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Module 4.3 - Advanced NNs

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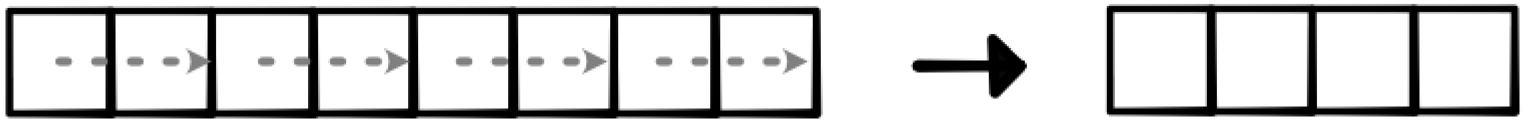
"Pooling"

Reduction applied to each region:



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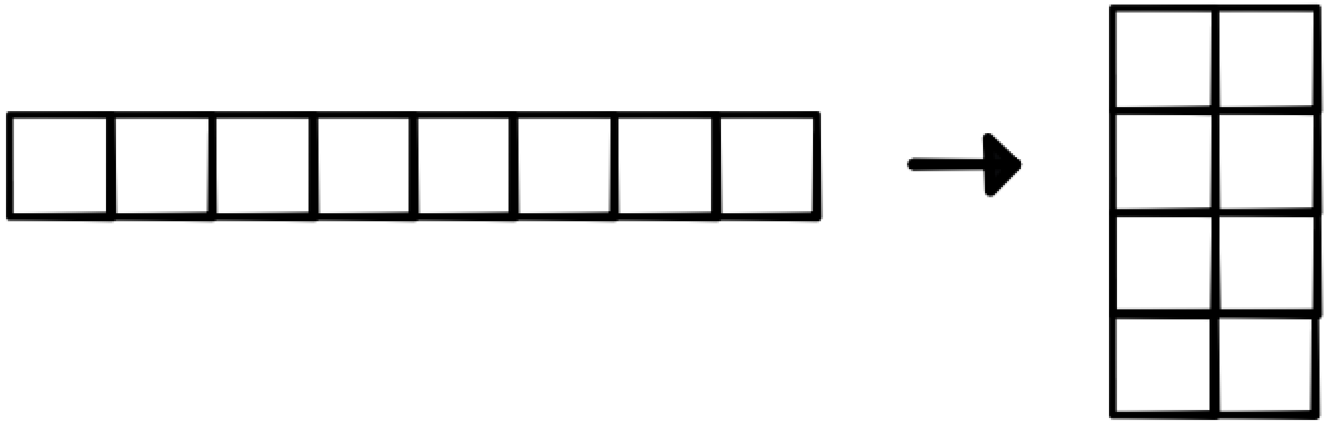
Simple Implementation

- Ensure that it is contiguous
- Use View to "fold" the tensor



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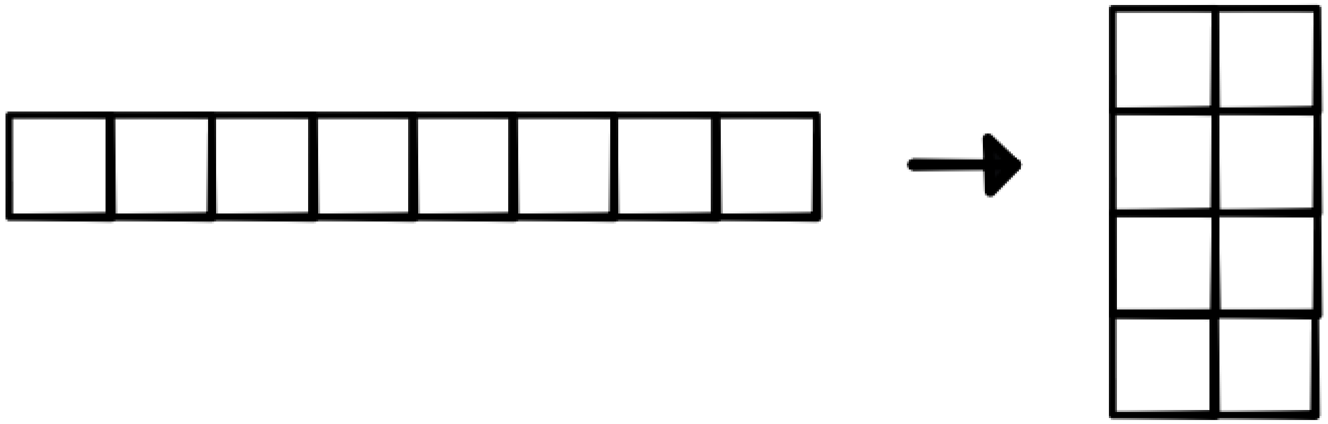
Why does folding work?

