

NEURAL NETWORKS

&

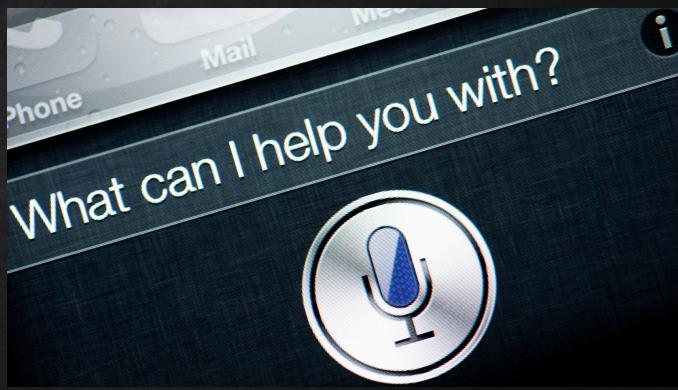
DEEP

LEARNING

A **ADI** TYA PRAKASH

Jan 30, 2017

[latest version](#)



Winter is here. Go to the store and buy some snow shovels.

Winter is here. Go to the store and buy some snow shovels.



WHAT WE WILL LEARN

Neural
Networks

Deep
Learning

Applications
(lots)

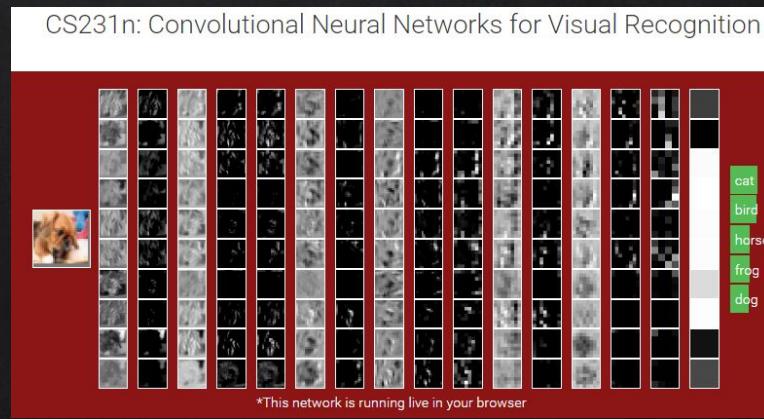
BOOK

[HTTP://WWW.DEEPLEARNINGBOOK.ORG](http://www.deeplearningbook.org)



COURSE

[HTTP://CS231N.STANFORD.EDU](http://cs231n.stanford.edu)



Machine Learning recap

Apply a prediction function to a feature representation of given input (x) and get the desired output.

$$f(\text{apple icon}) = \text{"apple"}$$

$$f(\text{bird icon}) = \text{"bird"}$$

$$f(\text{bike icon}) = \text{"bike"}$$

Machine Learning recap

Training Data \rightarrow model \rightarrow output

x

f

\tilde{y}

$f(x) \rightarrow \tilde{y}$

$y - \tilde{y} \rightarrow \text{error}$

$L(y, \tilde{y}) \rightarrow \text{Loss/Objective}$

Loss function L quantifies how unhappy you would be if you used ' f ' to make predictions on x .
It is the objective we want to minimize

Machine Learning recap

Training Data → model → output

x f \tilde{y}

$$\text{TrainLoss} = \sum_i \text{Loss}(f(x_i), y_i)$$

Minimize TrainLoss
 f

Find ' f ' such that it minimizes the 'training loss', and
hope that this is also true for 'test' loss.

Machine Learning recap

Training Data → model → output

x f \tilde{y}

Minimize TrainLoss
 f

$f \rightarrow W$

$$W \leftarrow W - \eta \nabla_w \text{TrainLoss}(f)$$

Process of updating ‘weights’ like this is called
gradient descent.

1.

ARTIFICIAL NEURAL NETWORK



ARTIFICIAL NEURAL NETWORK

But first some motivation !



A scatter plot showing 100 data points (x,y) plotted against a black background. The points are colored green if $x \geq y$ and red if $x < y$. The points are arranged to form the shape of the number '100'. The x and y axes both range from 0 to 100, with major grid lines every 10 units.

| x | y | Color |
|----|---|-------|
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IMAGE CLASSIFICATION



Choose among the following ---

Cairn terrier

(b) Norwich terrier

(c) Australian terrier

IMAGE CLASSIFICATION



Choose among the following ---

Cairn terrier

(b) Norwich terrier

(c) Australian terrier



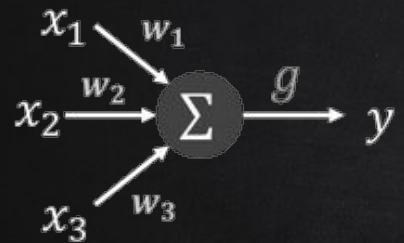
USING MAGIC

Neural networks and **back**propagation

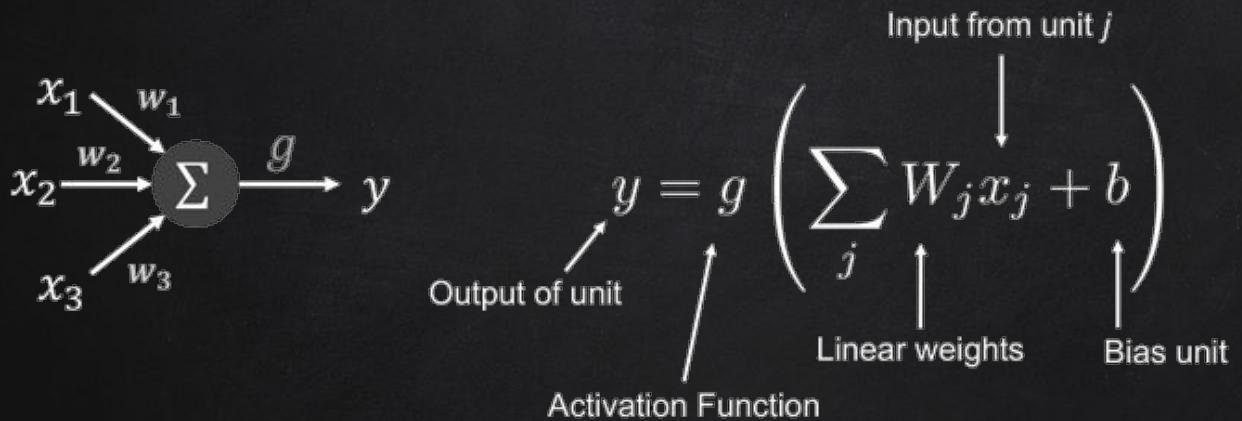
NEURON



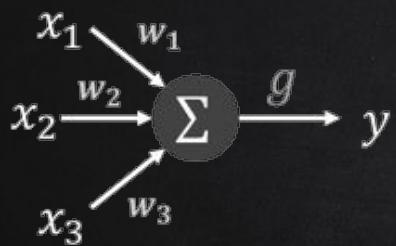
ARTIFICIAL NEURON



ARTIFICIAL NEURON



ARTIFICIAL NEURON

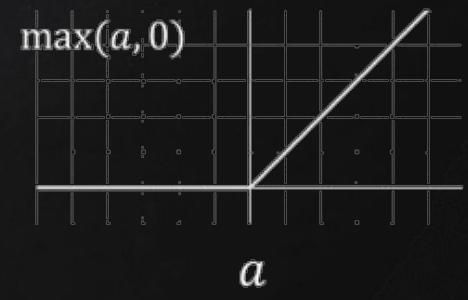
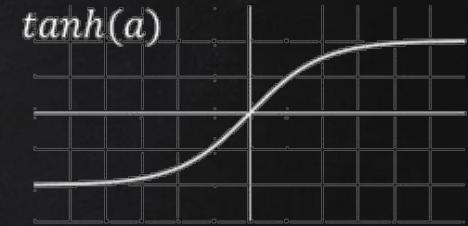


The mathematical formula for an artificial neuron is:

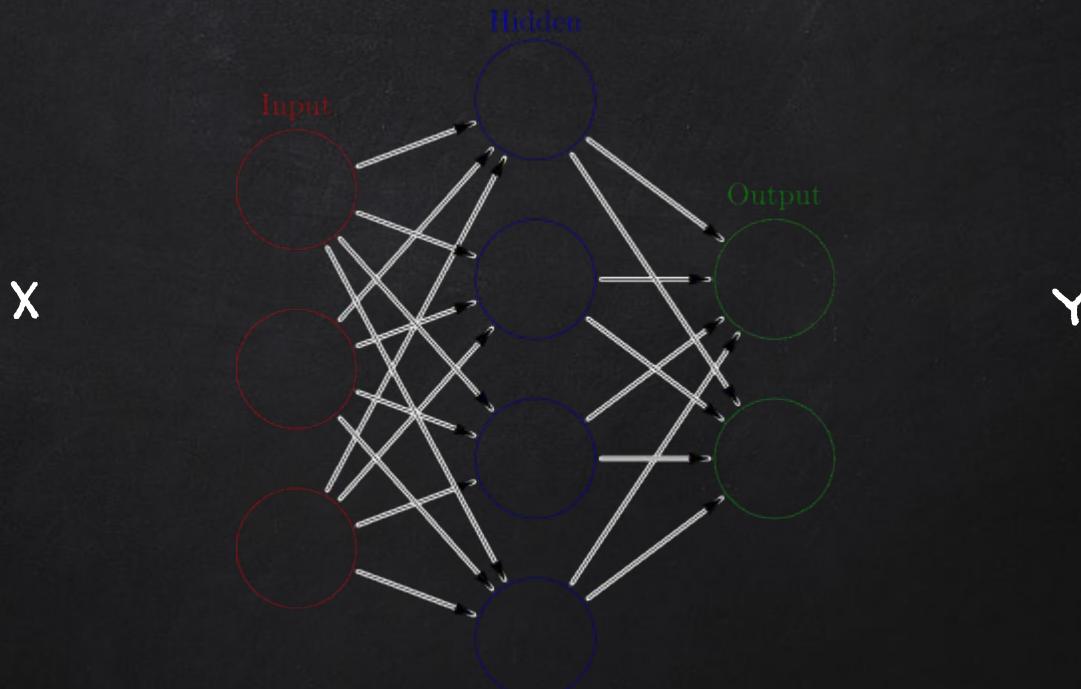
$$y = g \left(\sum_j W_j x_j + b \right)$$

Annotations explain the components:

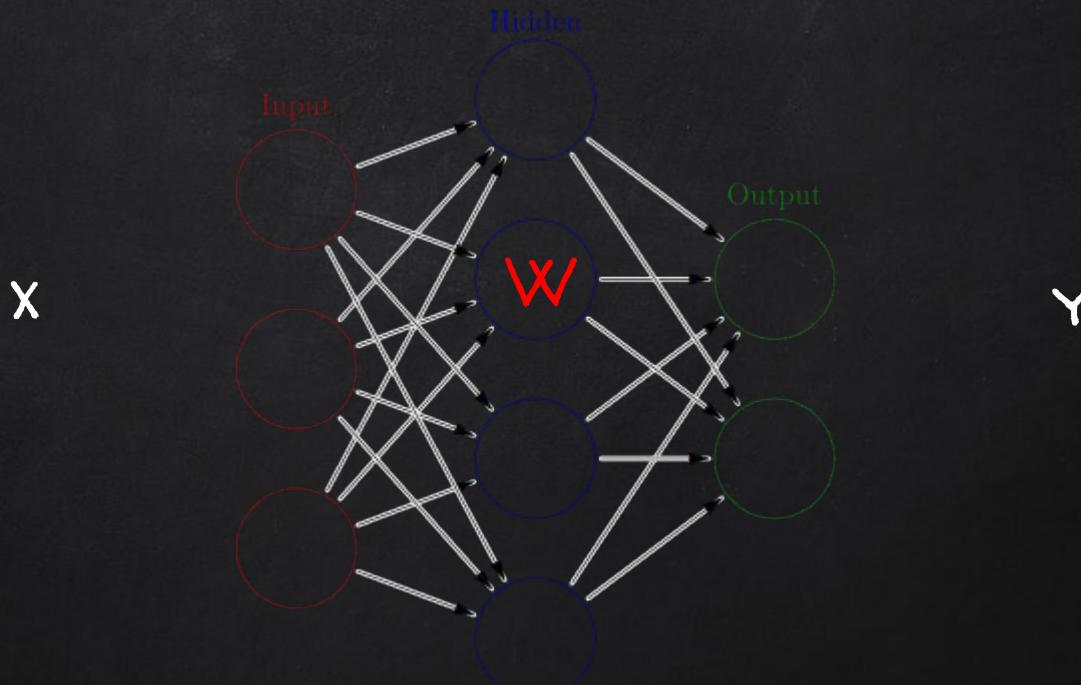
- "Input from unit j " points to the term $W_j x_j$.
- "Output of unit" points to the variable y .
- "Linear weights" points to the term $\sum_j W_j x_j$.
- "Bias unit" points to the term b .
- "Activation Function" points to the function g .



