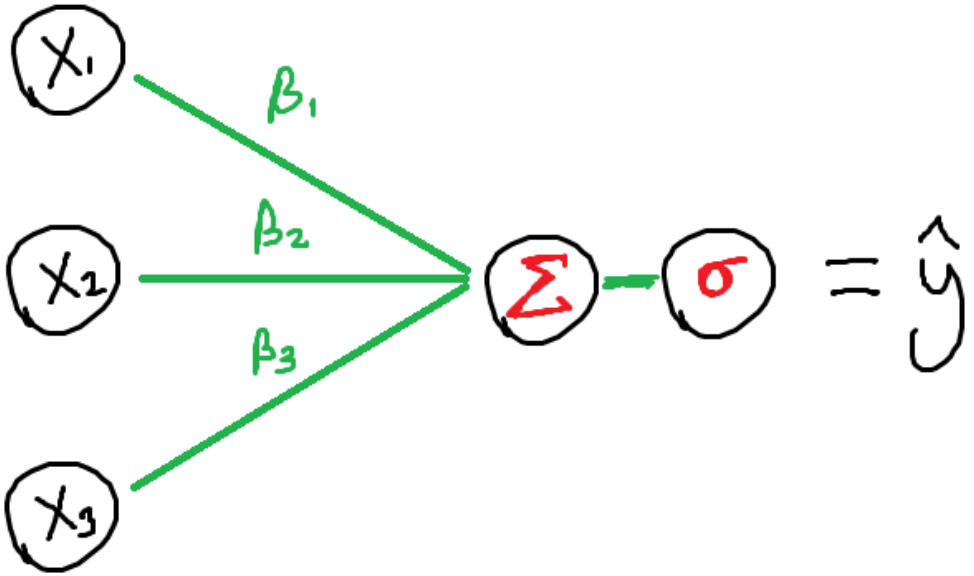

$$\sigma(X \quad W) \quad = \hat{y}$$

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Gradient Descent

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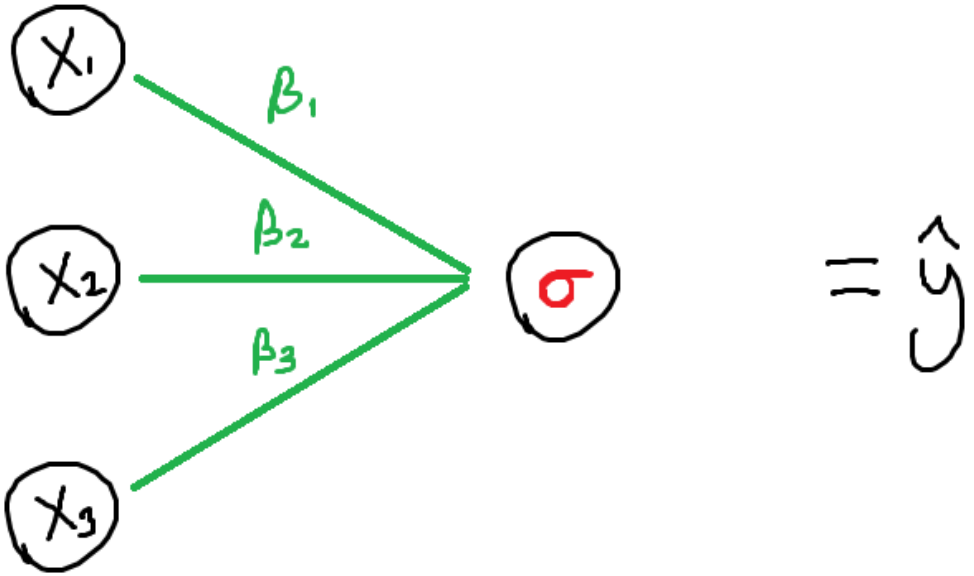

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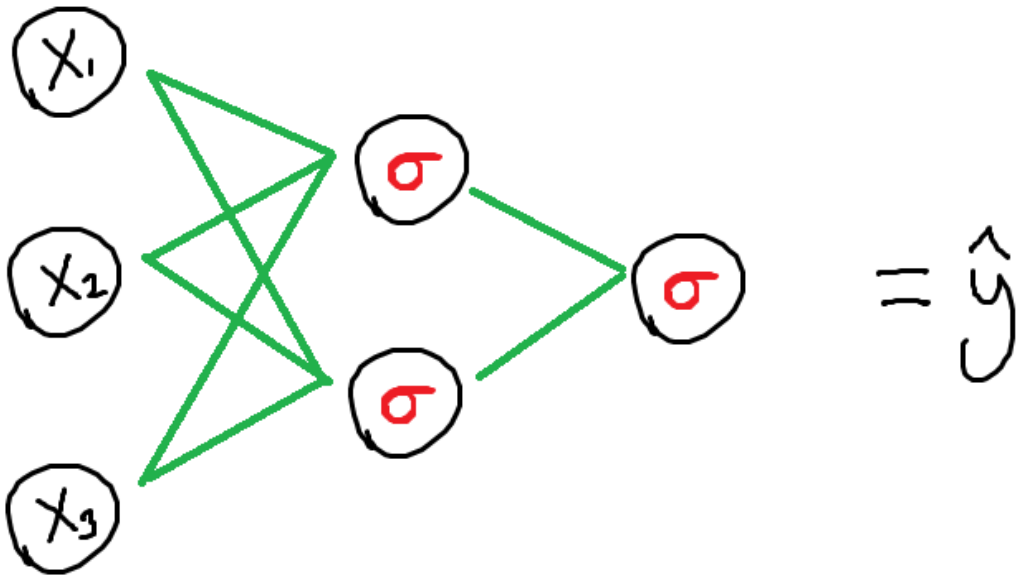
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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Gradient Descent
Backprop
Activations
How to train your pet network
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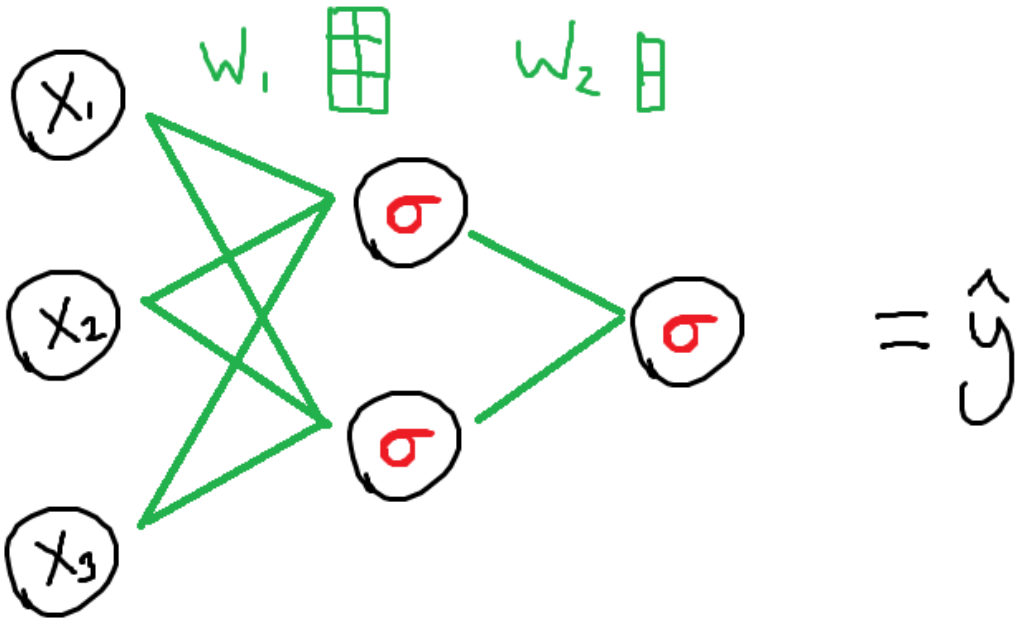

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Gradient Descent
Backprop
Activations
How to train your pet network
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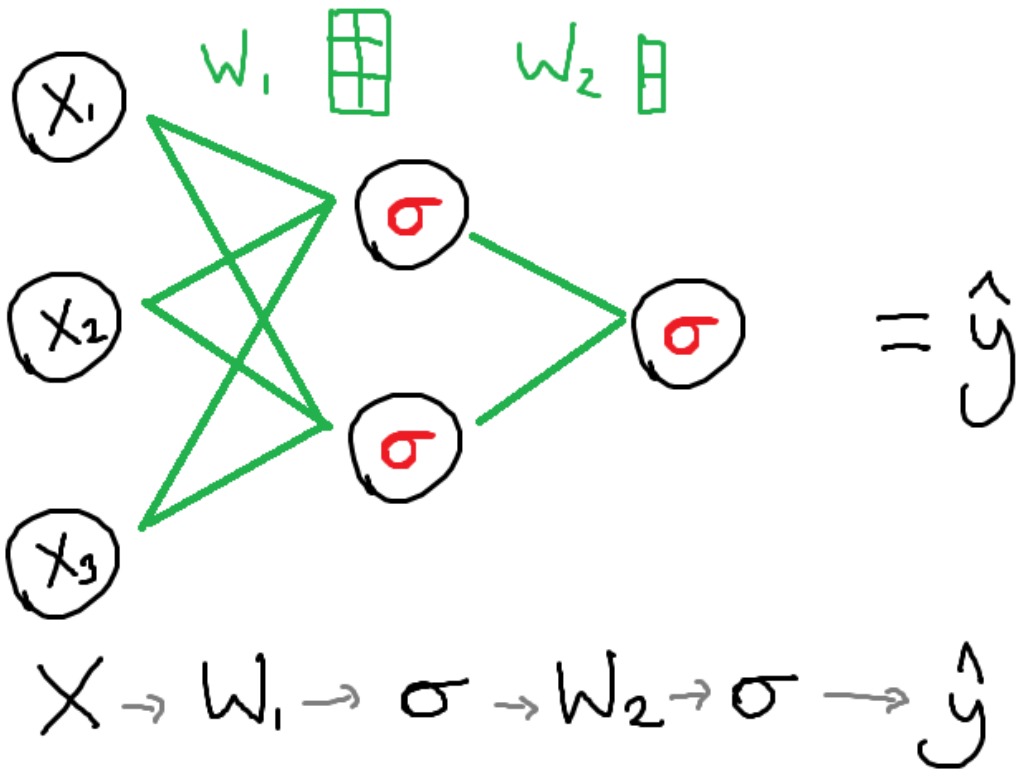

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Gradient Descent
Backprop
Activations
How to train your pet network
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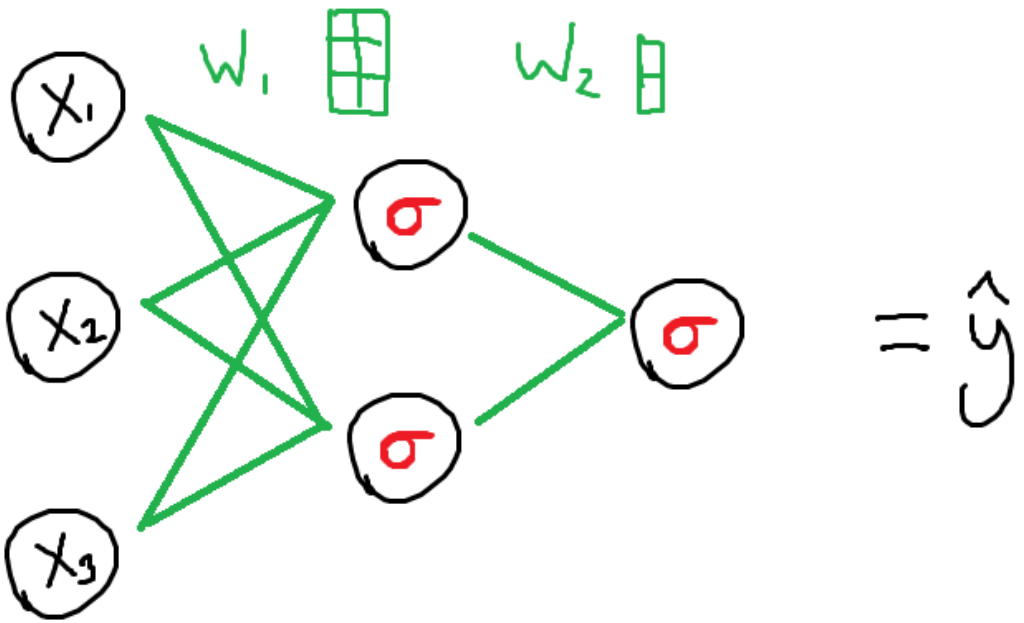

$$X \rightarrow W_1 \rightarrow \sigma \rightarrow W_2 \rightarrow \sigma \rightarrow \hat{y}$$

$$\sigma(\sigma(XW_1)W_2) = \hat{y}$$

A multilayer multinomial classifier

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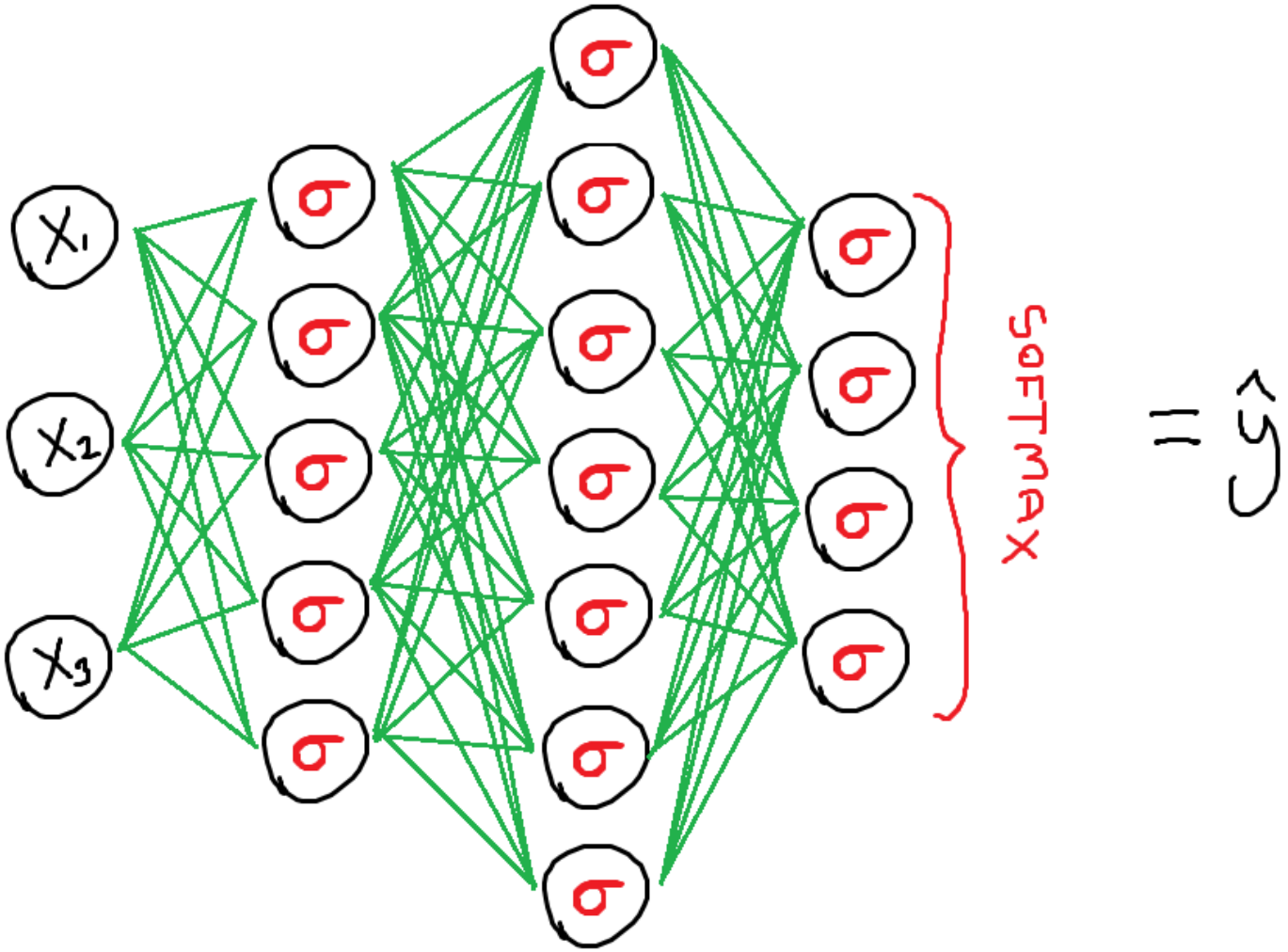
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