- View requires "contiguous" tensor
- View(4, 2) makes strides (2, 1)



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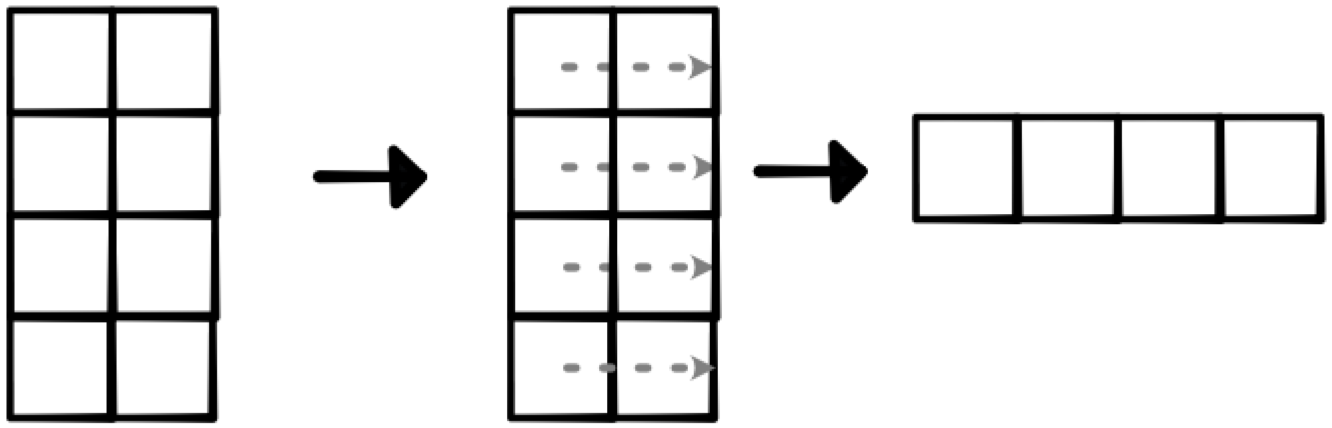
Simple Implementation

- Reduce along created fold



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Quiz

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Gradient Flow

- Layers that are used get more updates
- Gradient signals which aspect was important
- Can have extra layers

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More Reductions

- Heading for a `max` reduction
- Heading for a `softmax` output
- Quick detour

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ReLU, Step, Sigmoid

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Basic Operations

- Introduced in Module-0
- Widely used in ML
- What is it?

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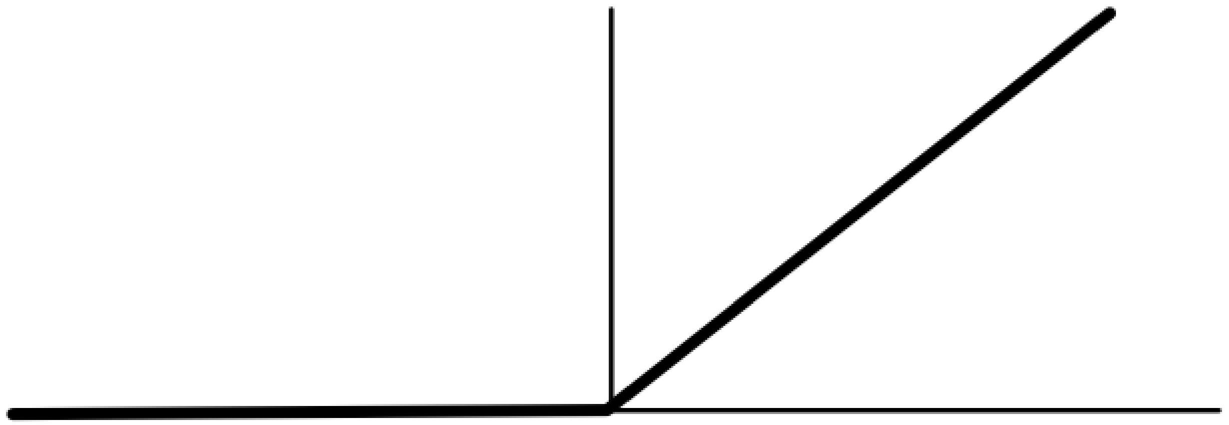
Simple Function: ReLU