ARTIFICIAL NEURAL NETWORKS



ARTIFICIAL NEURAL NETWORKS



ARTIFICIAL NEURAL NETWORKS

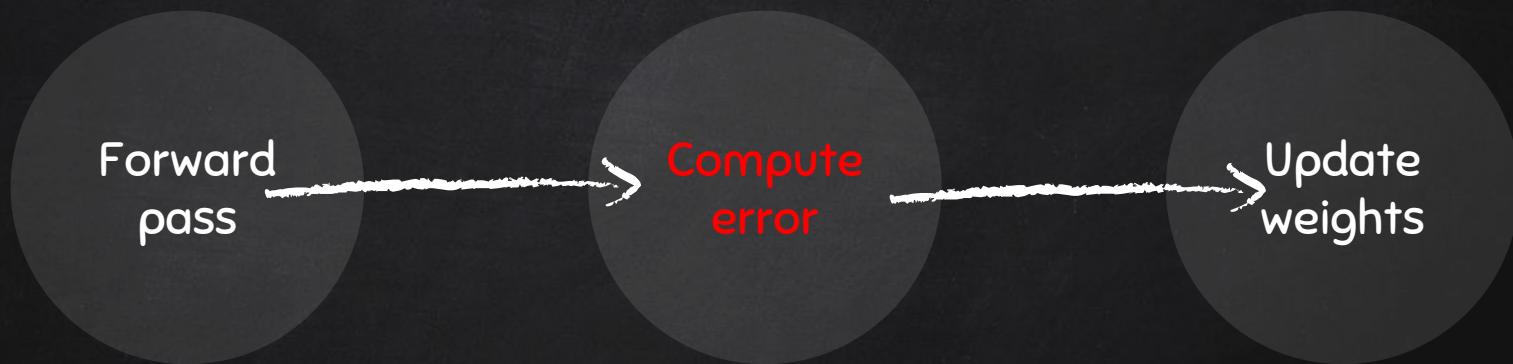
$H(x, w) \rightarrow y$

ARTIFICIAL NEURAL NETWORKS

$H(x, w)$  $+ b$



BACK PROPAGATION

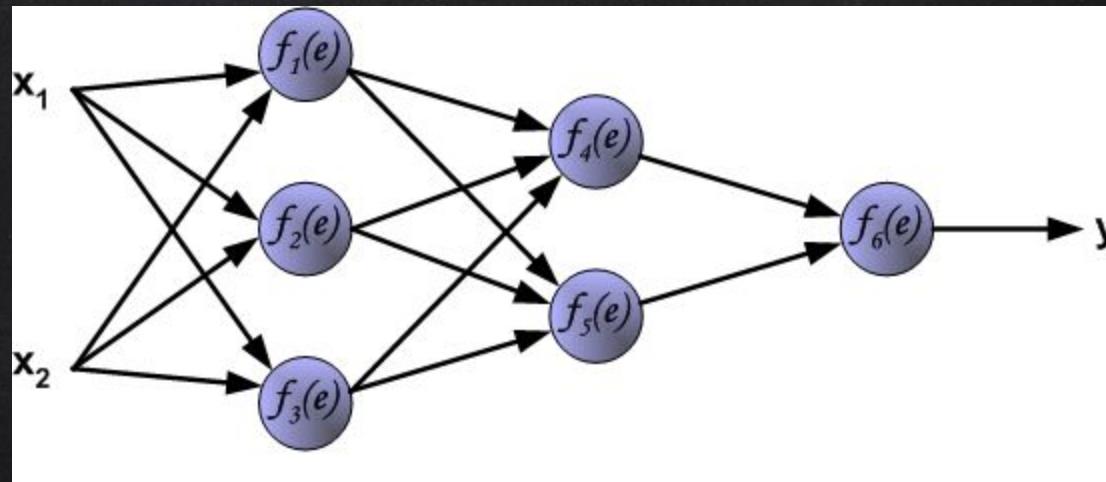




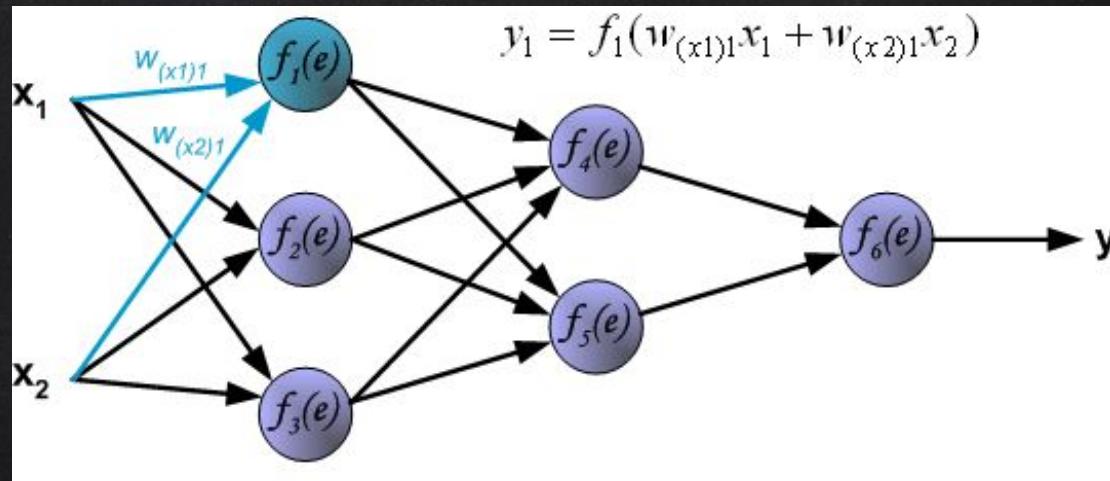
BACK PROPAGATION

Forward
Pass

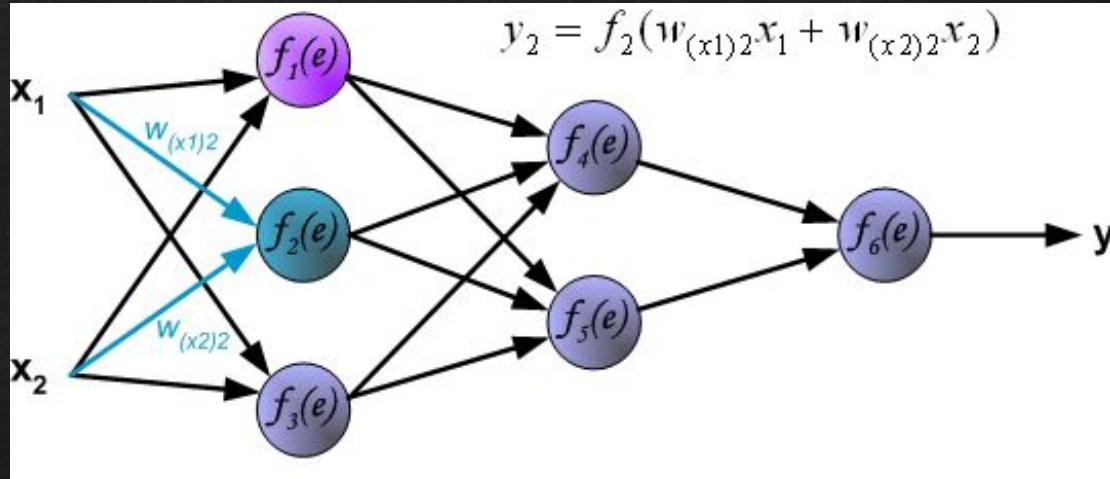
FORWARD PASS



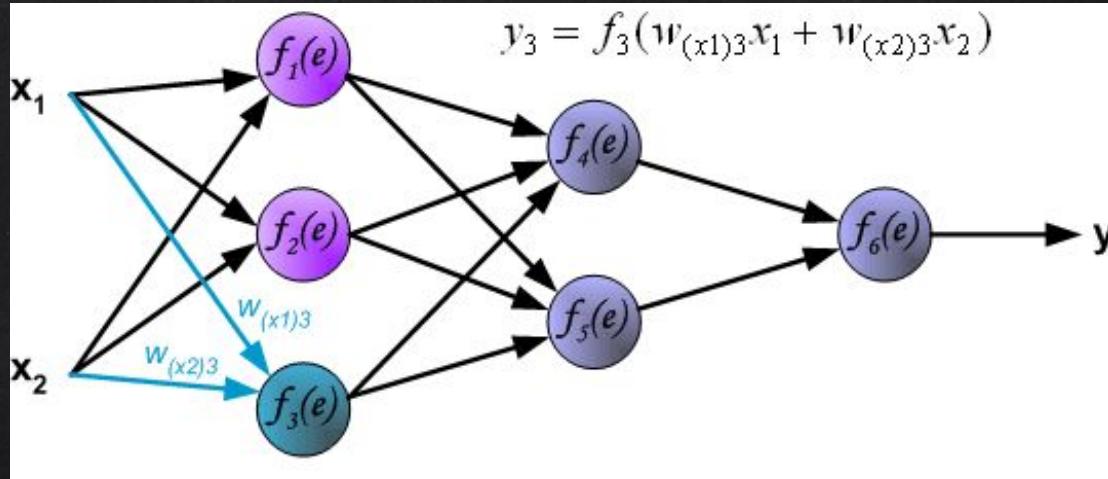
FORWARD PASS



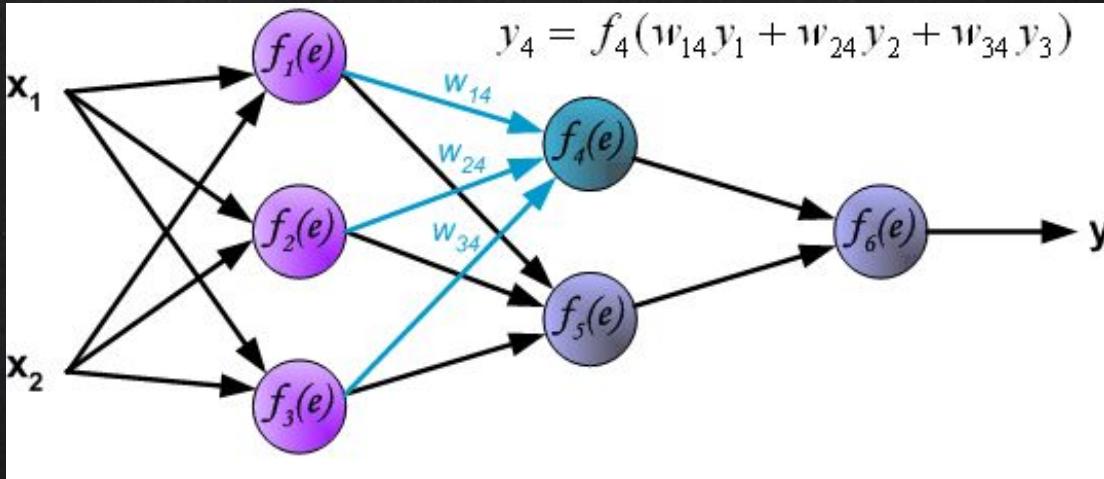
FORWARD PASS



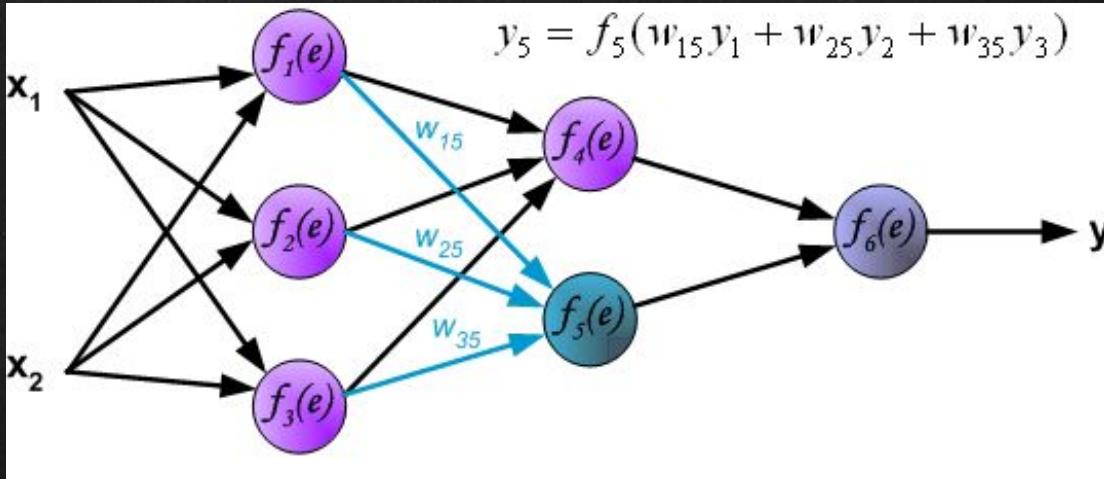
FORWARD PASS



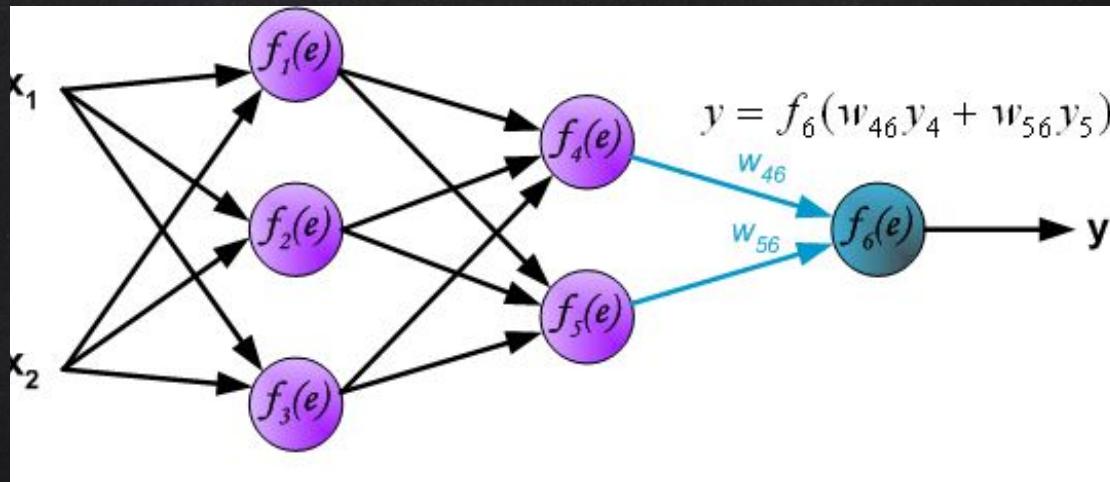
FORWARD PASS



FORWARD PASS



FORWARD PASS





BACK PROPAGATION

Compute
error



BACK PROPAGATION

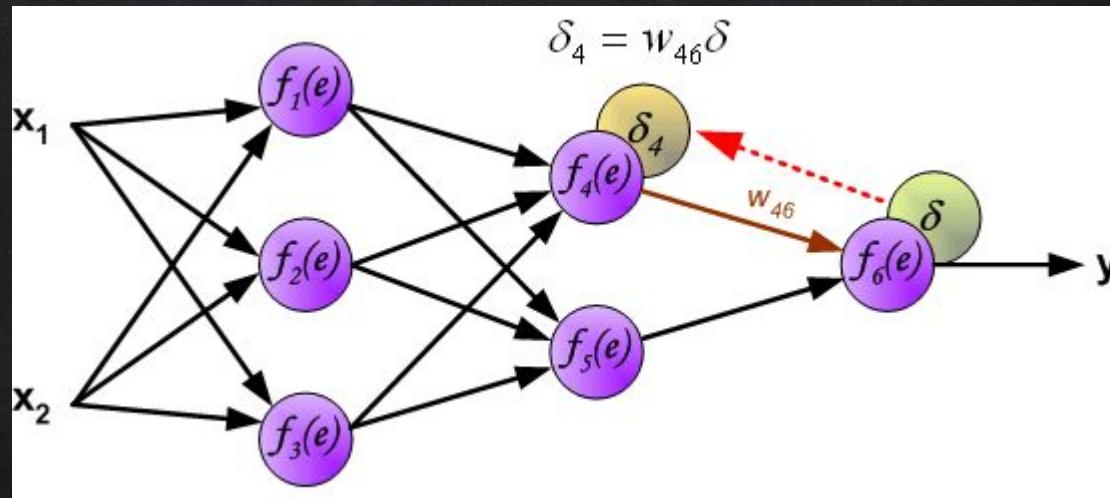
DERIVATIVE CHAIN RULE

$$\begin{aligned} (f \circ g(x))' &= g'(x)f'(g(x)) \\ \text{or } \frac{dy}{dx} &= \frac{dy}{du} \frac{du}{dx} \end{aligned}$$