Gradient Descent

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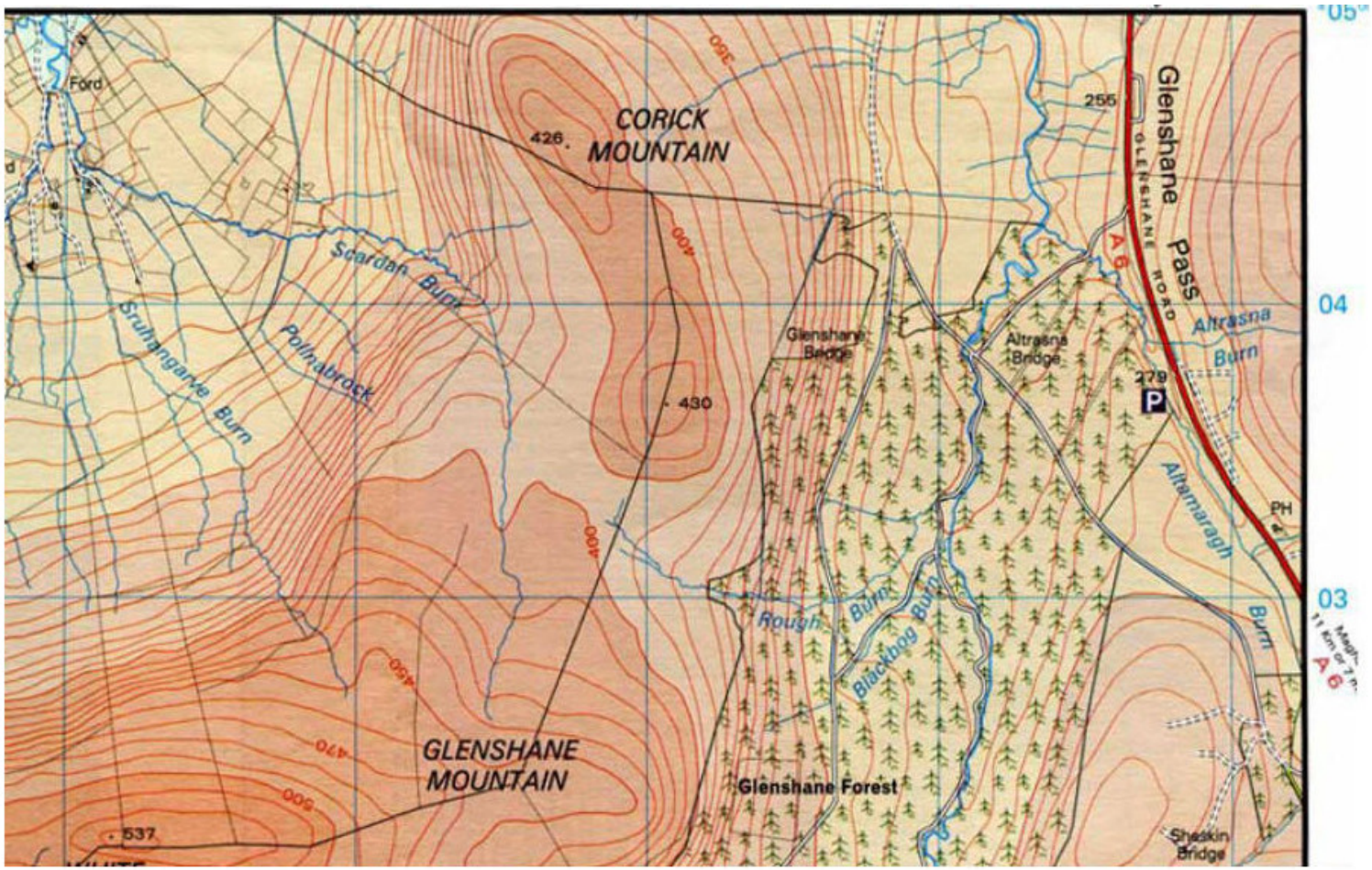
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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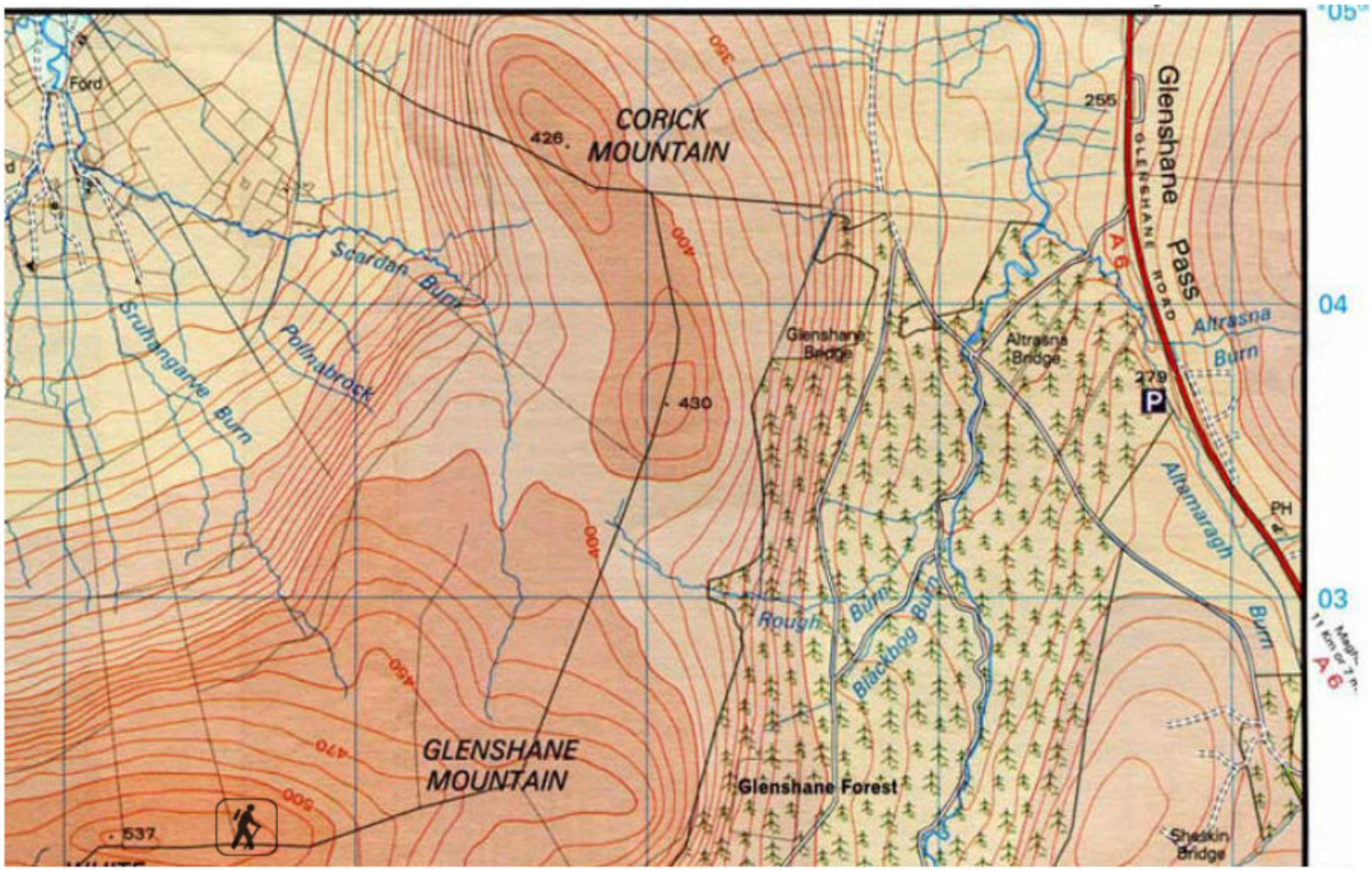
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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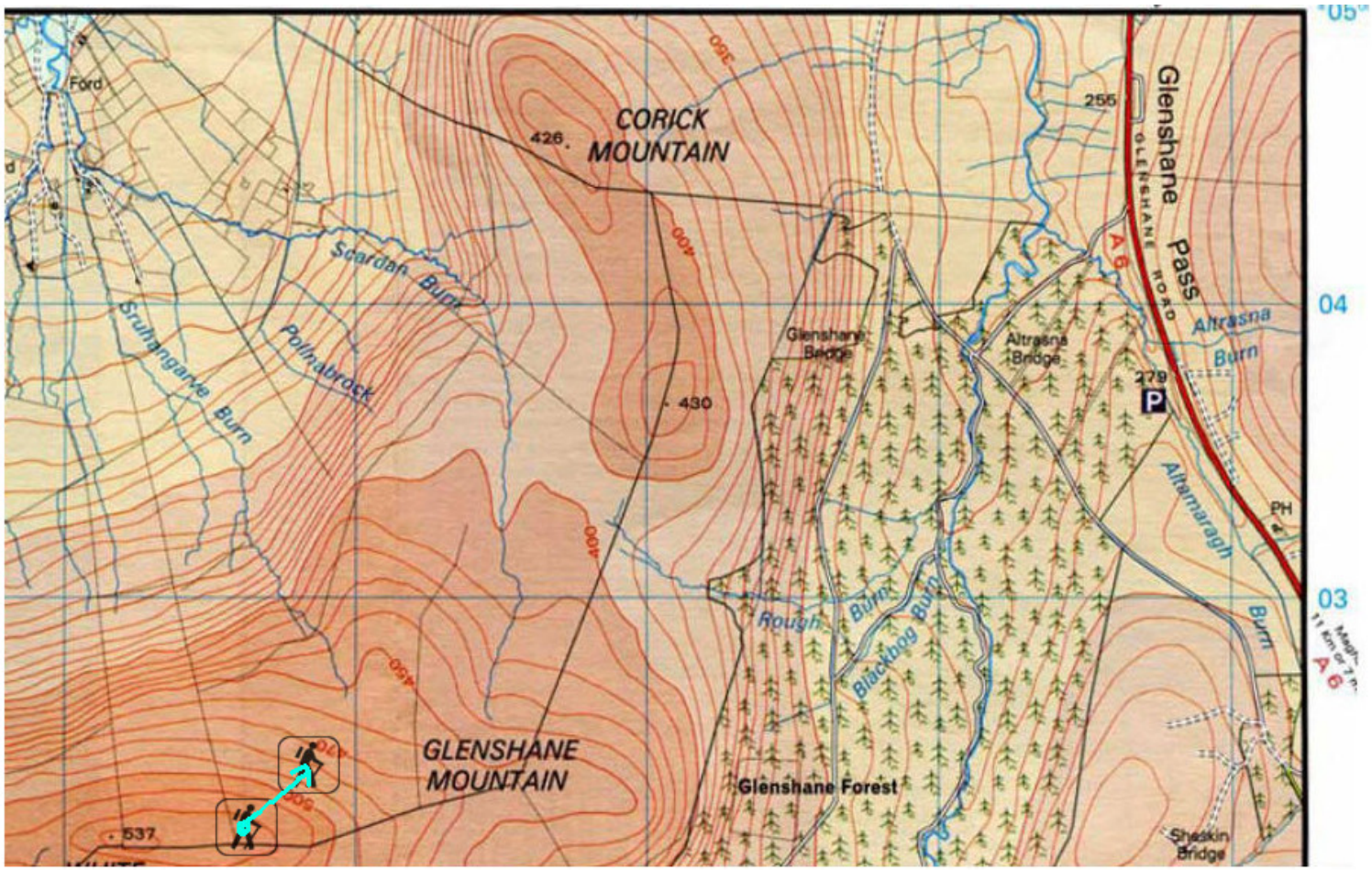
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$L_{N+1} = L_N - \gamma \nabla f(L_N)$$

