



DEEP
LEARNING
INSTITUTE

Image Classification with DIGITS

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DEEP LEARNING INSTITUTE

DLI Mission

Helping people solve challenging problems using AI and deep learning.

- Developers, data scientists and engineers
- Self-driving cars, healthcare and robotics
- Training, optimizing, and deploying deep neural networks

TOPICS

- Lab Perspective
- What is Deep Learning
- Handwritten Digit Recognition
- Caffe
- DIGITS
- Lab
 - Discussion / Overview
 - Launching the Lab Environment
 - Lab Review

LAB PERSPECTIVE

WHAT THIS LAB IS

- An introduction to:
 - Deep Learning
 - Workflow of training a network
 - Understanding the results
- Hands-on exercises using Caffe and DIGITS for computer vision and classification

WHAT THIS LAB IS NOT

- Intro to machine learning from first principles
- Rigorous mathematical formalism of neural networks
- Survey of all the features and options of Caffe, DIGITS, or other tools

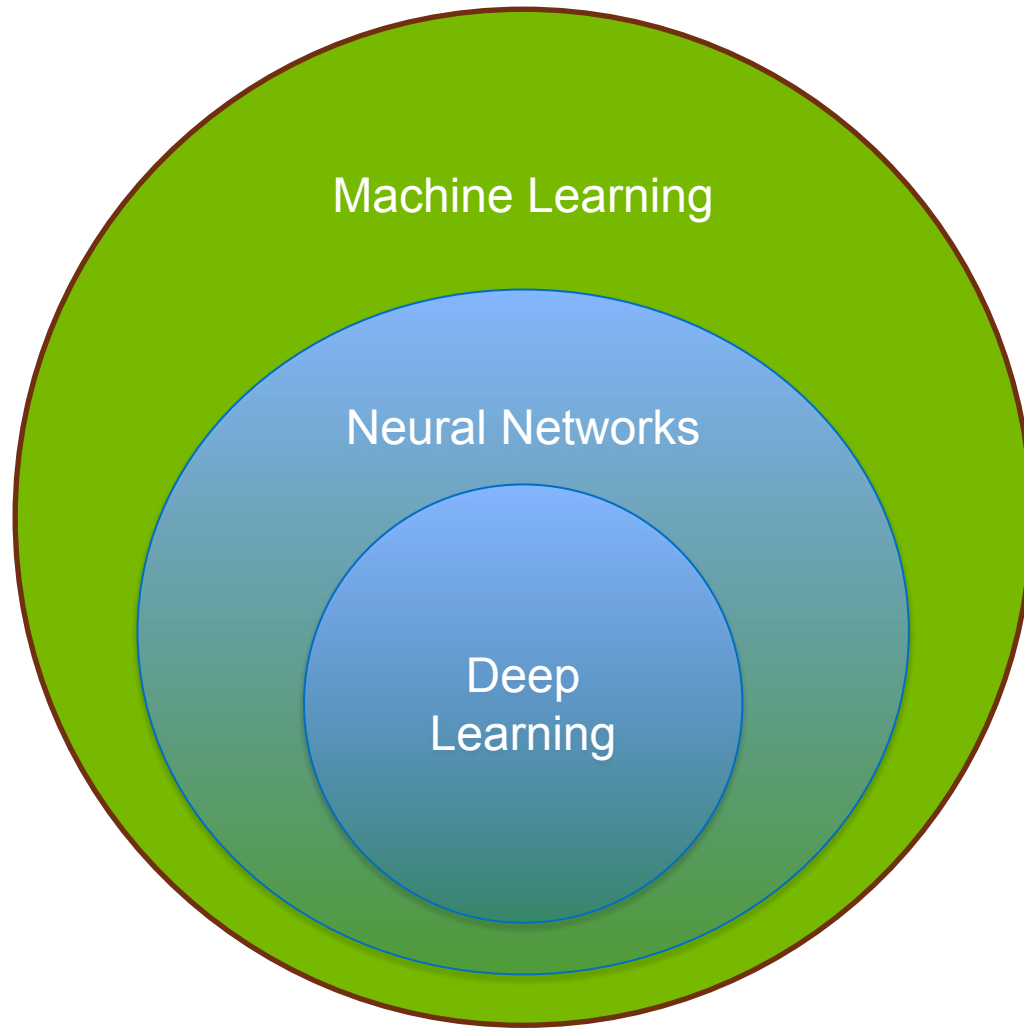
ASSUMPTIONS

- No background in Deep Learning needed
- Understand how to:
 - Navigate a web browser
 - Download files
 - Locate files in file managers