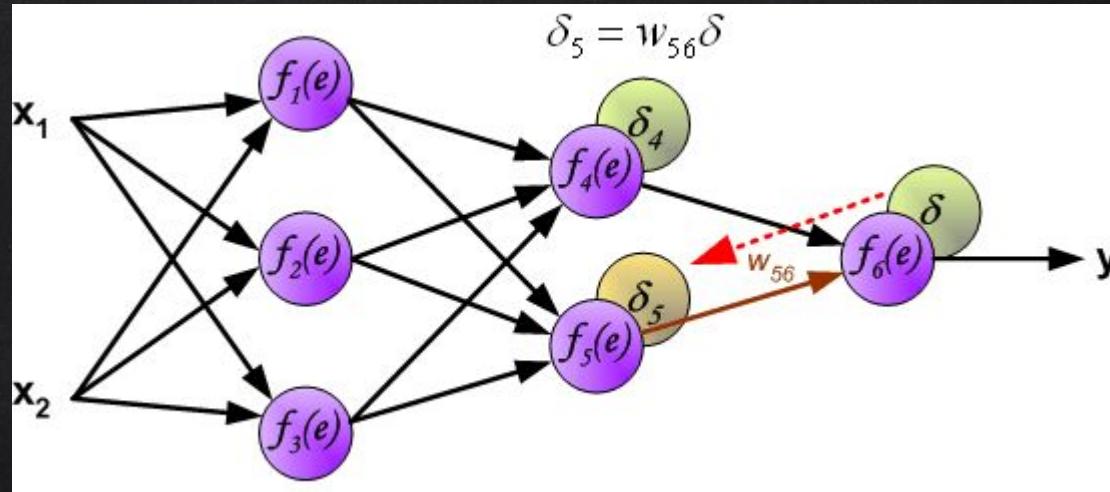
$$f(x) = \sin(5x) \cdot$$

$$f'(x) = 5 \cdot [\cos(5x)] = 5 \cos(5x) \cdot$$

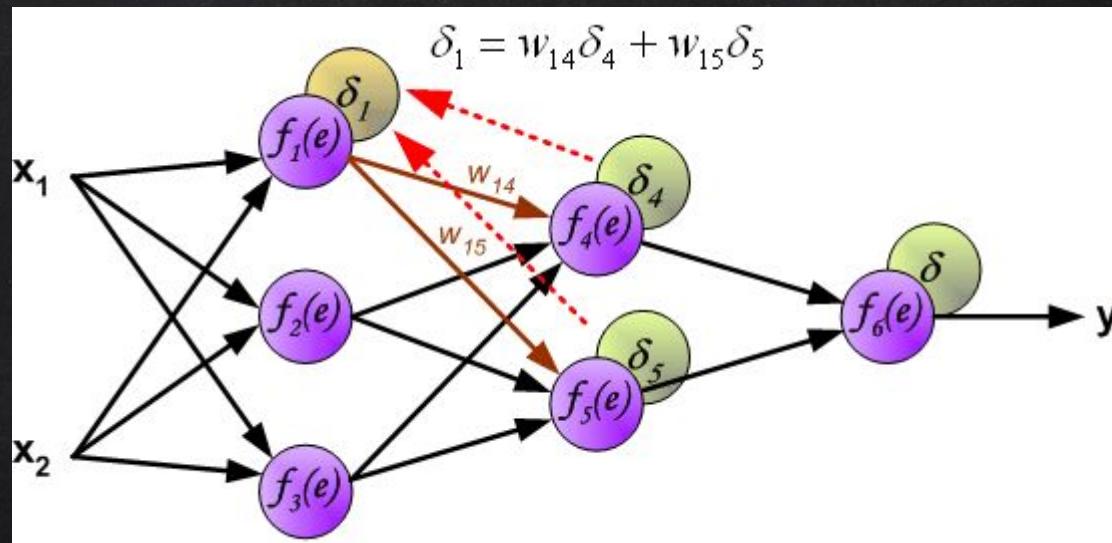
COMPUTE ERROR



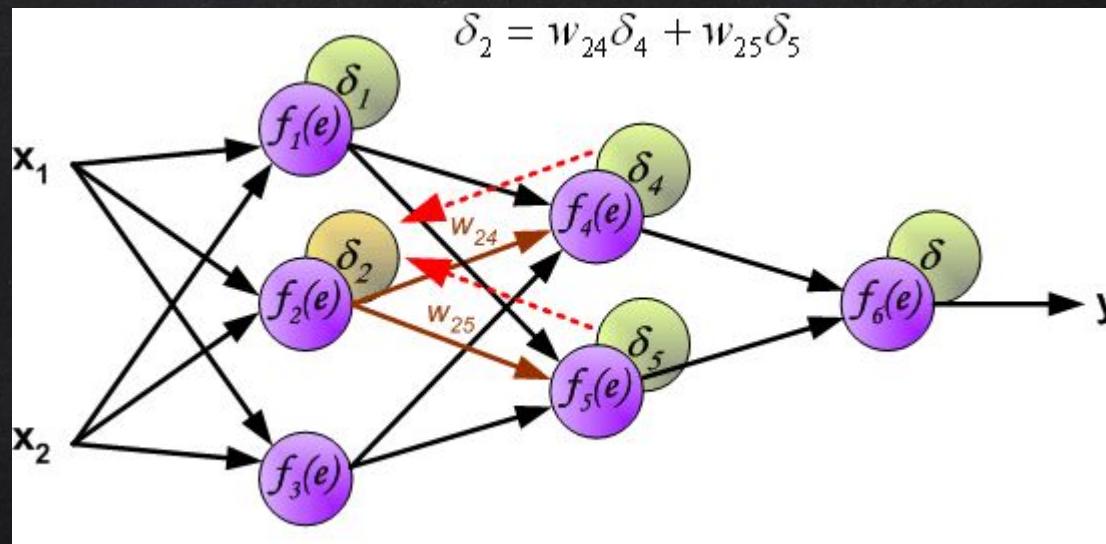
COMPUTE ERROR



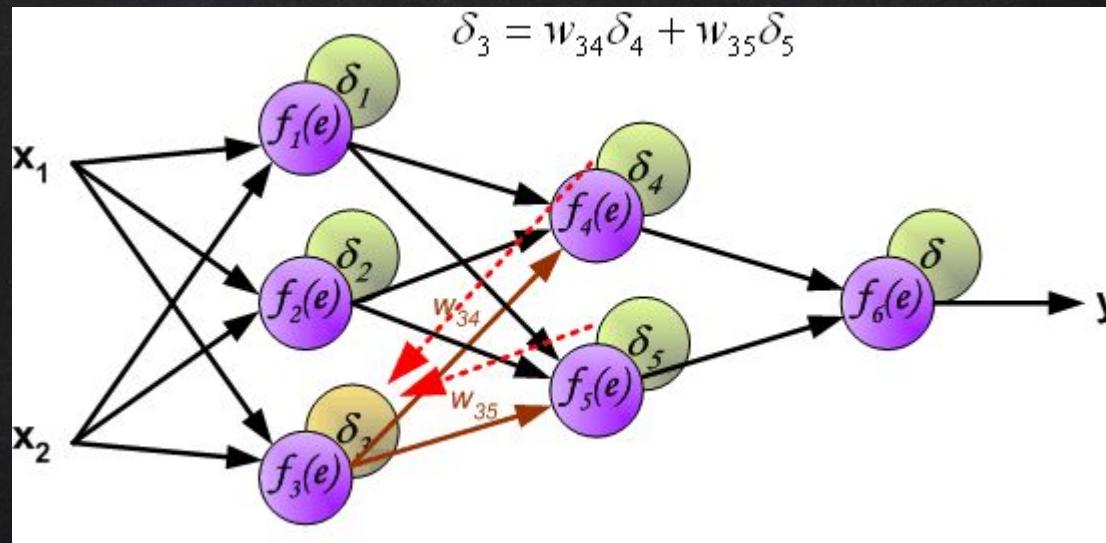
COMPUTE ERROR



COMPUTE ERROR



COMPUTE ERROR

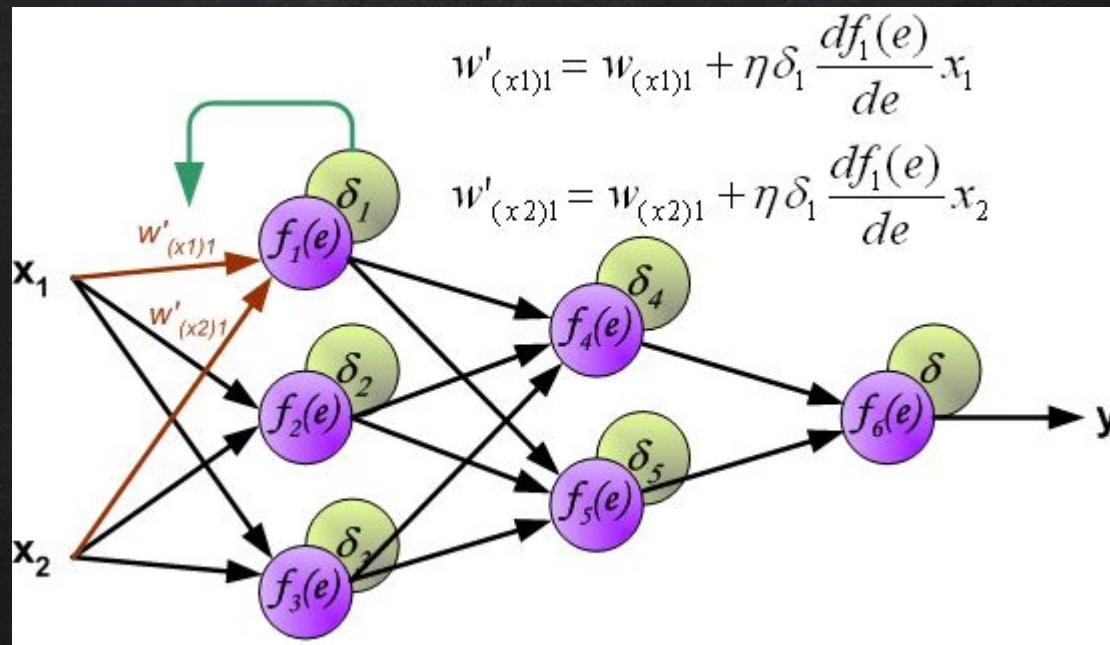




BACK PROPAGATION

Update
weights

UPDATE WEIGHTS

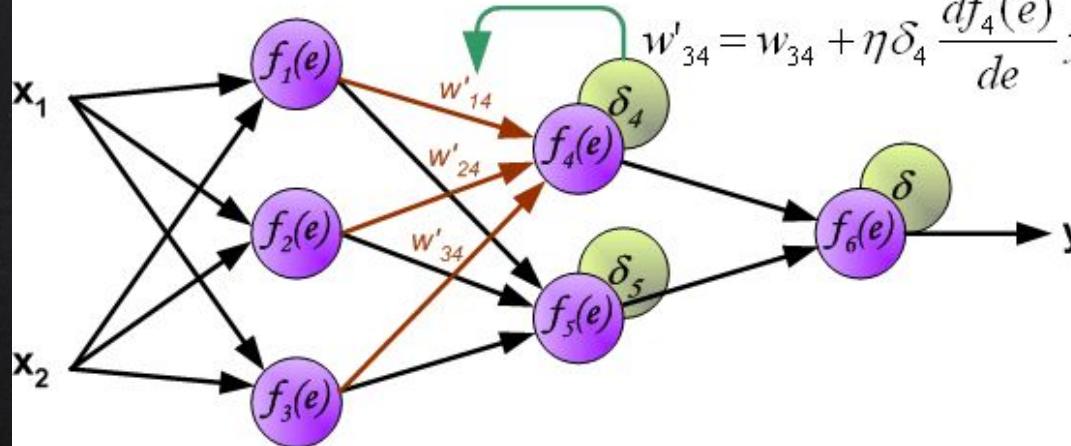


UPDATE WEIGHTS

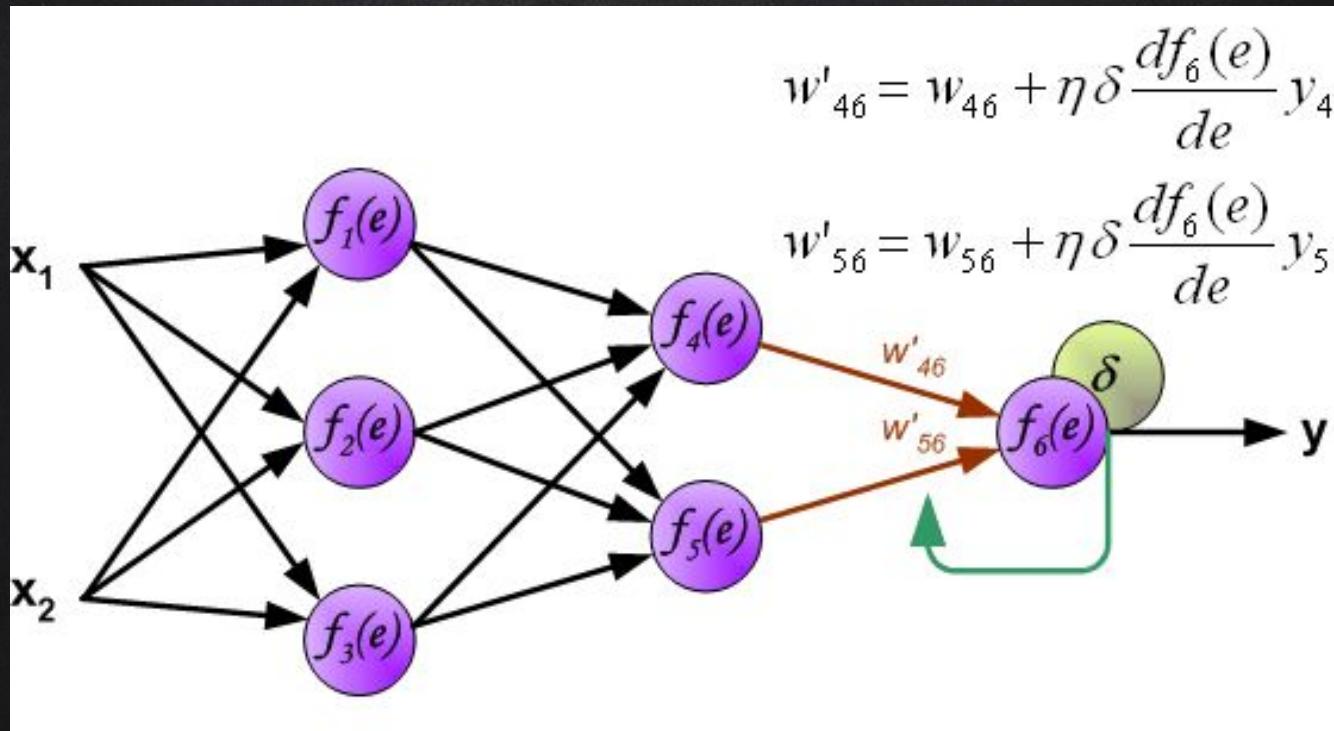
$$w'_{14} = w_{14} + \eta \delta_4 \frac{df_4(e)}{de} y_1$$

$$w'_{24} = w_{24} + \eta \delta_4 \frac{df_4(e)}{de} y_2$$

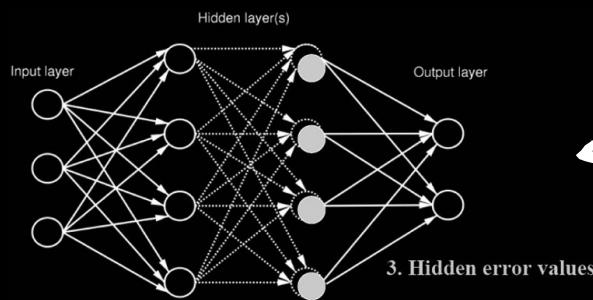
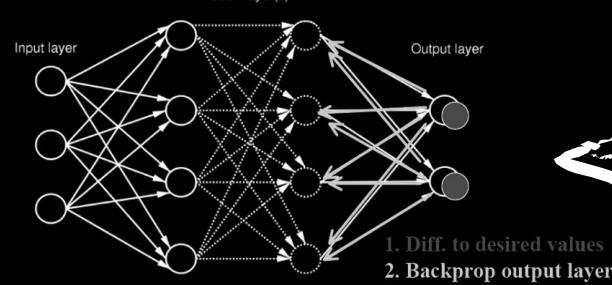
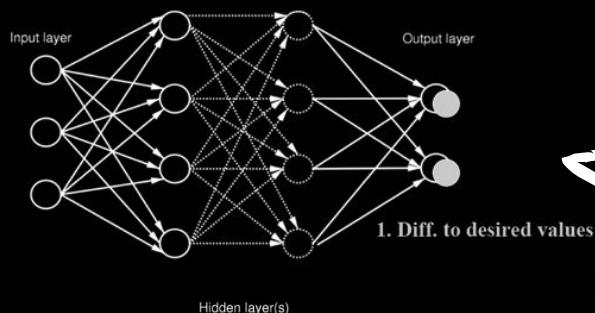
$$w'_{34} = w_{34} + \eta \delta_4 \frac{df_4(e)}{de} y_3$$



UPDATE WEIGHTS



JUST SHOW ME THE MATH !