Gradient Descent

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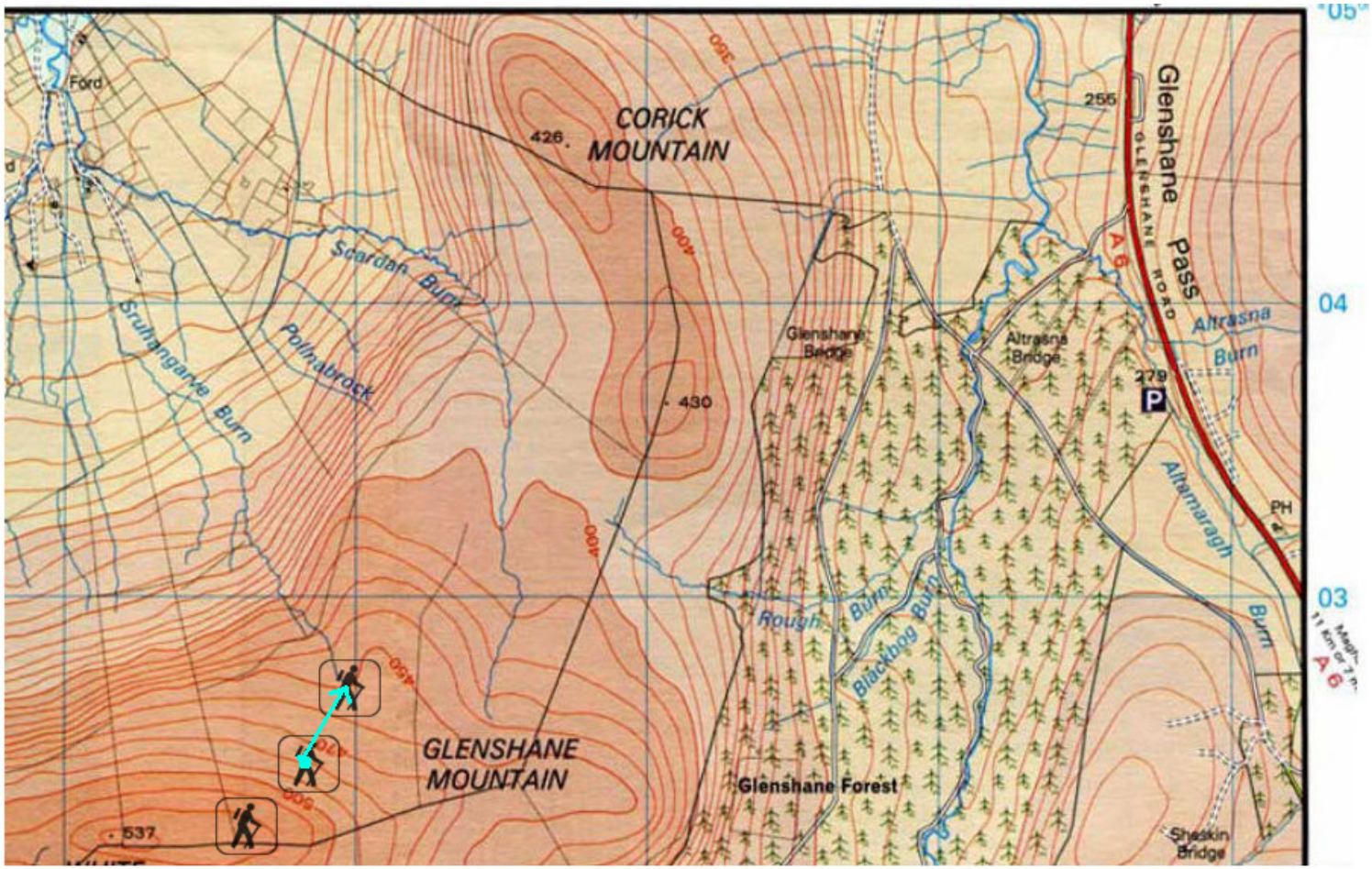
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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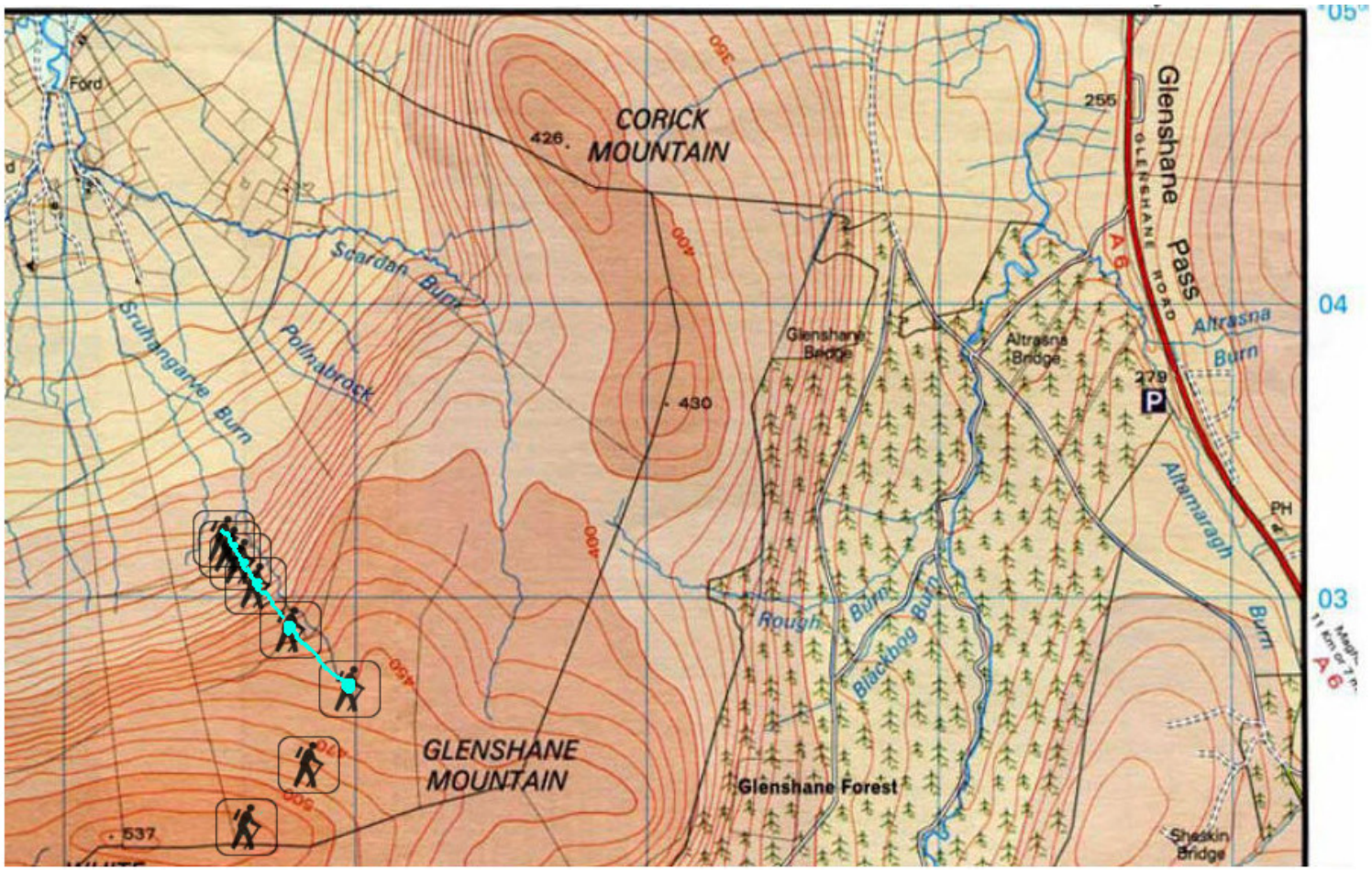
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$L_{N+1} = L_N - \gamma \nabla f(L_N)$$

Gradient Descent and Momentum

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What is a Neural Network?

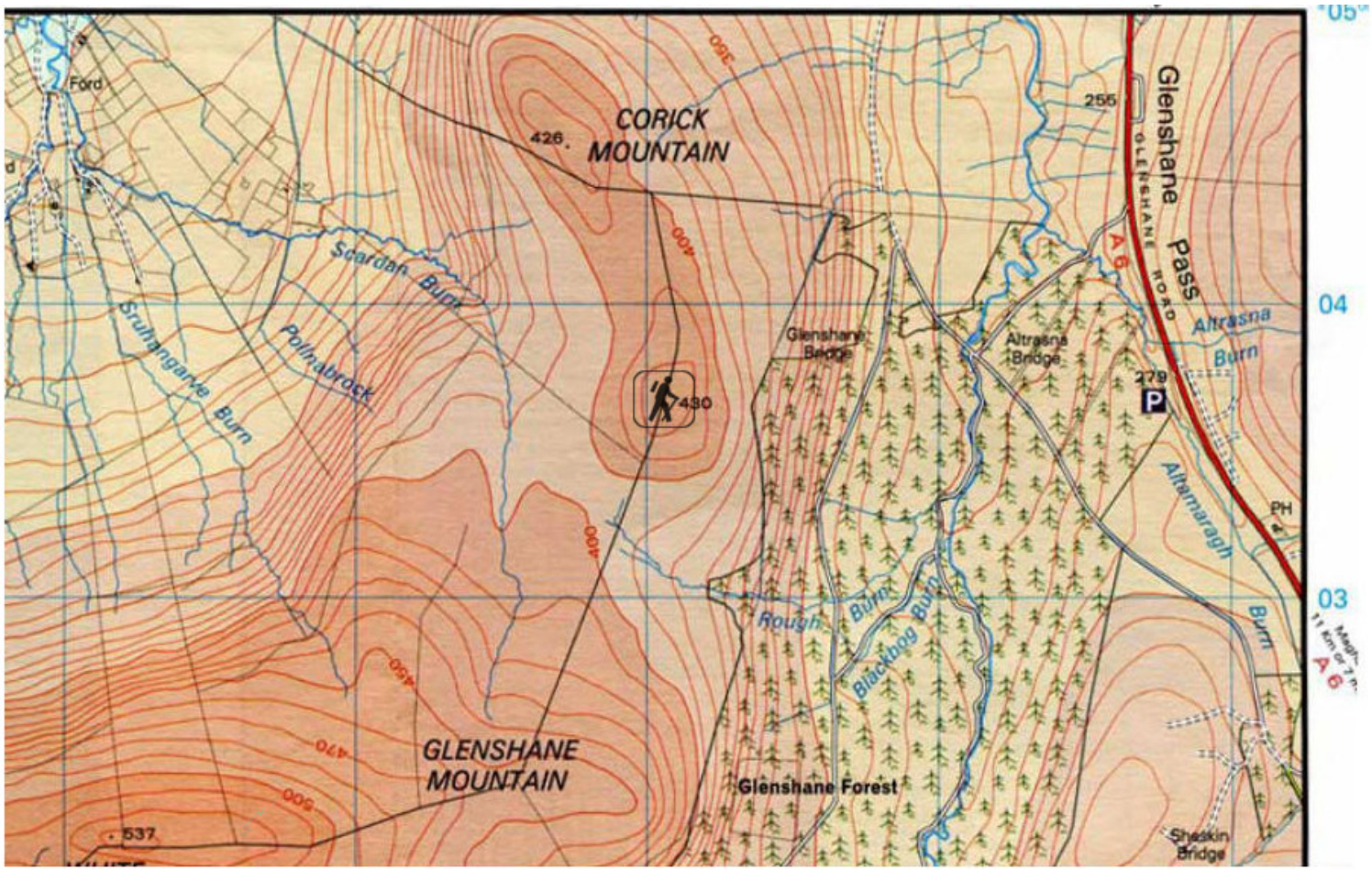
Gradient Descent

Backprop

Activations

How to train your pet network

Convolutional Neural Networks



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What is a Neural Network?

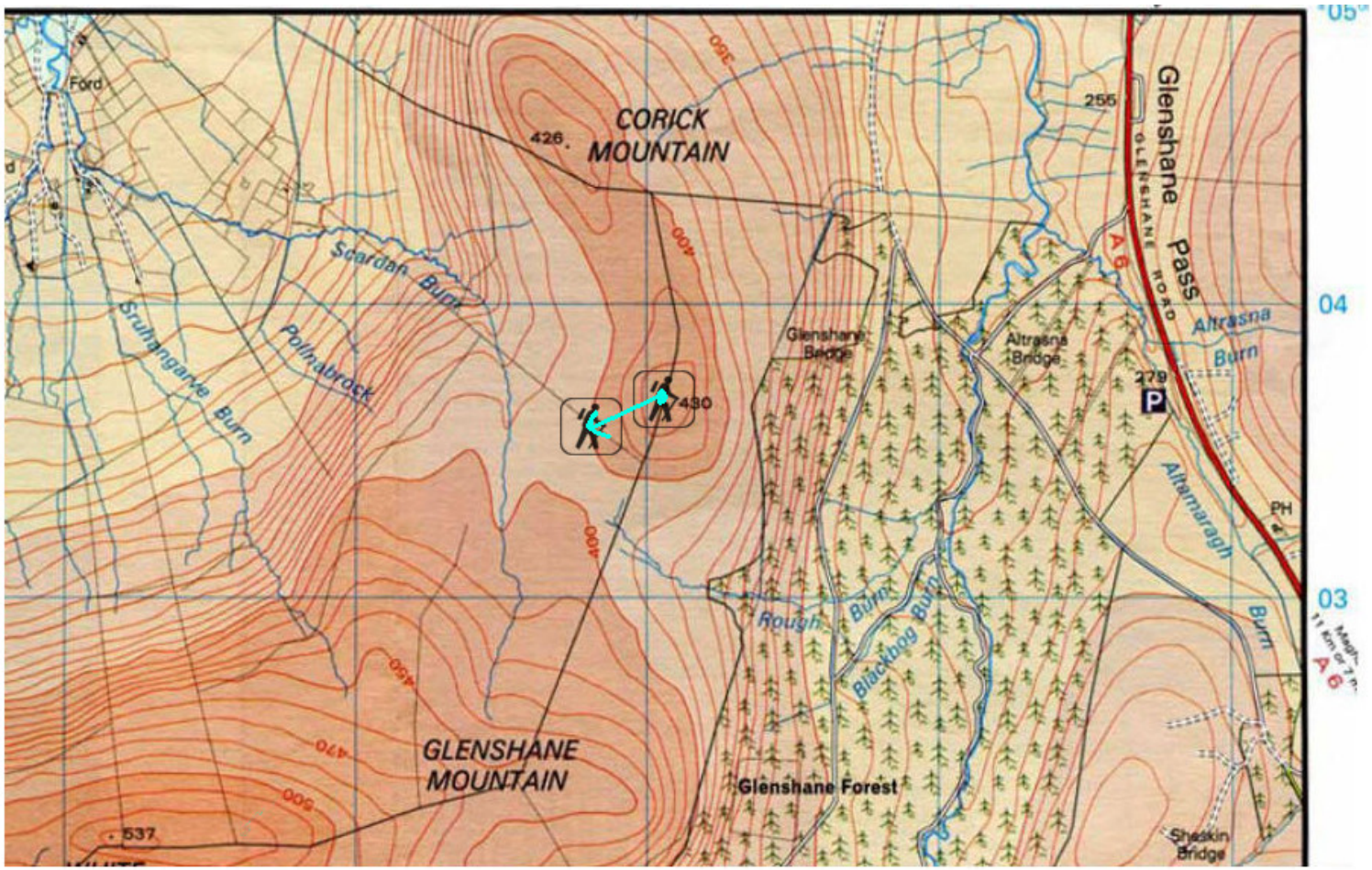
Gradient Descent

Backprop

Activations

How to train your pet network

Convolutional Neural Networks



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What is a Neural Network?

