ConvLens:
Visualizing Internal Components of Convolutional Neural Networks

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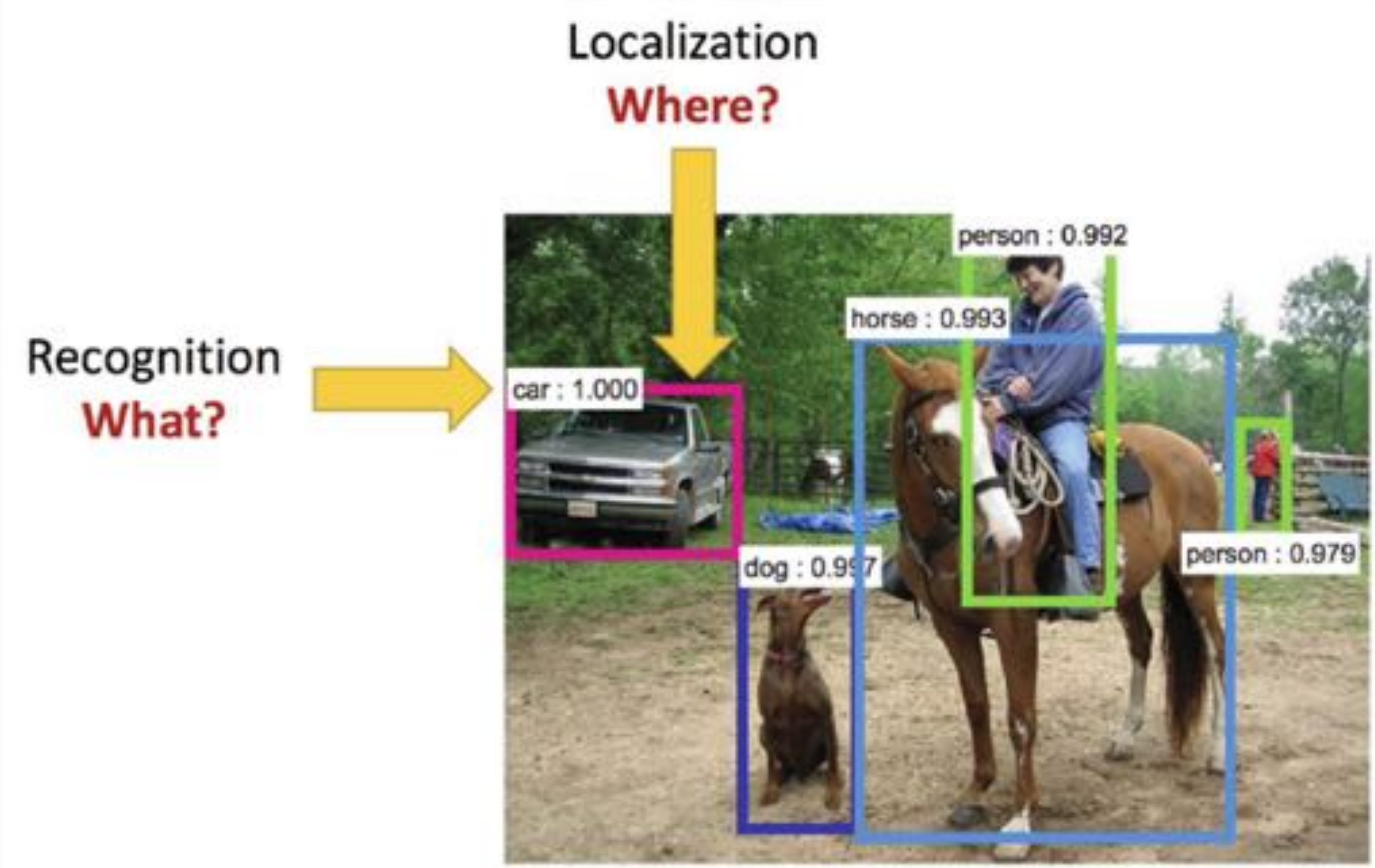
INTRODUCTION

What's a ConvNet?

- a Supervised Machine Learning Algorithm

- Used in:
  - Image and Video Recognition
  - Recommender Systems
  - Natural Language Processing

Recognition + Localization



Source: Kaiming He, ICCV 2015

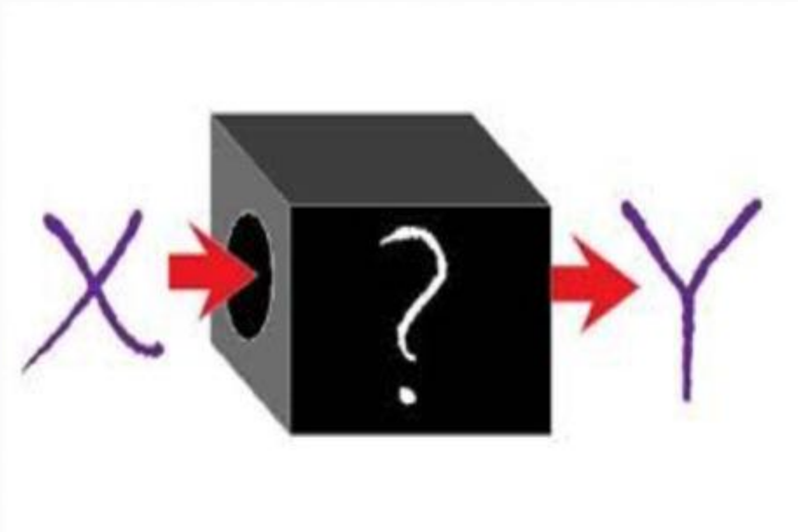
Image Captioning

Source: Kuarrpaeth y1 an9d F-e i-8Fei, "Deep Visual-Semantic Alignments for Generating Imag6e D eDsceripctio n2s",0 CV1P6R 2015