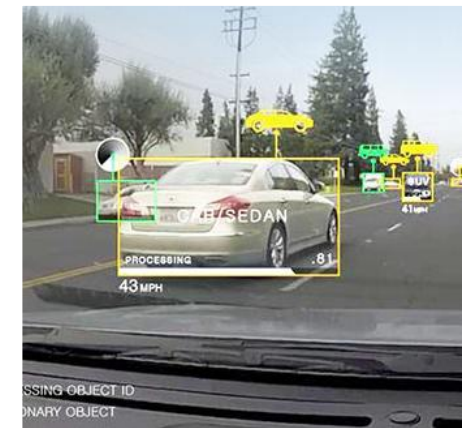
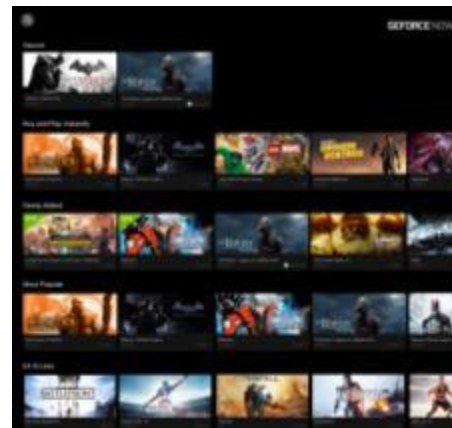
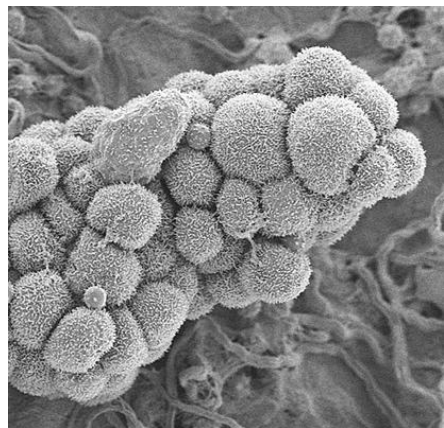
TAKE AWAYS

- Understanding of the workflow of Deep Learning
- Ability to setup and train a convolutional neural network
- Enough info to be “dangerous”
 - i.e., you can setup your own CNN and know where to go to learn more

WHAT IS DEEP LEARNING?



DEEP LEARNING EVERYWHERE



INTERNET & CLOUD

Image Classification
Speech Recognition
Language Translation
Language Processing
Sentiment Analysis
Recommendation