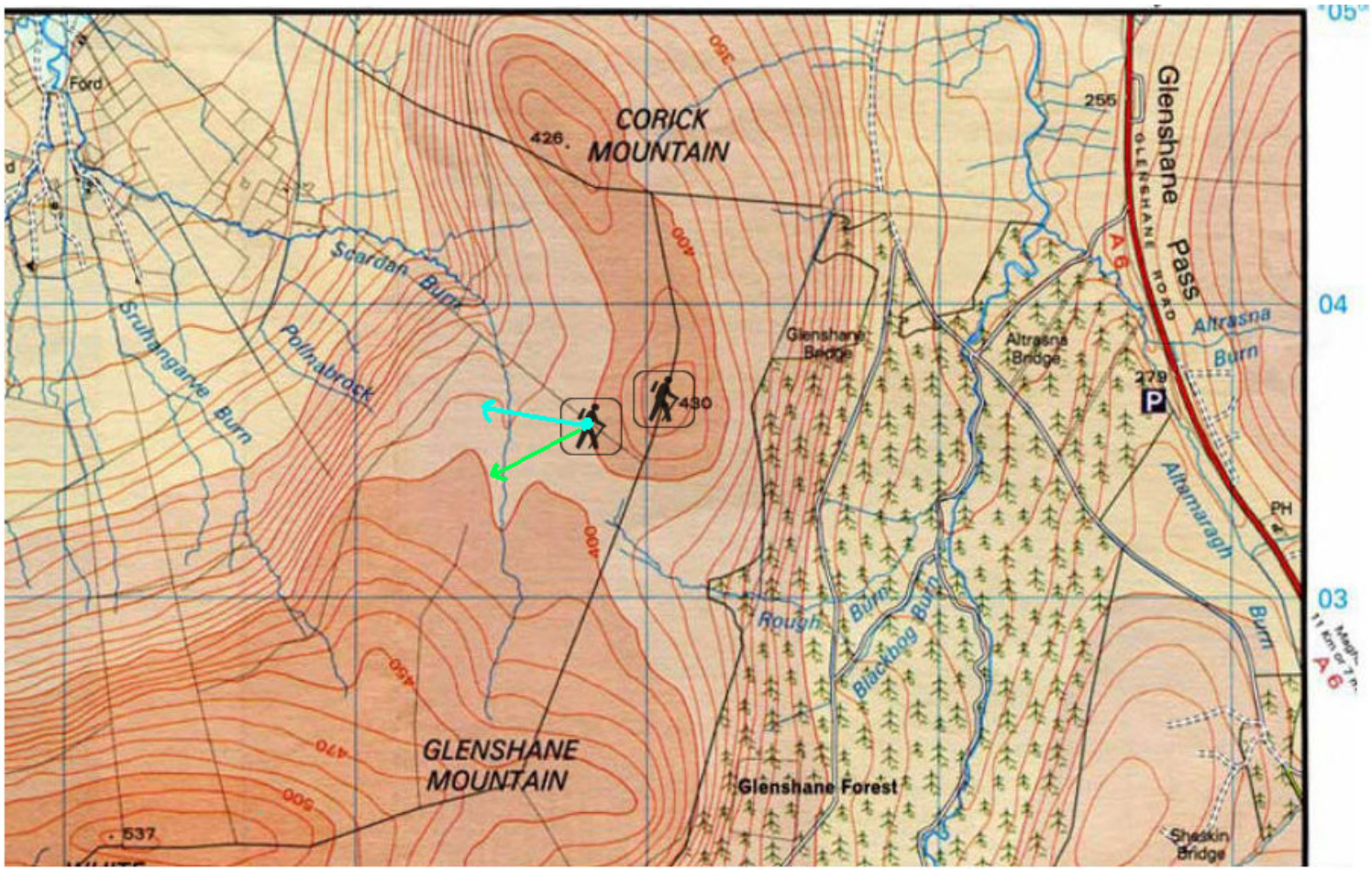
Gradient Descent

Backprop

Activations

How to train your pet network

Convolutional Neural Networks



$$L_{N+1} = L_N - \gamma \nabla f(L_N) - m\gamma \nabla f(L_{N-1})$$

Gradient Descent and Momentum

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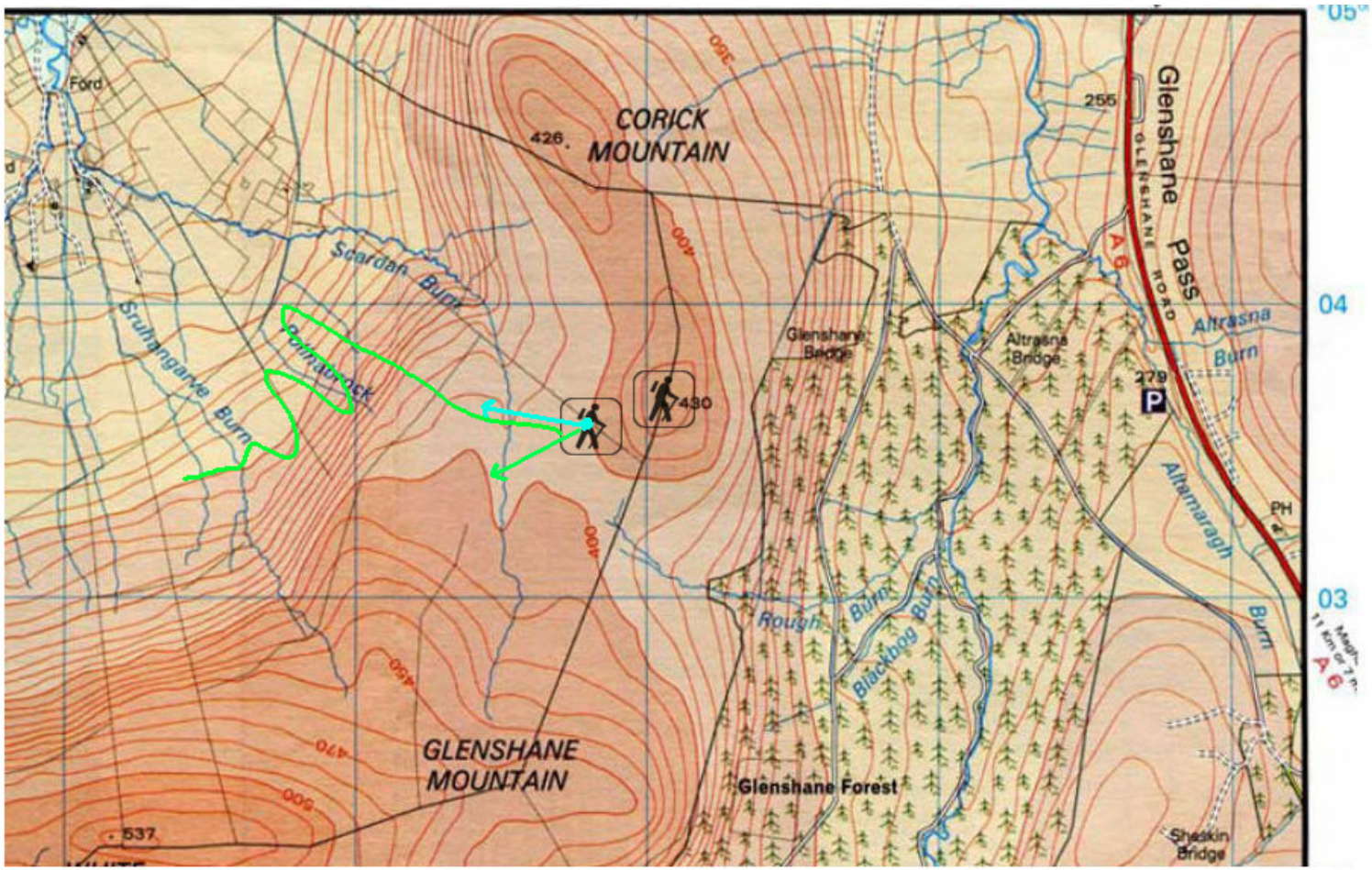
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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Ravines

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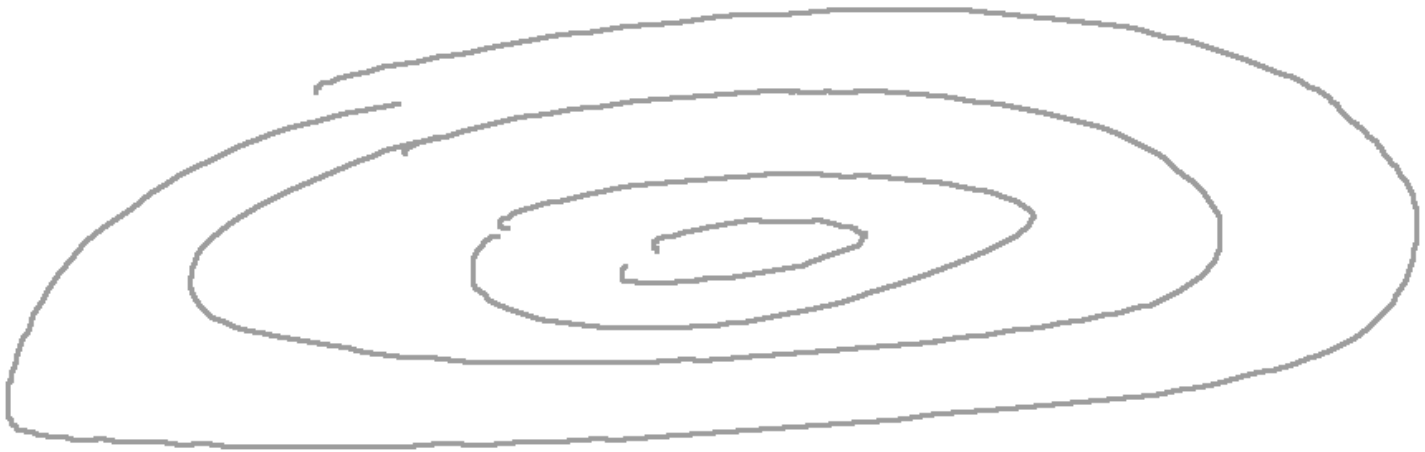
Gradient Descent

Backprop

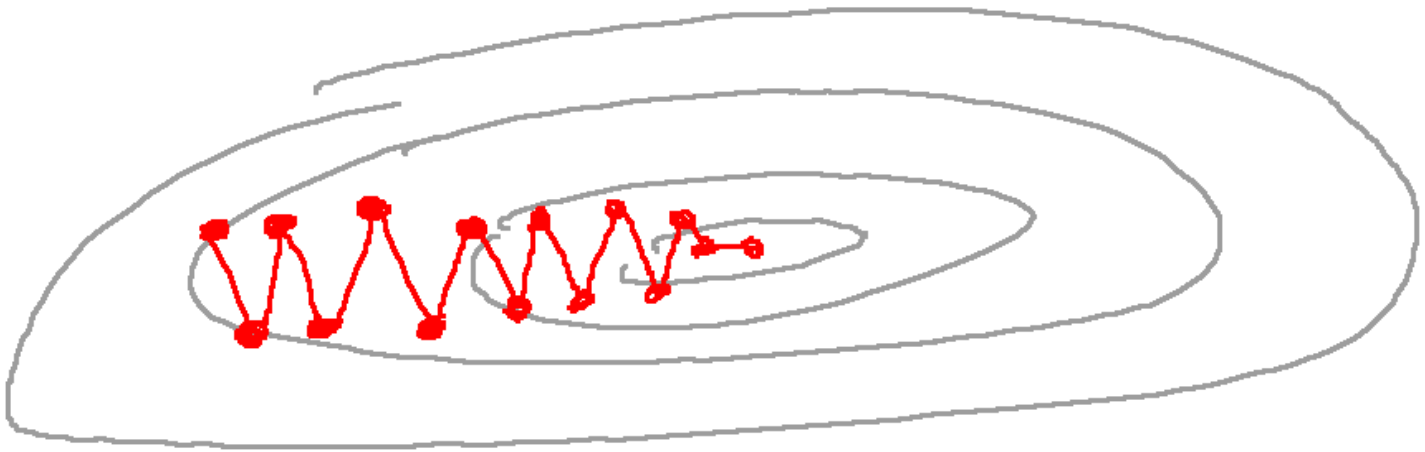
Activations

How to train your pet network

Convolutional Neural Networks



Ravines - without momentum



Ravines - with momentum

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What is a Neural Network?

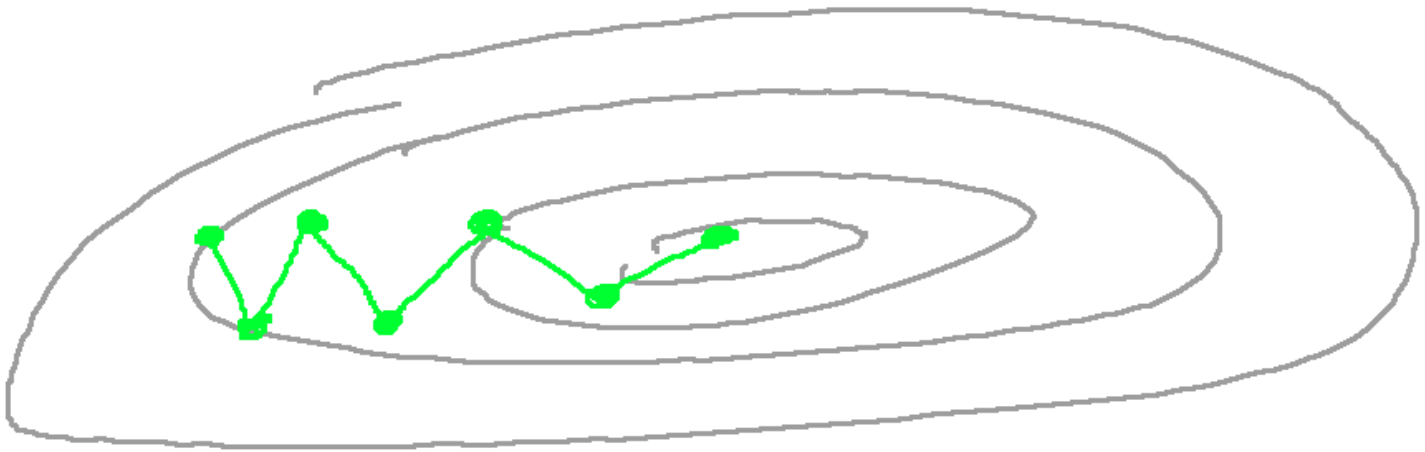
Gradient Descent

Backprop

Activations

How to train your pet network

Convolutional Neural Networks



Stochastic gradient descent

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Gradient Descent
Backprop
Activations
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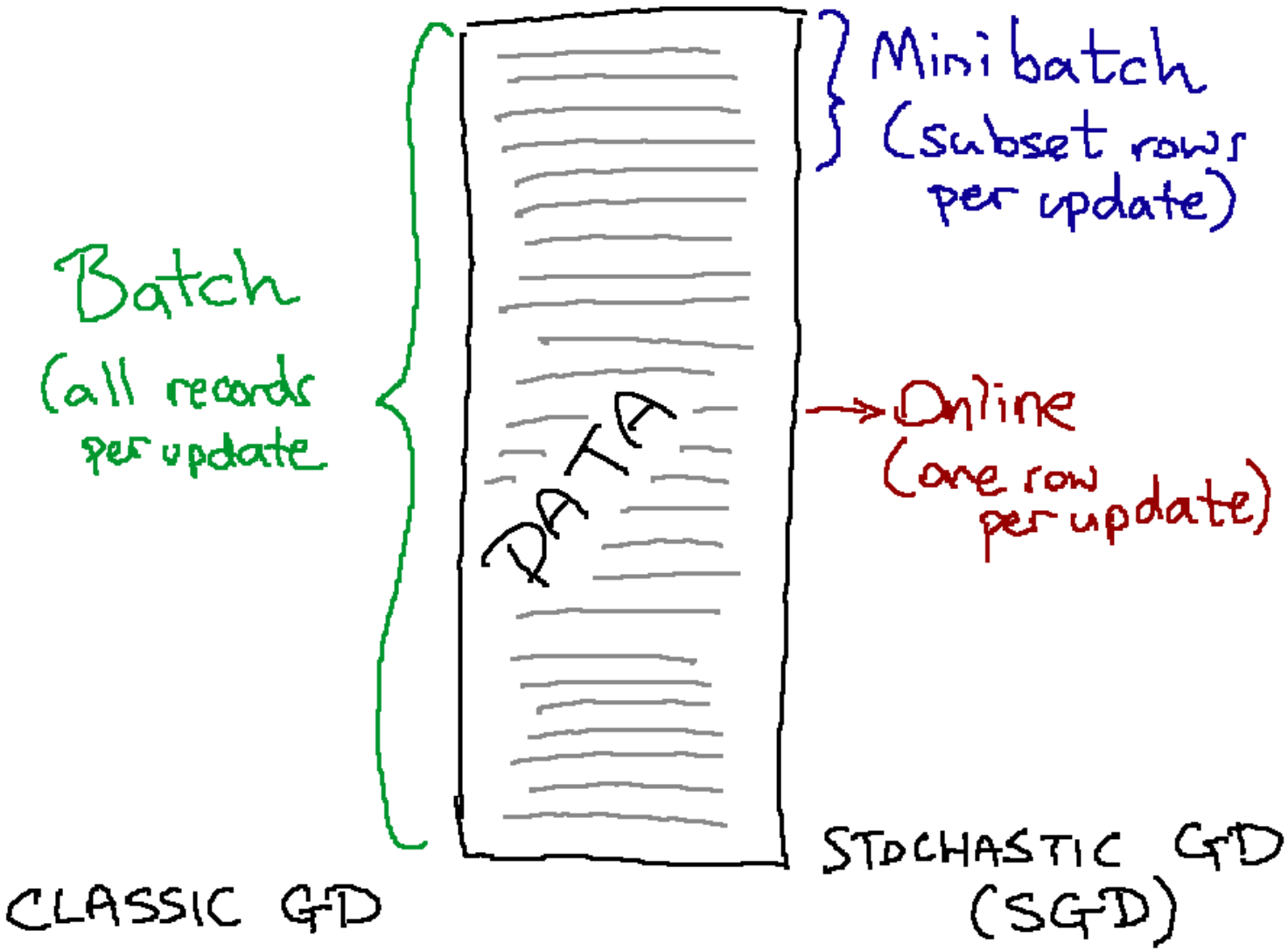

