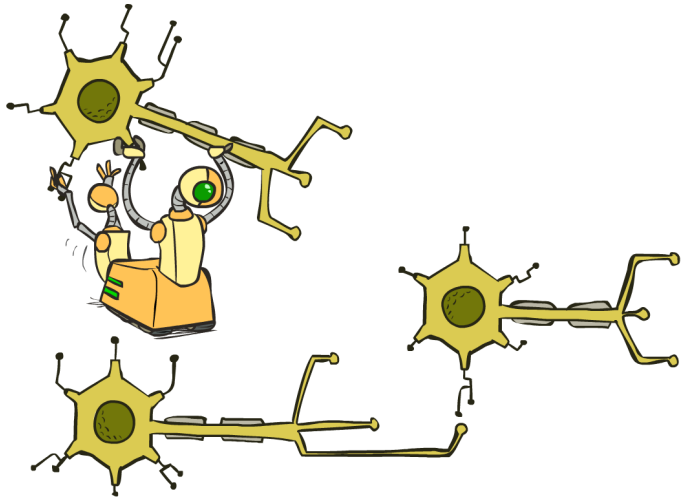
CSE 573: Artificial Intelligence

Hanna Hajishirzi

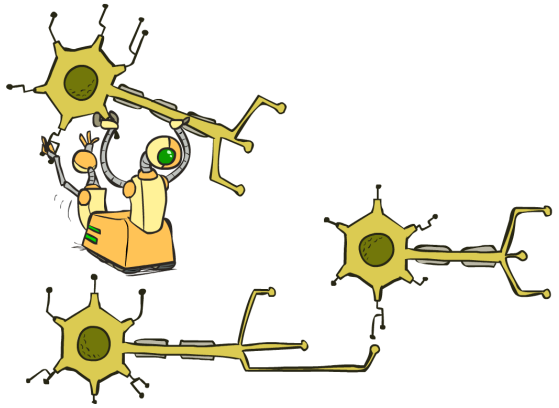
Neural Nets



slides adapted from
Dan Klein, Pieter Abbeel ai.berkeley.edu
And Dan Weld, Luke Zettelmoyer

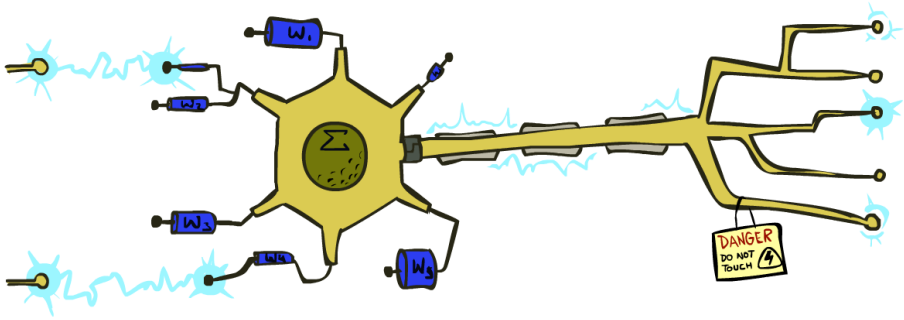
Trend in NLP

- Over time:
  - Learning HMMs (or related Probabilistic-based methods) with hand-designed features (tokens, syntactic features)
  - Recurrent Neural Networks:
    - replaces probabilistic dynamic model with neural functions (mostly non-linear functions)
  - Attention-based methods:
    - Adds the capability to go beyond Markov Models



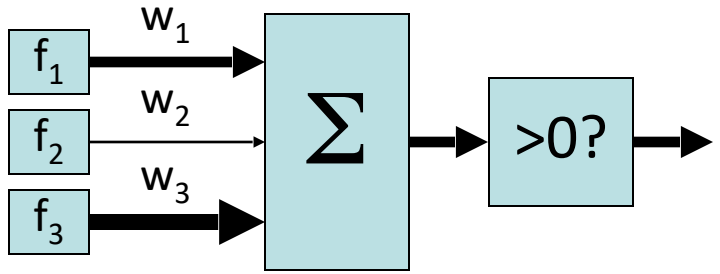
Linear Classifiers

- Inputs are feature values
- Each feature has a weight
- Sum is the activation



$$\text{activation}_w(x) = \sum_i w_i \cdot f_i(x) = w \cdot f(x)$$

- If the activation is:
  - Positive, output +1
  - Negative, output -1

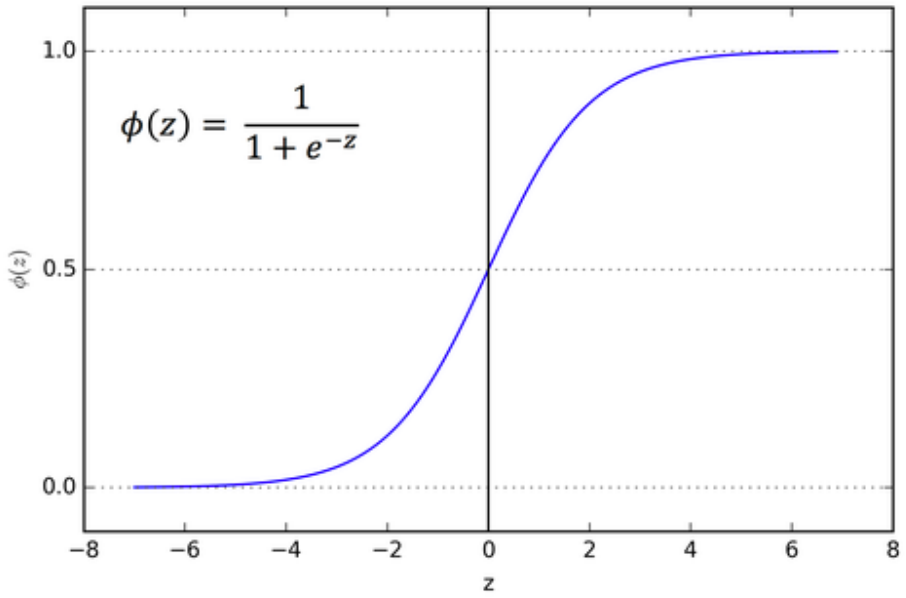


How to get probabilistic decisions?

- Activation: $z = w \cdot f(x)$
- If $z = w \cdot f(x)$ very positive → want probability going to 1
- If $z = w \cdot f(x)$ very negative → want probability going to 0

- Sigmoid function

$$\phi(z) = \frac{1}{1 + e^{-z}}$$



Best w?

- Maximum likelihood estimation:

$$\max_w \; ll(w) = \max_w \; \sum_i \log P(y^{(i)}|x^{(i)}; w)$$

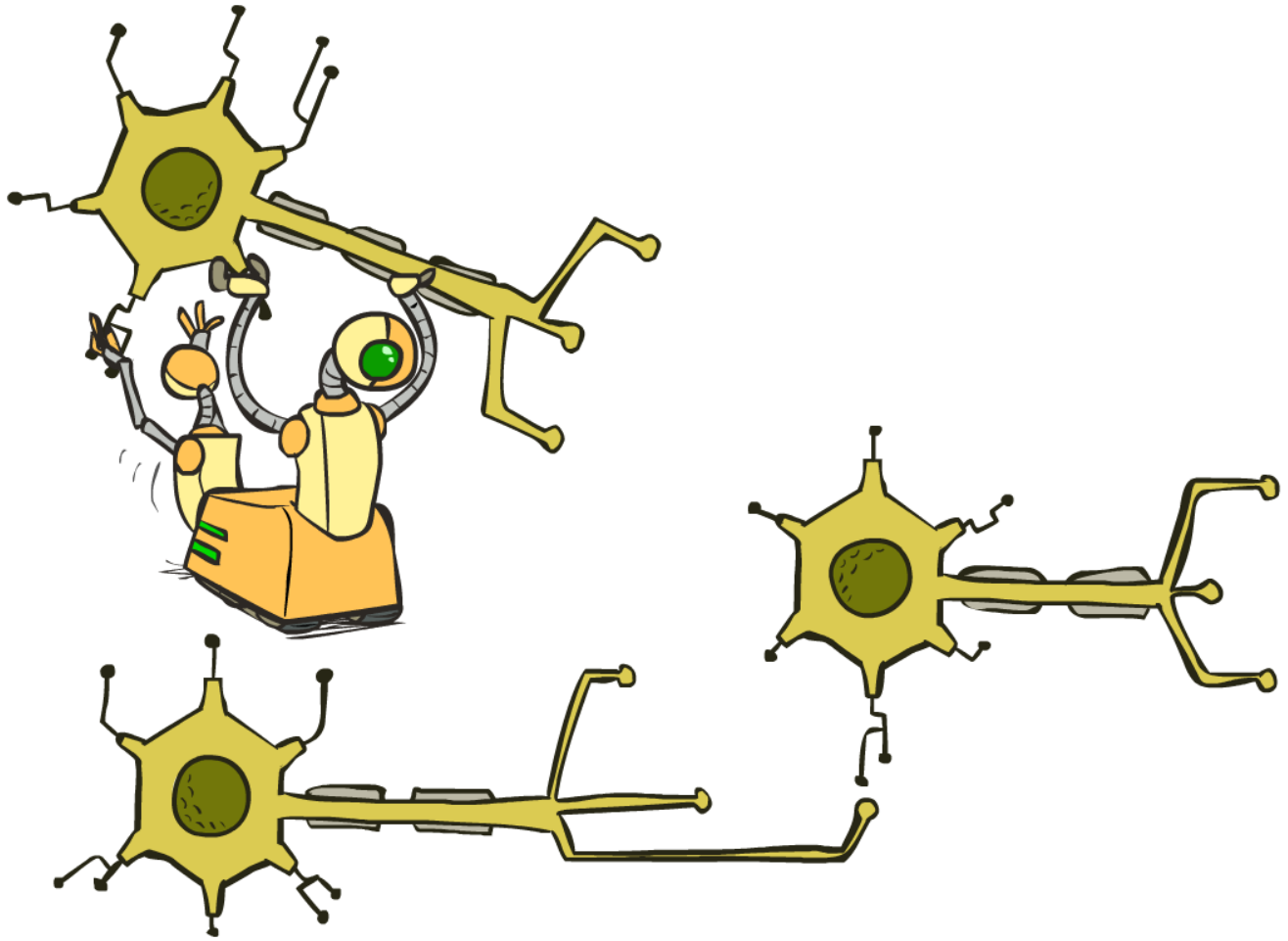
with:

$$P(y^{(i)} = +1|x^{(i)}; w) = \frac{1}{1 + e^{-w \cdot f(x^{(i)})}}$$

$$P(y^{(i)} = -1|x^{(i)}; w) = 1 - \frac{1}{1 + e^{-w \cdot f(x^{(i)})}}$$

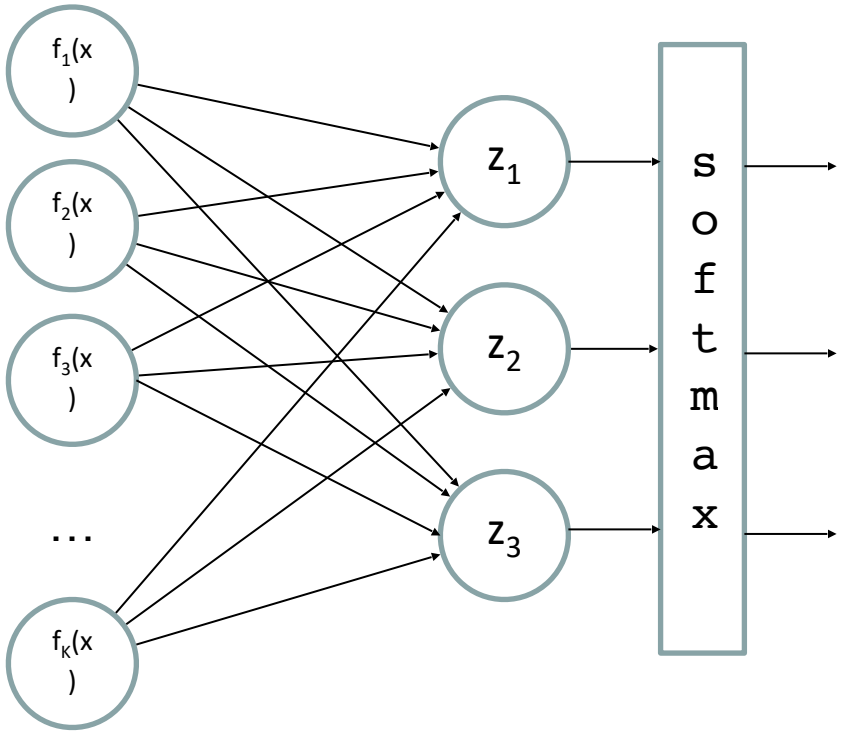
= Logistic Regression

Neural Networks



Multi-class Logistic Regression

- = special case of neural network

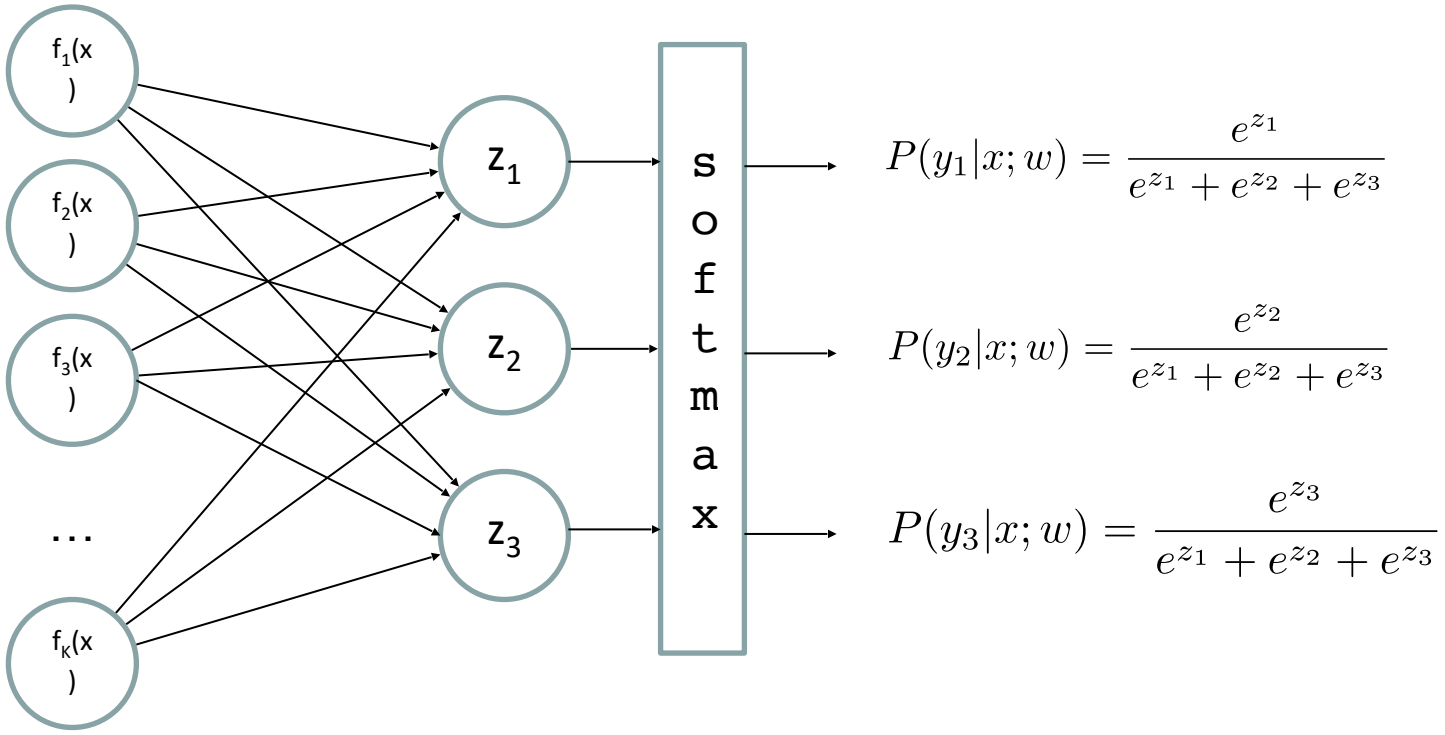


$$P(y_1|x;w) = \frac{e^{z_1}}{e^{z_1} + e^{z_2} + e^{z_3}}$$

$$P(y_2|x;w) = \frac{e^{z_2}}{e^{z_1} + e^{z_2} + e^{z_3}}$$

$$P(y_3|x;w) = \frac{e^{z_3}}{e^{z_1} + e^{z_2} + e^{z_3}}$$

Deep Neural Network = Also learn the features!



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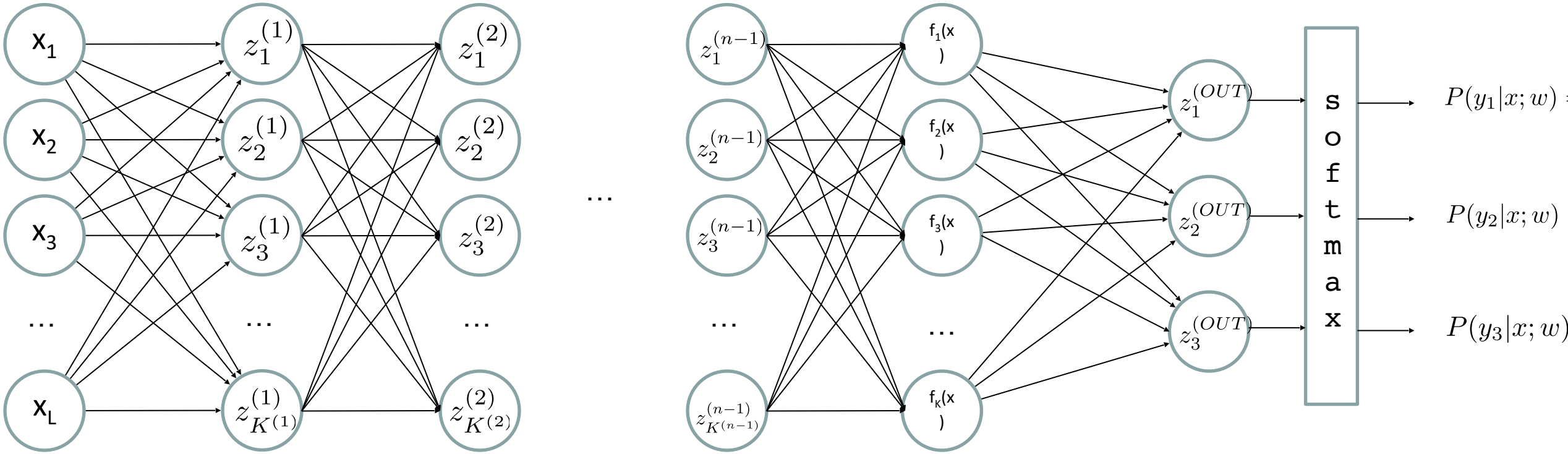
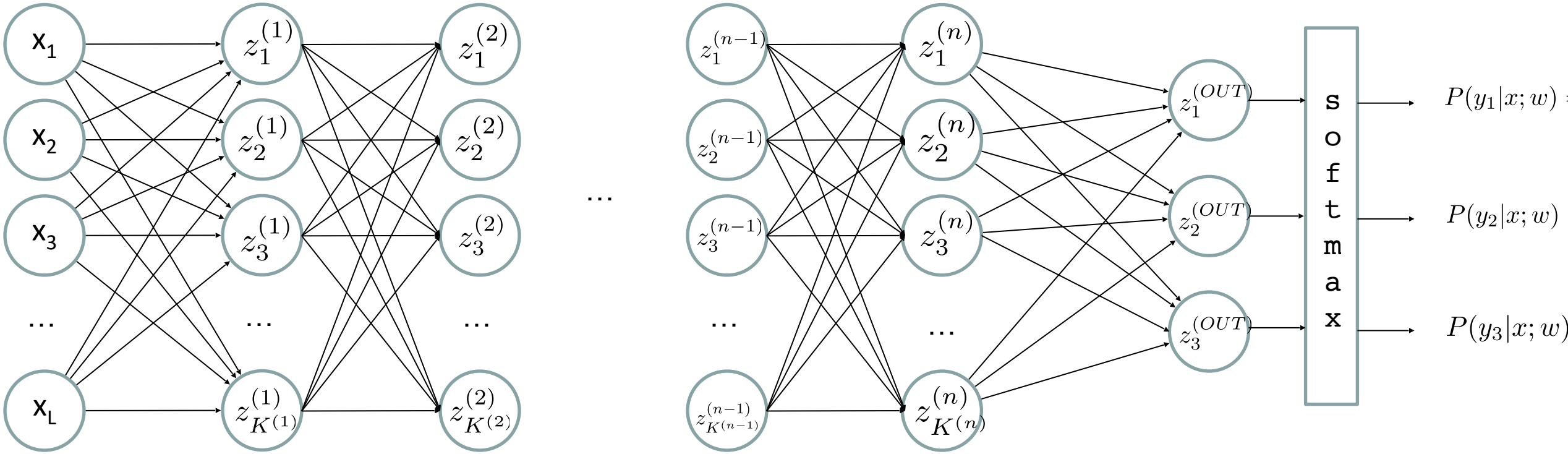


$$z_i^{(k)} = g(\sum_j W_{i,j}^{(k-1,k)} z_j^{(k-1)})$$

g = nonlinear activation function

Deep Neural Network = Also learn the features!