Main "activation" function



Primarily used to split the data.

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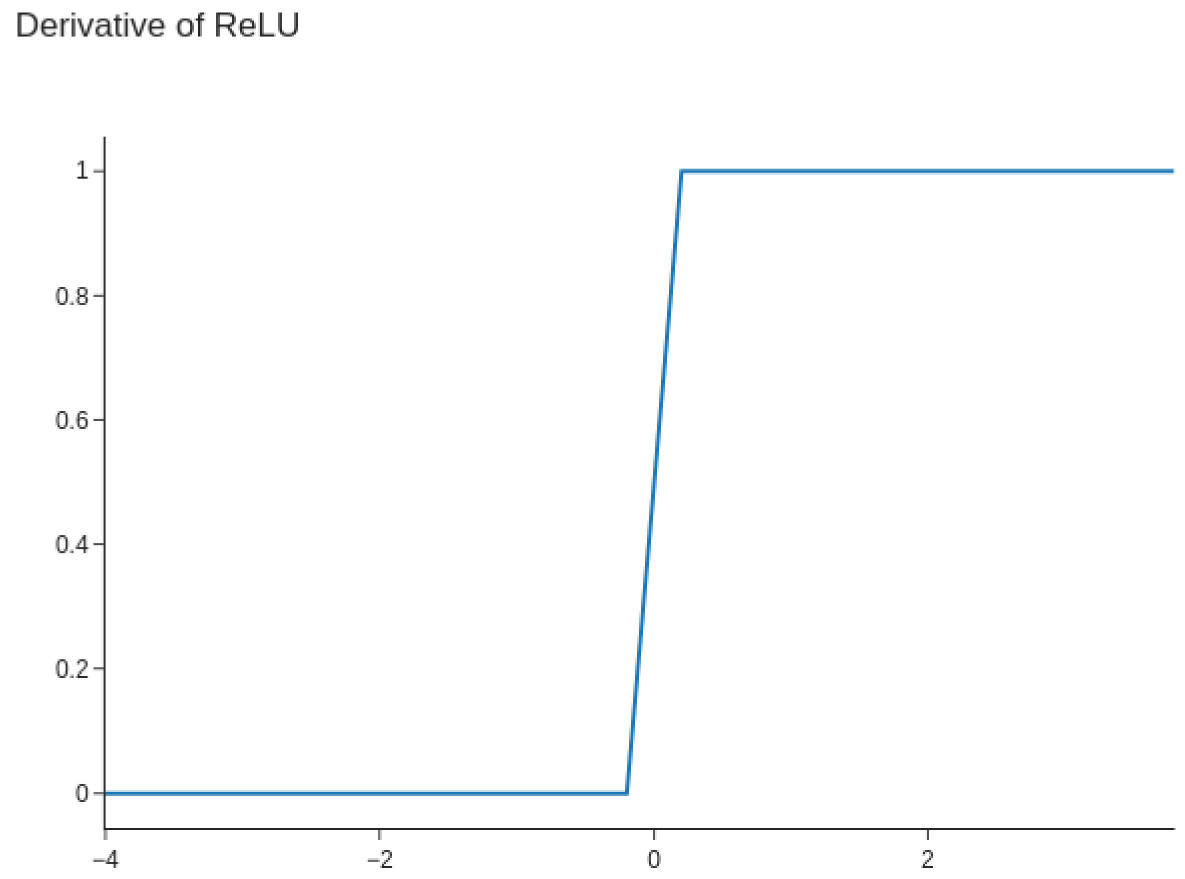
Simple Function: Step

Step function $f(x) = x > 0$ determines correct answer



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ReLU

Mathematically,

$\mathrm{ReLU}(x) = \max$

Simplest `max` function.