Forward pass

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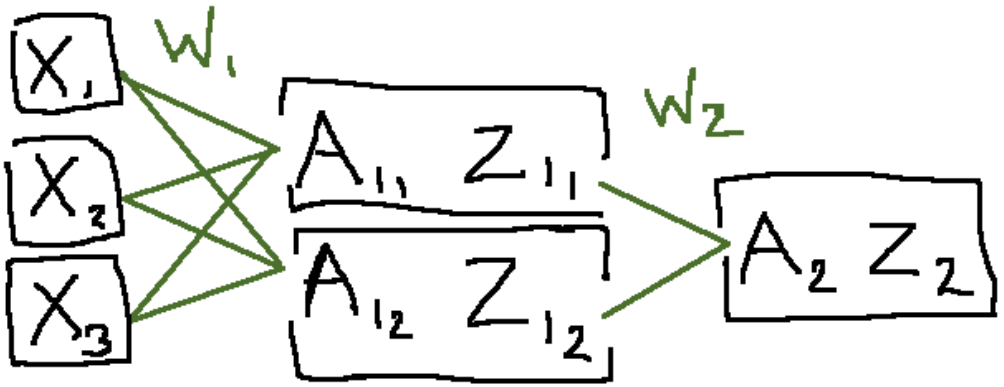
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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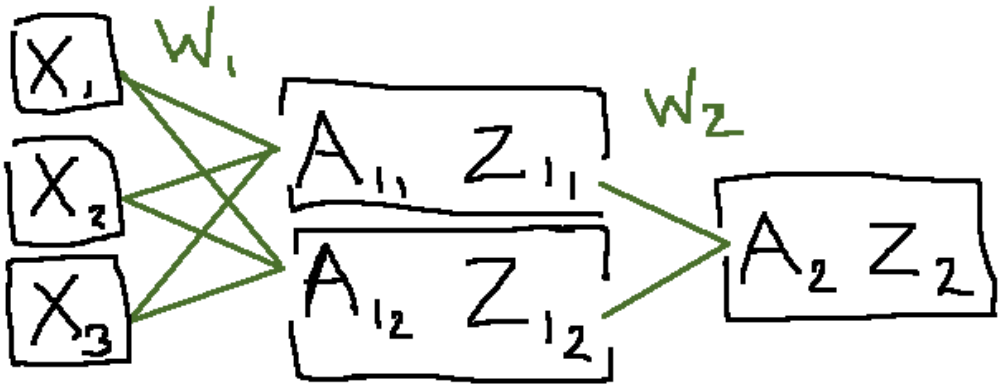
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$A_1 = XW_1$$
$$Z_1 = \sigma(A_1)$$
$$A_2 = Z_1 W_2$$
$$Z_2 = \sigma(A_2) = \hat{y}$$

Forward pass

Backwards pass

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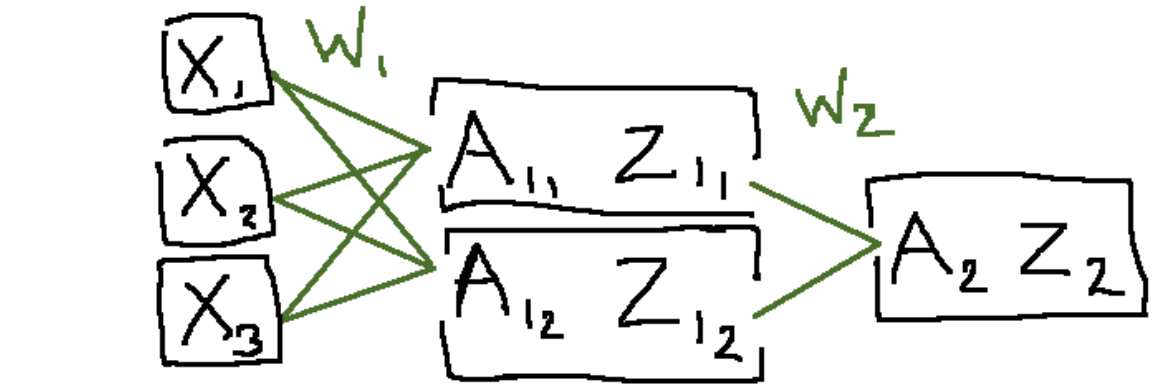
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$J = \text{err}(y, \hat{y}) \; ; \; J \leftarrow \frac{1}{2}(y - \hat{y})^2$$

Backwards pass

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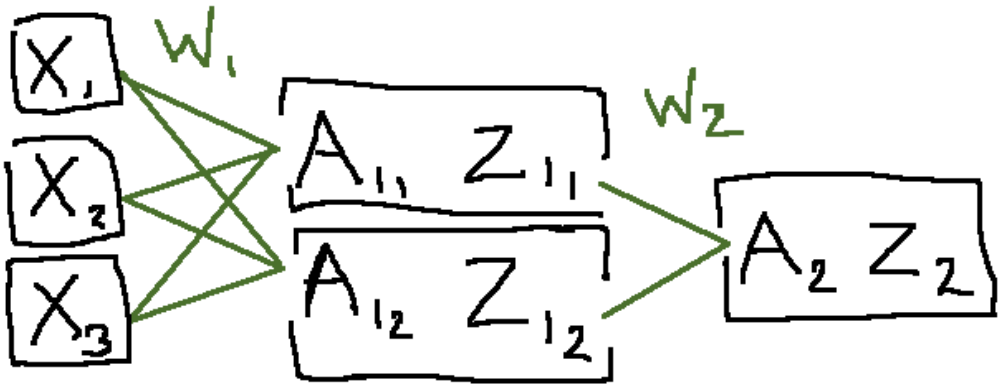
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$J = err(y, \hat{y})$; $J \leftarrow \frac{1}{2}(y - \hat{y})^2$

$\partial J / \partial W_2 =$

Backwards pass

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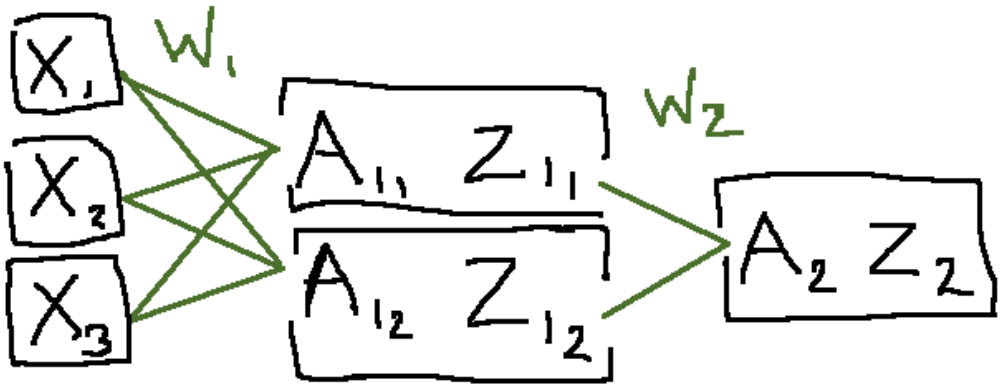
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$J = err(y, \hat{y}) \; ; \; J \leftarrow \frac{1}{2}(y - \hat{y})^2$$

$$\partial J / \partial W_2 = \partial J / \partial \hat{y} \; \partial \hat{y} / \partial W_2$$

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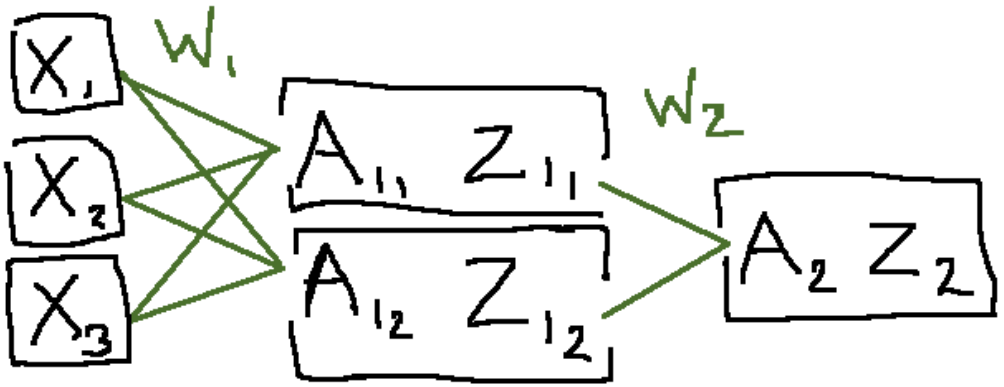
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$J = err(y, \hat{y}) \; ; \; J \leftarrow \frac{1}{2}(y - \hat{y})^2$$

$$\partial J / \partial W_2 = \partial J / \partial \hat{y} \; \partial \hat{y} / \partial A_2 \; \partial A_2 / \partial W_2$$

Backwards pass

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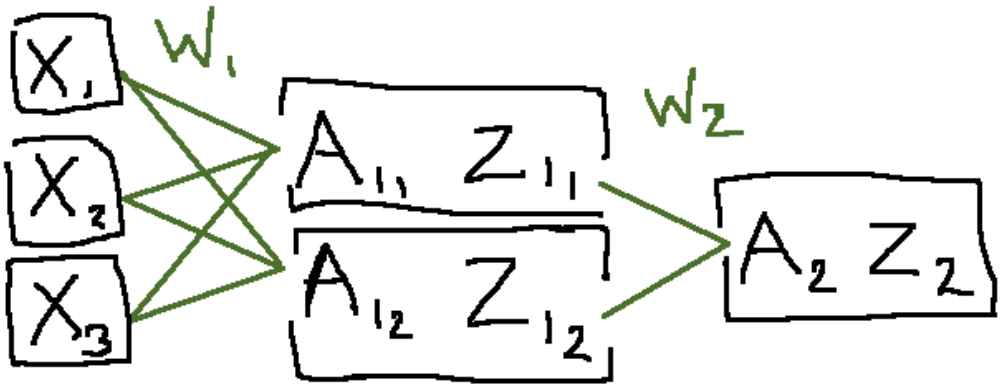
Declan Groves
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$J = err(y, \hat{y}) \; ; \; J \leftarrow \frac{1}{2}(y - \hat{y})^2$$

$$\partial J / \partial W_2 = \partial J / \partial \hat{y} \; \partial \hat{y} / \partial A_2 \; \partial A_2 / \partial W_2$$

$$= \underbrace{(y - \hat{y}) \; \sigma'(A_2)}_{\delta} \; Z_1$$

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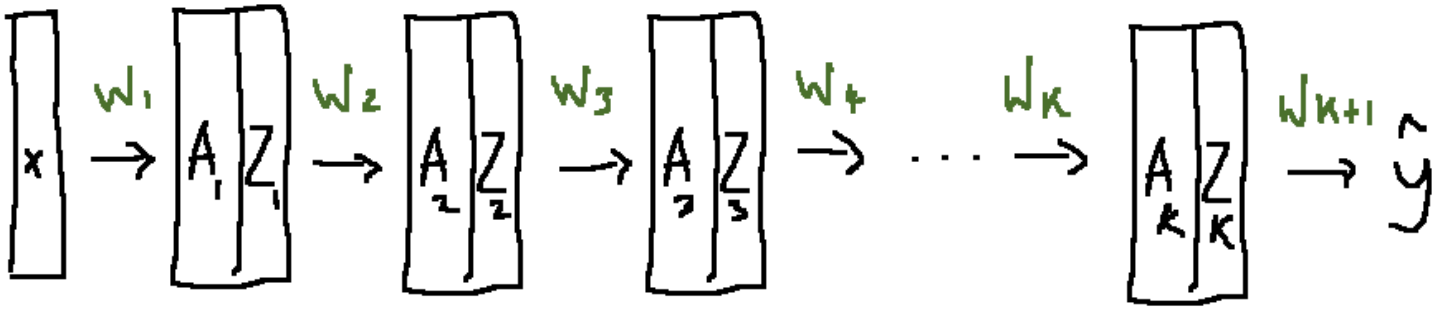
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



$$\partial J / \partial W_i =$$

$$(\partial J / \partial \hat{y}) \sigma'(A_K) W_K \sigma'(A_{K-1}) W_{K-1} \cdots$$

$$\cdots W_{i+1} \sigma'(A_i) Z_{i-1}$$

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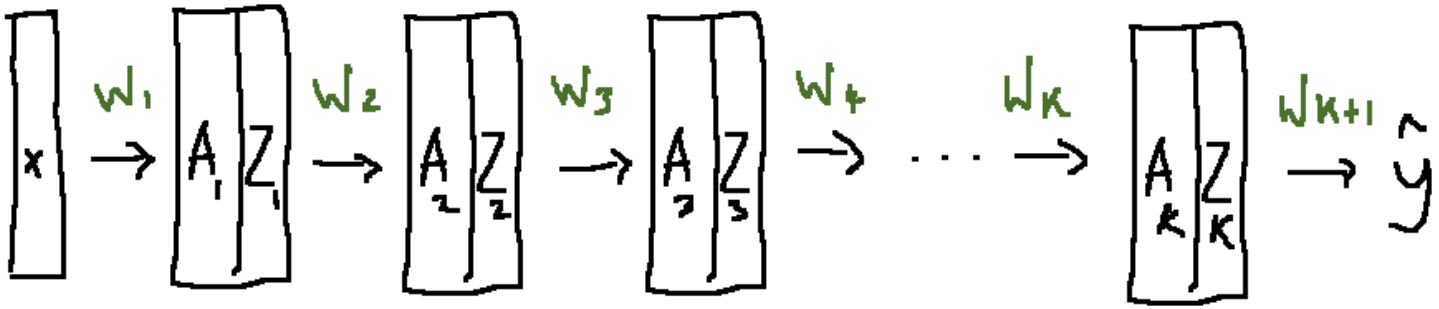
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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$$\cdots W_{i+1} \sigma'(A_i) Z_{i-1}$$

!!

Backwards pass

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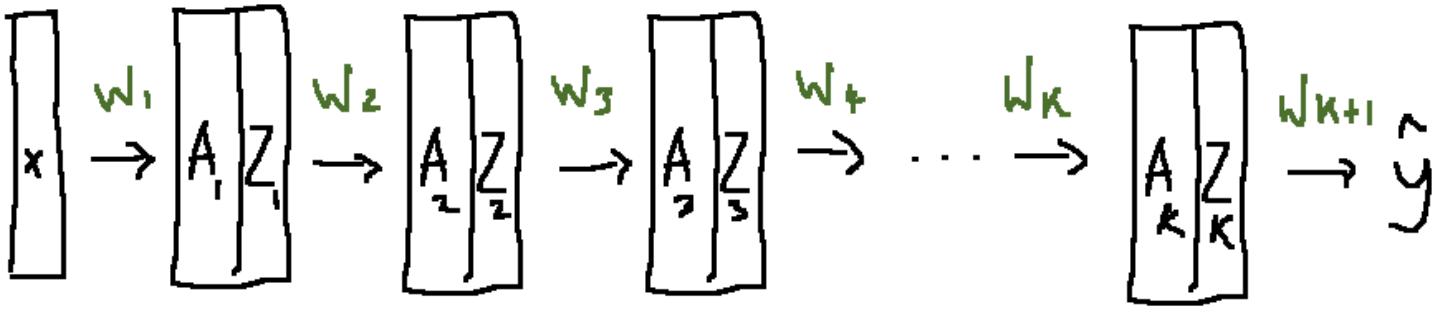
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks



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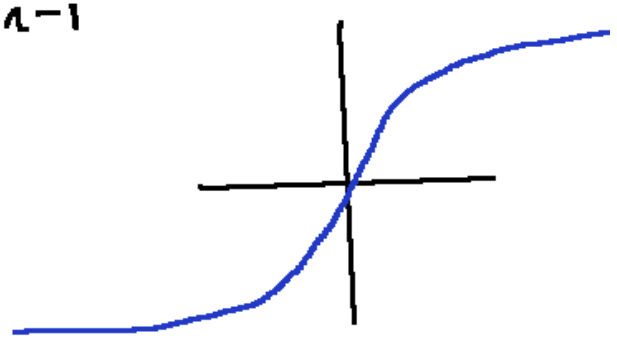
$$\cdots W_{i+1} \sigma'(A_i) Z_{i-1}$$



