ECS 289 Paper Presentation

“How transferable are features in deep neural networks?”

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Slides originally made by Jason Yosinski and his colleagues
Layer 1
Gabor +
color blobs
Layer 1
Gabor + color blobs

Layer 2

Layer 5

Zeiler et al.
arXiv 2013, ECCV 2014
Layer 1
Gabor + color blobs

Layer 2

Layer 5

Zeiler et al.
arXiv 2013, ECCV 2014

Nguyen et al.
arXiv 2014

Last Layer
Layer number

general

specific

Lion
Main idea:
Quantify the *general* to *specific* transition by using transfer learning.
Main idea:
Quantify the *general* to *specific* transition by using transfer learning.

Depends on tasks A and B.
Main idea:
Quantify the general to specific transition by using transfer learning.

Depends on tasks A and B.

Very useful to know!
ImageNet

1000 Classes

Deng et al., 2009
ImageNet

1000 Classes

dataset A

500 Classes

Deng et al., 2009
Images
500 Classes

Train using Caffe framework (Jia et al.)

A Labels
A Images

500 Classes

Train using Caffe framework (Jia et al.)

A Labels
Train using Caffe framework (Jia et al.)
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- transfer AnB
Compare to baseB
Layer $n$ at which network is chopped and retrained
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- transfer AnB
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

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- transfer AnB
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

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- selffer BnB
- transfer AnB
Layer \( n \) at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- self-fer BnB
- transfer AnB
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

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Top-1 accuracy (higher is better)

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Performance drops due to...
Performance drops due to...

Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- transfer AnB

Fragile co-adaptation
Performance drops due to...

Layer \( n \) at which network is chopped and retrained
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- selffer BnB$^+$
- transfer AnB
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

- **baseB**
- **selffer BnB**
- **selffer BnB$^+$**
- **transfer AnB**

Accuracy values for different layers and methods.

0.52
0.54
0.56
0.58
0.60
0.62
0.64
0.66
Layer $n$ at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- selffer BnB$^+$
- transfer AnB
- transfer AnB$^+$
Layer at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- selffer BnB+
- transfer AnB
- transfer AnB+
Transfer + fine-tuning improves generalization

Layer $n$ at which network is chopped and retrained
ImageNet has many related categories...

**Dataset A: random**
- gecko
- fire truck
- baseball
- panther
- gorilla

**Dataset B: random**
- garbage truck
- toucan
- radiator
- binoculars
- lion
- bookshop
ImageNet has many related categories...

<table>
<thead>
<tr>
<th>Dataset A: man-made</th>
<th>Dataset B: natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>garbage truck</td>
<td>gorilla</td>
</tr>
<tr>
<td>fire truck</td>
<td>gecko</td>
</tr>
<tr>
<td>radiator</td>
<td>toucan</td>
</tr>
<tr>
<td>baseball</td>
<td>rabbit</td>
</tr>
<tr>
<td>binoculars</td>
<td>panther</td>
</tr>
<tr>
<td>bookshop</td>
<td>lion</td>
</tr>
</tbody>
</table>
Layer $n$ at which network is chopped and retrained

Relative top-1 accuracy (higher is better)

- Similar A/B
- Reference
- Mean AnB, random splits

Random features
Layer $n$ at which network is chopped and retrained

Relative top-1 accuracy (higher is better)

- Similar A/B
- Dissimilar A/B

Legend:
- Reference
- Mean AnB, random splits
- Mean AnB, m/n split
Layer $n$ at which network is chopped and retrained

Relative top-1 accuracy (higher is better)

- Similar A/B
- Dissimilar A/B
- Random

Reference

Mean AnB, random splits

Mean AnB, m/n split

Random features

(Jarret et al. 2009)
Conclusions

Layer \( n \) at which network is chopped and retrained

Top-1 accuracy (higher is better)

- baseB
- selffer BnB
- selffer BnB+
- transfer AnB
- transfer AnB+

Relative top-1 accuracy (higher is better)

- reference
- mean AnB, random splits
- mean AnB, m/n split
- random features

fine-tuning helps
co-adaptation
specificity

fine-tuning helps
co-adaptation
specificity

reference
mean AnB, random splits
mean AnB, m/n split
random features
Conclusions

- Measure general to specific transition layer by layer
Conclusions

- Measure *general* to *specific* transition layer by layer
- Transferability governed by:
• Measure general to specific transition layer by layer

• Transferability governed by:
  • lost co-adaptations
Conclusions

- Measure general to specific transition layer by layer
- Transferability governed by:
  - lost co-adaptations
  - specificity
Conclusions

- Measure *general* to *specific* transition layer by layer
- Transferability governed by:
  - lost co-adaptations
  - specificity
  - difference between base and target dataset
Conclusions

- Measure *general* to *specific* transition layer by layer
- Transferability governed by:
  - lost co-adaptations
  - specificity
  - difference between base and target dataset
- Fine-tuning helps even on large target dataset