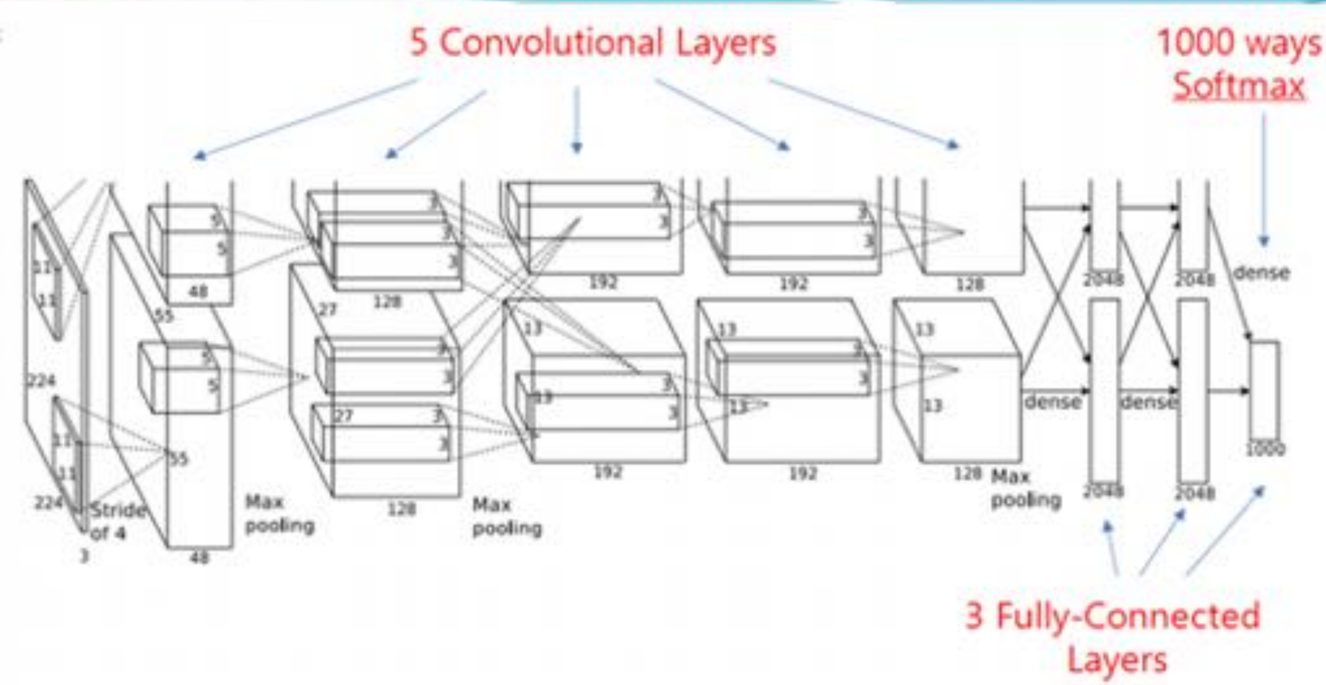
Problem

"Neural networks have long been known as "black boxes" because it is difficult to understand exactly how any particular, trained neural network functions due to **the large number of interacting, non-linear parts**."

Yajin Zhou



A l e x n e t



[227x227x3] INPUT
[55x55x96] CONV1: 96 11x11 filters at stride 4, pad 0
[27x27x96] MAX POOL1: 3x3 filters at stride 2
[27x27x96] NORM1: Normalization layer
[27x27x256] CONV2: 256 5x5 filters at stride 1, pad 2
[13x13x256] MAX POOL2: 3x3 filters at stride 2
[13x13x256] NORM2: Normalization layer
[13x13x384] CONV3: 384 3x3 filters at stride 1, pad 1
[13x13x384] CONV4: 384 3x3 filters at stride 1, pad 1
[13x13x256] CONV5: 256 3x3 filters at stride 1, pad 1
[6x6x256] MAX POOL3: 3x3 filters at stride 2

VggNet

ConvNet Configuration					
A	A-LRN	B	C	D	E
11 weight layers	11 weight layers	13 weight layers	16 weight layers	16 weight layers	19 weight layers
input (224 × 224 RGB image)					
conv3-64	conv3-64 **LRN**	conv3-64 **conv3-64**	conv3-64 conv3-64	conv3-64 conv3-64	conv3-64 conv3-64
maxpool					
conv3-128	conv3-128	conv3-128 **conv3-128**	conv3-128 conv3-128	conv3-128 conv3-128	conv3-128 conv3-128
maxpool					
conv3-256 conv3-256	conv3-256 conv3-256	conv3-256 conv3-256	conv3-256 conv3-256 **conv1-256**	conv3-256 conv3-256 **conv3-256**	conv3-256 conv3-256 conv3-256 **conv3-256**
maxpool					
conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512 **conv1-512**	conv3-512 conv3-512 **conv3-512**	conv3-512 conv3-512 conv3-512 **conv3-512**
maxpool					
conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512 **conv1-512**	conv3-512 conv3-512 **conv3-512**	conv3-512 conv3-512 conv3-512 **conv3-512**
maxpool					
FC-4096					
FC-4096					
FC-1000					
soft-max					

The 6 different architecures of VGG Net. Configuration D produced the best results