Linear

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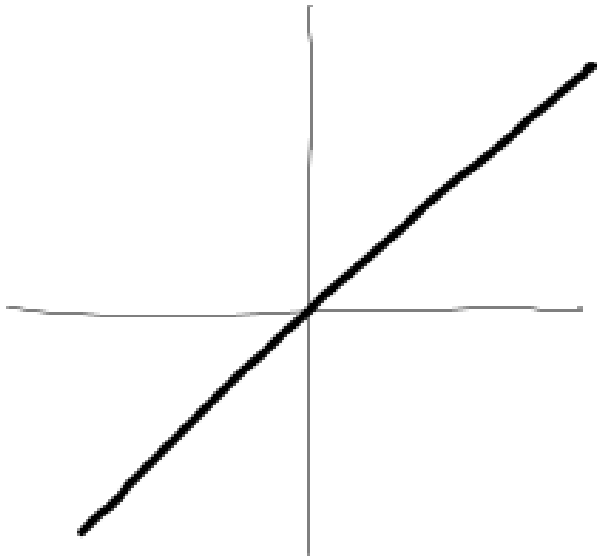
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks

- Useless



Threshold

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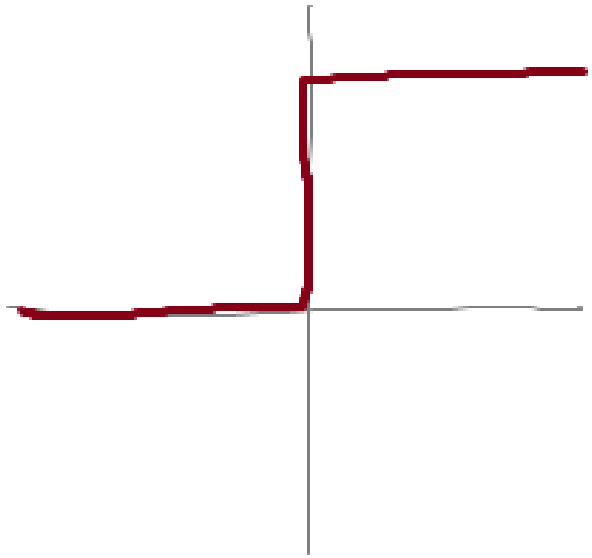
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks

- Similar to biological neuron
- No gradient



Sigmoid

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Gradient Descent
Backprop
Activations
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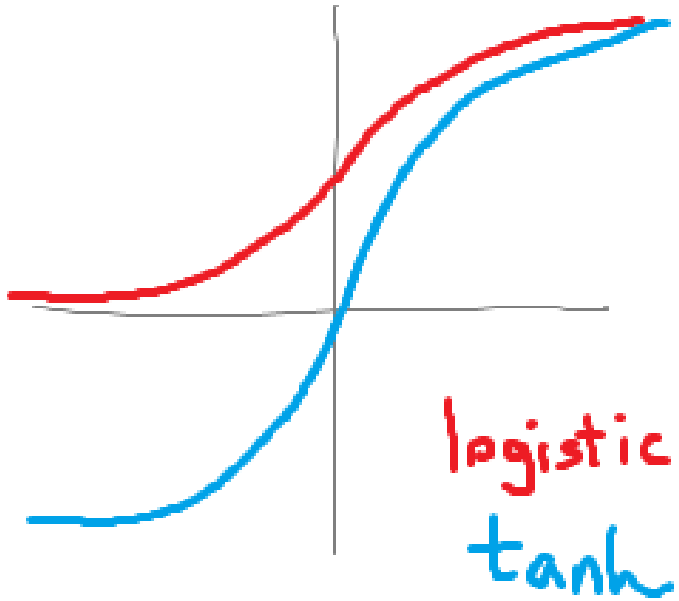
- *tanh* preferred
- Gradients can vanish



ReLU

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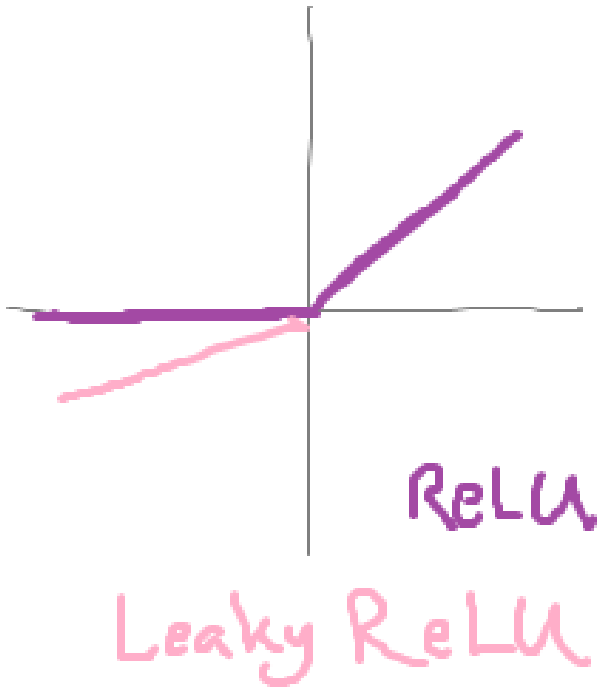
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks

- No vanishing gradient
- Cheap to compute
- Can explode and die
- Popular with CNNs



Radial basis functions

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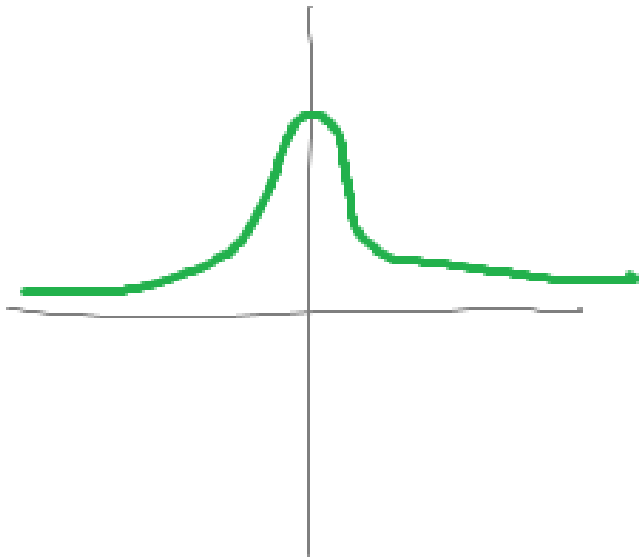
What is a Neural Network?
Gradient Descent
Backprop
Activations
How to train your pet network
Convolutional Neural Networks

- Gaussian + others
- Train very quickly
- Good at interpolation



How to train your pet network (generally)

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Gradient Descent
Backprop
Activations
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Convolutional Neural Networks

- Use ReLU
- Use minibatch GD with Nesterov momentum
- ≤ 3 layers (unless convolutional)
- Use dropout (≈ 0.2 input layer, ≈ 0.5 else)
- Prefer wider with L2 over smaller
- Be careful with weight initialization!

Convolutional Neural Networks

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Backprop
Activations
How to train your pet network
Convolutional Neural Networks

- Image recognition killer

Conceptual structure

Neural Networks

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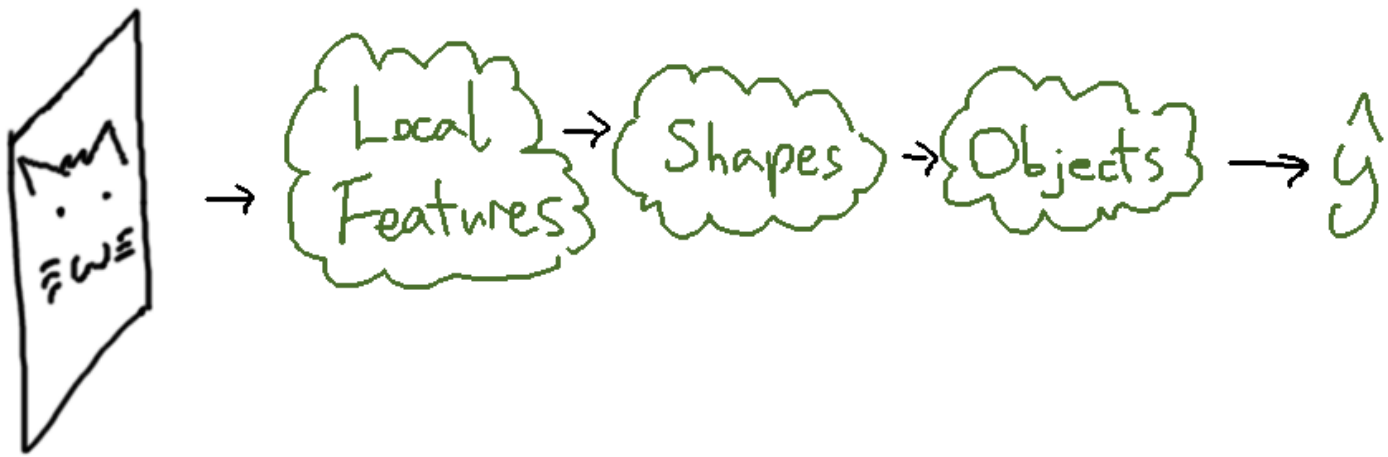

MLP $\rightarrow$ too many weights!

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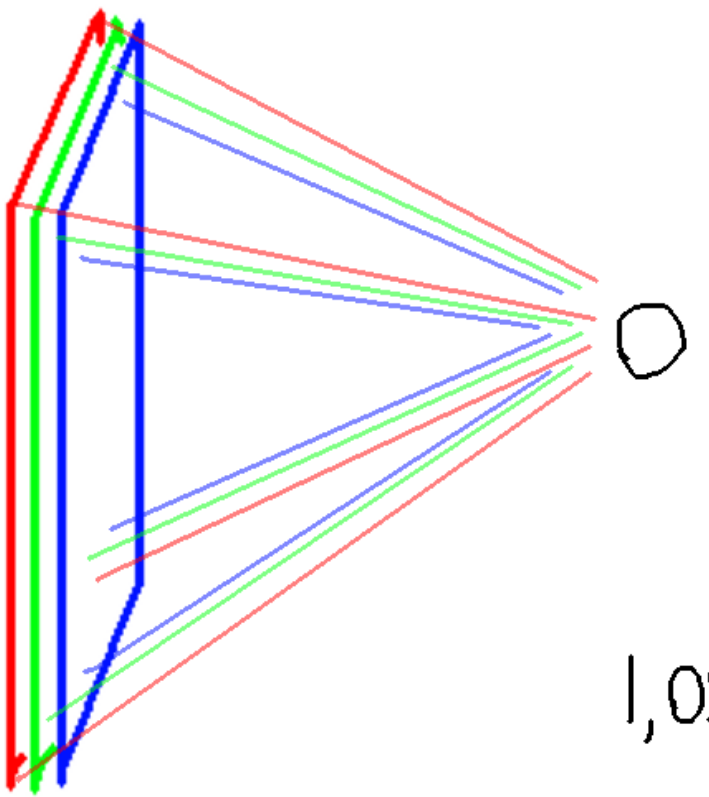

$32 \times 32 \times 3$

$= 3,072$ weights N^{-1}

1,024 Neurons

$\rightarrow$ >3M weights

Local connectivity

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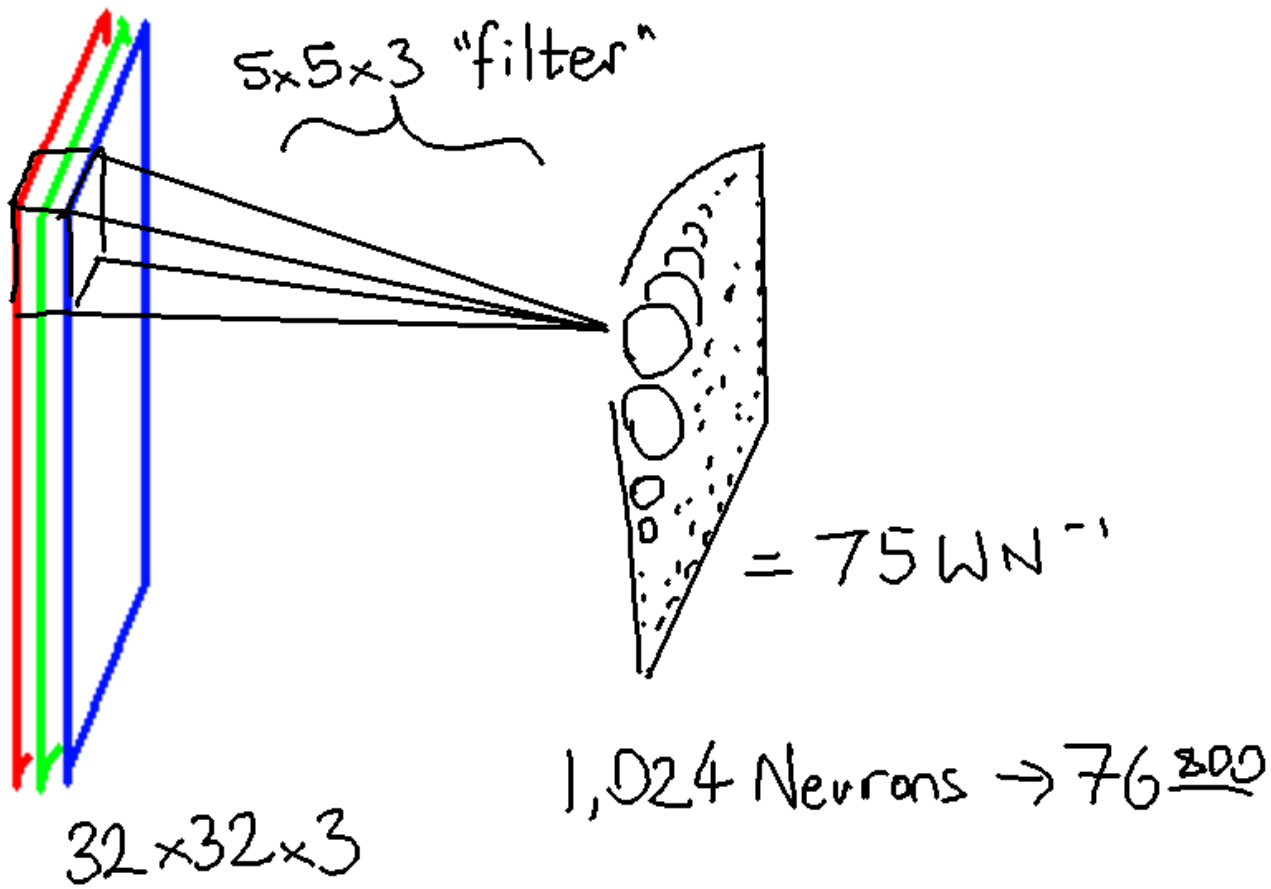