$$o_j = \varphi(\text{net}_j) = \varphi \left(\sum_{k=1}^n w_{kj} o_k \right)$$

$$\frac{\partial E}{\partial w_{ij}} = \delta_j o_i$$

$$\frac{\partial E}{\partial w_{ij}} = \frac{\partial E}{\partial o_j} \frac{\partial o_j}{\partial \text{net}_j} \frac{\partial \text{net}_j}{\partial w_{ij}}$$

$$\Delta w_{ij} = -\alpha \frac{\partial E}{\partial w_{ij}}$$

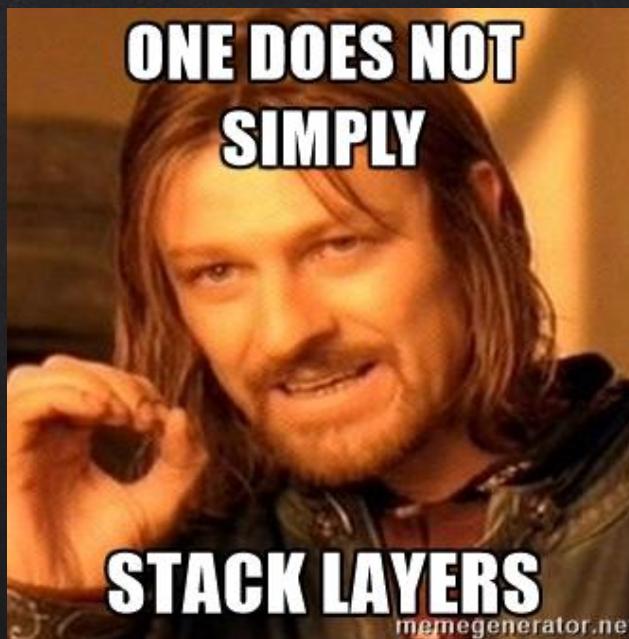
SUMMARY

1. RANDOMLY SEED WEIGHTS
2. FORWARD PASS
3. COST
4. BACKWARD PASS
5. UPDATE WEIGHTS

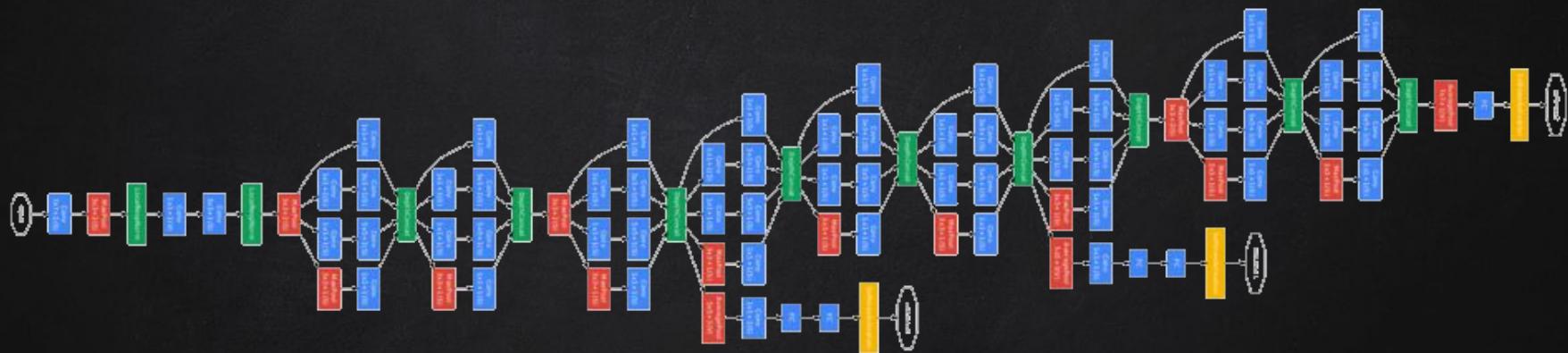
N. PROFIT???

JUST ADD MORE LAYERS

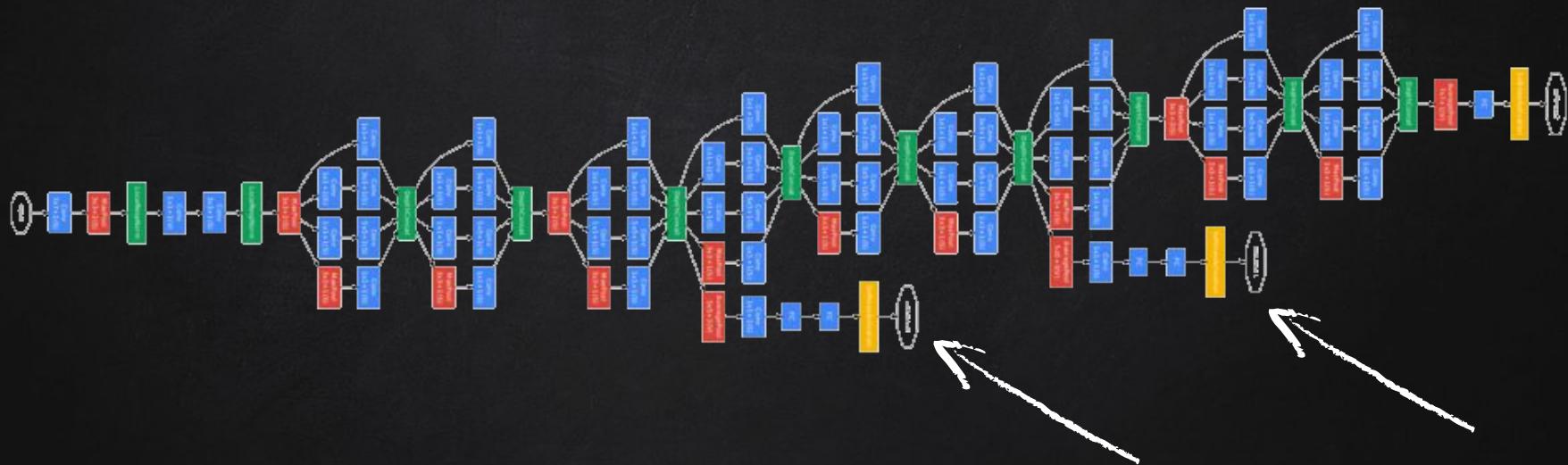
JUST ADD MORE LAYERS



REAL SIZED NETWORK GOOGLENET



VANISHING GRADIENT



ALGORITHM

INITIALIZE NETWORK WEIGHTS (OFTEN SMALL RANDOM VALUES)

DO

FOR EACH TRAINING EXAMPLE NAMED EX

PREDICTION = NEURALNET-OUTPUT(NETWORK, EX) // FORWARD PASS

COMPUTE ERROR (**PREDICTION - ACTUAL**) AT THE OUTPUT UNITS

COMPUTE \DELTA W_H FOR ALL WEIGHTS FROM HIDDEN LAYER TO OUTPUT LAYER //

BACKWARD PASS

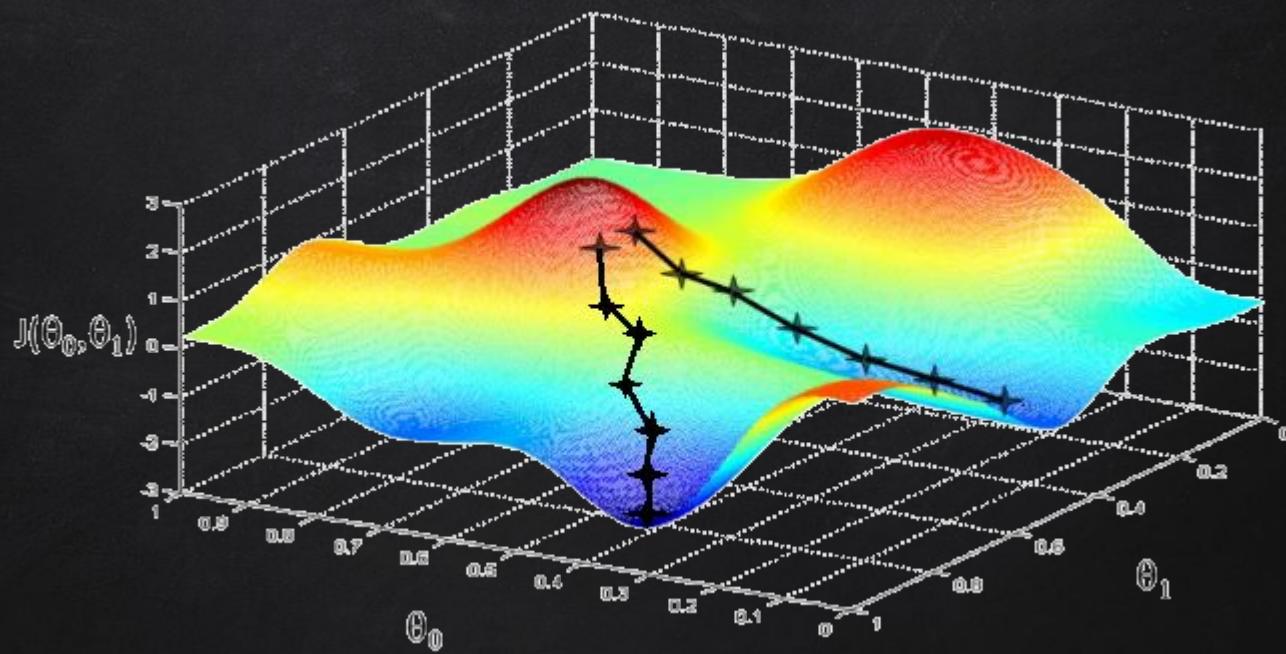
COMPUTE \DELTA W_I FOR ALL WEIGHTS FROM INPUT LAYER TO HIDDEN LAYER //

UPDATE WEIGHTS

UPDATE NETWORK WEIGHTS // INPUT LAYER NOT MODIFIED BY ERROR ESTIMATE

UNTIL ALL EXAMPLES CLASSIFIED CORRECTLY OR ANOTHER STOPPING CRITERION SATISFIED
RETURN THE NETWORK

GRADIENT DESCENT



GRADIENT DESCENT



STOCHASTIC GRADIENT DESCENT

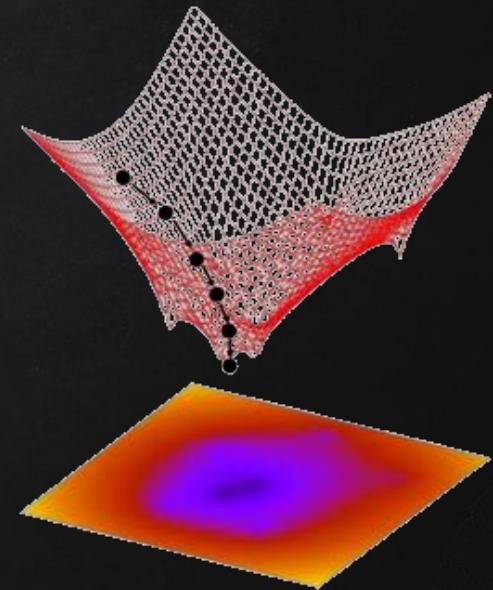
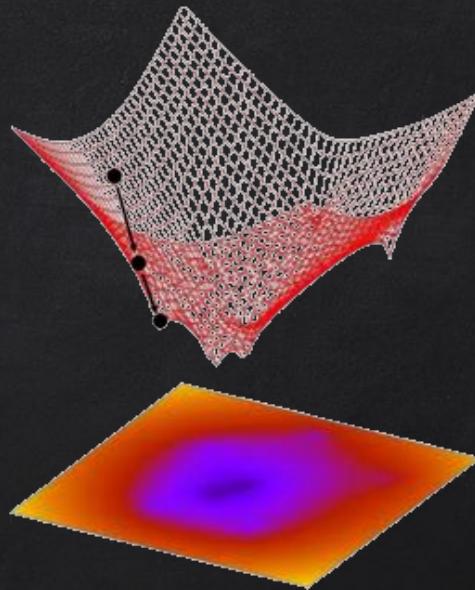
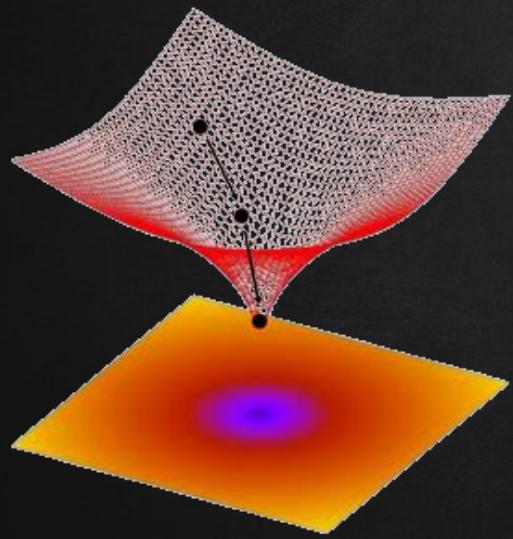


