# Instructors

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<th>Thamar Solorio</th>
</tr>
</thead>
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<td><strong>Full Professor</strong></td>
<td><strong>Associate Professor</strong></td>
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</tbody>
</table>
Intro to DL
Backpropagation

\[
\begin{align*}
    w'_{(x1)} &= w_{(x1)} + \eta \delta_1 \frac{df(e)}{de} x_1 \\
    w'_{(x2)} &= w_{(x2)} + \eta \delta_1 \frac{df(e)}{de} x_2
\end{align*}
\]

**Learning representations by back-propagating errors**

David E. Rumelhart*, Geoffrey E. Hinton† & Ronald J. Williams*

* Institute for Cognitive Science, C-015, University of California, San Diego, La Jolla, California 92093, USA
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Deep Learning
Deep learning boom

FACEBOOK TAPS ‘DEEP LEARNING’ GIANT FOR NEW AI LAB

GOOGLE HIRES HELPED SUPERCD MACHINE LEARN
Deep Learning is Born
Deep learning recipe

Data

Algorithm

Feature learning

Tricks

Size

HPC

Feature

Object models

Object parts

Edges

Pixels

[Honglak]
Deep learning recipe

Data

- object models
- object parts
- features
- edges
- pixels

Algorithms

- Feature learning
- Size
- Tricks

- HPC
- Data

HPC

- Size

Deep learning recipe

- Data
- Algorithms
- Tricks

- HPC

Deep learning recipe

- Data
- Algorithms
- Tricks

- HPC

Deep learning recipe

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- Tricks

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Feature learning
Deep learning recipe

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HPC

Tricks
Deep -> Bigger

Revolution of Depth

ILSVRC'15 ResNet: 3.57
ILSVRC'14 GoogleNet: 6.7
ILSVRC'14 VGG: 7.3
ILSVRC'13: 11.7
ILSVRC'12 AlexNet: 16.4
ILSVRC'11: 25.8
ILSVRC'10: 28.2

ImageNet Classification top-5 error (%)
Deep learning recipe

Data

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HPC
Data...

- Images annotated with WordNet concepts
- Concepts: 21,841
- Images: 14,197,122
- Bounding box annotations: 1,034,908
- Crowdsourcing
Deep learning recipe

Data

HPC

Algorithms

Tricks

Feature learning

Size
HPC

**SPECIFICATIONS**

- **GPU Architecture**: NVIDIA Pascal
- **NVIDIA CUDA® Cores**: 3584
- **Double-Precision Performance**: 4.7 TeraFLOPS
- **Single-Precision Performance**: 9.3 TeraFLOPS
- **Half-Precision Performance**: 18.7 TeraFLOPS
- **GPU Memory**: 16GB CoWoS HBM2 at 732 GB/s or 12GB CoWoS HBM2 at 549 GB/s
- **System Interface**: PCIe Gen3
- **Max Power Consumption**: 250 W
- **ECC**: Yes
- **Thermal Solution**: Passive
- **Form Factor**: PCIe Full Height/Length

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**NVIDIA Tesla P100 for PCIe Performance**

Dual CPU server, Intel E5-2698 v3 @ 2.3 GHz, 256 GB System Memory, Pre-Production Tesla P100
# Deep learning recipe

## Data

- Feature learning
- Object models
- Object parts
- Edges
- Pixels

## Algorithms

- HPC
- Tricks

## Size

<table>
<thead>
<tr>
<th>Size</th>
<th>Parameters</th>
<th>MAC ops</th>
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<tbody>
<tr>
<td>4M</td>
<td>FULL CONNECT</td>
<td>4.1M</td>
</tr>
<tr>
<td>16M</td>
<td>FULL 4096/ReLU</td>
<td>15M</td>
</tr>
<tr>
<td>37M</td>
<td>FULL 4096/ReLU</td>
<td>25M</td>
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<tr>
<td>44K</td>
<td>MAX POOLING</td>
<td>222M</td>
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<tr>
<td>894K</td>
<td>CONV 3x3/ReLU</td>
<td>222M</td>
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<tr>
<td>1.2M</td>
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<tr>
<td>307K</td>
<td>LOCAL CONTRAST NORM</td>
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<tr>
<td>35K</td>
<td>MAX POOLING 2x2sub</td>
<td>222M</td>
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<tr>
<td></td>
<td>CONV 11x11/ReLU 966</td>
<td>100M</td>
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</tbody>
</table>

## Tricks

- Neural Networks: Tricks of the Trade
- Second Edition

- Grégoire Montavon
- Geoffrey B. Orr
- Klaus-Robert Müller

- Springer
Algorithms

• Backpropagation
• Backpropagation through time
• Online learning (stochastic gradient descent)
• Softmax
Deep learning recipe

Data

Algorithms

Feature learning

Size

HPC

Tricks
Tricks

• DL is mainly an engineering problem

• DL networks are hard to train

• Several tricks product of years of experience

• Layer-wise training

• RELU, maxout units

• Dropout

• Batch normalization

• Adaptive learning rates

• Initialization

• Preprocessing
Applications

- Computer vision:
  - Image: annotation, detection, segmentation, captioning
  - Video: object tracking, action recognition, segmentation
- Speech recognition and synthesis
- Text: language modeling, word/text representation, text classification, translation
- Biomedical image analysis