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Step

Mathematically,

$$\text{step}(x) = x > 0 = \arg\max\{0, x\}$$

Simplest `argmax` function.

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Relationship

Step is derivative of ReLU

$$\mathrm{ReLU}'(x) = \begin{cases} 0 & \text{if } x \leq 0 \\ 1 & \text{ow} \end{cases}$$

$$\mathrm{step}(x) = \mathrm{ReLU}'(x)$$

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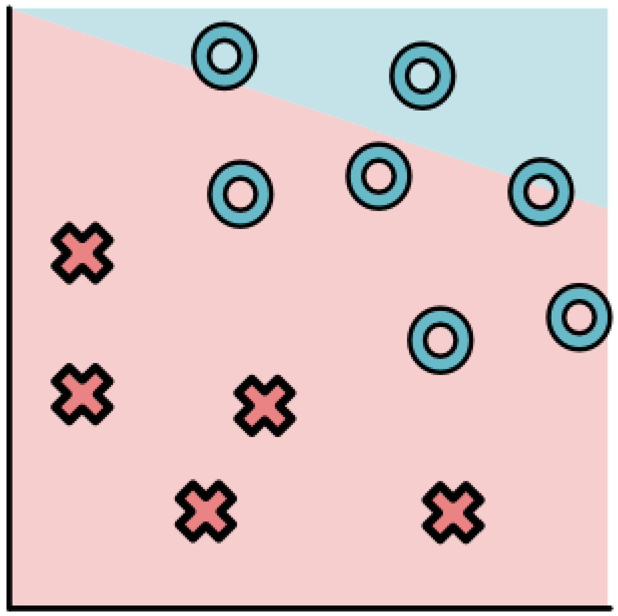

Loss of step tells us how many points are wrong.

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Derivative of Step?

Mathematically,

\text{step}'(x) =

$$\begin{cases} 0 & \text{if } x \leq 0 \\ 0 & \text{ow} \end{cases}$$

Not a useful function to differentiate

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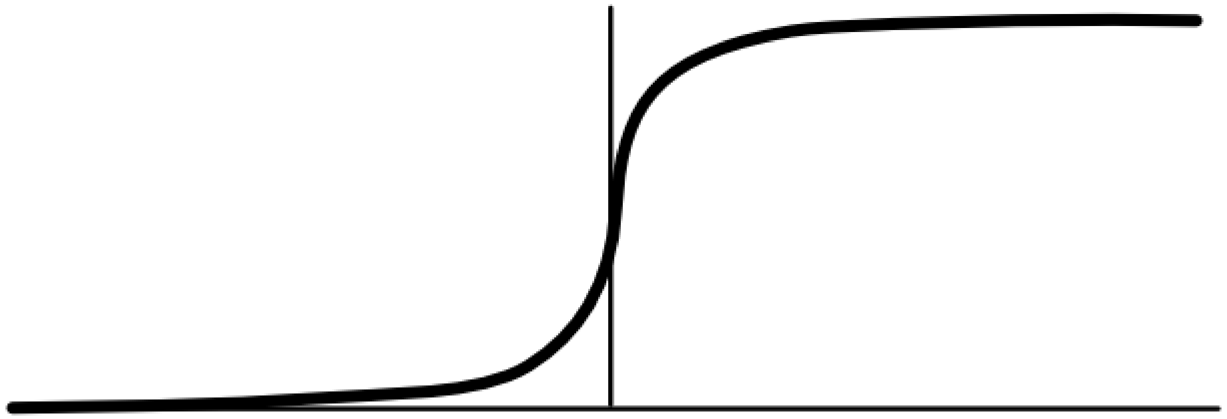
Altenative Function: Sigmoid