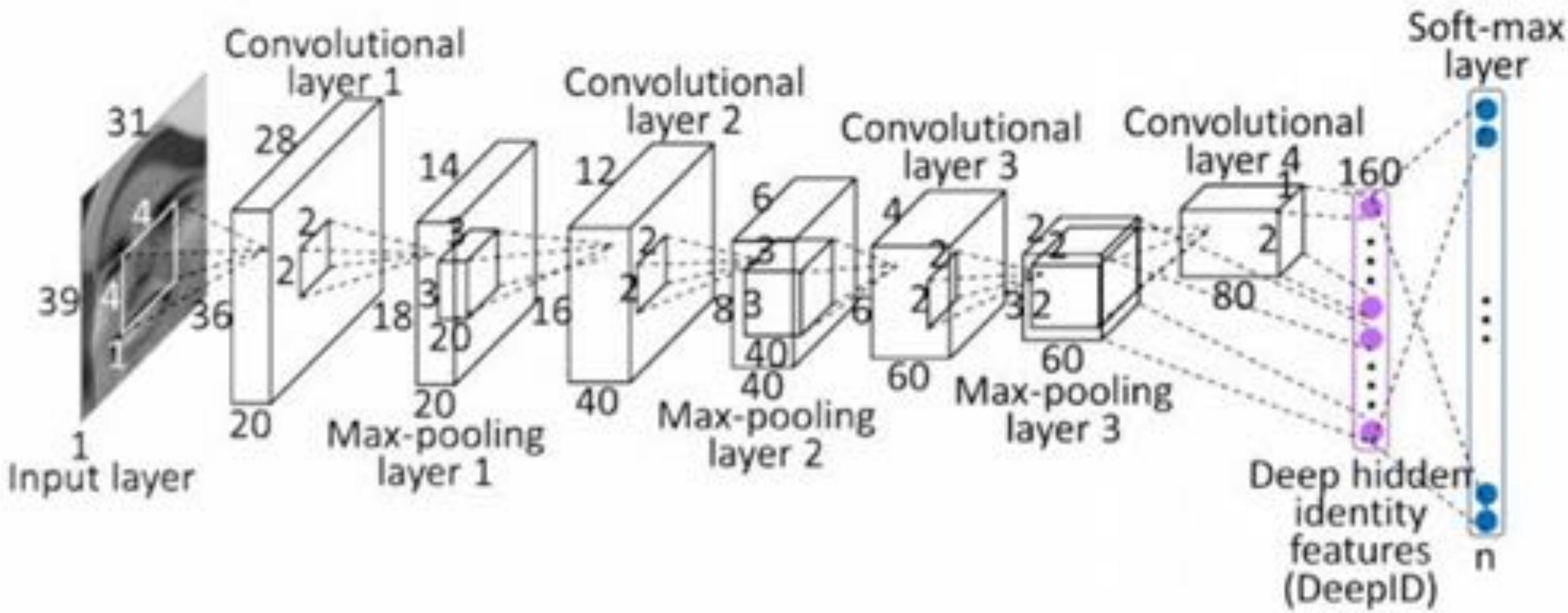
Source: Simonyan and Zisserman, ArXiv 2014

To Optimize a ConvNet:

1. Need to understand its structure
2. Need to know what it has learned given its training

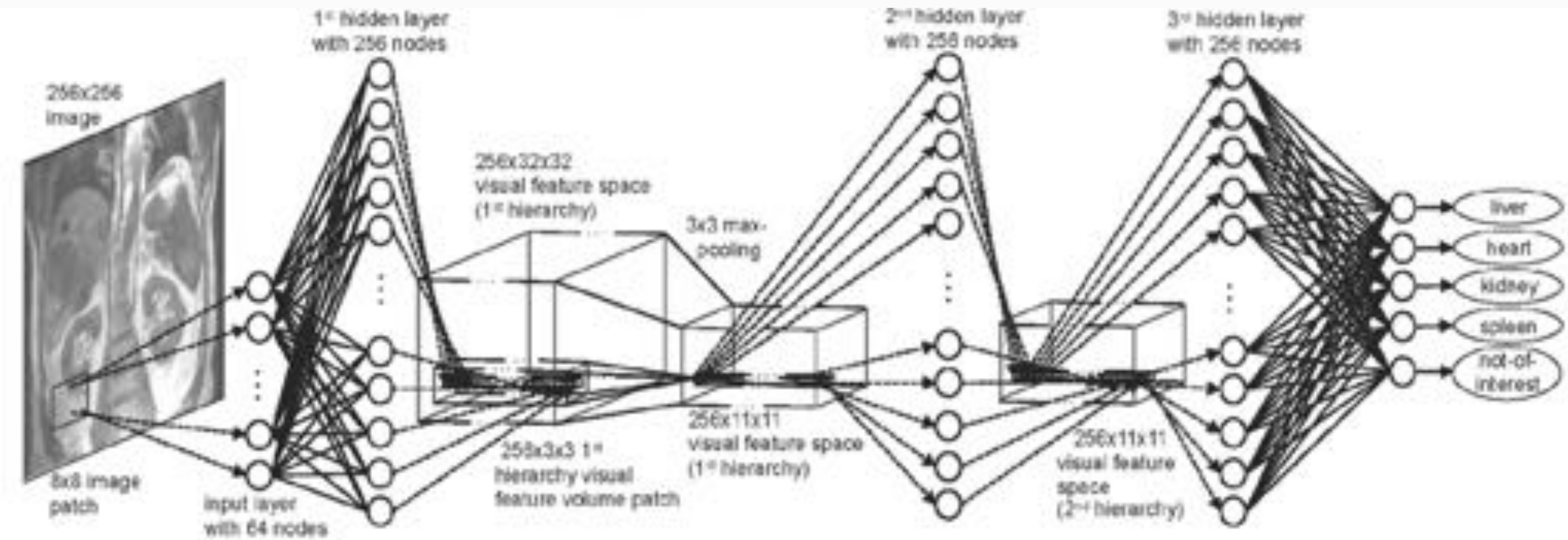
Existing Visualizations

Structure: Mental Model



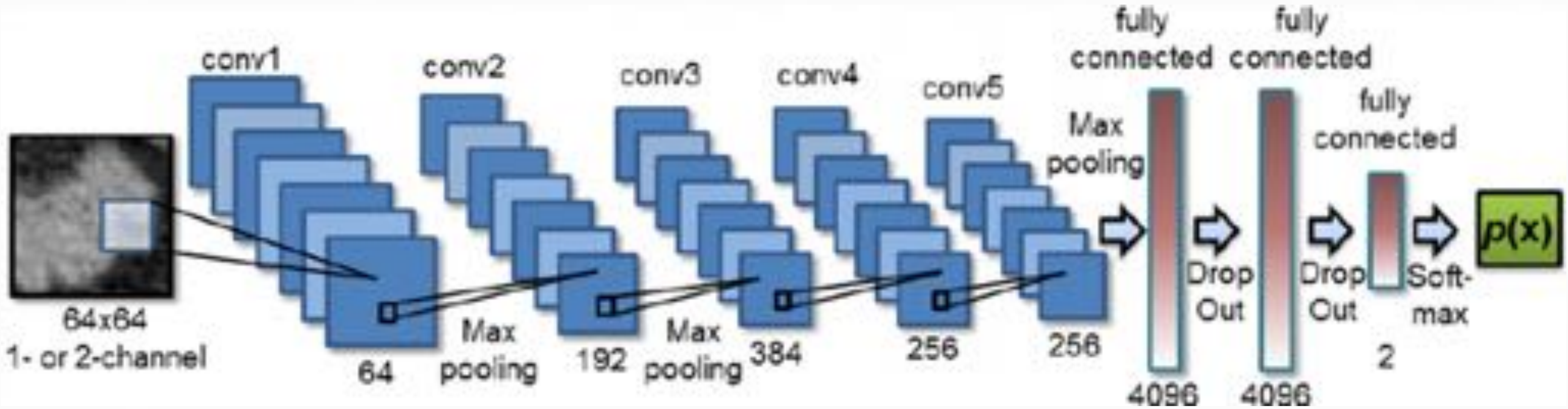
Source: Krizhevsky, Alex, 2013

Structure: Too Much



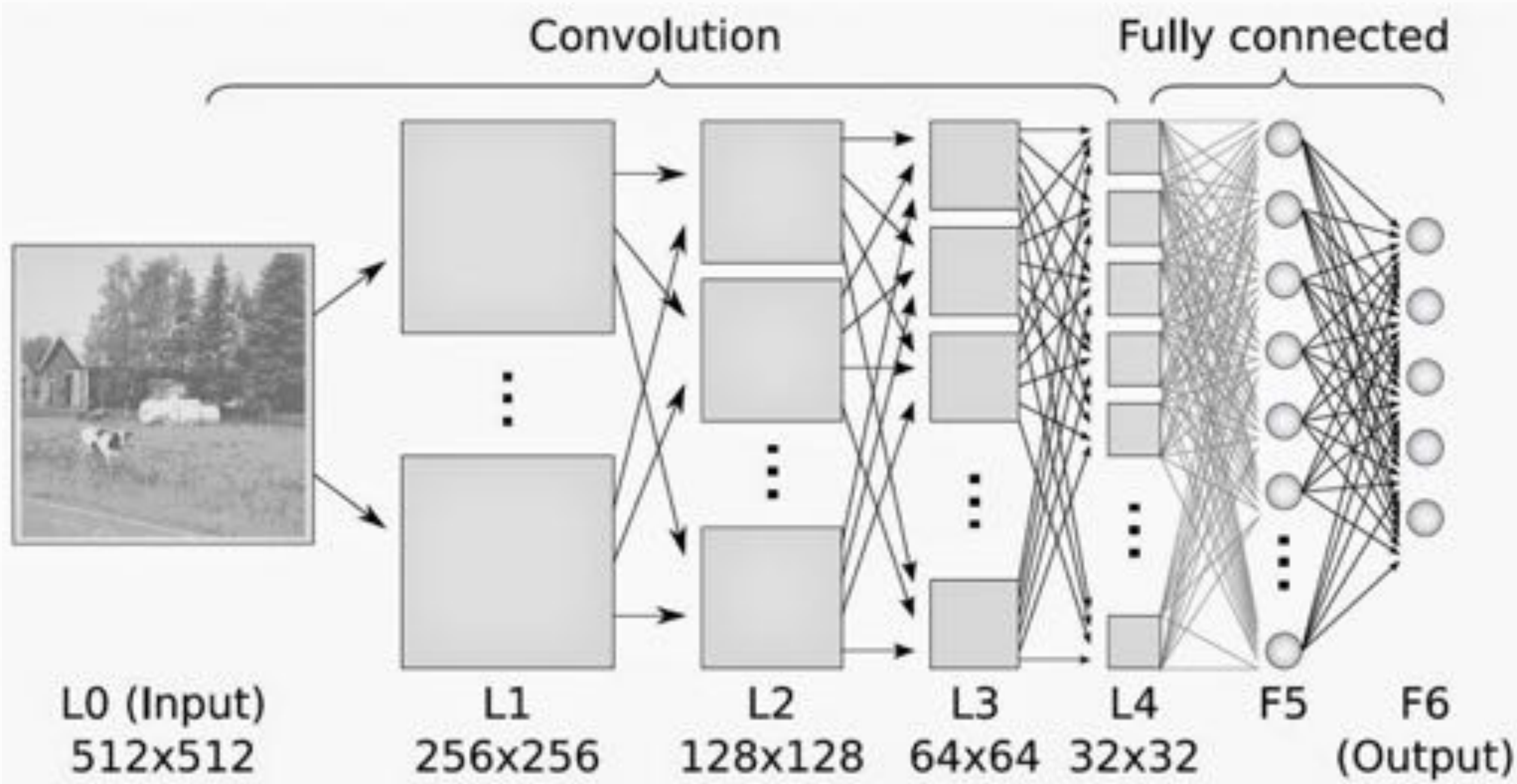
Source: Hoo-Chang Shin, IEEE 2013

Structure: Too Little



Source: Holger R. Roth, ArXiv 2015

Structure: Seems Right

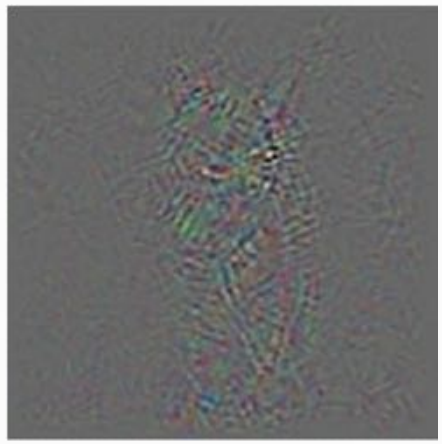


Source: Sven Behnke, 2013

Learning: Forward Activation

Learning: Guided Back Propagation

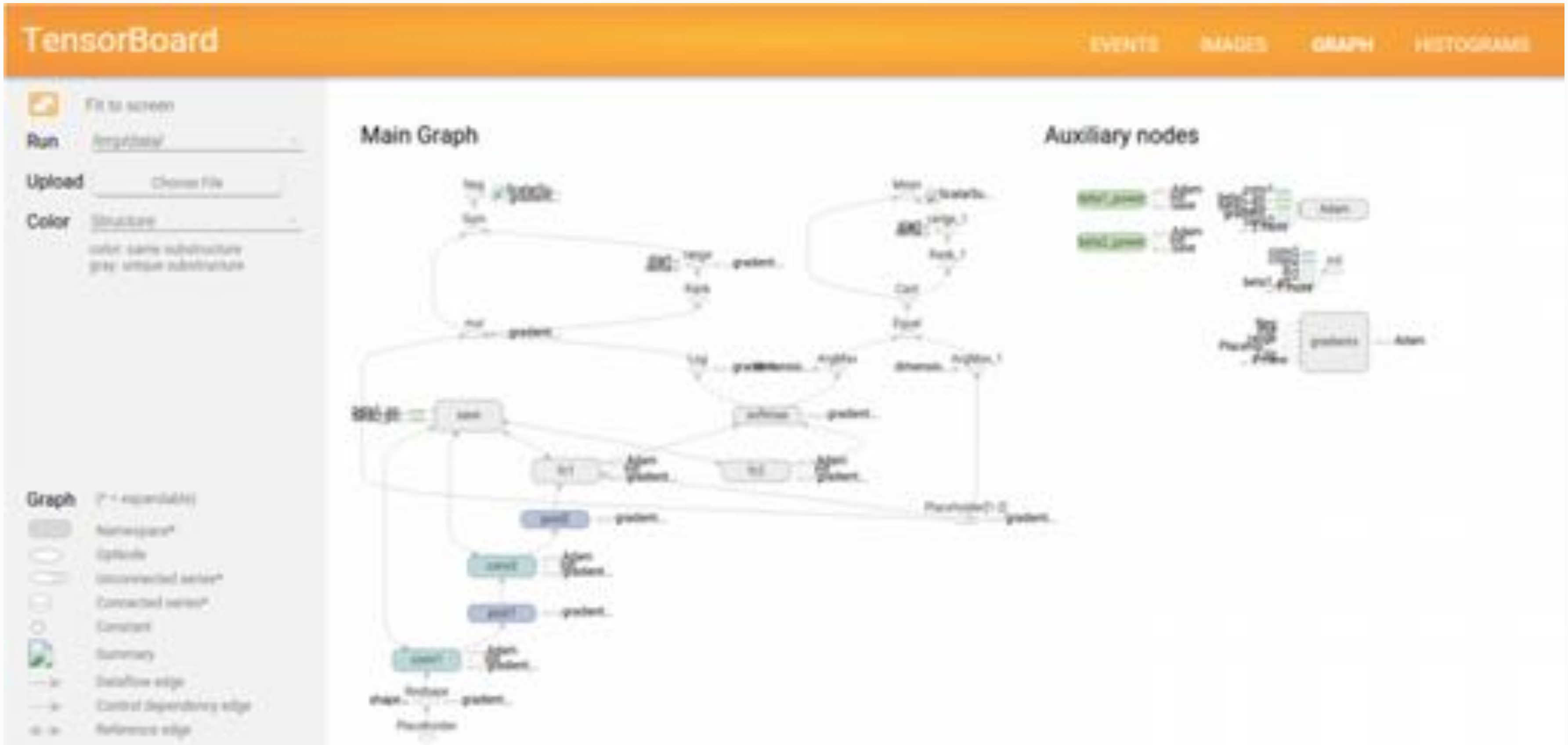
Input



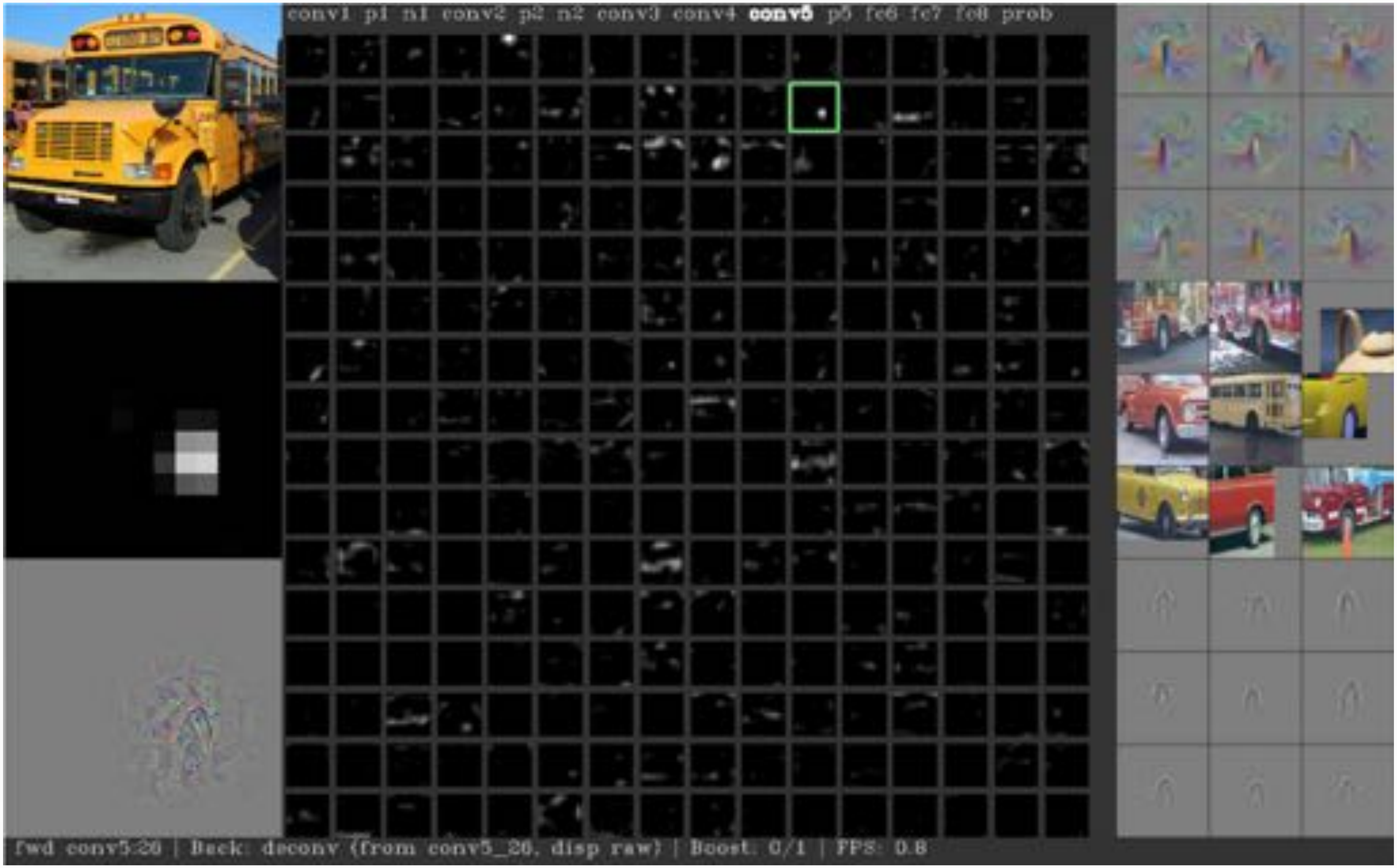
BackPropagation