Mini-batch weight
update #1

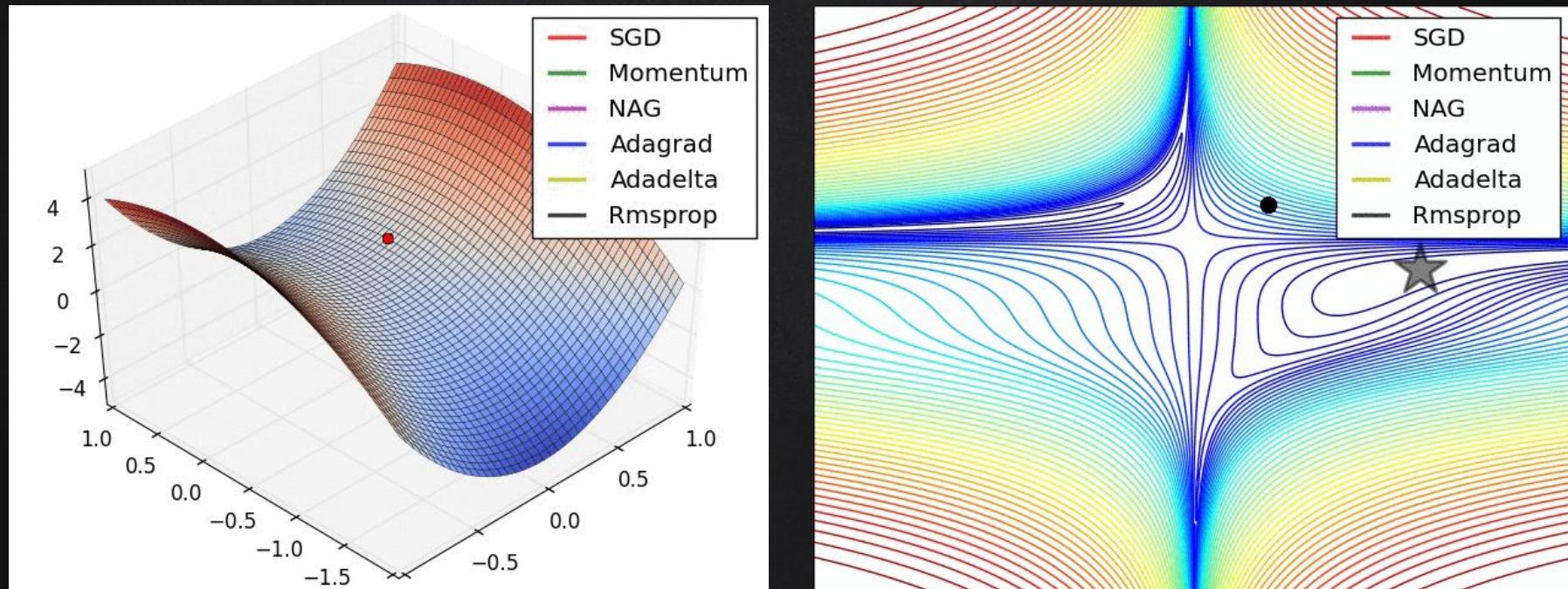


Mini-batch weight
update #2

STOCHASTIC GRADIENT DESCENT



STOCHASTIC GRADIENT DESCENT



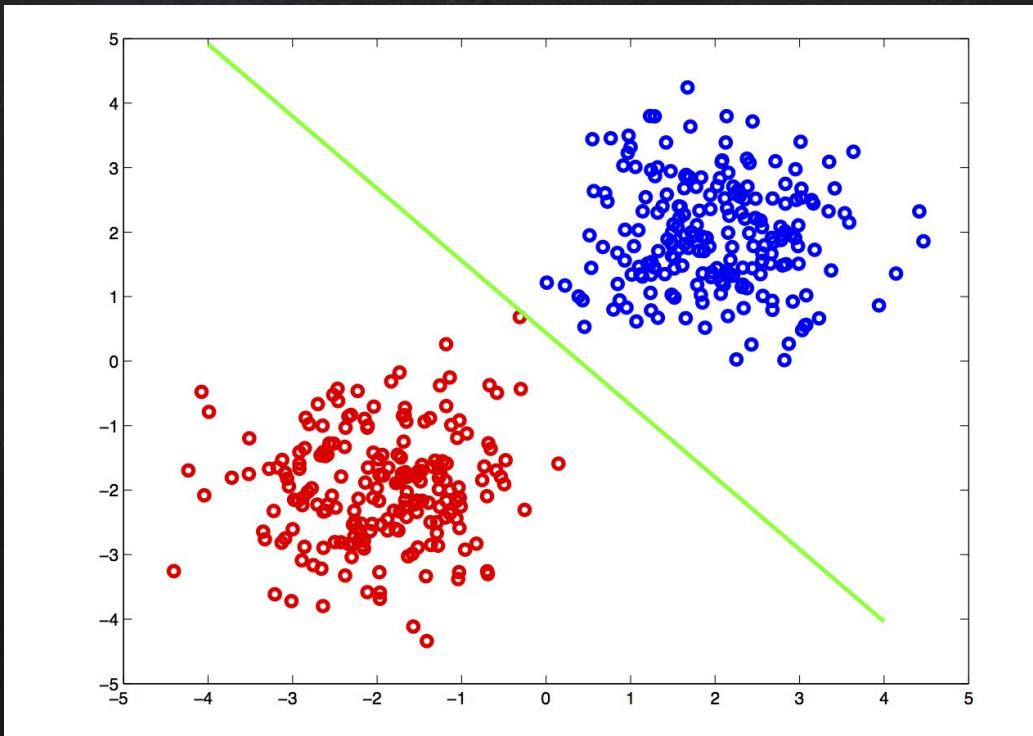
Credit: Sebastian Rudder

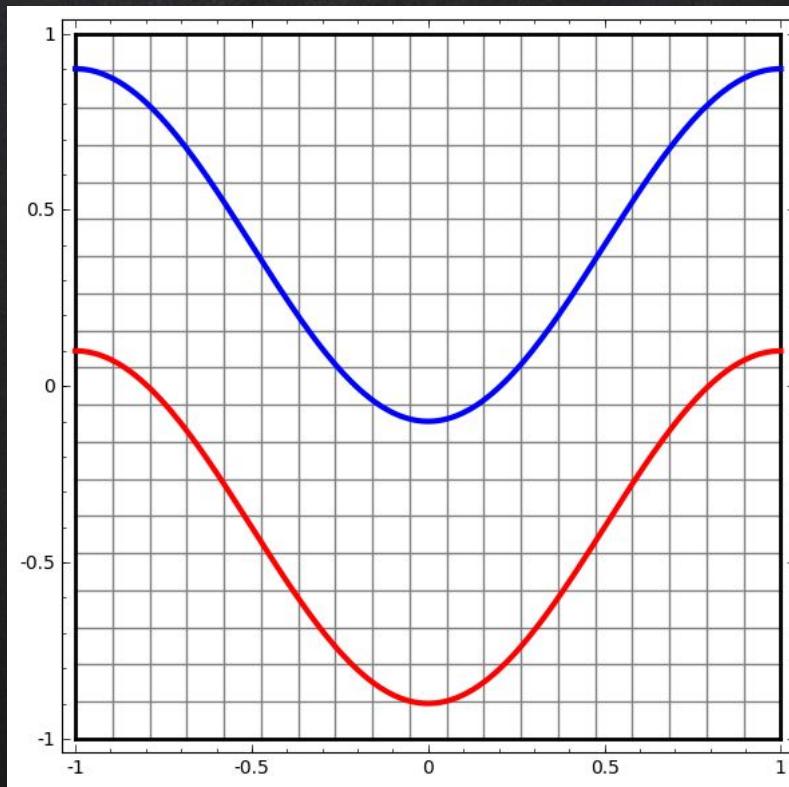


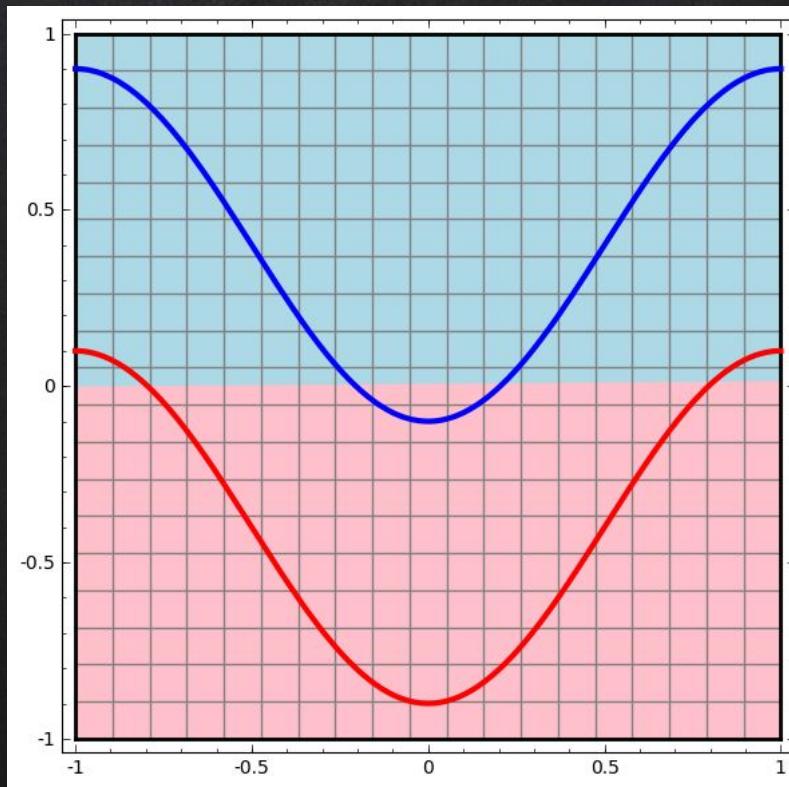
But what is the intuition for doing
this? --**everyone** in the
classroom!

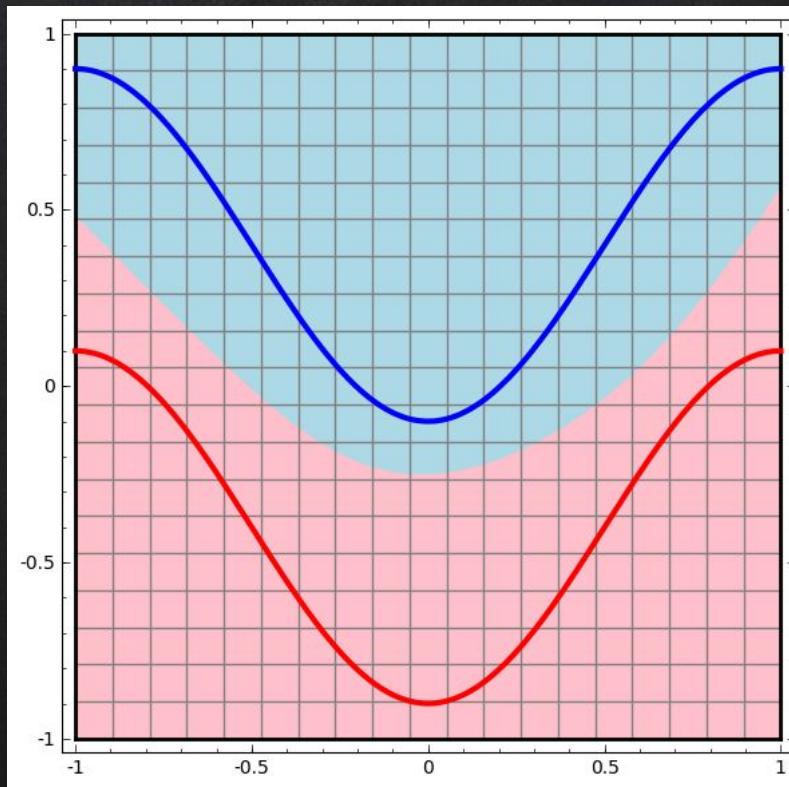
Also, reading formula and text from slides is not fun, we have a book for that !

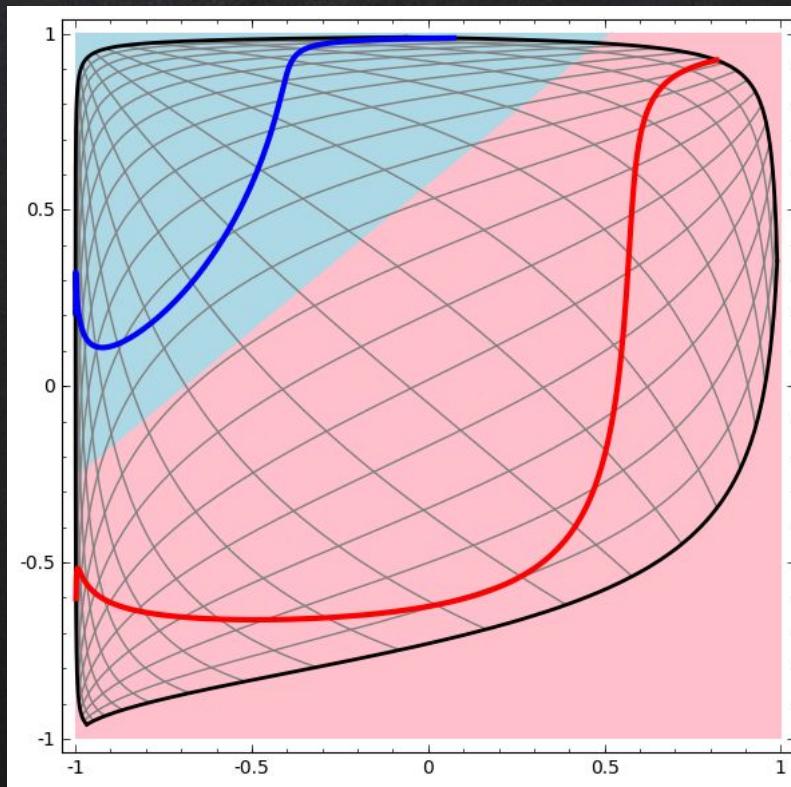
SEPARATING DATA







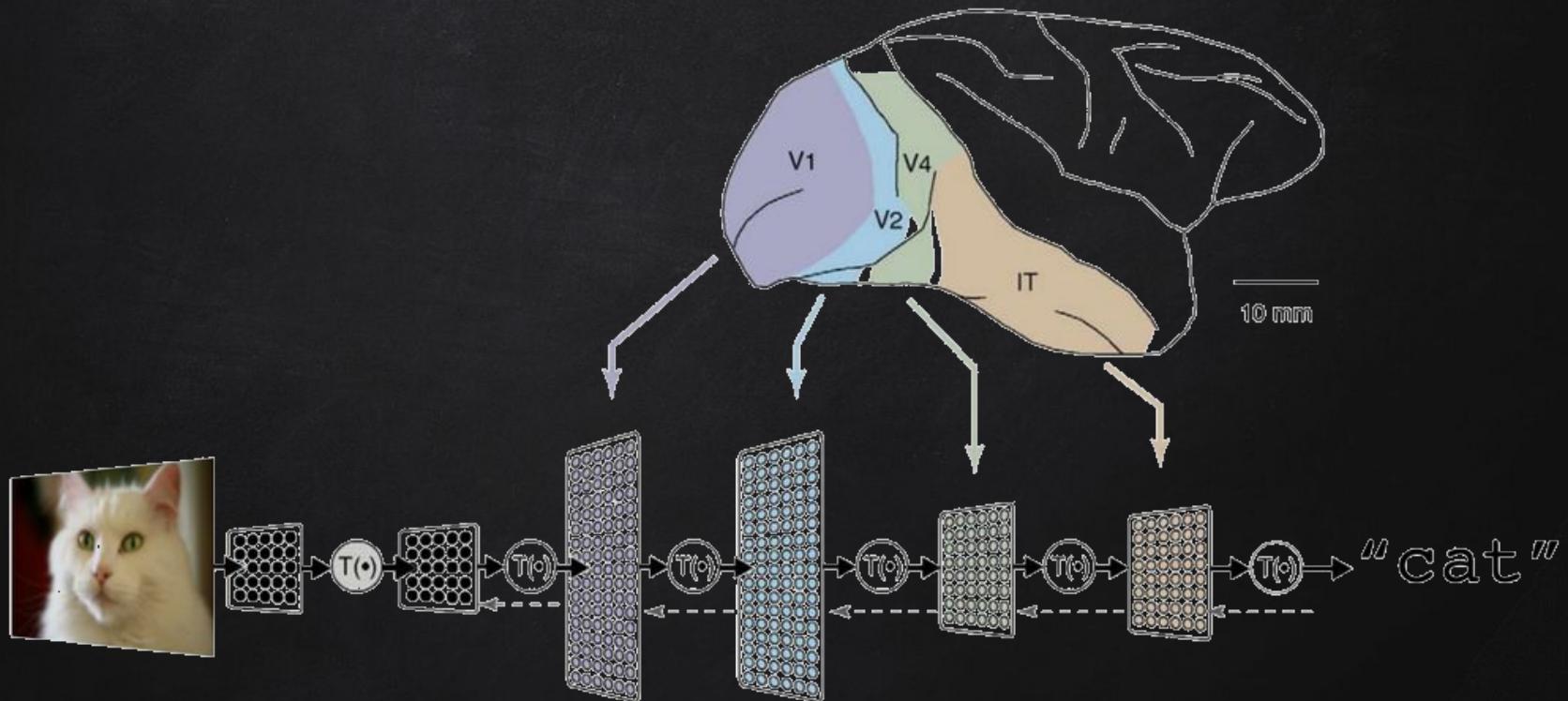


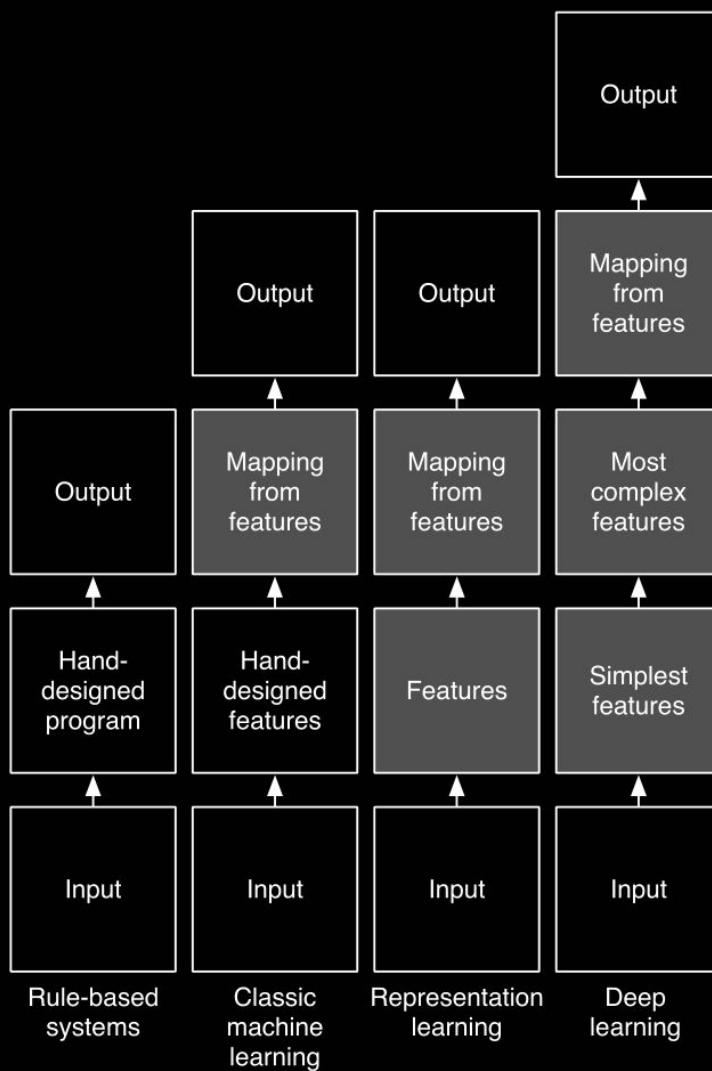


CHOICES

| INITIALIZATIONS | ACTIVATION | COST | OPTIMIZERS |
|-----------------|------------|-----------|------------|
| - UNIFORM | - TANH | - CROSS | - SGD |
| - GAUSSIAN | - SIGMOID | - ENTROPY | - WITH |
| - GLOROTUNI | - RELU | - MSE | - MOMENTUM |
| - XAVIER | - PRELU | - L1 LOSS | - RMSPROP |
| - KAIMING | | | - ADAGRAD |
| | | | - ADADELTA |
| | | | - ADAM |