MEDICINE & BIOLOGY

Cancer Cell Detection
Diabetic Grading
Drug Discovery

MEDIA & ENTERTAINMENT

Video Captioning
Video Search
Real Time Translation

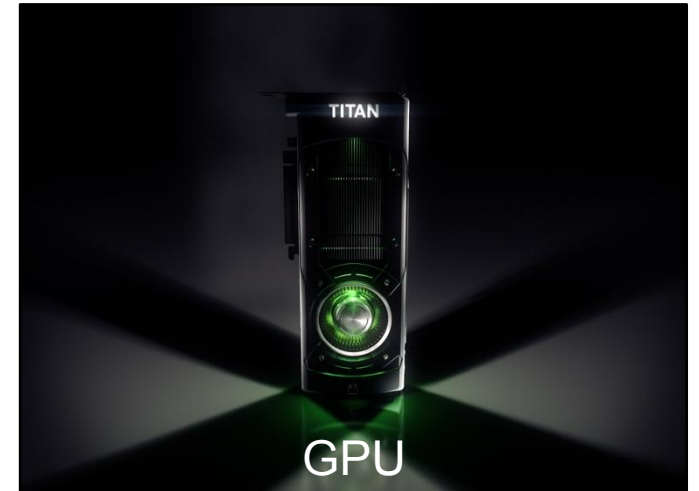
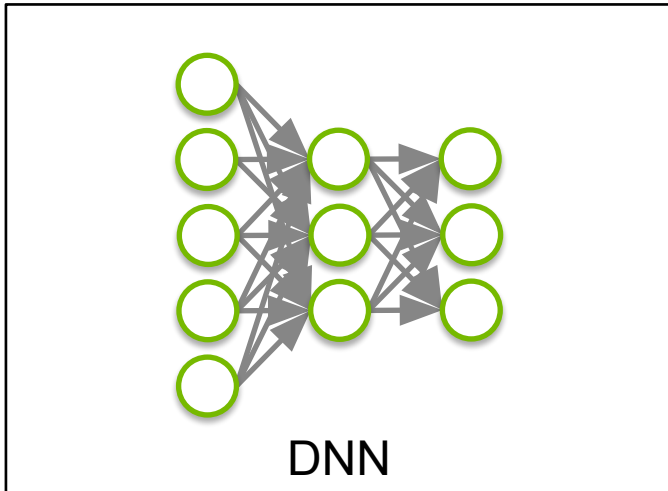
SECURITY & DEFENSE

Face Detection
Video Surveillance
Satellite Imagery

AUTONOMOUS MACHINES

Pedestrian Detection
Lane Tracking
Recognize Traffic Sign

THE BIG BANG IN MACHINE LEARNING

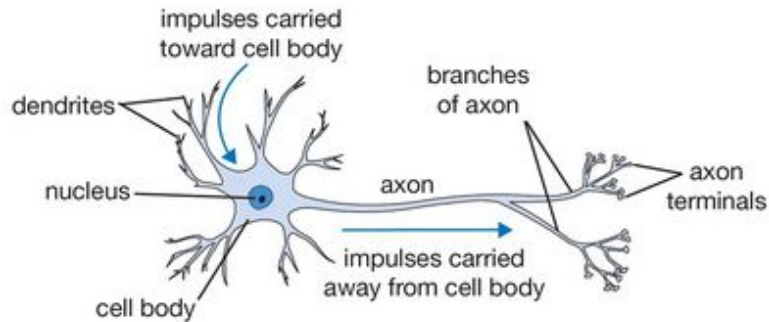


“ Google’s AI engine also reflects how the world of computer hardware is changing. (It) depends on machines equipped with GPUs... And it depends on these chips more than the larger tech universe realizes.”