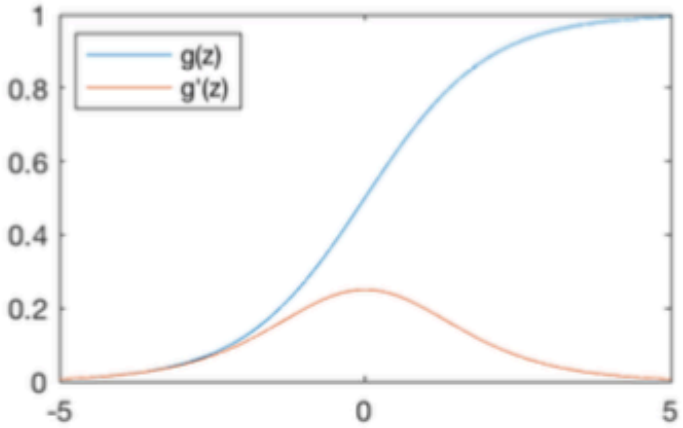


$$z_i^{(k)} = g\left(\sum_j W_{i,j}^{(k-1,k)} z_j^{(k-1)}\right)$$

g = nonlinear activation function

Common Activation Functions

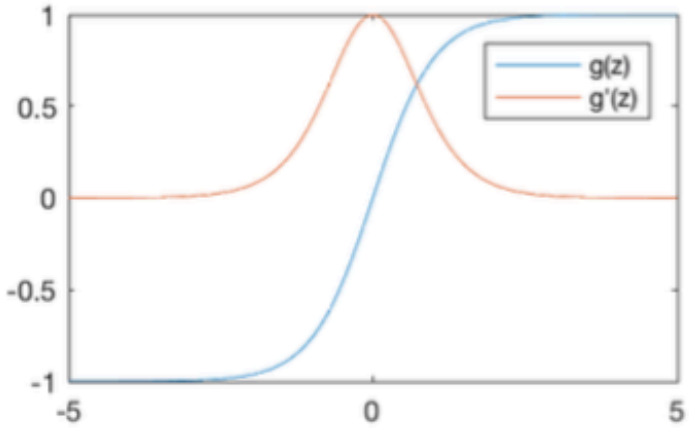
Sigmoid Function



$$g(z) = \frac{1}{1 + e^{-z}}$$

$$g'(z) = g(z)(1 - g(z))$$

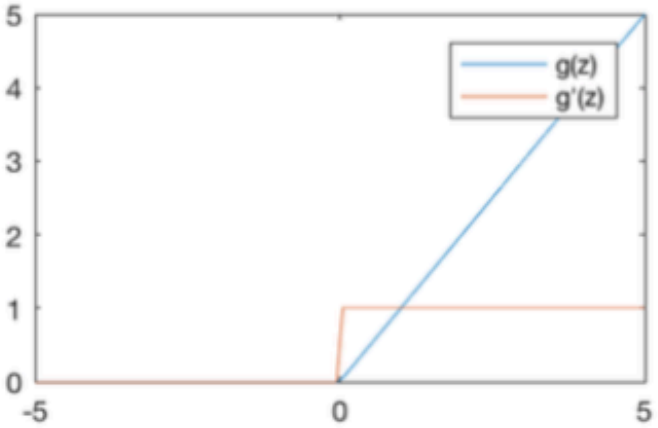
Hyperbolic Tangent



$$g(z) = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$$

$$g'(z) = 1 - g(z)^2$$

Rectified Linear Unit (ReLU)



$$g(z) = \max(0, z)$$

$$g'(z) = \begin{cases} 1, & z > 0 \\ 0, & \text{otherwise} \end{cases}$$

[source: MIT 6.S191 introtodeeplearning.com]

Deep Neural Network: Also Learn the Features!

- Training the deep neural network is just like logistic regression:

$$\max_w \quad ll(w) = \max_w \quad \sum_i \log P(y^{(i)}|x^{(i)}; w)$$

Neural Networks Properties

- Theorem (Universal Function Approximators). A two-layer neural network with a sufficient number of neurons can approximate any continuous function to any desired accuracy.

- Practical considerations
  - Can be seen as learning the features
  - Large number of neurons
    - Danger for overfitting
    - (hence early stopping!)

Fun Neural Net Demo Site

- Demo-site:
  - http://playground.tensorflow.org/

Automatic Differentiation

- Automatic differentiation software
  - e.g. Theano, TensorFlow, PyTorch, Chainer
  - Only need to program the function g(x,y,w)
  - Can automatically compute all derivatives w.r.t. all entries in w
  - This is typically done by caching info during forward computation pass of f, and then doing a backward pass = "backpropagation"
  - Autodiff / Backpropagation can often be done at computational cost comparable to the forward pass
- Need to know this exists
- How this is done? -- outside of scope of CSE573

Summary of Key Ideas

- Optimize probability of label given input

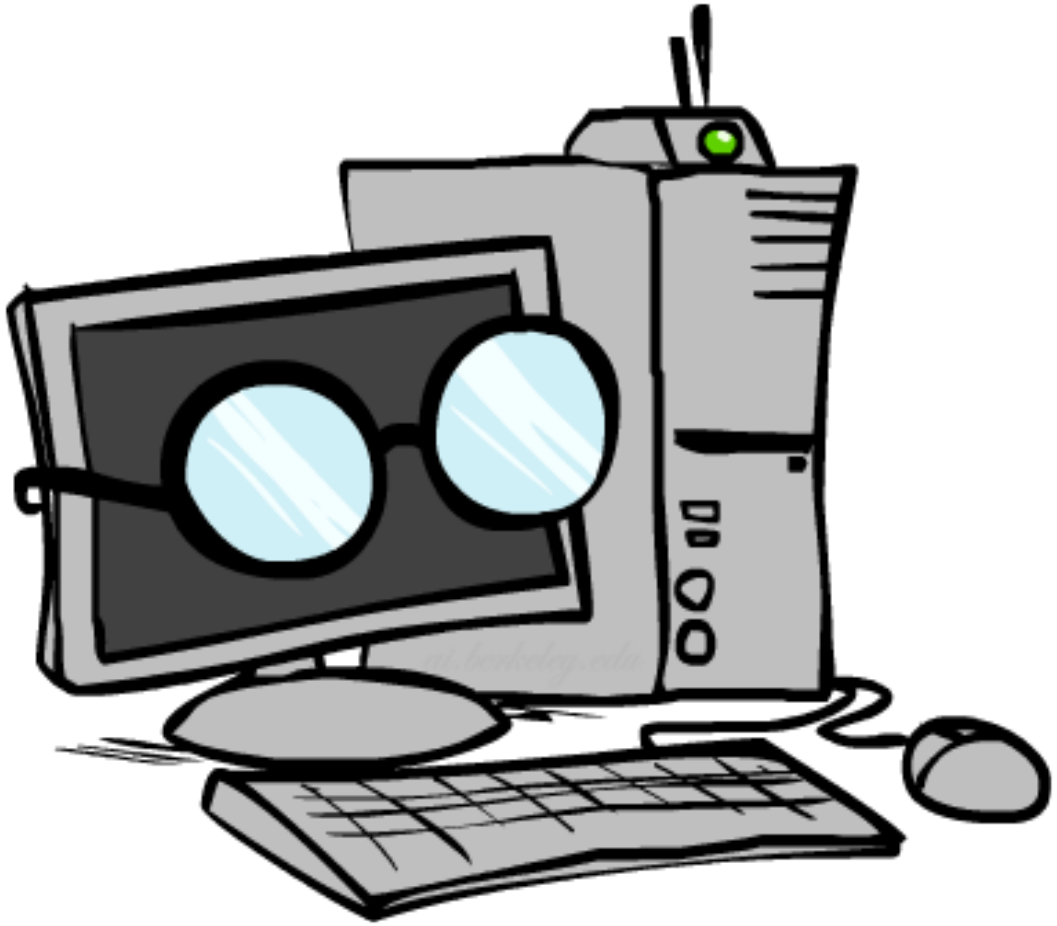
$$\max_w \; ll(w) = \max_w \; \sum_i \log P(y^{(i)}|x^{(i)};w)$$

- Continuous optimization
  - Gradient ascent:
    - Compute steepest uphill direction = gradient (= just vector of partial derivatives)
    - Take step in the gradient direction
    - Repeat (until held-out data accuracy starts to drop = "early stopping")

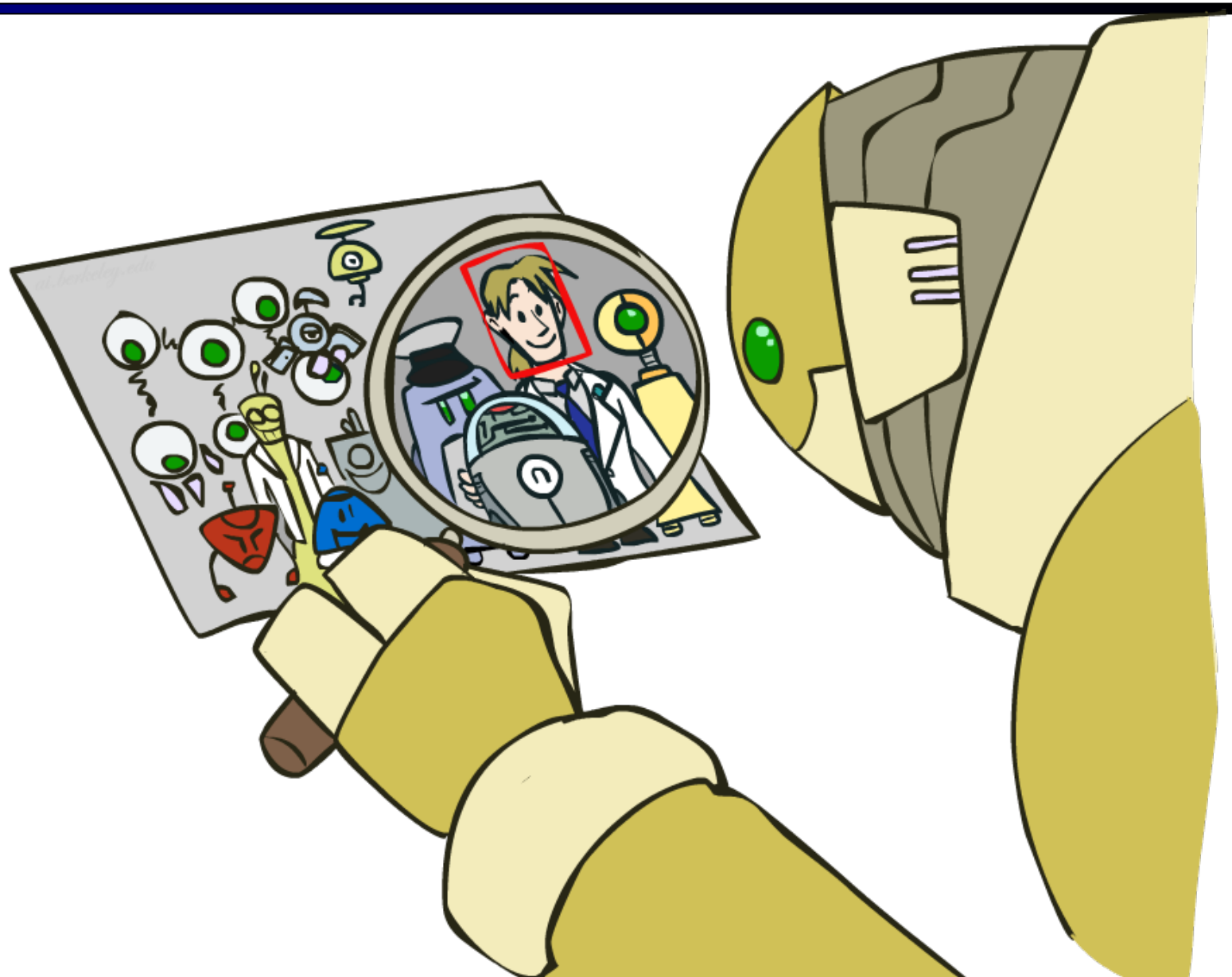
- Deep neural nets
  - Last layer = still logistic regression
  - Now also many more layers before this last layer
    - = computing the features
    - → the features are learned rather than hand-designed
  - Universal function approximation theorem
    - `If` neural net is large enough
    - `Then` neural net can represent any continuous mapping from input to output with arbitrary accuracy
    - But remember: need to avoid overfitting / memorizing the training data → early stopping!
  - Automatic differentiation gives the derivatives efficiently (how? = outside of scope of 573)

How well does it work?