DEEP NEURAL NETWORKS

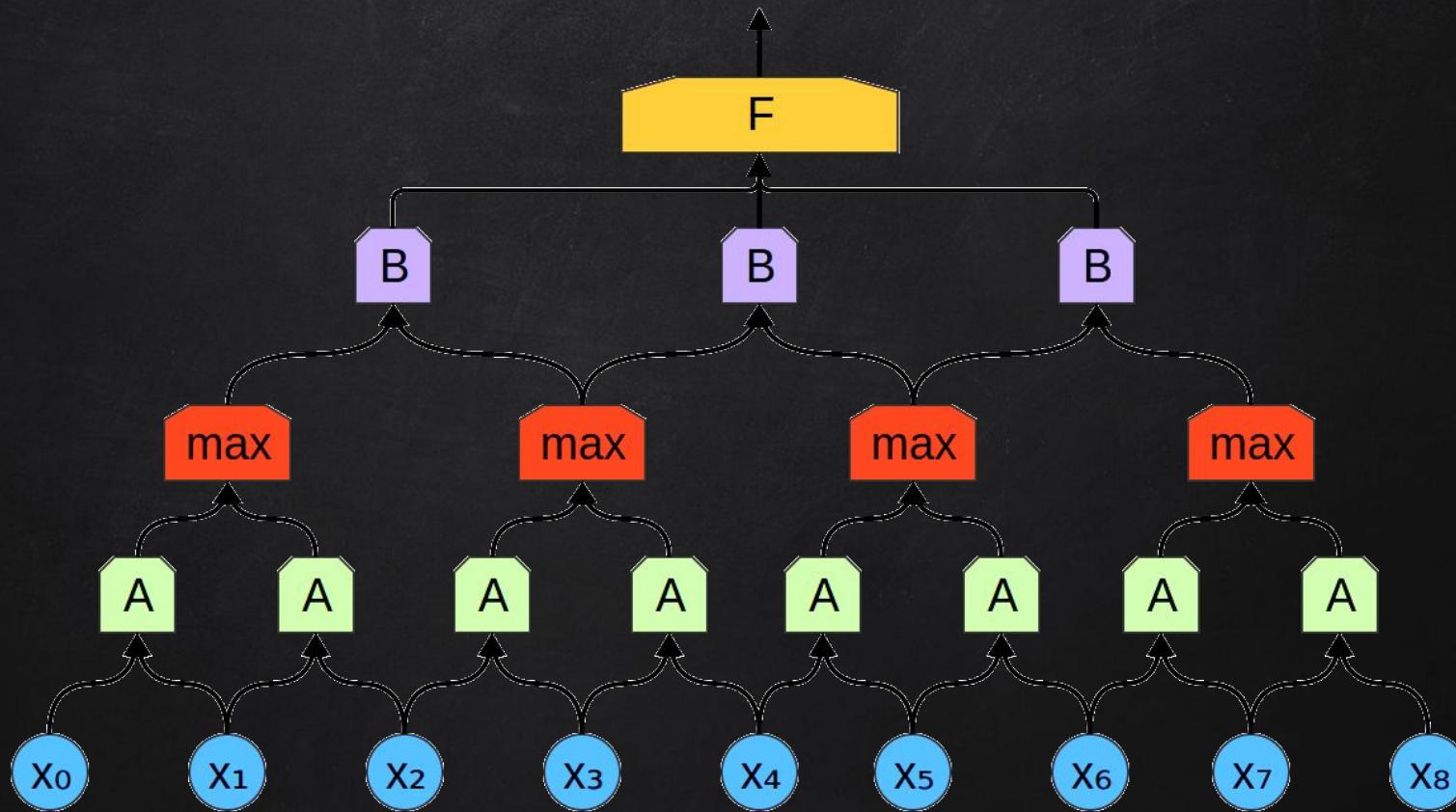




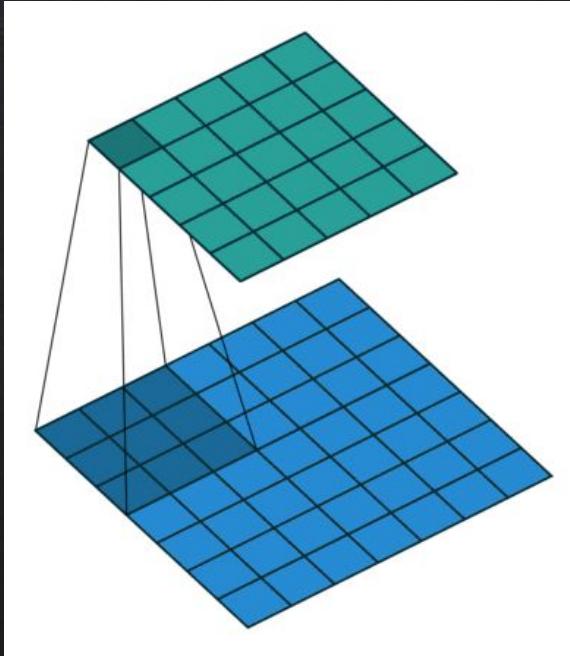
2.