Local connectivity + convolution

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Gradient Descent
Backprop
Activations
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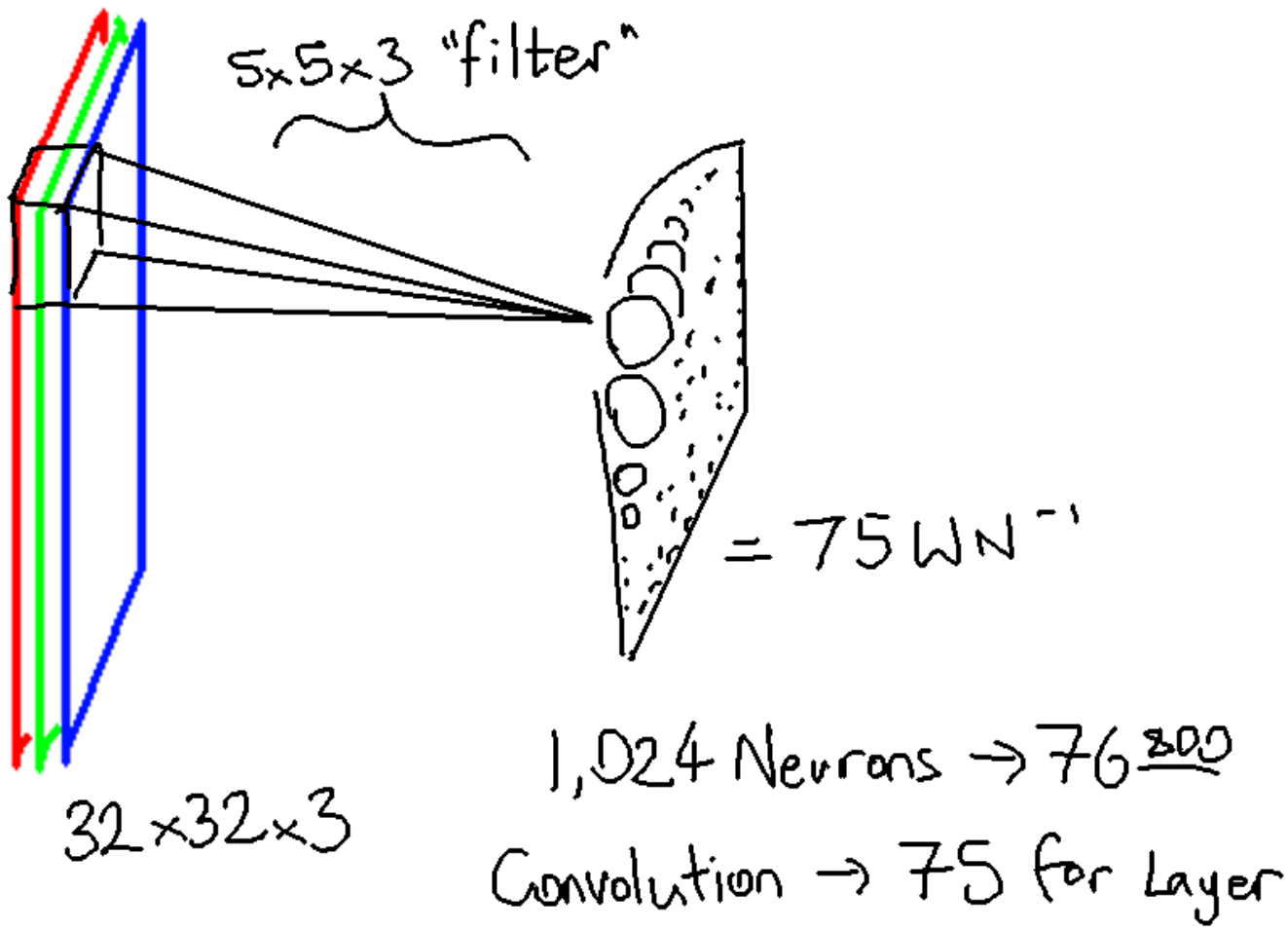

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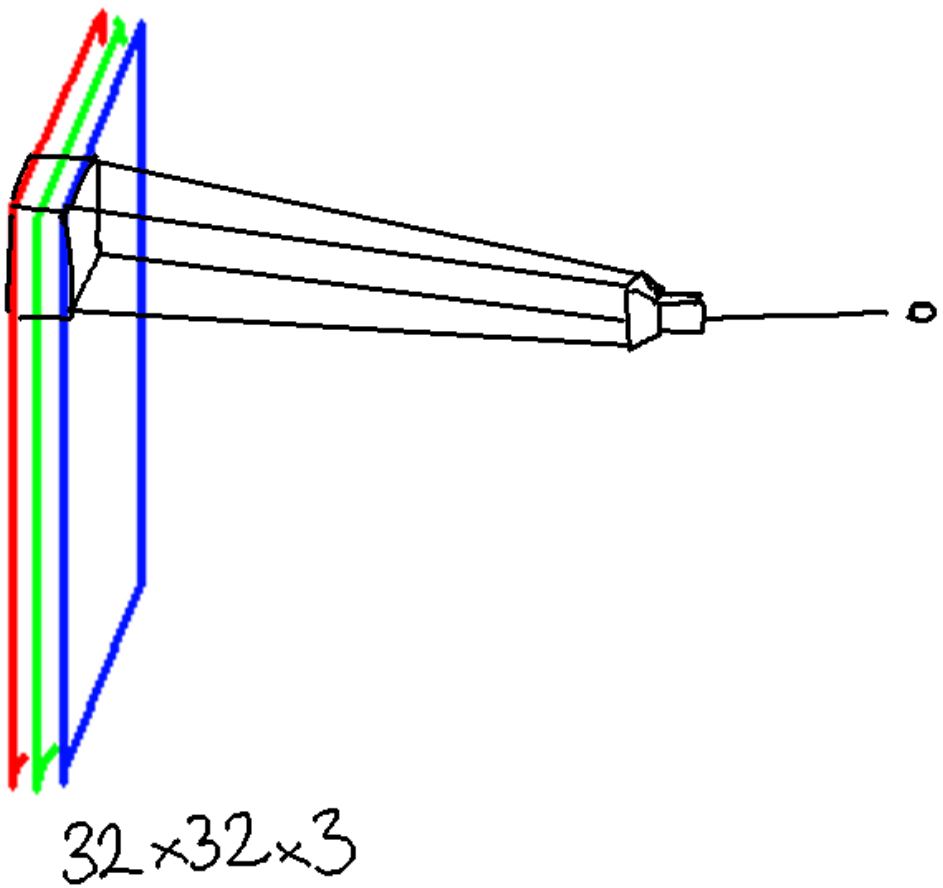

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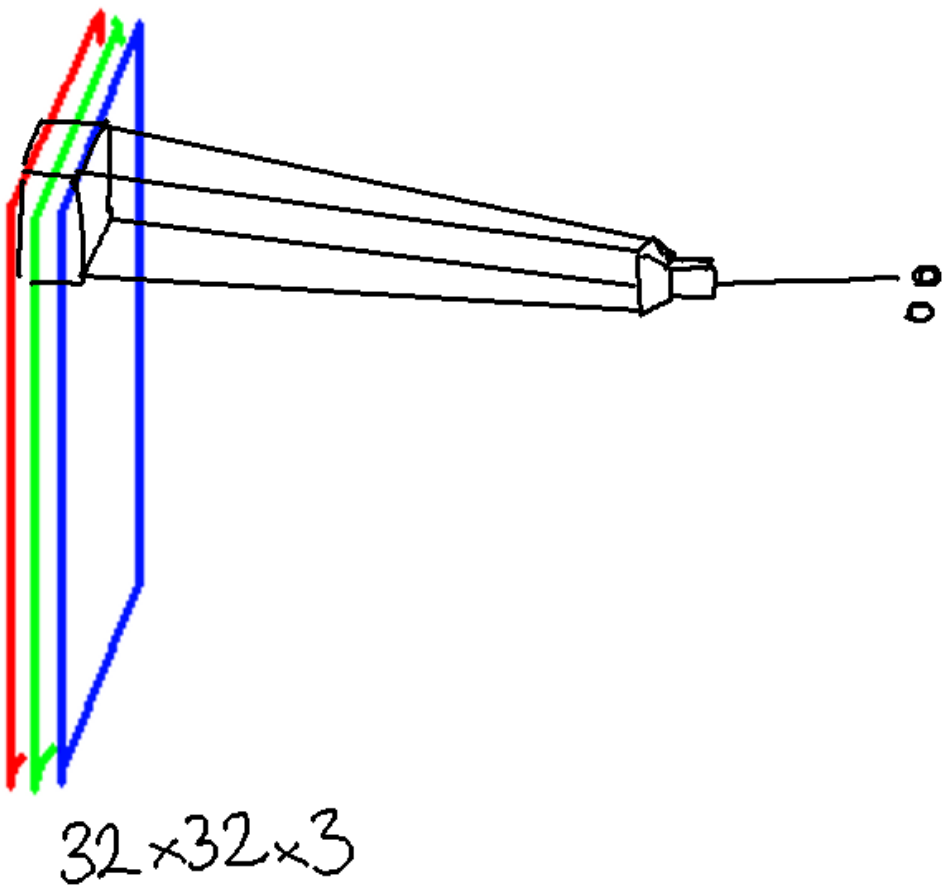

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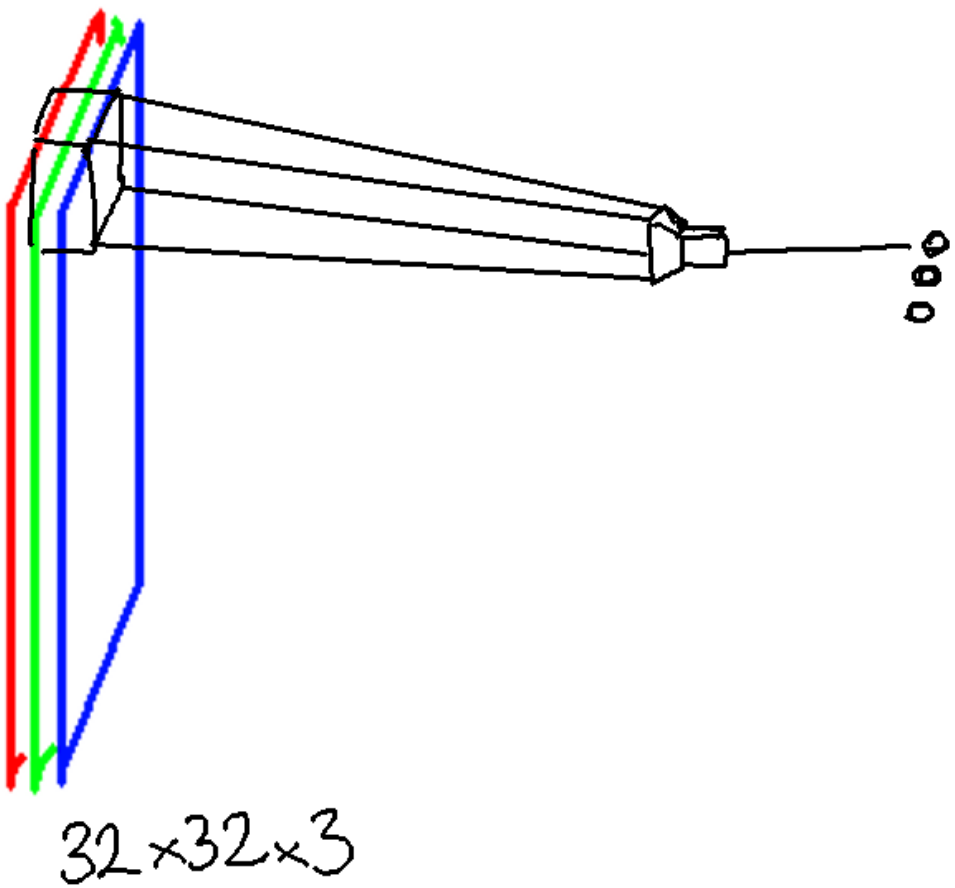

Local connectivity + convolution

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Backprop
Activations
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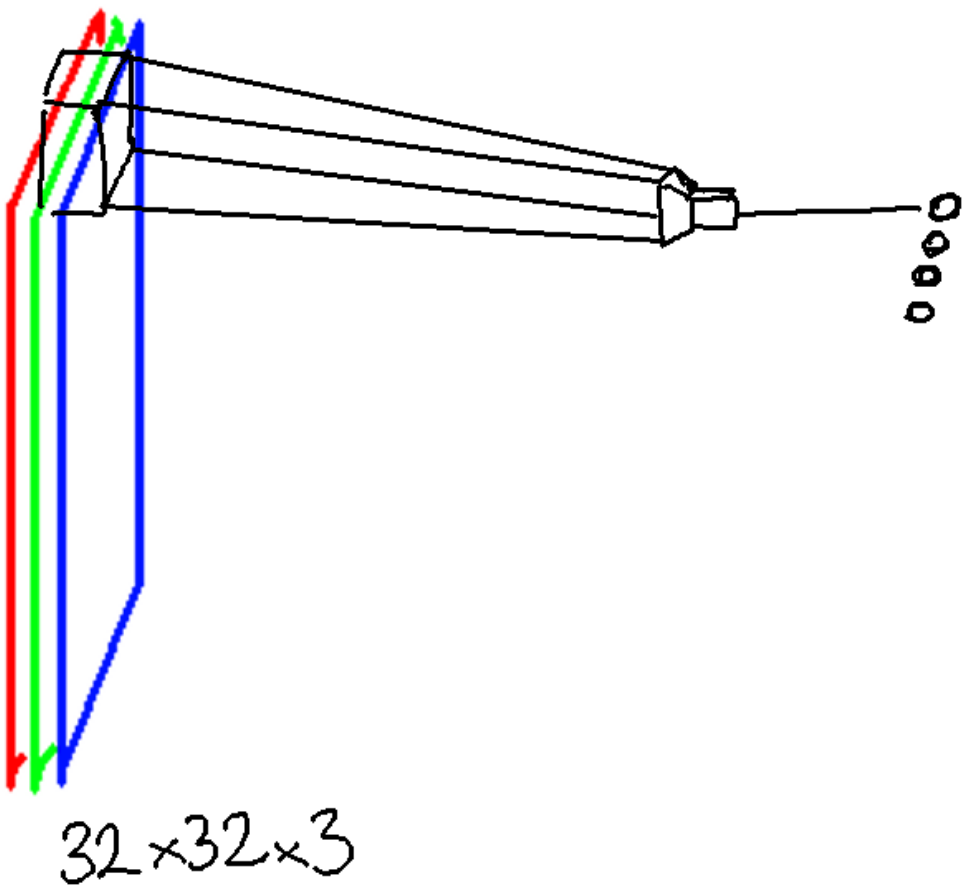

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Gradient Descent
Backprop
Activations
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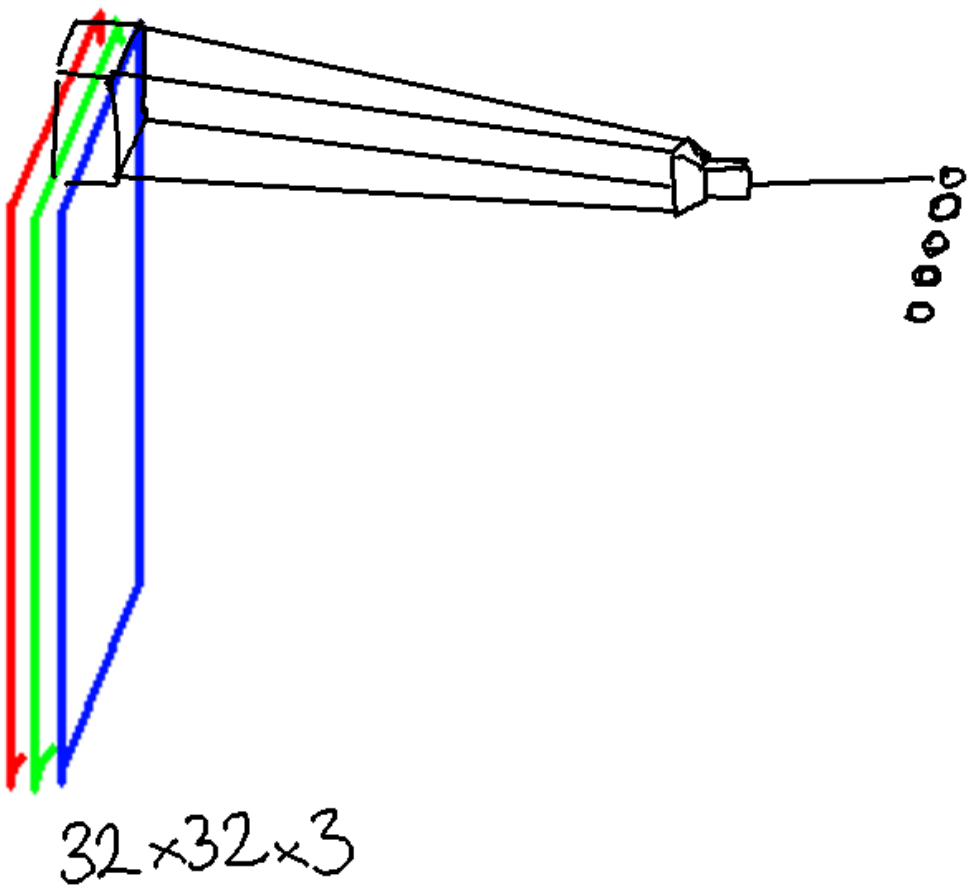