WIRED

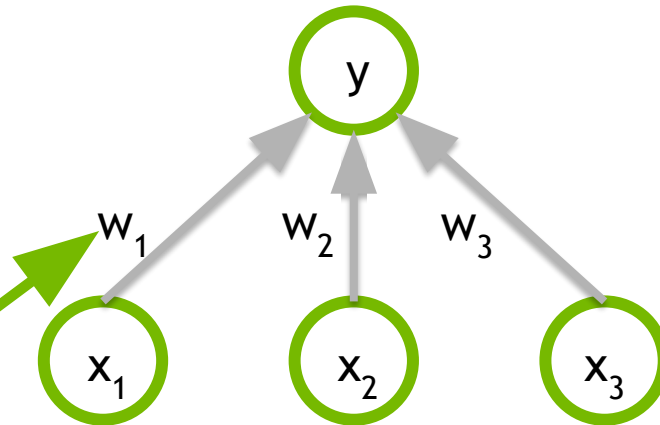
ARTIFICIAL NEURONS

Biological neuron



From Stanford cs231n lecture notes

Artificial neuron

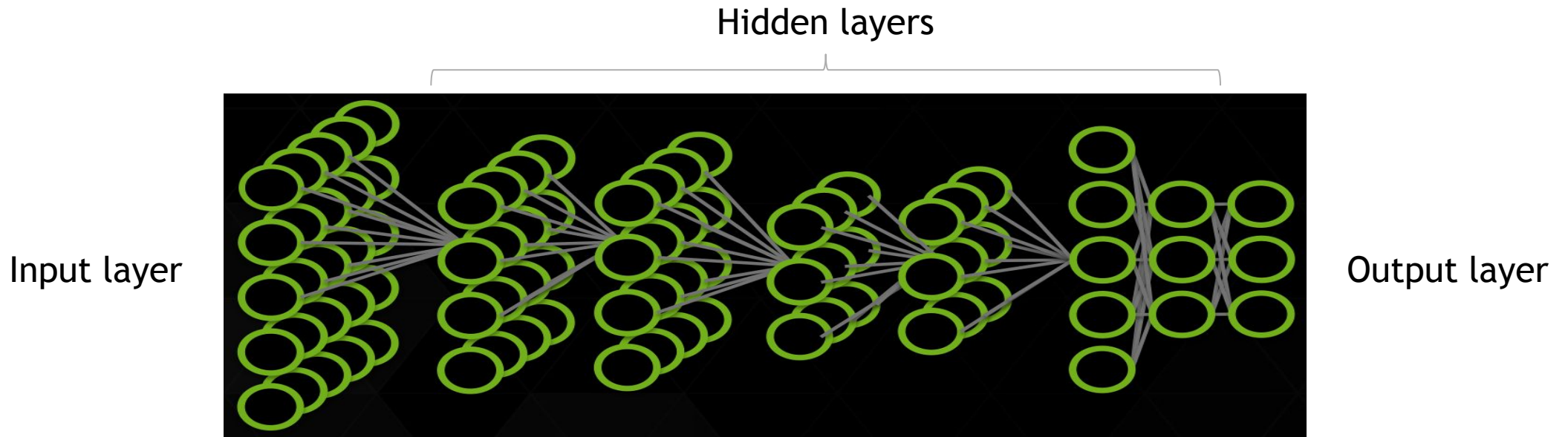


Weights (w_n)
= parameters

$$y = F(w_1x_1 + w_2x_2 + w_3x_3)$$

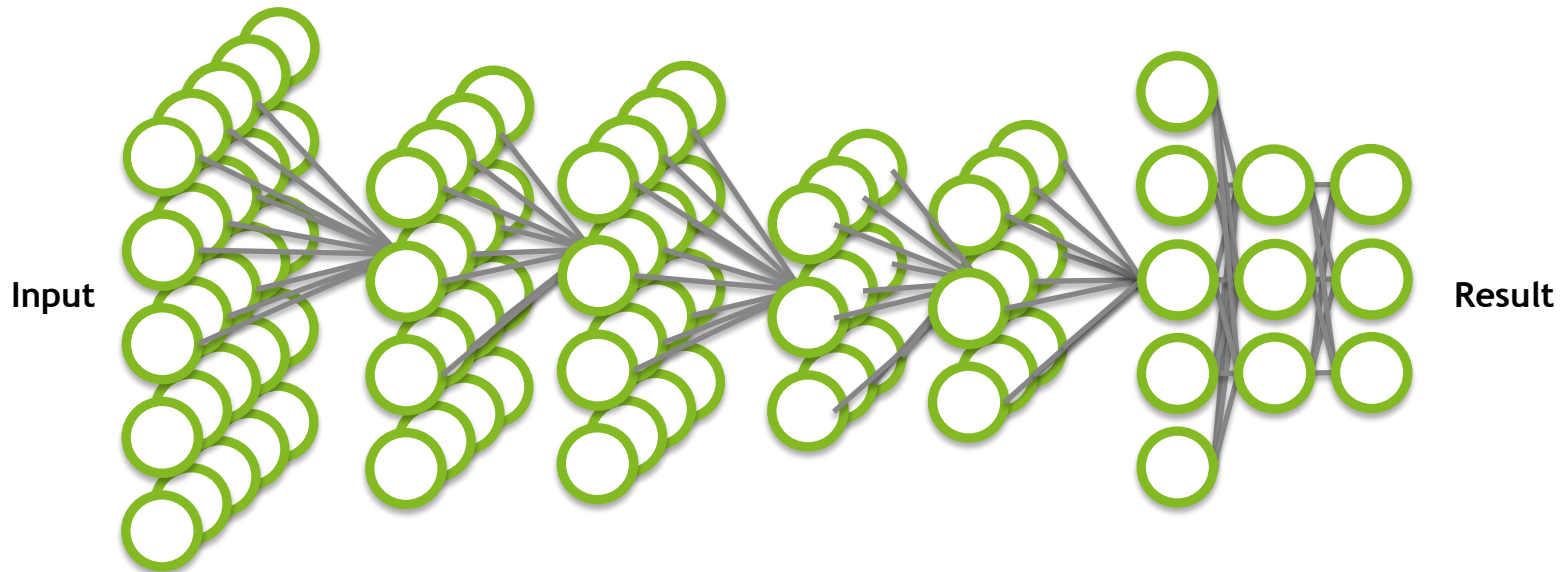
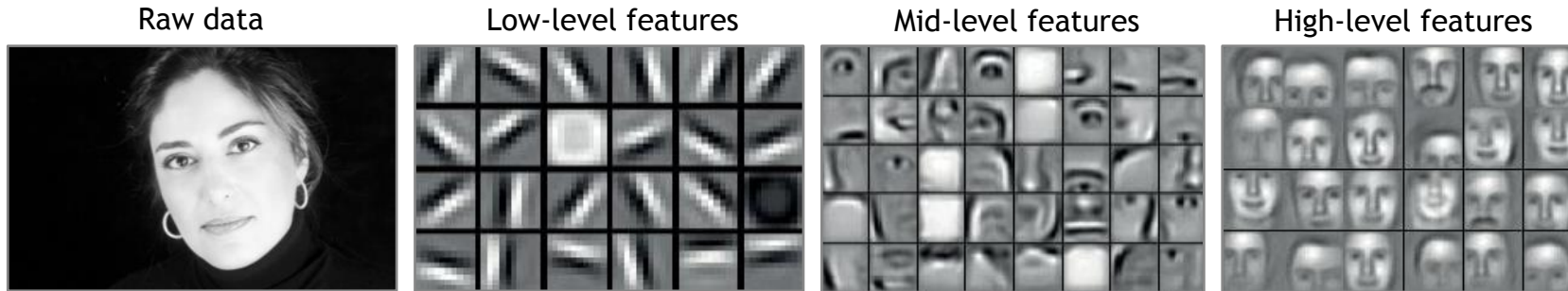
ARTIFICIAL NEURAL NETWORK

A collection of simple, trainable mathematical units that collectively learn complex functions



Given sufficient training data an artificial neural network can approximate very complex functions mapping raw data to output decisions

DEEP NEURAL NETWORK (DNN)



Application components:

Task objective
e.g. Identify face

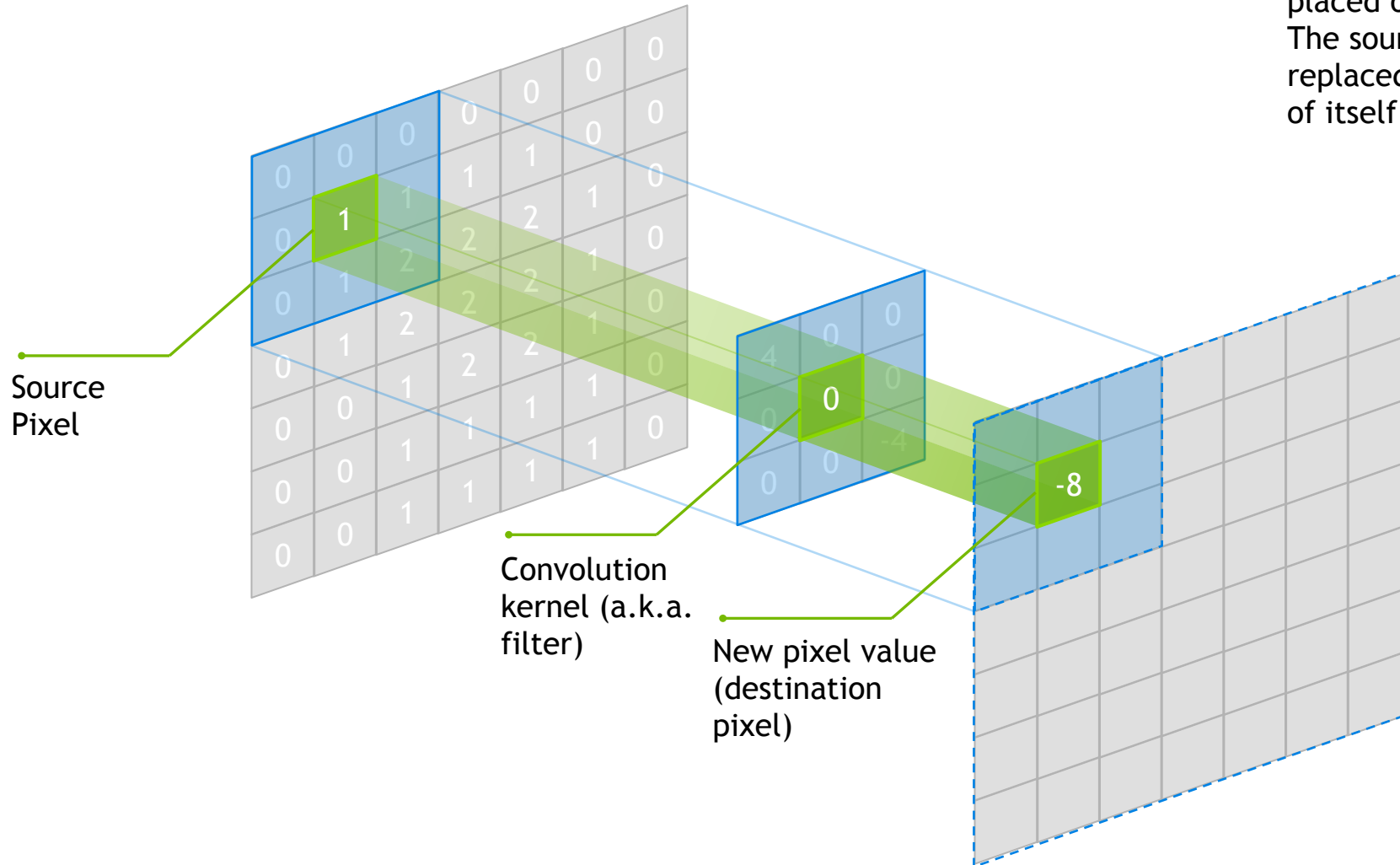
Training data
10-100M images

Network architecture
~ 10s-100s of layers
1B parameters

Learning algorithm
~ 30 Exaflops
1-30 GPU days

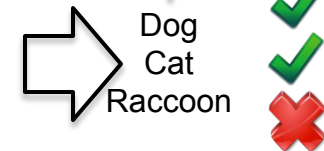
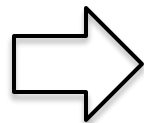
CONVOLUTION

Center element of the kernel is placed over the source pixel. The source pixel is then replaced with a weighted sum of itself and nearby pixels.

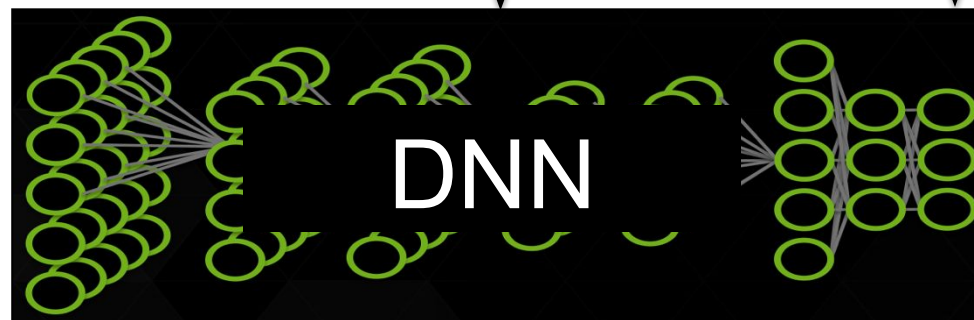
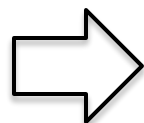