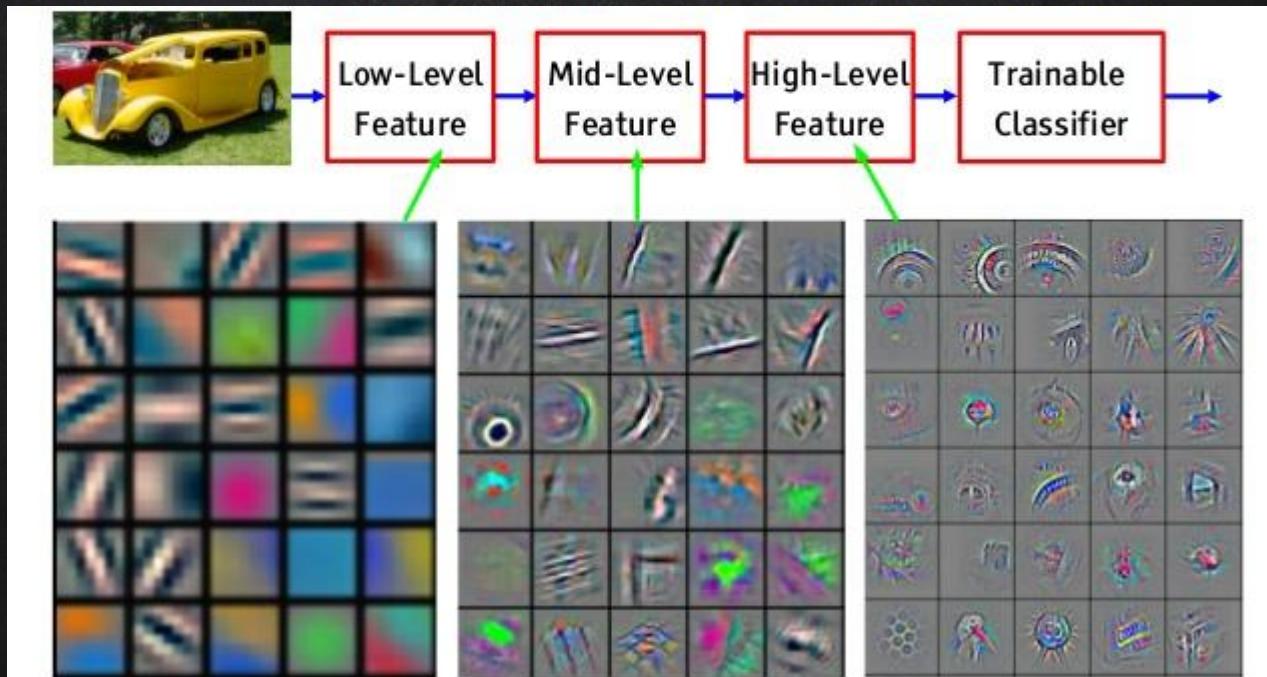
CONVOLUTION AND RECURRENT NEURAL NETWORK

CONVOLUTIONAL NEURAL NETWORK

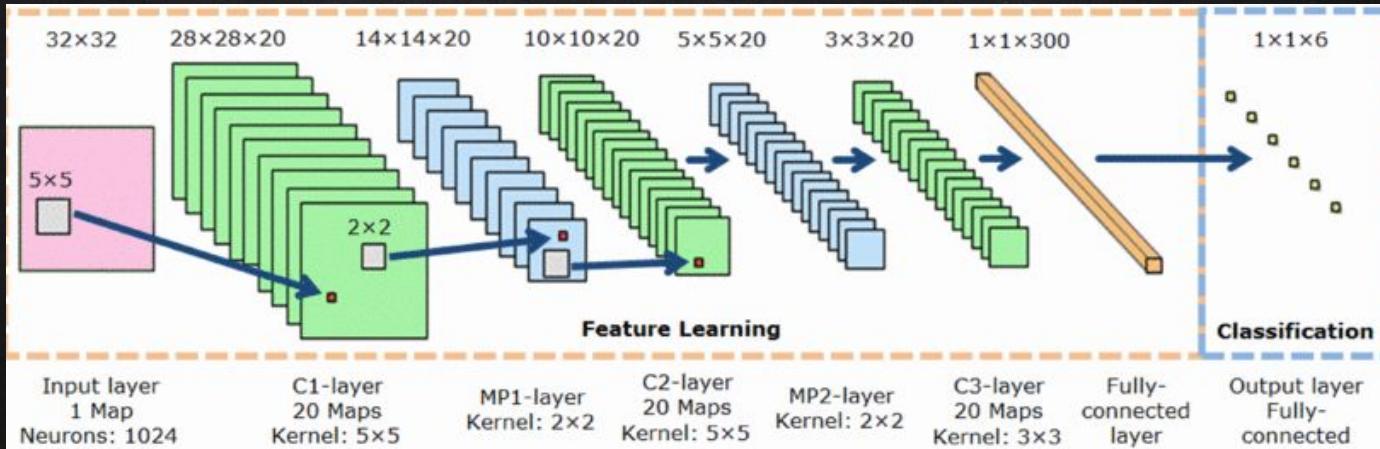


CONVOLUTION

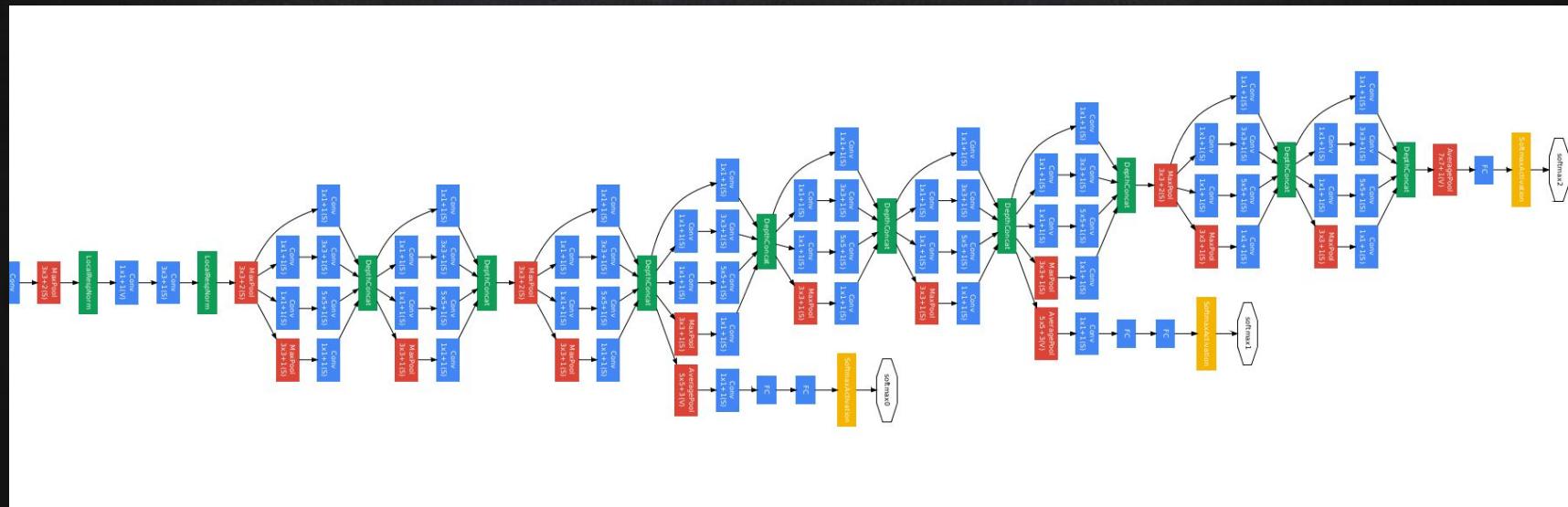




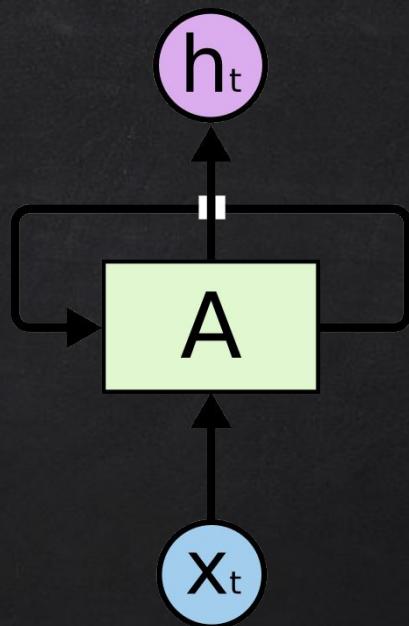
ALEXNET



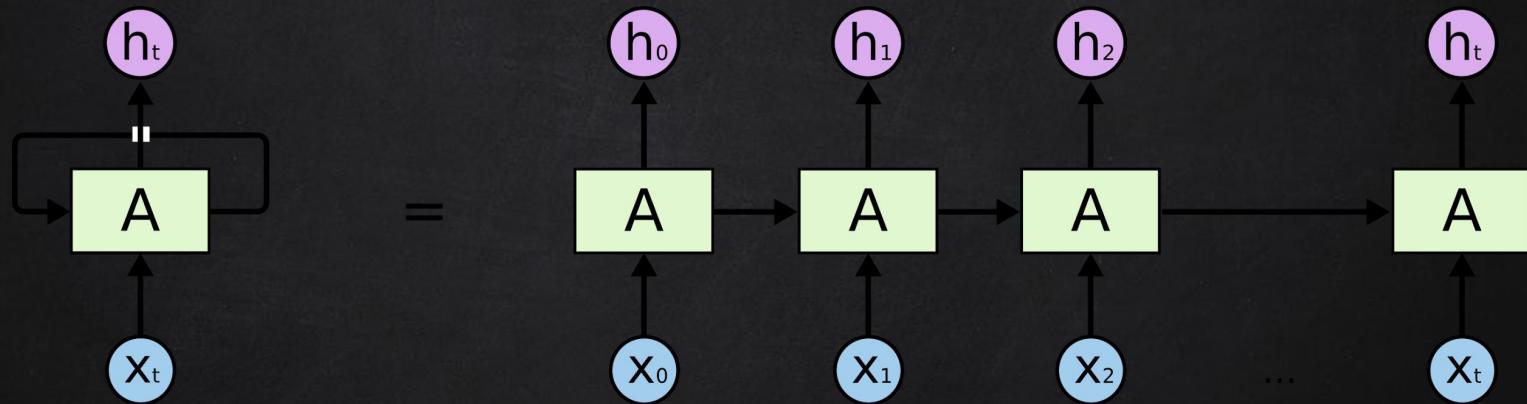
GOOGLENET



RECURRENT NEURAL NETWORK

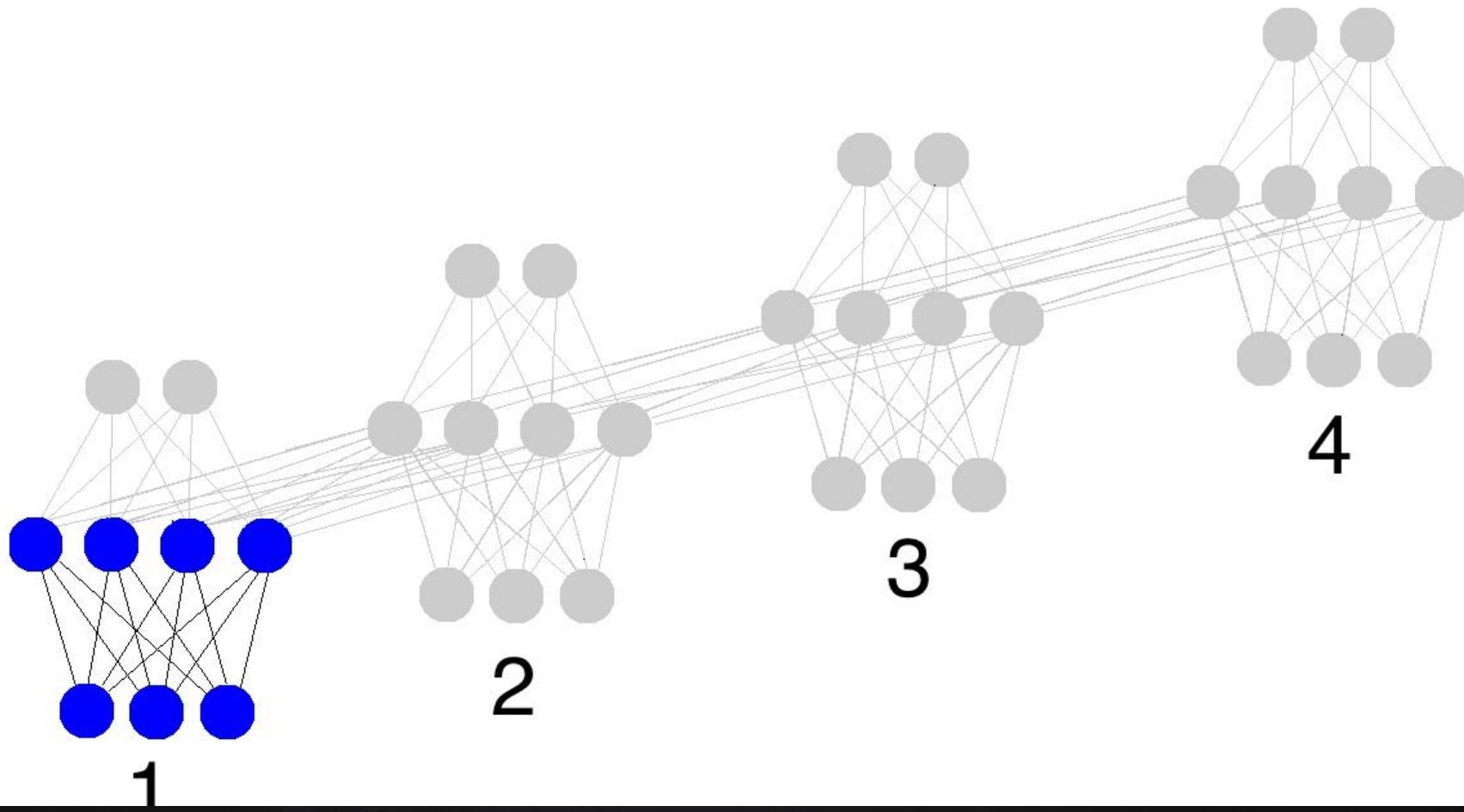


RECURRENT NEURAL NETWORK



An unrolled recurrent neural network

RNN – BACK PROPAGATION THROUGH TIME





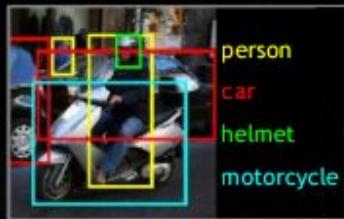
APPLICATIONS
SOME COOL AND SOME FUNNY

APPLICATION : COMPUTER Vision

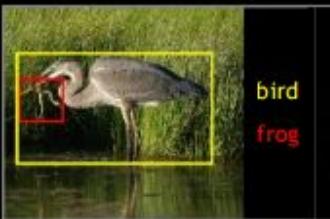
Image Recognition Challenge

1.2M training images • 1000 object categories

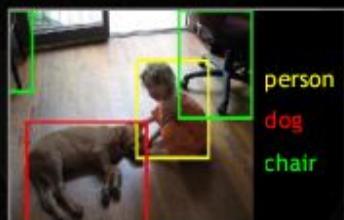
Hosted by



person
car
helmet
motorcycle



bird
frog



person
dog
chair



person
hammer
flower pot
power drill

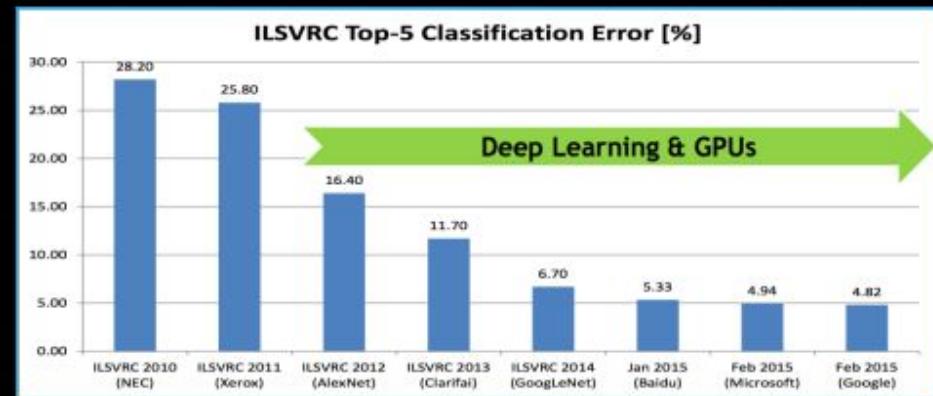
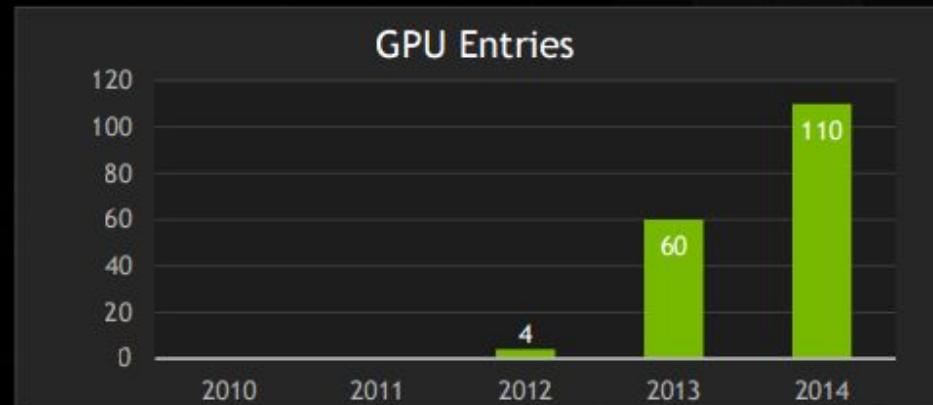
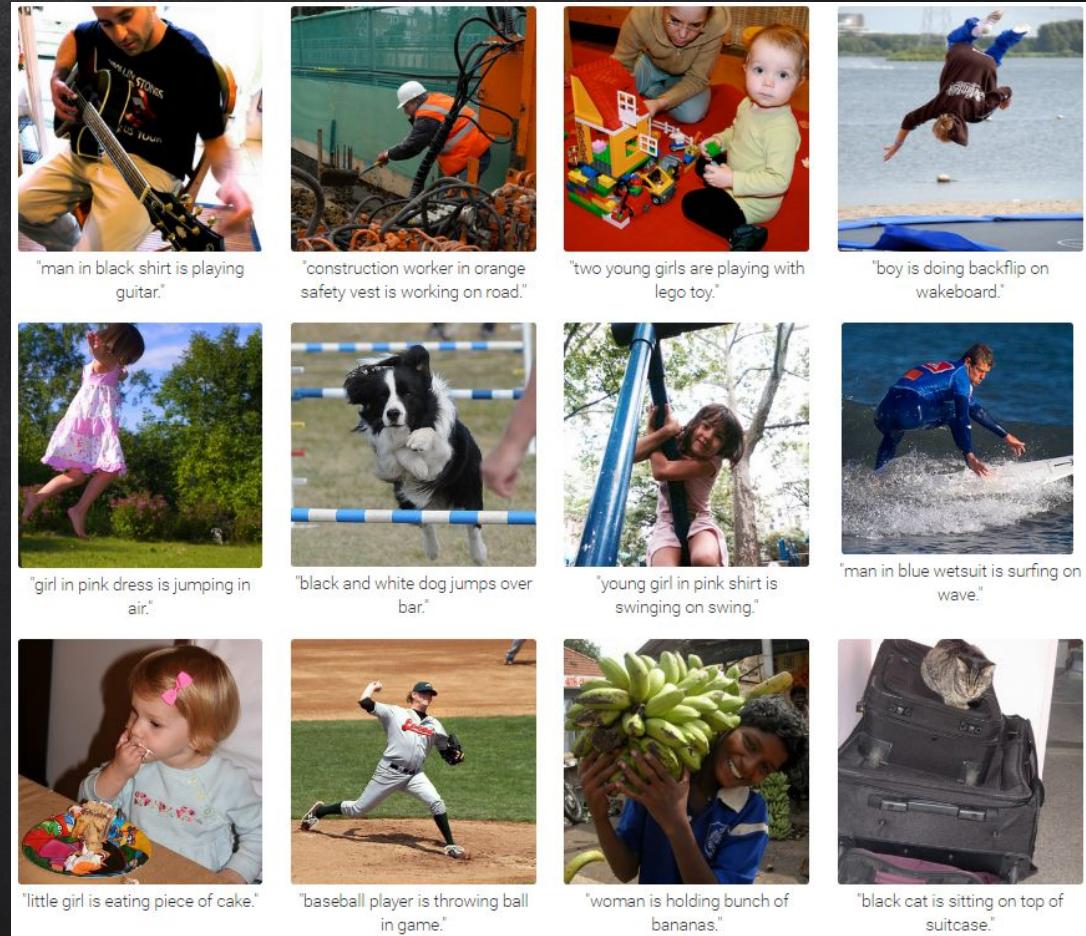
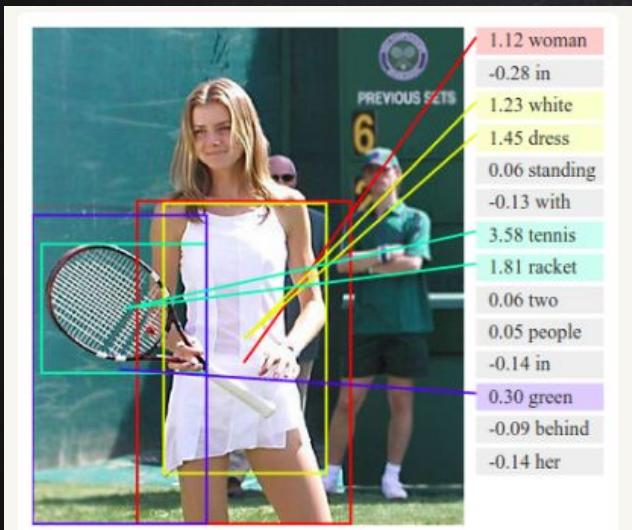
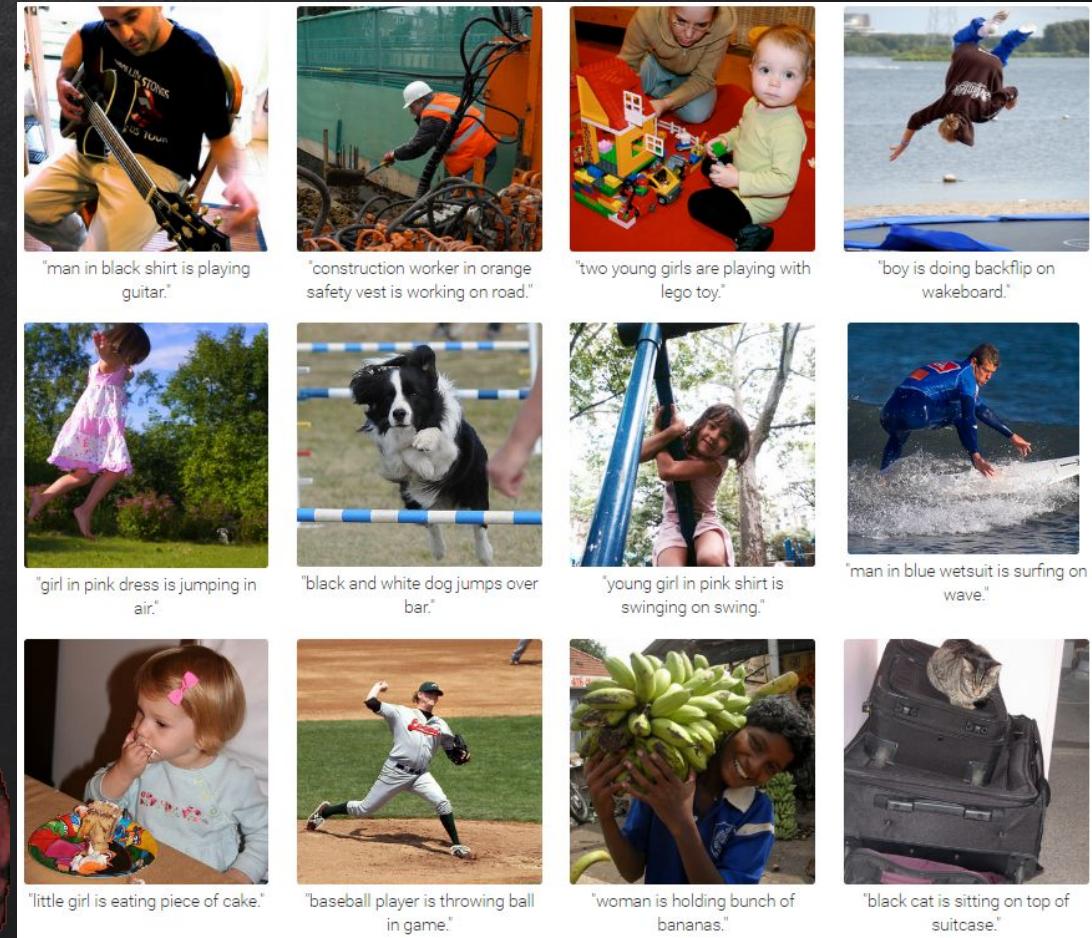
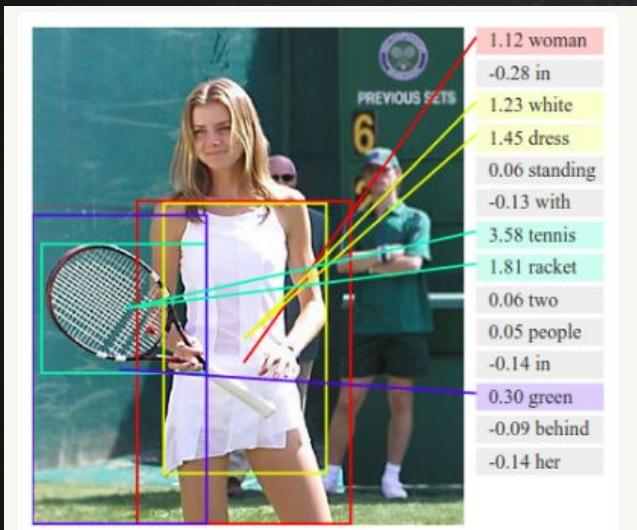


IMAGE CAPTIONING



ALEXNET

IMAGE CAPTIONING



~~ALEXNET~~
SKYNET



UPLOADED TO SHERV.NET

ART

A. (Photo: Andreas Praefcke)

The painting that provided the style for the respective generated image is shown in the bottom left corner of each panel.

B. The Shipwreck of the Minotaur by J.M.W. Turner, 1805.

C. The Starry Night by Vincent van Gogh, 1889.

D. Der Schrei by Edvard Munch, 1893.



VISUAL QUESTION ANSWERING



What vegetable is on the plate?