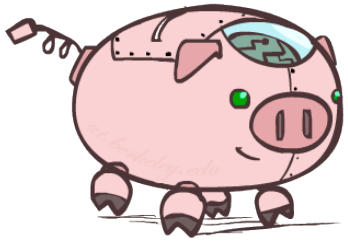
Computer Vision

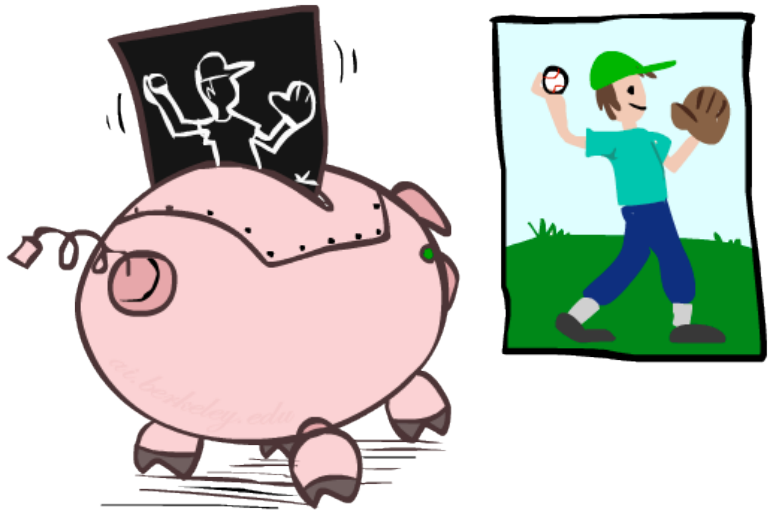


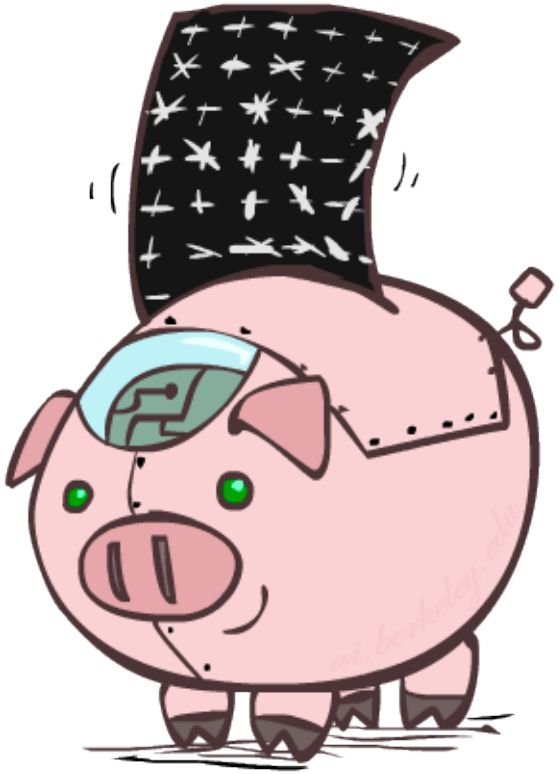
Object Detection



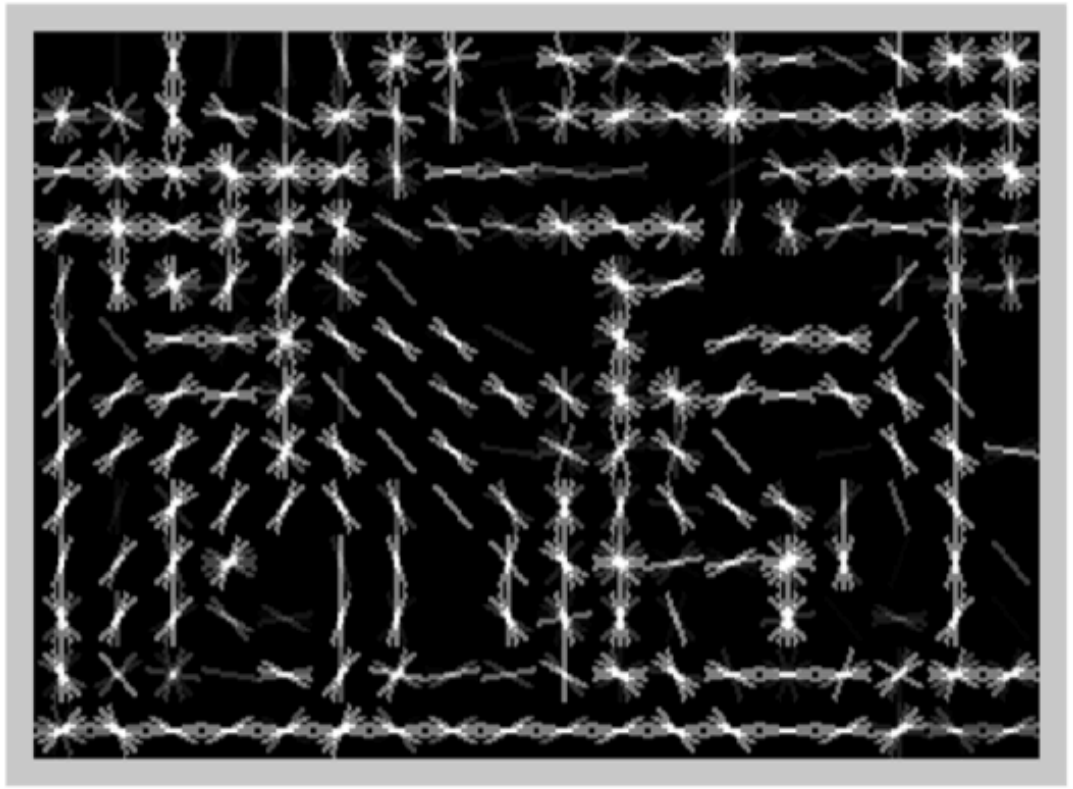
Manual Feature Design







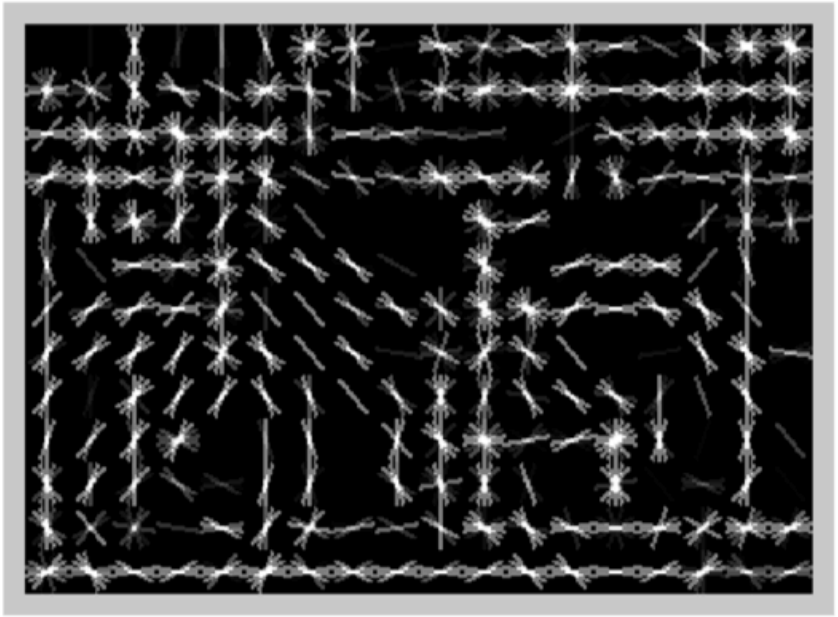
Features and Generalization



[HoG: Dalal and Triggs, 2005]