Guided BackProp

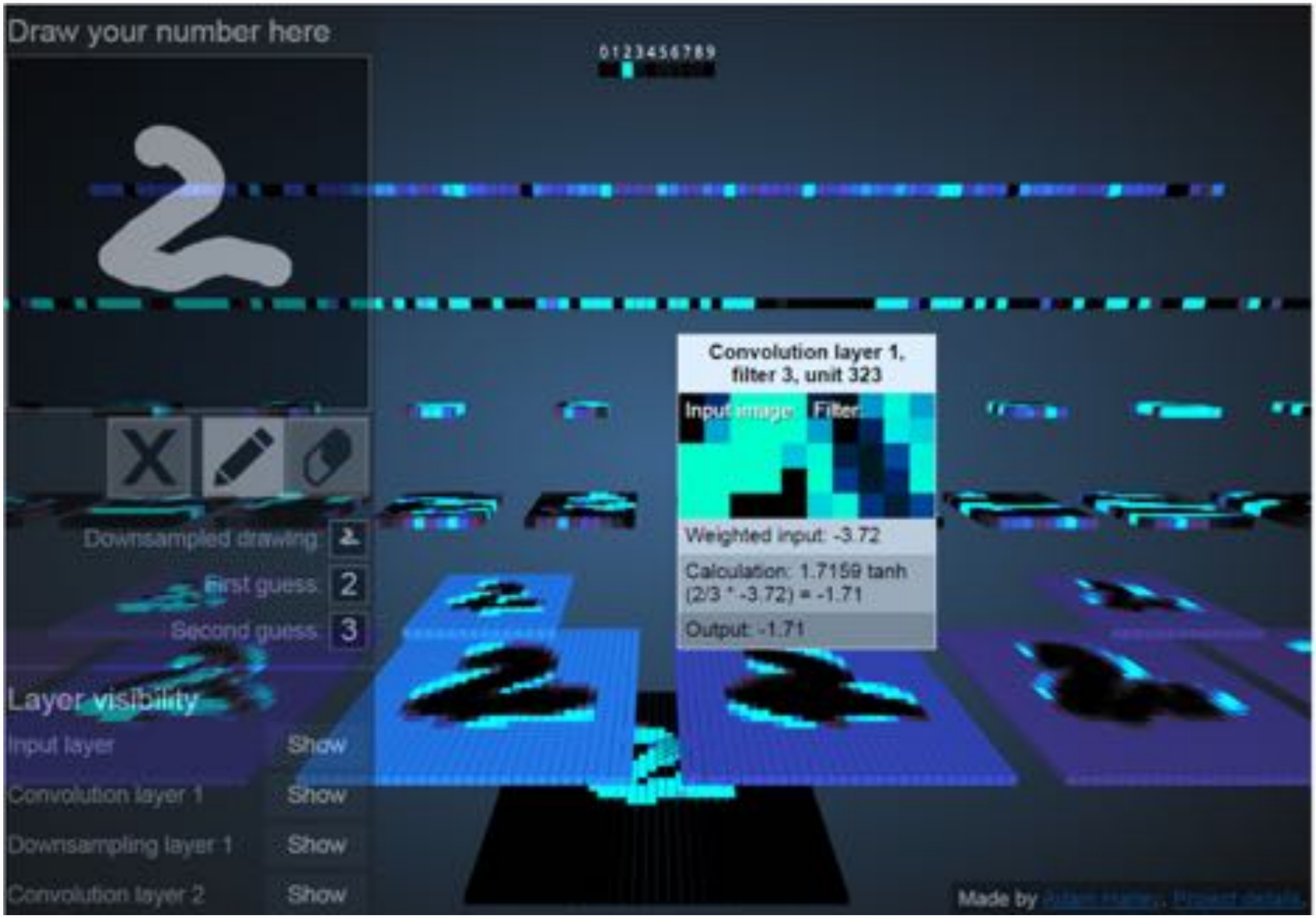
Existing Tools: TensorBoard



Existing Tools: VisToolBox

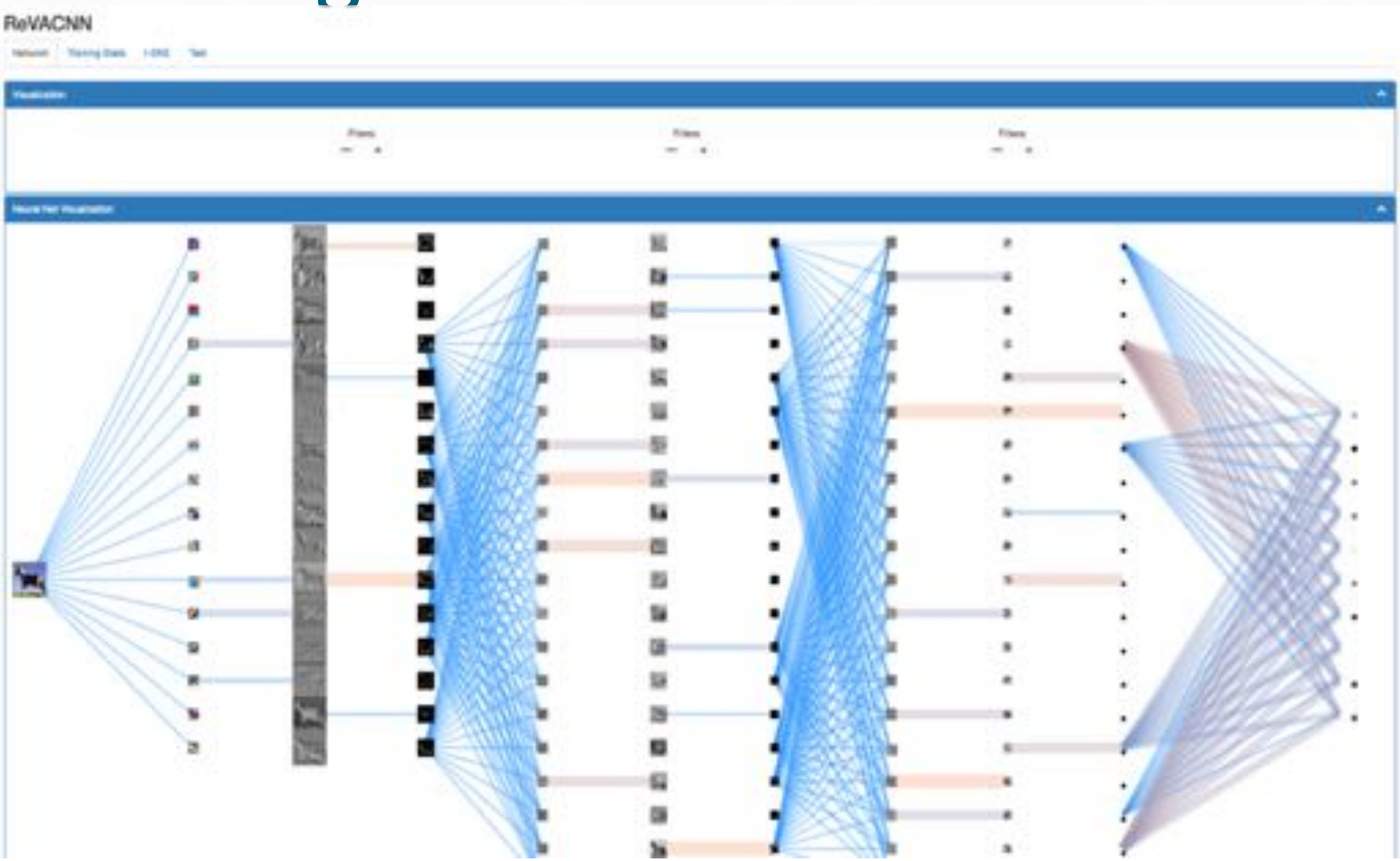


Existing Tools: Harley's



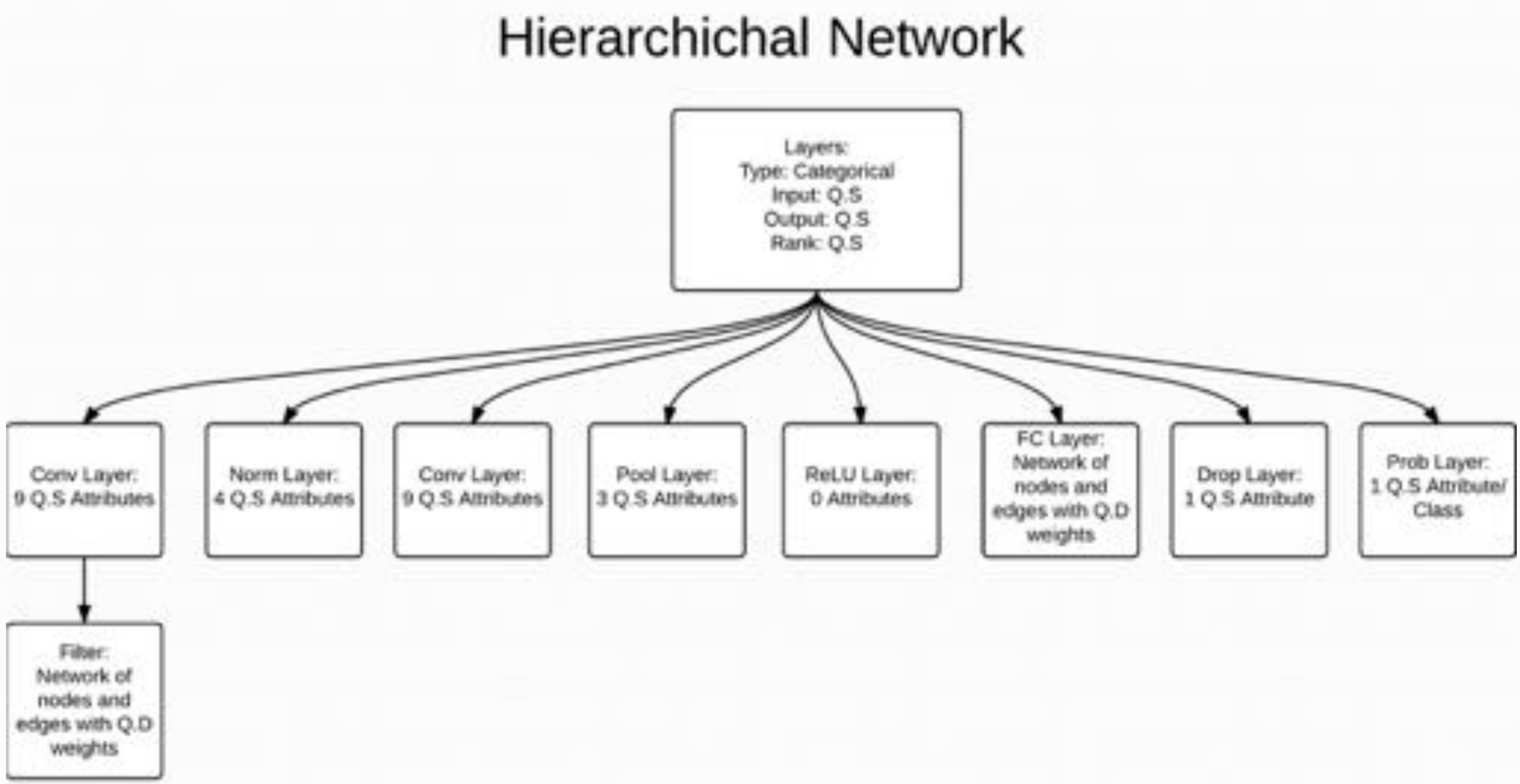
Existing Tools: CNNVis

Existing Tools: ReVACNN



Our Design Process

What: Data



Hierarchichal Network
Layers:
Type: Categorical
Input: Q.S
Output: Q.S
Rank: Q.S
Conv Layer:
9 Q.S Attributes
Norm Layer:
4 Q.S Attributes
Conv Layer:
9 Q.S Attributes
Pool Layer:
3 Q.S Attributes
ReLU Layer:
0 Attributes
FC Layer:
Network of nodes and edges with Q.D weights
Drop Layer:
1 Q.S Attribute
Prob Layer:
1 Q.S Attribute/ Class
Filter:
Network of nodes and edges with Q.D weights

What: Derived

- **For each Filter:**
  - **Activation Images: Diverging**
  - **Guided Back Propagation: Sequential**

Why: Tasks

- **Explore → Summarize**
  - Over all Architecture of ConvNet
  - Parameters in each layer
- **Locate → Identify**
  - Filters that have learned useful features
  - Filters that are useless

Demo

How: Encode

- Layers: Nodes in a chain
- Rank: Position in the chain, text label on the node
- Output size: Text Label on chain links
- All other attributes: Extra information on click
- Filter number (inside a conv layer): Text label and position in the stack of images.

How: Facet

- Juxtaposed and Coordinate Side-by-Side Views
- Shared data (Magnified, and related content)

How: Manipulate

- Select
  - a layer to show more details for
  - a specific filter to show more details for
  - A filter visualization method to be used for the overview of filters
- Annotate useful/ useless filters

How: Aggregate

- Aggregation: Grouped all the nodes with the same depth into a single layer
- Aggregation: Grouped the information contained in all nodes and edges of each filter into a single image
- Filtering: Eliminated low probability outcomes from Prob Layers.

How: Reduce

- Our Guided BackPropagation reduces the data by eliminating negative weights

How: Scale

- Layers: Hundreds
  - No limit on the complexity of layers.
- Filters: Hundreds
  - No limit on the complexity of the NN inside filters.

Future Works & Limitations

- More dynamic front-end for screens with different aspect ratios
- Display the filter visualization images in a sorted order according to the importance of the filter.
  - Importance is implied by the sizes of weights in each filter.
- Find a meaningful visualization for the Fully Connected layers.
  - Deep Dream is one possible solution, but it only shows what the network has learned during training.
- Integrate the data generation tools (scripts) into ConvLens.
  - This requires heavy computation on the server side.