One filter forms a surface

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Backprop
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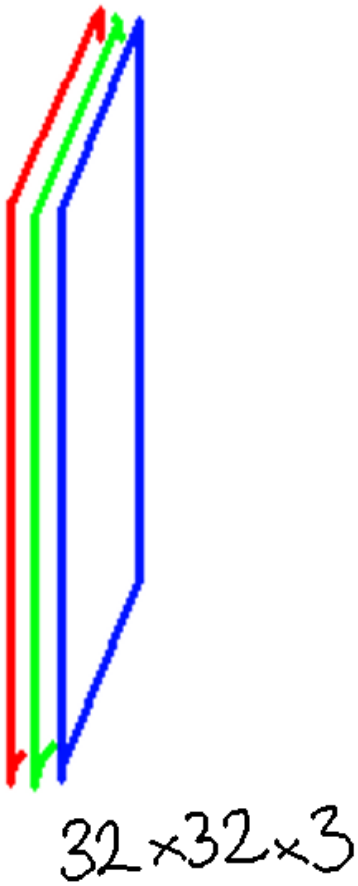

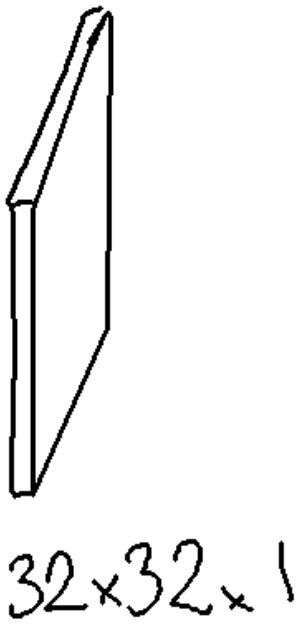

Many filters form a volume

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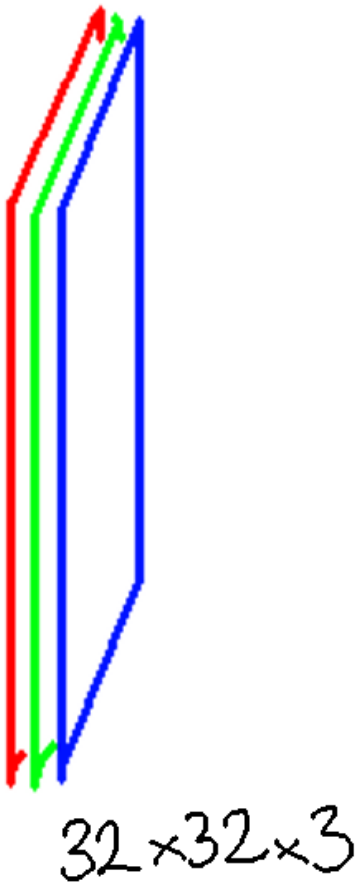

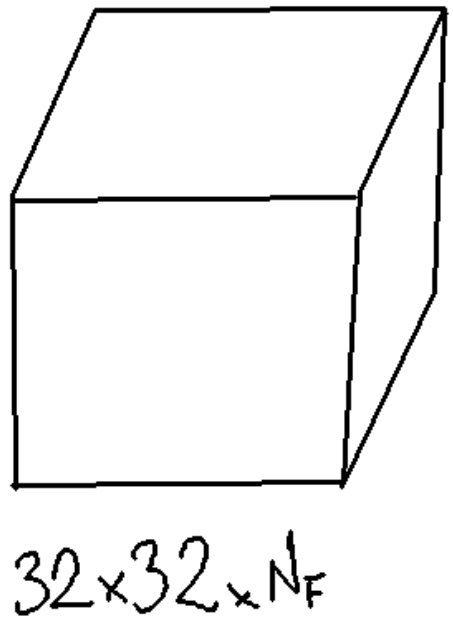

Typical processing structure

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Backprop
Activations
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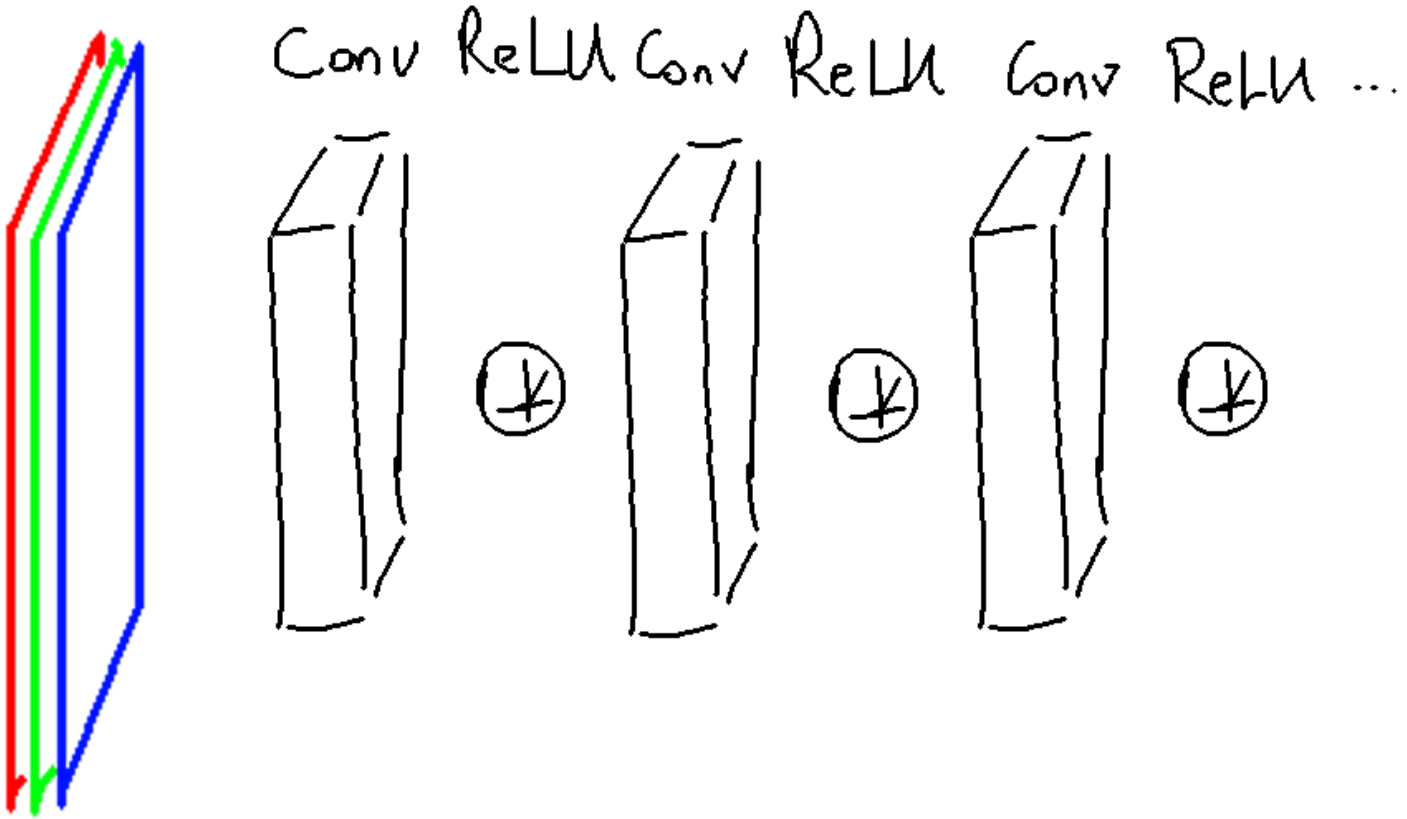

AlexNet's filters

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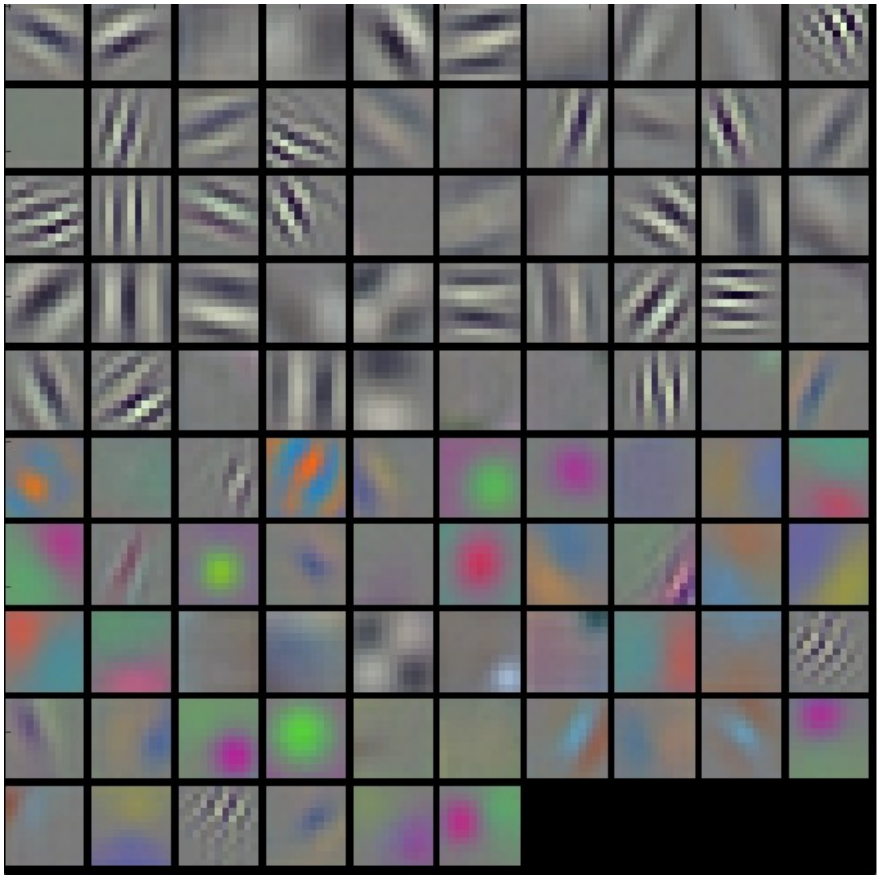

Image credit: Krizhevsky et al. 2012

Pooling

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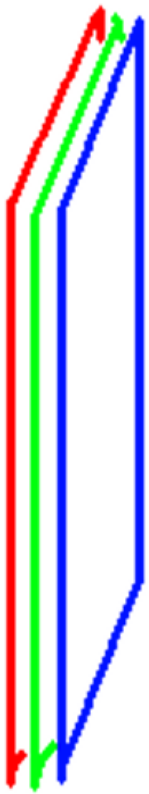
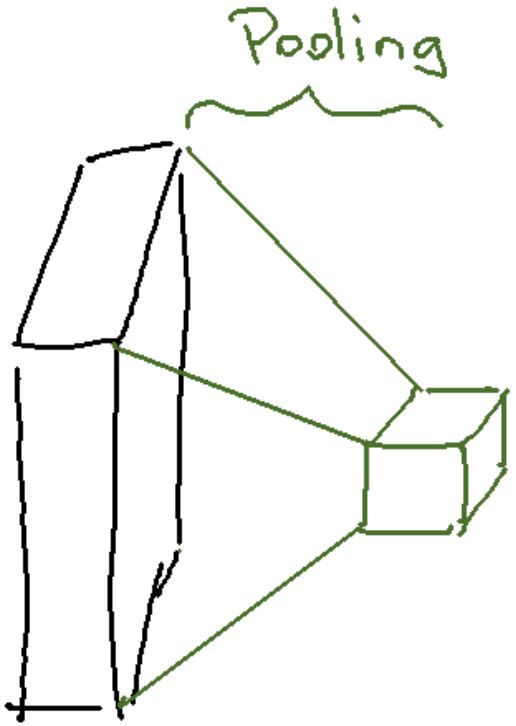


$\{Conv, ReLU\}_M$



$\{X, Y, 3\} \rightarrow \{X, Y, K\} \rightarrow \{<X, <Y, K\}$

Pooling

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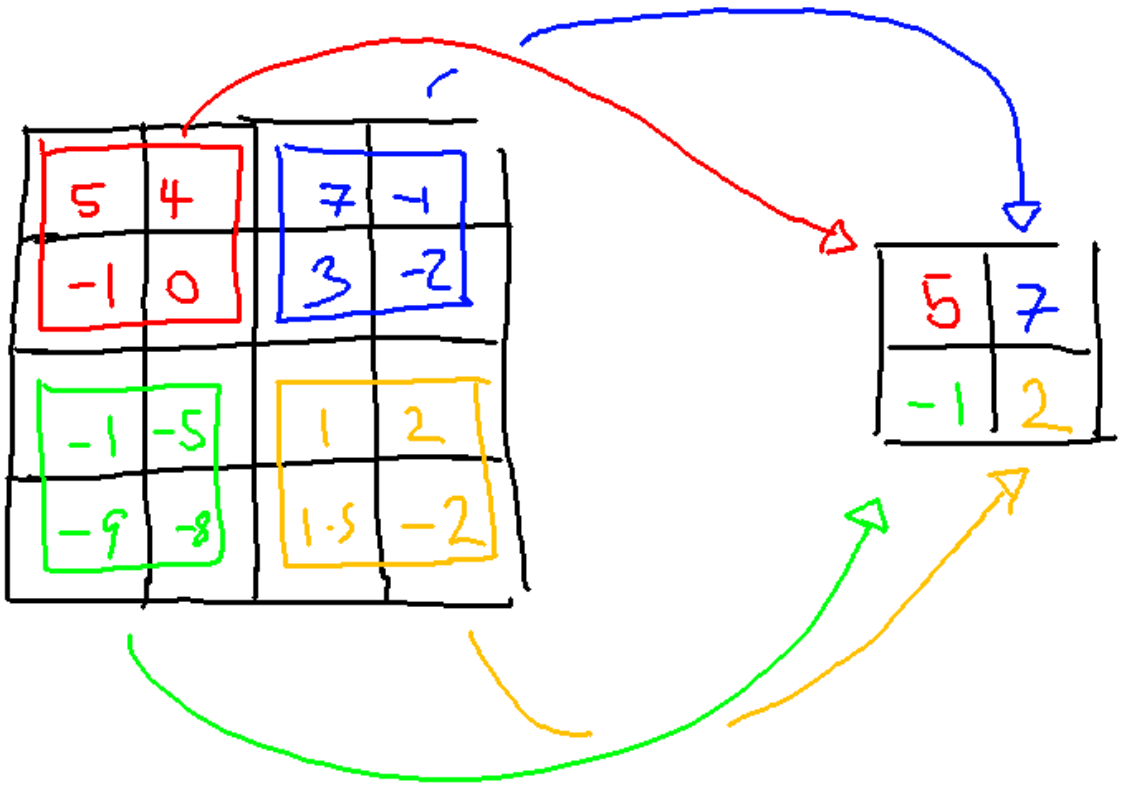

Typical structure of a CNN

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Gradient Descent
Backprop
Activations
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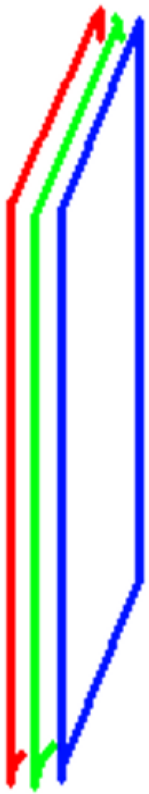

Standard Convnet

$$\{\{\text{Conv}, \text{ReLU}\}_M \ \text{Pool}\}_N \quad \{\text{FC}\}_K \rightarrow \hat{y}$$