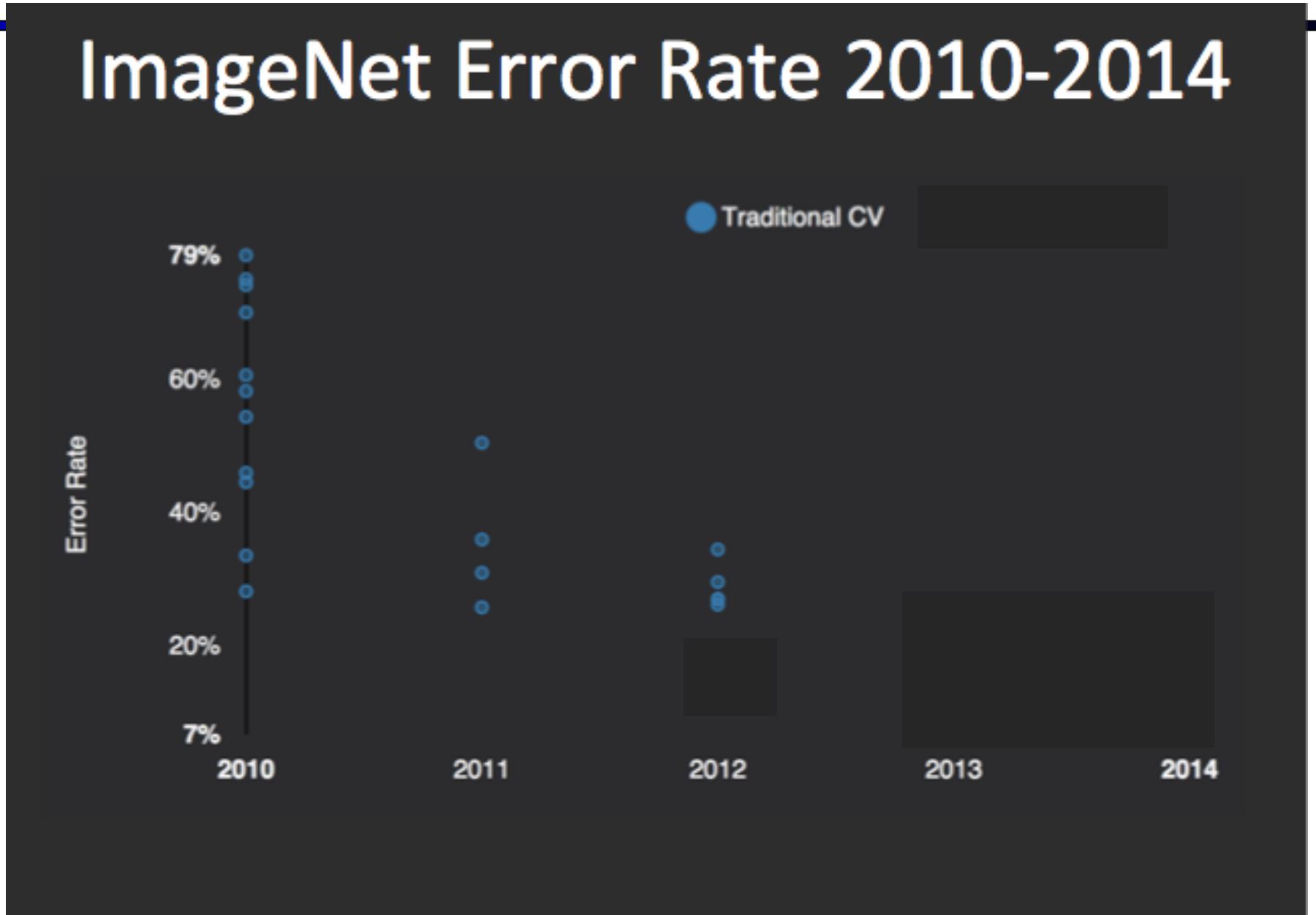
Features and Generalization

Image



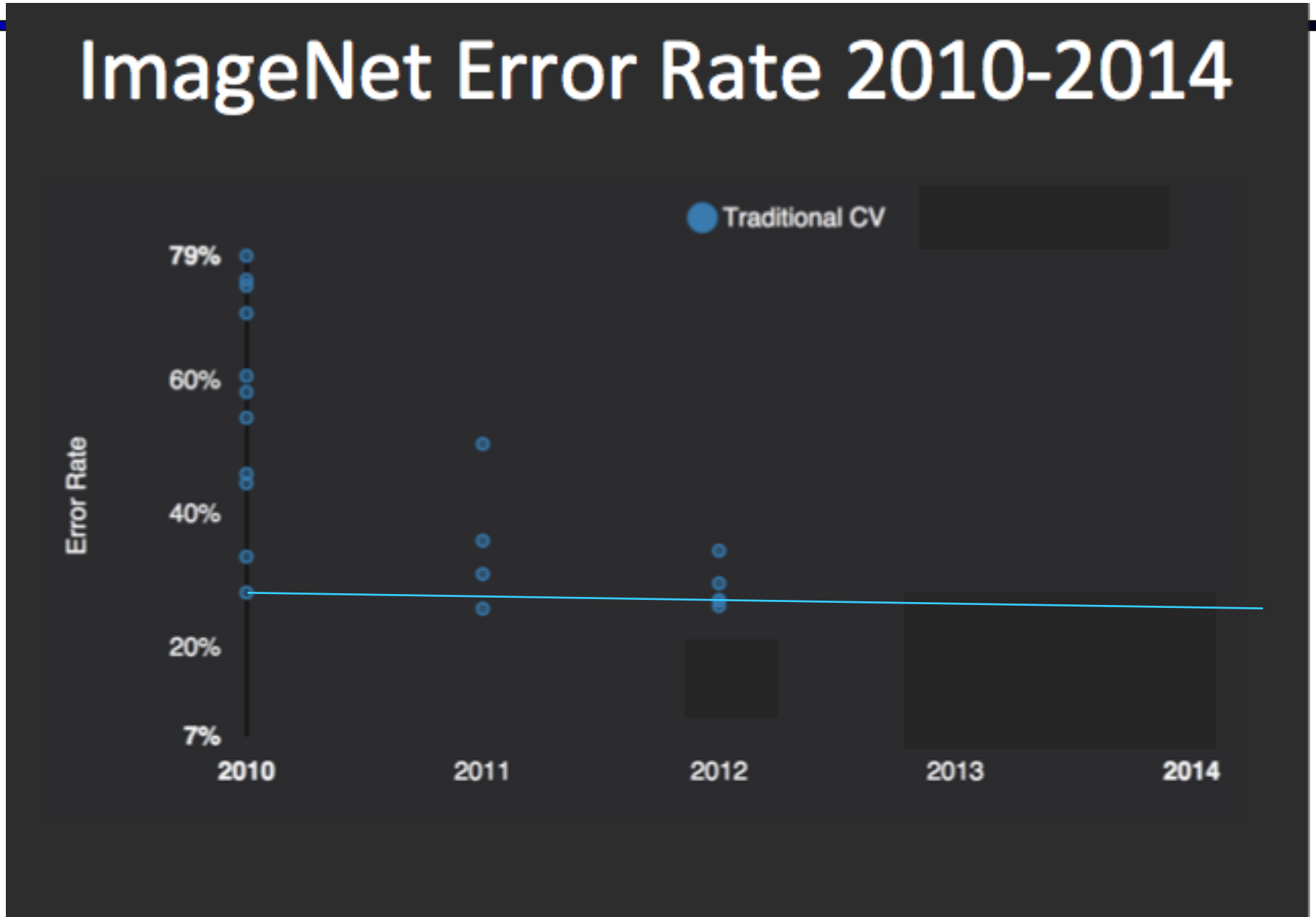
HoG

Performance



graph credit Matt Zeiler, Clarifai

Performance



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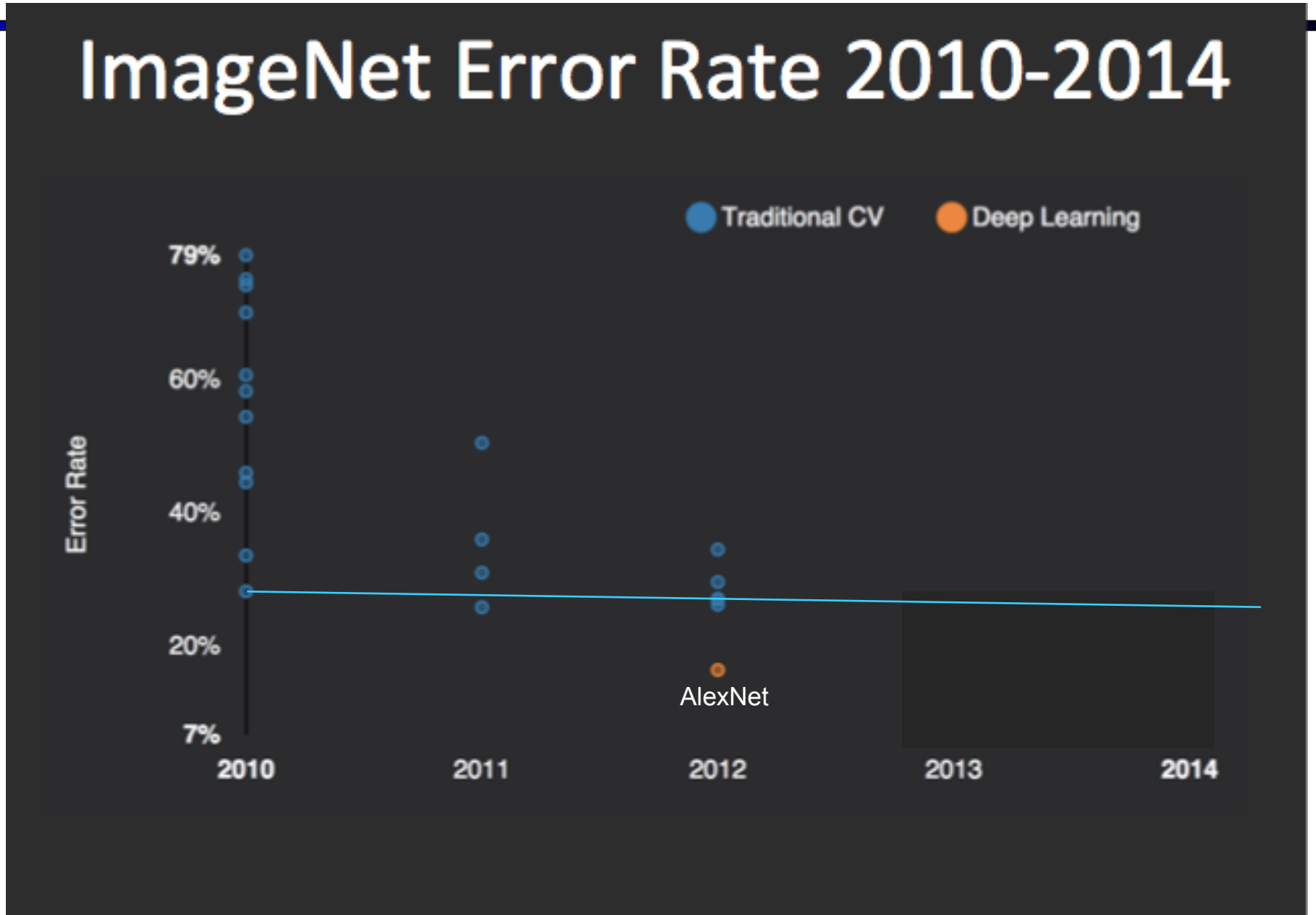

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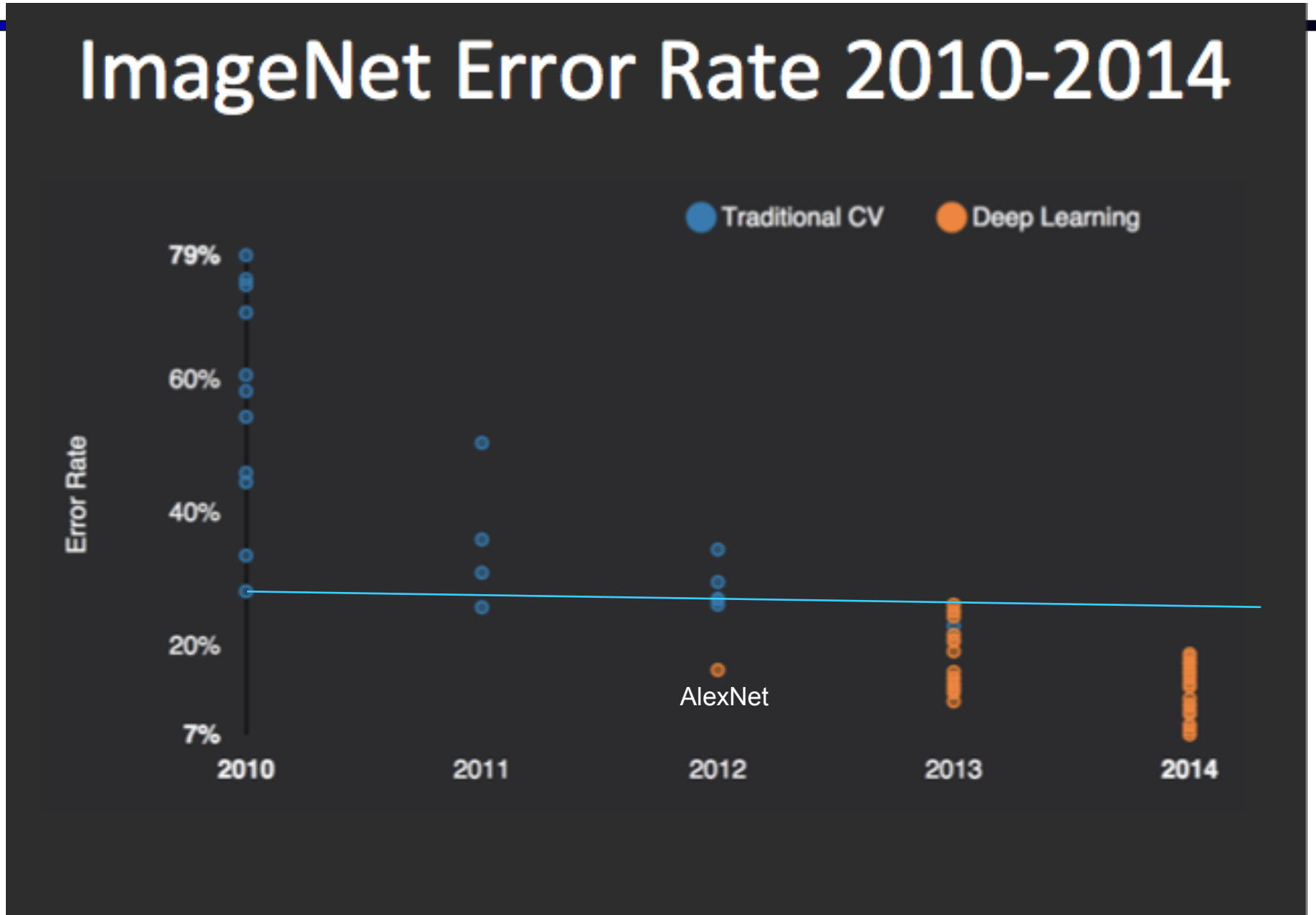