Used to determine the loss function



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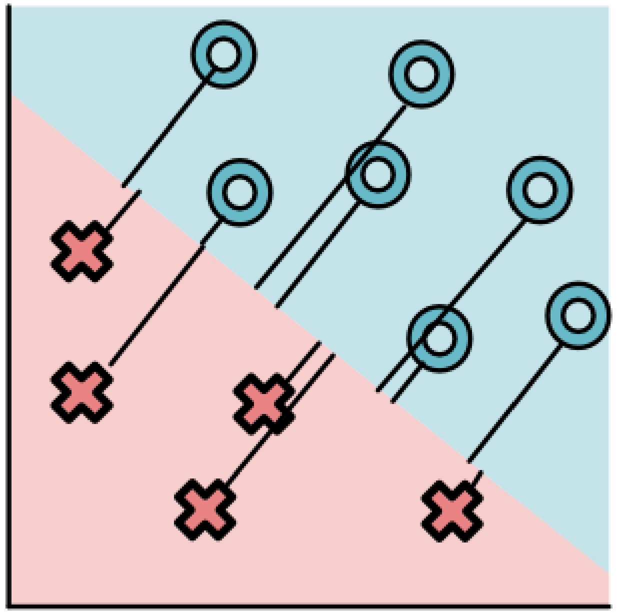

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Soft (arg)max?

Would be nice to have a version that with a useful derivative

\text{sigmoid}(x) = \text{softmax} \{0, x\}

Useful soft version of argmax.

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Max, Argmax, Softmax

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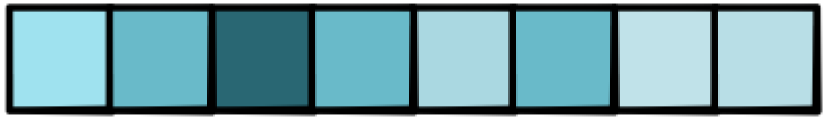
Challenge

How do we generalize sigmoid to multiple outputs?



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Max reduction

- Max is a binary associative operator
- $\max(a, b)$ returns max value
- Generalized $\text{ReLU}(a) = \max(a, 0)$

Max Pooling

- Common to apply pooling with max
- Sets pooled value to "most active" in block
- Forward code is easy to implement

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Max Backward

- Unlike sum, max throws away other values
- Only top value gets used
- Backward needs to know this.

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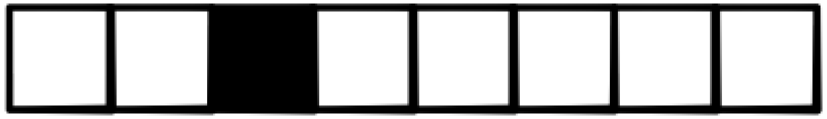
Argmax

- Function that returns `argmax`, one-hot
- Generalizes step



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Max Backward

- First compute `argmax`
- Only send gradient to `argmax` gradinput
- Everything else is 0

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Ties

- What if there are two or more argmax's?
- Max is non-differentiable, like `ReLU(0)`.
- Short answer: Ignore, pick one

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HW

- When writing tests for max, ties will break finite-differences
- Suggestion: perturb your input by adding a small amount of random noise.

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Soft argmax?

- Need a soft version of argmax.
- Generalizes sigmoid for our new loss function
- Standard name -> softmax

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Softmax

\text{softmax}(\textbf{x}) = \frac{\exp \textbf{x}}{\sum_i \exp x_i}

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Sigmoid is Softmax

$$\text{softmax}([0, x])[1] = \frac{\exp x}{\exp x + \exp 0} = \sigma(x)$$

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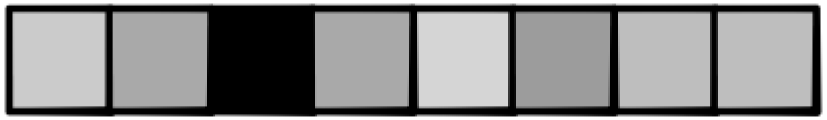
Softmax

