DEEP NETWORKS WITH DENSE CONNECTIVITY

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Part I

What is the weakness of deep learning?
VERY DEEP NETWORKS

Input 

Convolution 

Max, ReLU 

Fully connected
It's a car!!

training
TELEPHONE

(input)

testing

It’s a bar!!
(output)
VERY DEEP NETWORKS

- More likely with more layers.
- Undetectable during training.

But you can **reduce the impact of bad layers**!
RESIDUAL NETWORKS

Layers still work too perfectly during training.

ResNet Architecture: [He, Zhang, Ren, Sun, CVPR’16]
STOCHASTIC DEPTH
STOCHASTIC DEPTH

minibatch 1

minibatch 2
STOCHASTIC DEPTH

minibatch 1

minibatch 2

minibatch 3

...
STOCHASTIC DEPTH

minibatch 1

minibatch 2

minibatch 3

...
STOCHASTIC DEPTH
Implicit ensemble of $2^L$ models
STOCHASTIC DEPTH

- Improved information flow
  - Short during training
  - Deep during testing

Training data

Test data
STOCHASTIC DEPTH

Improved information flow

Training data: short during training

Test data: deep during testing
STOCHASTIC DEPTH

25% speedup during training

improved information flow

training data

short during training

test data

deep during testing
Why does Deep Learning work so well on Images?
Claim 1: Images lie on a sub-manifold
MANIFOLD HYPOTHESIS

Claim 2: Deep Nets learn the Image Manifold
Experiment: Does linear interpolation in activation space generate a path of images.
1. DEEP FEATURE SPACE

VGG Network:
- 19 layers deep
- 5 Max Pooling Layers
- 144 Million parameters
- trained on ImageNet

[Simonyan and Zisserman, 2014]
2. DEEP FEATURE INTERPOLATION

Can Interpolation make shaven me bearded?

[Celeb A, Liu et al.]
2. DEEP FEATURE INTERPOLATION

Can Interpolation make shaven me bearded?
2. DEEP FEATURE INTERPOLATION

Can Interpolation make shaven me bearded?
3. PICTURE RECONSTRUCTION

Reconstruct a plausible image.

[Gatys et al. 2015]
CHANGING FACES

original
<table>
<thead>
<tr>
<th>Original</th>
<th>Beard</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Original Image 1" /> <img src="image2" alt="Original Image 2" /></td>
<td><img src="beard_image1" alt="Beard Image 1" /> <img src="beard_image2" alt="Beard Image 2" /></td>
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<td><img src="beard_image5" alt="Beard Image 5" /> <img src="beard_image6" alt="Beard Image 6" /></td>
</tr>
</tbody>
</table>
BEARDED BOY
BEARDED BOY
LIMITATIONS
CONCLUSION

Use ResNets with Stochastic Depth!
- lower training time
- lower testing error

Try out Dense Connectivity!
- Explicit long term connections
- Best generalization performance
Why does Deep Learning work so well on Images?

Maybe because Deep Networks linearize parts of the manifolds of natural images.