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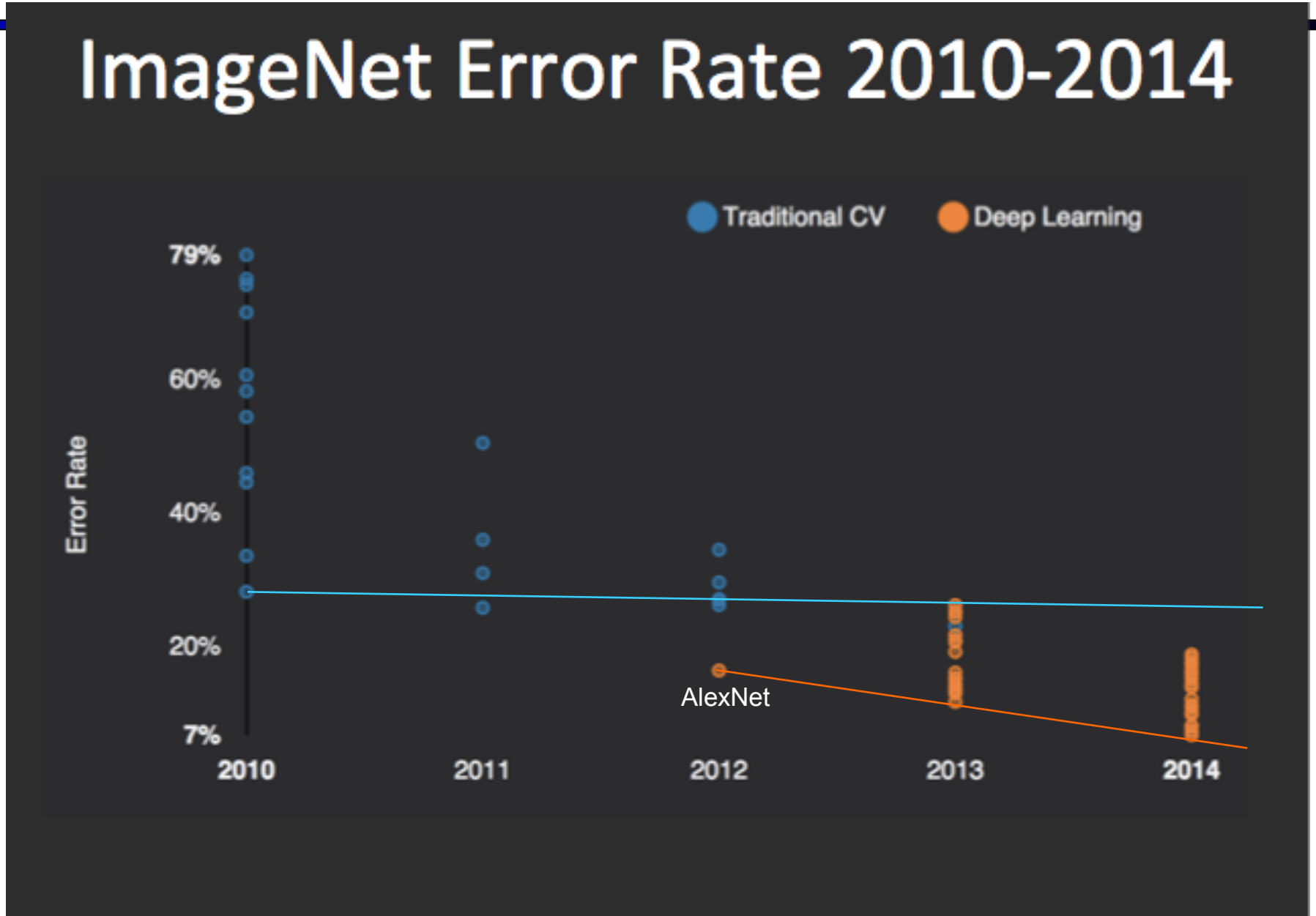


graph credit Matt Zeiler, Clarifai

MS COCO Image Captioning Challenge

"man in black shirt is playing guitar."

"construction worker in orange safety vest is working on road."

"two young girls are playing with lego toy."

"boy is doing backflip on wakeboard."

"girl in pink dress is jumping in air."

"black and white dog jumps over bar."

"young girl in pink shirt is swinging on swing."

"man in blue wetsuit is surfing on wave."

Karpathy & Fei-Fei, 2015; Donahue et al., 2015; Xu et al, 2015; many more

Visual QA Challenge

Stanislaw Antol, Aishwarya Agrawal, Jiasen Lu, Margaret Mitchell, Dhruv Batra, C. Lawrence Zitnick, Devi Parikh

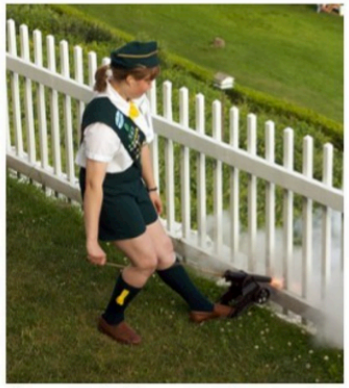
What vegetable is on the plate?
Neural Net: broccoli
Ground Truth: broccoli

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

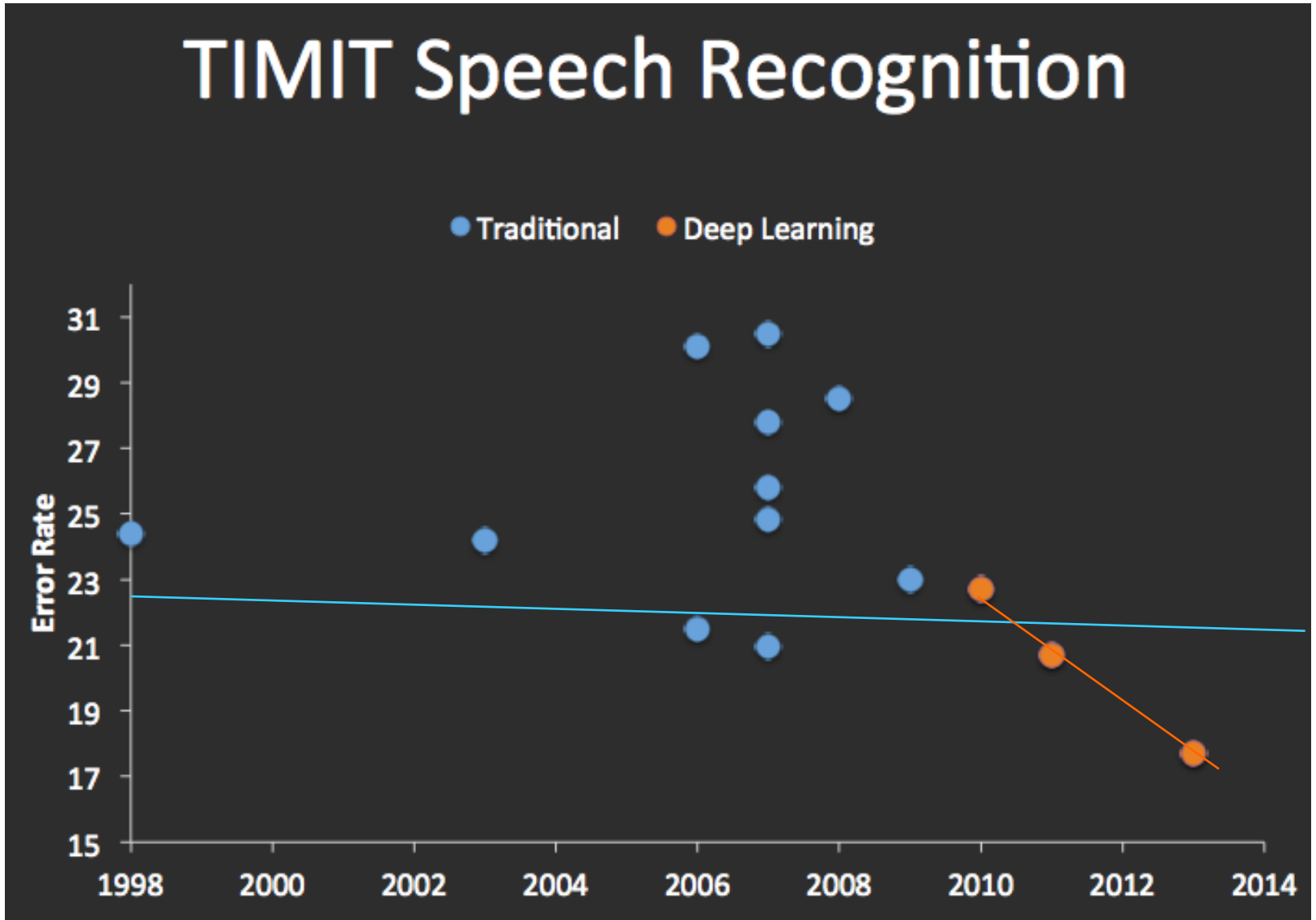
What is the table number?
Neural Net: 4
Ground Truth:40

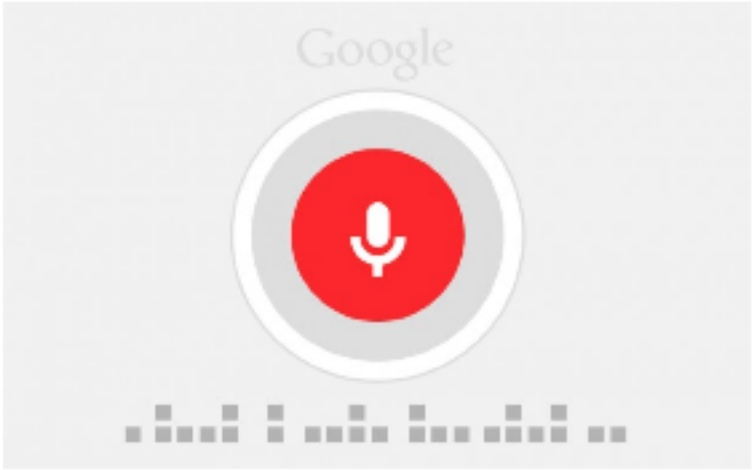
What are people sitting under in the back?
Neural Net: bench
Ground Truth: tent

Speech and Natural Language Processing

- Different approaches to:
  - Modeling sequences of tokens
- Language Modeling: $P(x_t | x_{t-1})$
- Applications:
  - Machine Translation
  - Document Classification
    - Sentiment
    - Document types
  - Question Answering
  - etc