Softmax



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Review

- ReLU -> Max
- Step -> Argmax
- Sigmoid -> Softmax

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Softmax

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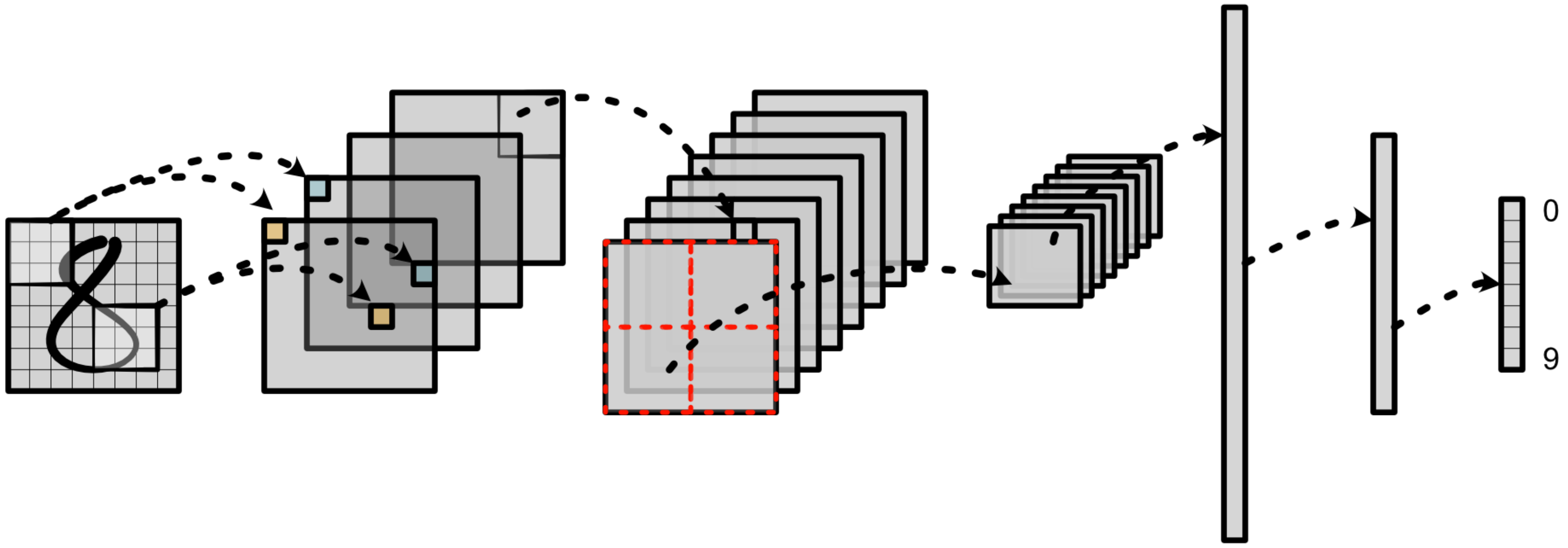
Network

Network



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Softmax Layer

- Produces a probability distribution over outputs (Sum to 1)
- Derivative similar to sigmoid
- Lots of interesting practical properties

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Softmax in Context

- Not a map!
- Gradient spreads out from one point to all.

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Softmax

- (Colab) [https://colab.research.google.com/drive/1EB7MI_3gzAR1g

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Soft Gates

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New Methods

- Sigmoid and softmax produce distributions
- Can be used to "control" information flow

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Example

Returns a combination of x and y f(x, y, r) = x * \sigma(r) + y * (1 - \sigma(r))

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Gradient is controlled

$$\begin{aligned} f'_x(x,y,r) &= \sigma(r) \\ f'_y(x,y,r) &= (1-\sigma(r)) \\ f'_r(x,y,r) &= (x-y)\sigma'(r) \end{aligned}$$

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Neural Network Gates

Learn which one of the previous layers is most useful.

$$r = NN_1$$
$$x = NN_2$$
$$y = NN_3$$

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Gradient Flow

- Layers that are used get more updates
- Gradient signals which aspect was important
- Can have extra layers

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Selecting Choices

- Gating gives us a binary choice
- What if we want to select between many elements?
- Softmax!

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Softmax Gating

Combines many elements of X based on R

$f(X, R) = X \times softmax(R)$

Processing math: 7%

Softmax Gating

- Brand name: Attention

Processing math: 7%

Processing math: 7%

Example: Translation

- Show example

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Processing math: 7%

Example: GPT-3

- Show example

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QA

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