Neural Net: **broccoli**
Ground Truth: broccoli



What color are the shoes on the person's feet ?

Neural Net: **brown**
Ground Truth: brown



How many school busses are there?

Neural Net: **2**
Ground Truth: 2



What sport is this?

Neural Net: **baseball**
Ground Truth: baseball



What is on top of the refrigerator?

Neural Net: **magnets**
Ground Truth: cereal



What uniform is she wearing?

Neural Net: **shorts**
Ground Truth: girl scout



What is the table number?

Neural Net: **4**
Ground Truth: 40



What are people sitting under in the back?

Neural Net: **bench**
Ground Truth: tent

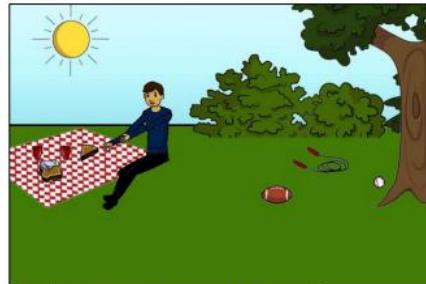
VISUAL QUESTION ANSWERING CHALLENGE



What color are her eyes?
What is the mustache made of?



How many slices of pizza are there?
Is this a vegetarian pizza?



Is this person expecting company?
What is just under the tree?



Does it appear to be rainy?
Does this person have 20/20 vision?

VQA is a new dataset containing open-ended questions about images. These questions require an understanding of vision, language and commonsense knowledge to answer.

Over 250K images (MS COCO and abstract scenes)

3 questions per image

10 ground truth answers per question

3 plausible (but likely incorrect) answers per question

Open-ended and multiple-choice answering tasks

Automatic evaluation metric

VISUAL QUESTION ANSWERING CHALLENGE



What color are her eyes?
What is the mustache made of?



How many slices of pizza are there?
Is this a vegetarian pizza?



Is this person expecting company?
What is just under the tree?



Does it appear to be rainy?
Does this person have 20/20 vision?

Object detection ?

A thick red curved arrow originates from the bottom left of the text "Object detection ?" and points upwards and to the right, ending near the top edge of the banana mustache image.

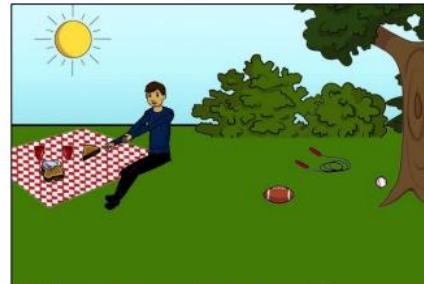
VISUAL QUESTION ANSWERING CHALLENGE



What color are her eyes?
What is the mustache made of?



How many slices of pizza are there?
Is this a vegetarian pizza?



Is this person expecting company?
What is just under the tree?



Does it appear to be rainy?
Does this person have 20/20 vision?

Object detection ? Reasoning ?

VISUAL QUESTION ANSWERING CHALLENGE



What color are her eyes?
What is the mustache made of?



How many slices of pizza are there?
Is this a vegetarian pizza?



Is this person expecting company?
What is just under the tree?



Does it appear to be rainy?
Does this person have 20/20 vision?

Object detection ?

Reasoning ?

Fine grained recognition ?

VISUAL QUESTION ANSWERING CHALLENGE



What color are her eyes?
What is the mustache made of?



How many slices of pizza are there?
Is this a vegetarian pizza?



Is this person expecting company?
What is just under the tree?



Does it appear to be rainy?
Does this person have 20/20 vision?

Object detection ?

Reasoning ?

Fine grained recognition ?

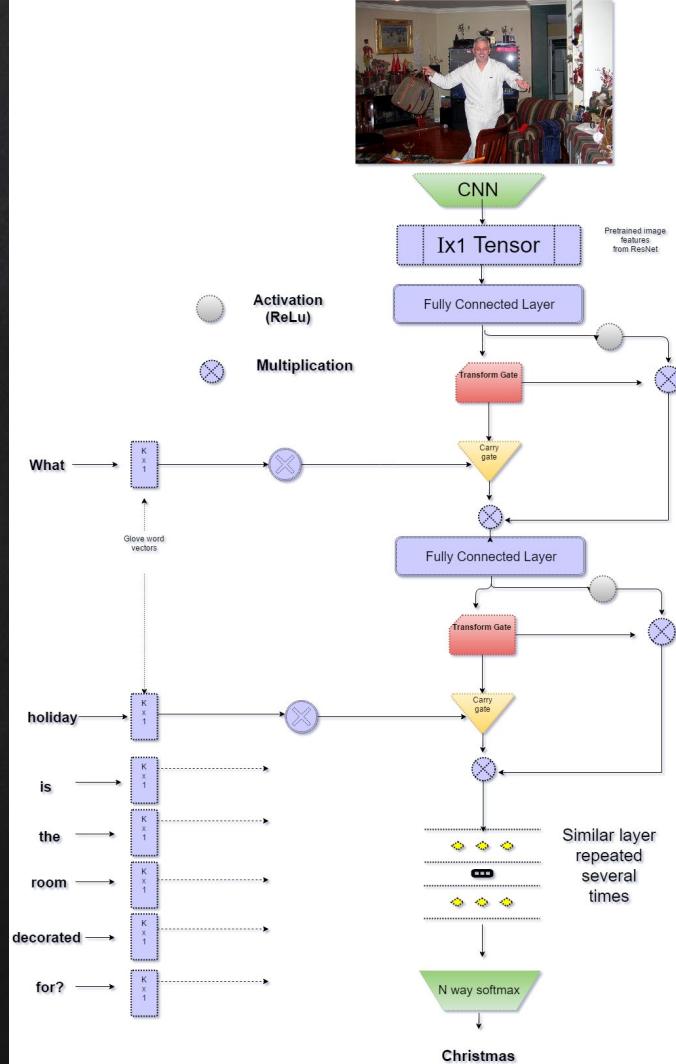
Common Sense?

WHAT KIND OF MODEL DOES THIS TASK REQUIRE ?

~~Deep Model~~

Deeper Model

These are called Highway Networks !



VIDEO CLASSIFICATION





But you promised **cool**
applications ?

SELFIE !

<= OR =>



LITERATURE SHAKESPEARE

PANDARUS:

Alas, I think he shall be come approached and the day
When little strain would be attain'd into being never fed,
And who is but a chain and subjects of his death,
I should not sleep.

Second Senator:

They are away this miseries, produced upon my soul,
Breaking and strongly should be buried, when I perish
The earth and thoughts of many states.

DUKE VINCENTIO:

Well, your wit is in the care of side and that.

Second Lord:

They would be ruled after this chamber, and
my fair nues begun out of the fact, to be conveyed,
Whose noble souls I'll have the heart of the wars.

Clown:

Come, sir, I will make did behold your worship.

VIOLA:

I'll drink it.

MATH – NO HOMEWORKS, NO MORE !

For $\bigoplus_{n=1,\dots,m}$ where $\mathcal{L}_{m,\bullet} = 0$, hence we can find a closed subset \mathcal{H} in \mathcal{H} and any sets \mathcal{F} on X , U is a closed immersion of S , then $U \rightarrow T$ is a separated algebraic space.

Proof. Proof of (1). It also start we get

$$S = \text{Spec}(R) = U \times_X U \times_X U$$

and the comparicoly in the fibre product covering we have to prove the lemma generated by $\coprod Z \times_U U \rightarrow V$. Consider the maps M along the set of points Sch_{fppf} and $U \rightarrow U$ is the fibre category of S in U in Section, ?? and the fact that any U affine, see Morphisms, Lemma ???. Hence we obtain a scheme S and any open subset $W \subset U$ in $\text{Sh}(G)$ such that $\text{Spec}(R') \rightarrow S$ is smooth or an

$$U = \bigcup U_i \times_{S_i} U_i$$

which has a nonzero morphism we may assume that f_i is of finite presentation over S . We claim that $\mathcal{O}_{X,x}$ is a scheme where $x, x', s'' \in S'$ such that $\mathcal{O}_{X,x'} \rightarrow \mathcal{O}'_{X',x'}$ is separated. By Algebra, Lemma ?? we can define a map of complexes $\text{GL}_{S'}(x'/S'')$ and we win. \square

To prove study we see that $\mathcal{F}|_U$ is a covering of \mathcal{X}' , and \mathcal{T}_i is an object of $\mathcal{F}_{X/S}$ for $i > 0$ and \mathcal{F}_p exists and let \mathcal{F}_i be a presheaf of \mathcal{O}_X -modules on \mathcal{C} as a \mathcal{F} -module. In particular $\mathcal{F} = U/\mathcal{F}$ we have to show that

$$\widetilde{M}^\bullet = \mathcal{I}^\bullet \otimes_{\text{Spec}(k)} \mathcal{O}_{S,s} - i_X^{-1} \mathcal{F}$$

is a unique morphism of algebraic stacks. Note that

$$\text{Arrows} = (\text{Sch}/S)_{fppf}^{\text{opp}}, (\text{Sch}/S)_{fppf}$$

and

$$V = \Gamma(S, \mathcal{O}) \hookrightarrow (U, \text{Spec}(A))$$

is an open subset of X . Thus U is affine. This is a continuous map of X is the inverse, the groupoid scheme S .

Proof. See discussion of sheaves of sets. \square

The result for prove any open covering follows from the less of Example ???. It may replace S by $X_{\text{spaces},\text{étale}}$ which gives an open subspace of X and T equal to S_{Zar} , see Descent, Lemma ???. Namely, by Lemma ?? we see that R is geometrically regular over S .

Lemma 0.1. Assume (3) and (3) by the construction in the description.

Suppose $X = \lim |X|$ (by the formal open covering X and a single map $\underline{\text{Proj}}_X(\mathcal{A}) = \text{Spec}(B)$ over U compatible with the complex

$$\text{Set}(\mathcal{A}) = \Gamma(X, \mathcal{O}_{X,\mathcal{O}_X}).$$

When in this case of to show that $\mathcal{Q} \rightarrow \mathcal{C}_{Z/X}$ is stable under the following result in the second conditions of (1), and (3). This finishes the proof. By Definition ?? (without element is when the closed subschemes are catenary. If T is surjective we may assume that T is connected with residue fields of S . Moreover there exists a closed subspace $Z \subset X$ of X where U in X' is proper (some defining as a closed subset of the uniqueness it suffices to check the fact that the following theorem

(1) f is locally of finite type. Since $S = \text{Spec}(R)$ and $Y = \text{Spec}(R)$.

Proof. This is form all sheaves of sheaves on X . But given a scheme U and a surjective étale morphism $U \rightarrow X$. Let $U \cap U = \coprod_{i=1,\dots,n} U_i$ be the scheme X over S at the schemes $X_i \rightarrow X$ and $U = \lim_i X_i$. \square

The following lemma surjective restrocomposes of this implies that $\mathcal{F}_{x_0} = \mathcal{F}_{x_0} = \mathcal{F}_{\mathcal{X},\dots,0}$.

Lemma 0.2. Let X be a locally Noetherian scheme over S , $E = \mathcal{F}_{X/S}$. Set $\mathcal{I} = \mathcal{J}_1 \subset \mathcal{J}_n$. Since $\mathcal{I}^n \subset \mathcal{J}^n$ are nonzero over $i_0 \leq p$ is a subset of $\mathcal{J}_{n,0} \circ \bar{A}_2$ works.

Lemma 0.3. In Situation ???. Hence we may assume $q' = 0$.

Proof. We will use the property we see that p is the next functor (??). On the other hand, by Lemma ?? we see that

$$D(\mathcal{O}_{X'}) = \mathcal{O}_X(D)$$

where K is an F -algebra where δ_{n+1} is a scheme over S . \square

CODE CAN WE DO ASSIGNMENT 1 NOW ?

```
/*
 * Increment the size file of the new incorrect UI_FILTER group information
 * of the size generatively.
 */
static int indicate_policy(void)
{
    int error;
    if (fd == MARN_EPT) {
        /*
         * The kernel blank will coeld it to userspace.
         */
        if (ss->segment < mem_total)
            unblock_graph_and_set_blocked();
        else
            ret = 1;
        goto bail;
    }
    segaddr = in_SB(in.addr);
    selector = seg / 16;
    setup_works = true;
    for (i = 0; i < blocks; i++) {
        seq = buf[i++];
        bpf = bd->bd.next + i * search;
        if (fd) {
            current = blocked;
        }
    }
}
```

BIBLE HALLELUJAH !



A screenshot of a Twitter profile for "RNN Bible". The profile picture is a dark, textured book cover with gold lettering. The bio reads: "Random bible verses generated using Recurrent Neural Networks (char-RNN)". Below the bio is a blue button labeled "Tweet to RNN Bible". The stats at the top show 1,008 tweets, 1 following, and 132 followers. The timeline displays four tweets from the account, each containing a verse from the Bible:

- RNN Bible @RNN_Bible · 9h**
23:13 Therefore thus saith the LORD God of Israel, Thus saith the LORD of hosts; I am a man or a desert spoil thereof.
- RNN Bible @RNN_Bible · Nov 17**
33:5 And the LORD shall set thee a battle in thy room, and shall be in the house of thy father be not destroyed.
- RNN Bible @RNN_Bible · Nov 16**
1:2 So the priests and the Levites prepared their heads, and the faces of the children of Israel.
- RNN Bible @RNN_Bible · Nov 16**
11:25 And the LORD spake unto Moses and Aaron, saying, This is the ordinance of the children of Israel, after they have destroyed them.

MAKE MACHINES GREAT AGAIN !



DeepDrumpf

@DeepDrumpf

#MakeLSTMGreatAgain
#MakeAmericaLearnAgain I'm a Neural Network trained on Donald Trump transcripts. (Priming text in [])s. Follow @hayeshb for more details.

Tweet to

Messa...

Photos and videos



TWEETS

183

FOLLOWING

7

FOLLOWERS

21.4K

LIKES

7

Tweets

Tweets & replies

Media

In reply to Eugene Scott

DeepDrumpf @DeepDrumpf · Apr 29

We don't win with healthcare, we win beating NATO and people running for office. I'm just doing what's right. @Eugene_Scott @CNNPolitics



3



25

...

[View conversation](#)

In reply to Donald J. Trump

DeepDrumpf @DeepDrumpf · Apr 29

I think we're going to win in November. Our leaders don't understand deal-making. We're going to be really good. #VP? @realDonaldTrump @TIME



6



8

...

[View conversation](#)

In reply to Ted Cruz

DeepDrumpf @DeepDrumpf · Apr 27

[If I get elected president], believe me folks. I will bring unbelievable aggression. I bring that out in people. @tedcruz #Trump2016



69



116

...

[View conversation](#)

In reply to Ted Cruz

DeepDrumpf @DeepDrumpf · Apr 27

[That's why you're a] real lightweight. I think it's just absolutely a horrible story. He's a bad negotiator. It's a disaster. @tedcruz



10



23

...

[View conversation](#)

In reply to The Hill

DeepDrumpf @DeepDrumpf · Apr 27

I mean, ultimately we're all immigrants, okay? I have total empathy. At the same time respect our constitution @tedcruz @thehill @Pudingtane



10



24

...

[View conversation](#)

BRANDEIS DEEP DREAM





THANKS!

CREDITS

- Presentation template by [SlidesCarnival](#)
- Awesome diagrams on CNN by <http://colah.github.io/>
- Formula's from, you know where, [wikipedia](#)
- Selfie <http://karpathy.github.io/2015/10/25/selfie/>
- [Neural Networks and Deep Learning](#)
- [Going Deeper - GoogLeNet](#)
- Back propagation images with formulas, [Mariusz Bernacki](#)
- Geoff Hinton, guy who started all this -- [NIPS 2015 tutorial](#)
- Yann LeCun, guy who made it popular, [Deep Representations](#)
- [CS231n](#) Lecture Slides
- Nervana presentation on [DL](#)

Any questions?

You can find me at
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Deep Learning



What society thinks I do



What my friends think I do



What other computer scientists think I do



What mathematicians think I do



What I think I do

FROM TENSORFLOW
IMPORT *

What I actually do