Speech Recognition

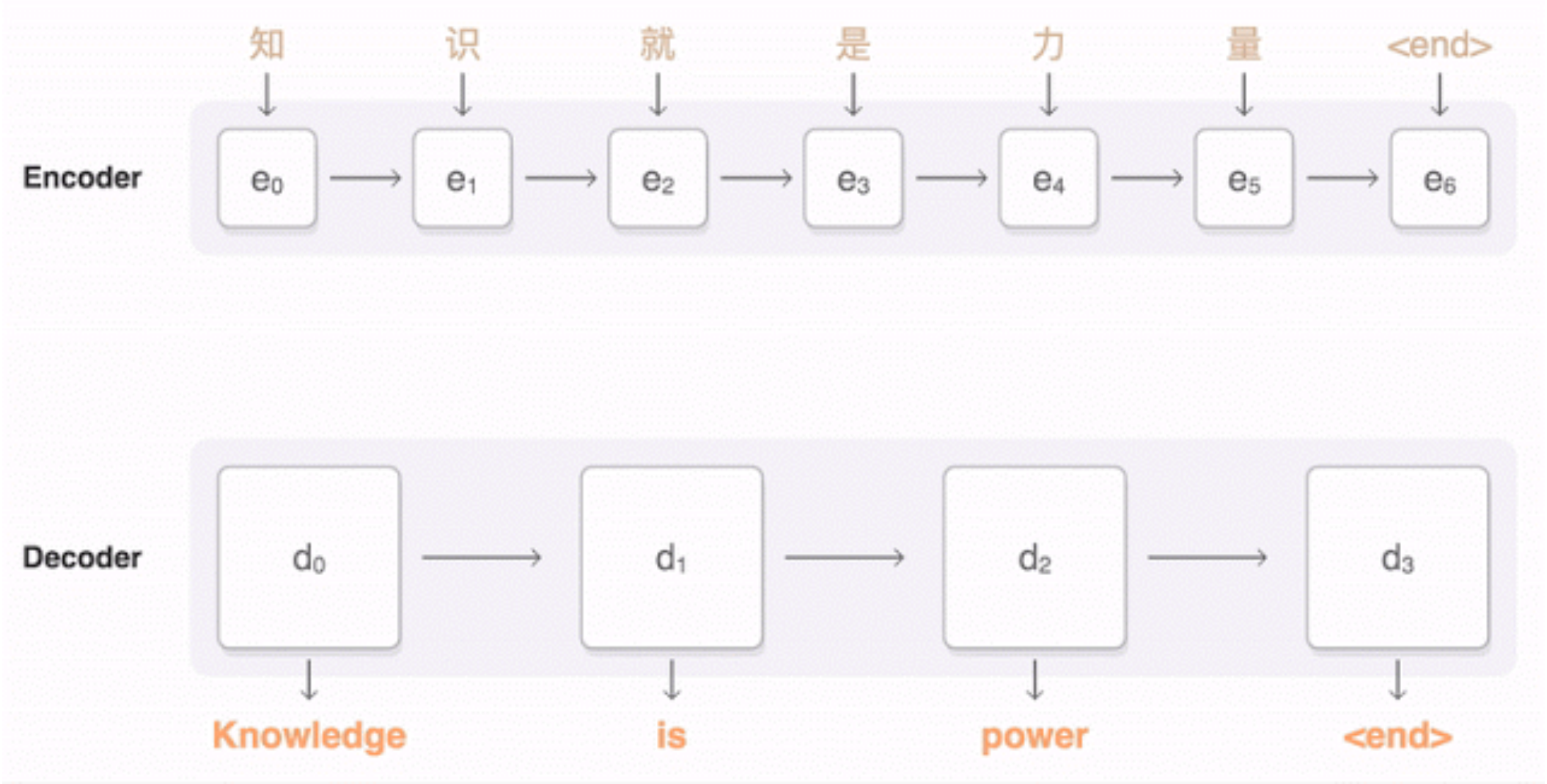




graph credit Matt Zeiler, Clarifai

Machine Translation

Google Neural Machine Translation (in production)



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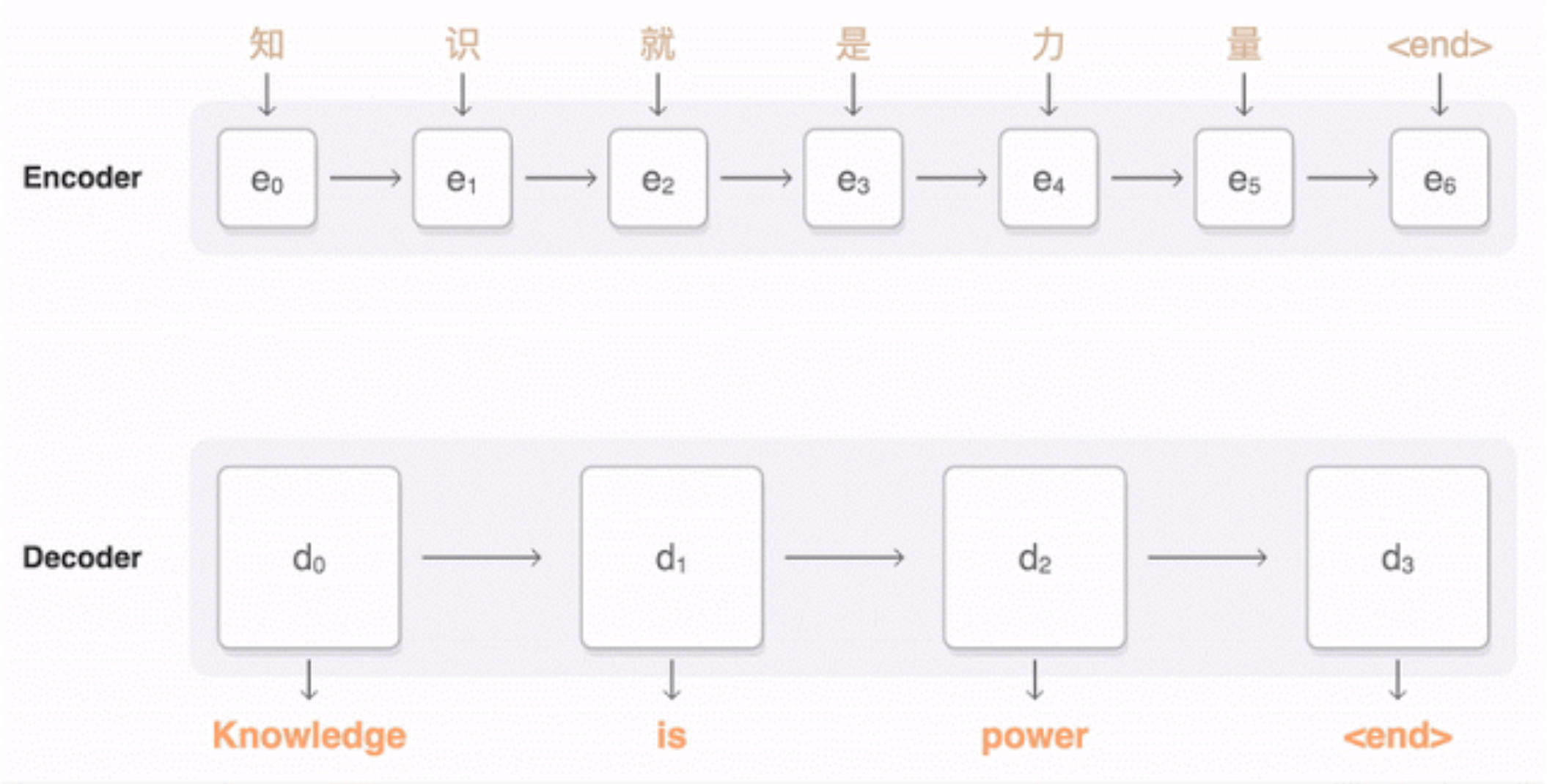


Question Answering

Context

Super Bowl 48 was an American football game to determine the champion of the National Football League (NFL) for the 2013 season. The National Football Conference champions Seattle Seahawks defeated the American Football Conference champions Denver Broncos. The Seahawks defeated the Broncos 43–8, the largest margin victory for an underdog and tied the third largest point differential overall (35) in Super Bowl history with Super Bowl XXVII (1993). It was the first time the winning scored over 40 points, while holding their opponent to under 10.

Question

Which NFL team represented the NFC at Super Bowl 48?

Answer

Seattle Seahawks

Pipeline Approach for Question Answering

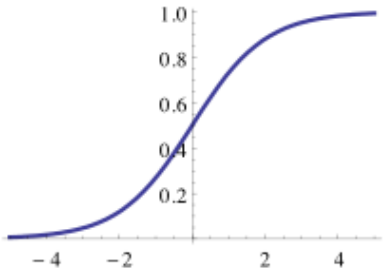
- Feature engineering
- Classifying phrases

Super Bowl 48 was an American football game to determine the champion of the National Football League (NFL) for the 2013 season. The National Football Conference champions Seattle Seahawks defeated the American Football Conference champions Denver Broncos. The Seahawks defeated the Broncos 43–8, the largest margin victory for an underdog and tied the third largest point differential overall (35) in Super Bowl history with Super Bowl XXVII (1993). It was the first time the winning scored over 40 points, while holding their opponent to under 10.

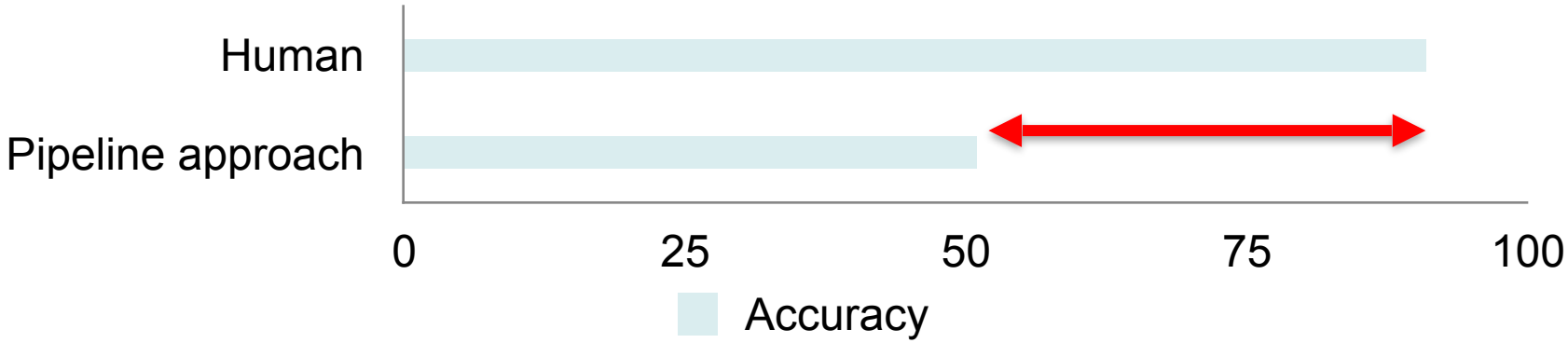
Which NFL team represented the NFC at Super Bowl 48?

words, types, frequencies
dependency relations

$f_1, f_2, \ldots, f_n$



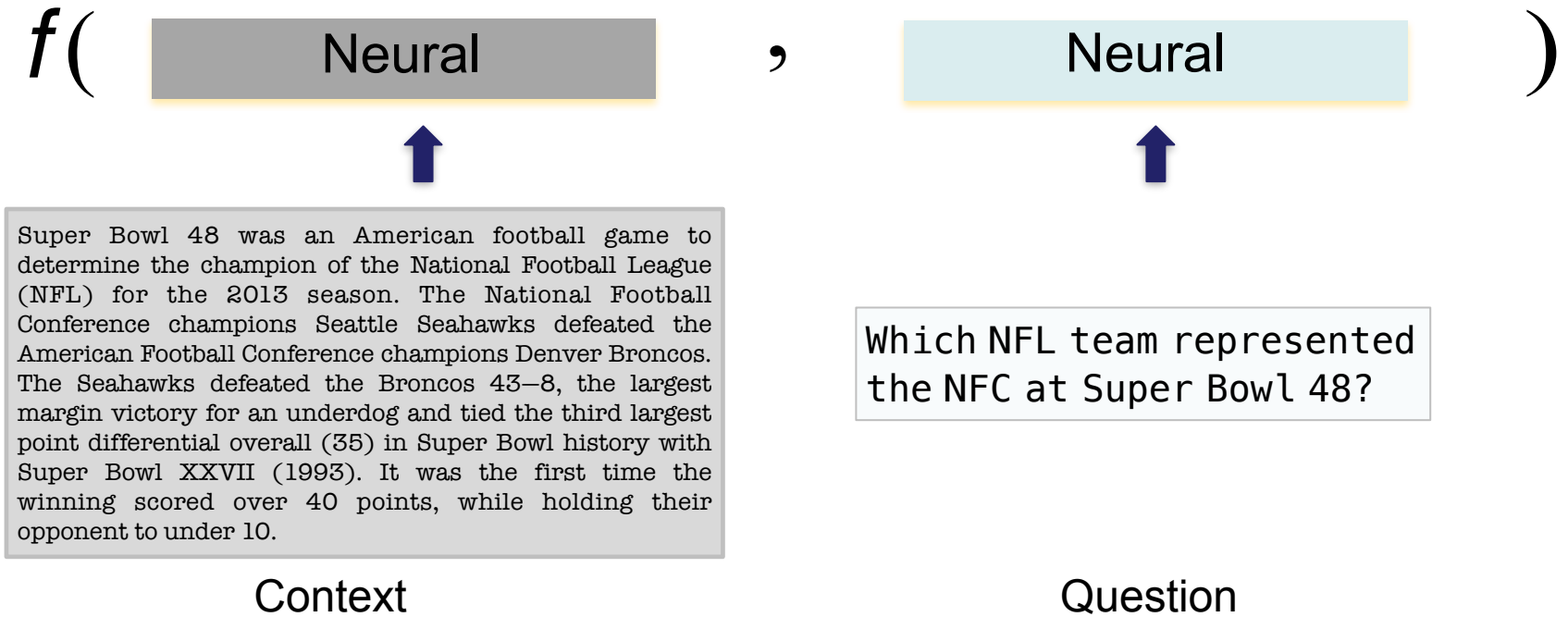
Pipeline Approach Results



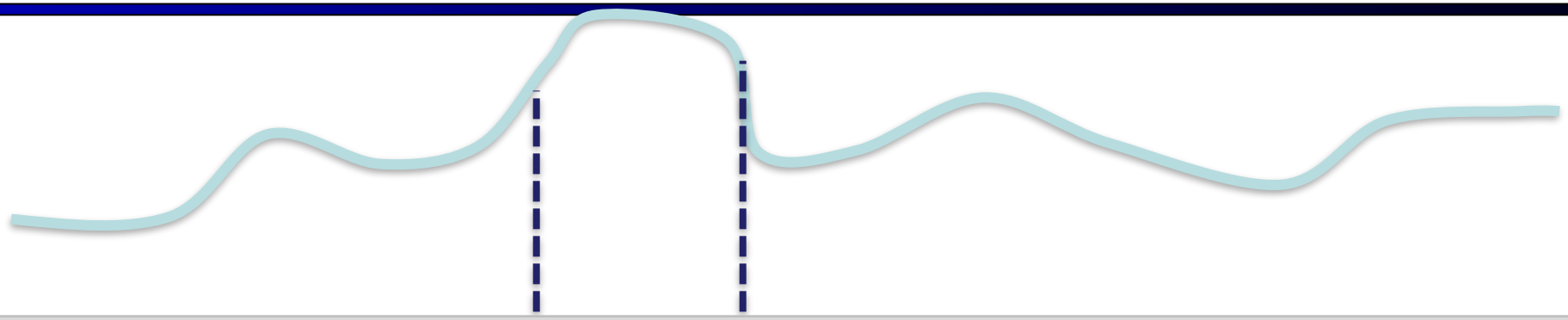
- Dataset: Stanford Question Answering Dataset (SQuAD) [Rajpurkar et al 2016]:
  - 100k Wikipedia documents with question
- Accuracy: percentage of correctly predicted phrases

Neural Approach [ICLR'17]

Find a function that assigns a high score to the the correct answer given the context and question



Seattle Seahawks



The National Football Conference champions Seattle Seahawks defeated the American Football Conference champions Denver Broncos.

$f($ Encoding , Encoding $)$

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Context

, Which NFL team represented the NFC at Super Bowl 48?

Question

Question Answering Leaderboard

Jan 1, 2017

Test Set Leaderboard

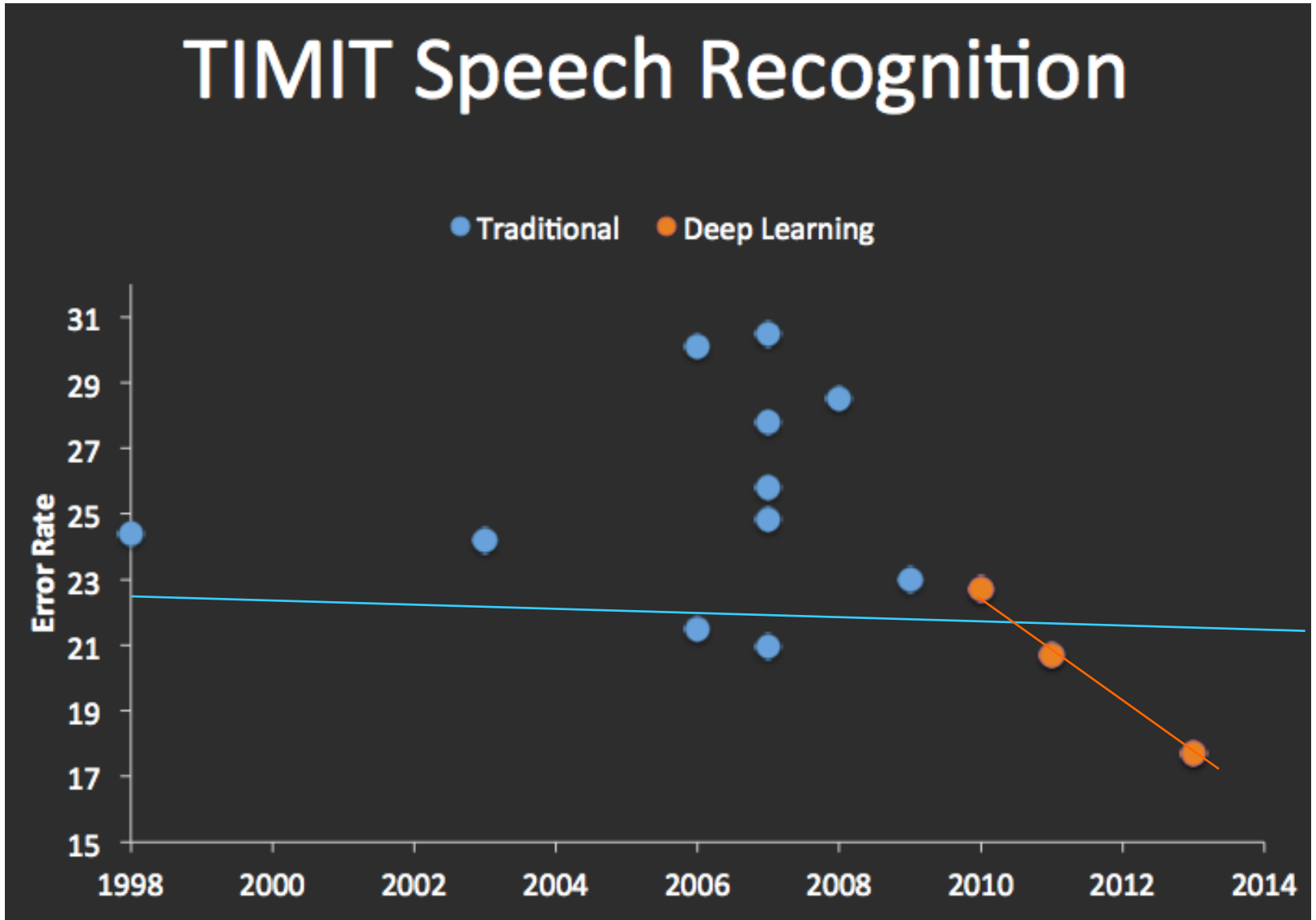
Since the release of our dataset (and paper), the community has made rapid progress! Here are the ExactMatch (EM) and F1 scores of the best models evaluated on the test and development sets of v1.1.

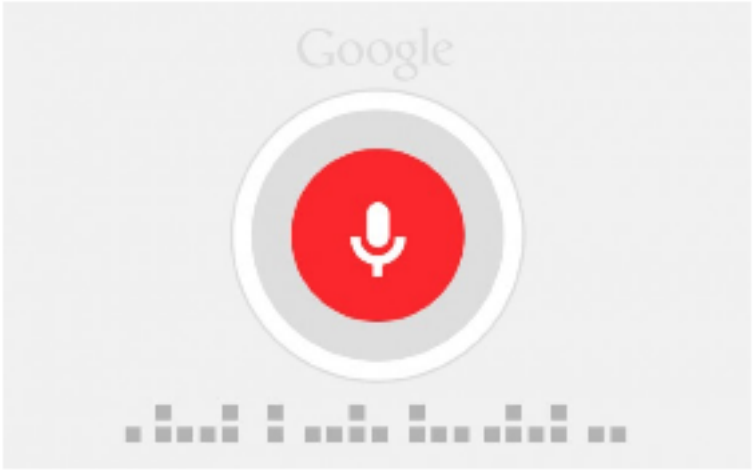
Rank	Model	Test EM	Test F1
1	BiDAF (ensemble) Allen Institute for AI & University of Washington (Seo et al. '16)	73.3	81.1
2	Dynamic Coattention Networks (ensemble) Salesforce Research (Xiong & Zhong et al. '16)	71.6	80.4
2	r-net (ensemble) Microsoft Research Asia	72.1	79.7
4	r-net (single model) Microsoft Research Asia	68.4	77.5
5	BiDAF (single model) Allen Institute for AI & University of Washington (Seo et al. '16)	68.0	77.3
5	Multi-Perspective Matching (ensemble) IBM Research	68.2	77.2

March 8, 2021

Rank	Model	EM	F1
	Human Performance *Stanford University* (Rajpurkar & Jia et al. '18)	86.831	89.452
1 Feb 21, 2021	FPNet (ensemble) *Ant Service Intelligence Team*	**90.871**	**93.183**
2 Feb 24, 2021	IE-Net (ensemble) *RICOH_SRCB_DML*	90.758	93.044
3 Apr 06, 2020	SA-Net on Albert (ensemble) *QIANXIN*	90.724	93.011
4 May 05, 2020	SA-Net-V2 (ensemble) *QIANXIN*	90.679	92.948
4 Apr 05, 2020	Retro-Reader (ensemble) *Shanghai Jiao Tong University* http://arxiv.org/abs/2001.09694	90.578	92.978
4 Feb 05, 2021	FPNet (ensemble) *YuYang*	90.600	92.899
5 Dec 01, 2020	EntitySpanFocusV2 (ensemble) *RICOH_SRCB_DML*	90.521	92.824
5 Jul 31, 2020	ATRLP+PV (ensemble) *Hithink RoyalFlush*	90.442	92.877
5 May 04, 2020	ELECTRA+ALBERT+EntitySpanFocus (ensemble) *SRCB_DML*	90.442	92.839

Speech Recognition





graph credit Matt Zeiler, Clarifai