DEEP LEARNING APPROACH

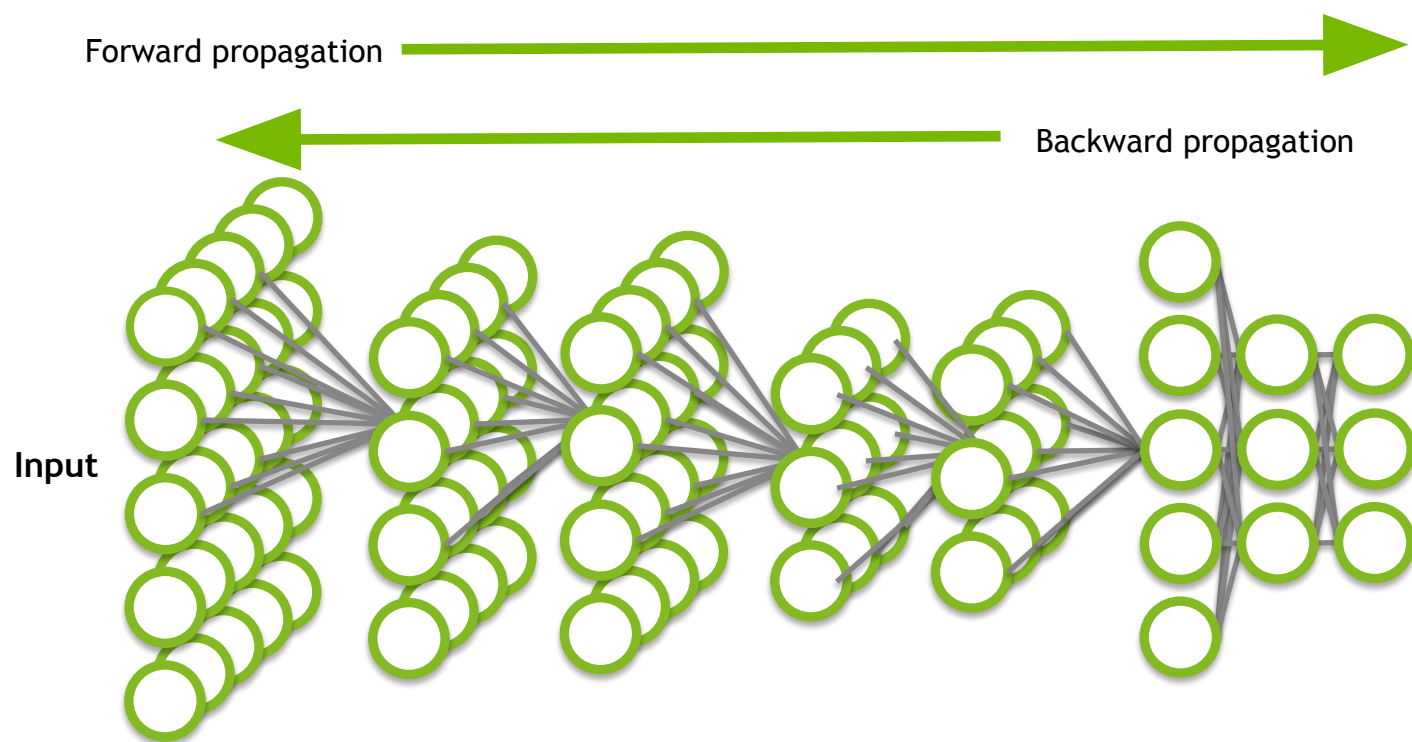
Train:



Deploy:



DEEP LEARNING APPROACH - TRAINING



Process

- Forward propagation yields an inferred label for each training image
- Loss function used to calculate difference between known label and predicted label for each image
- Weights are adjusted during backward propagation
- Repeat the process

ADDITIONAL TERMINOLOGY

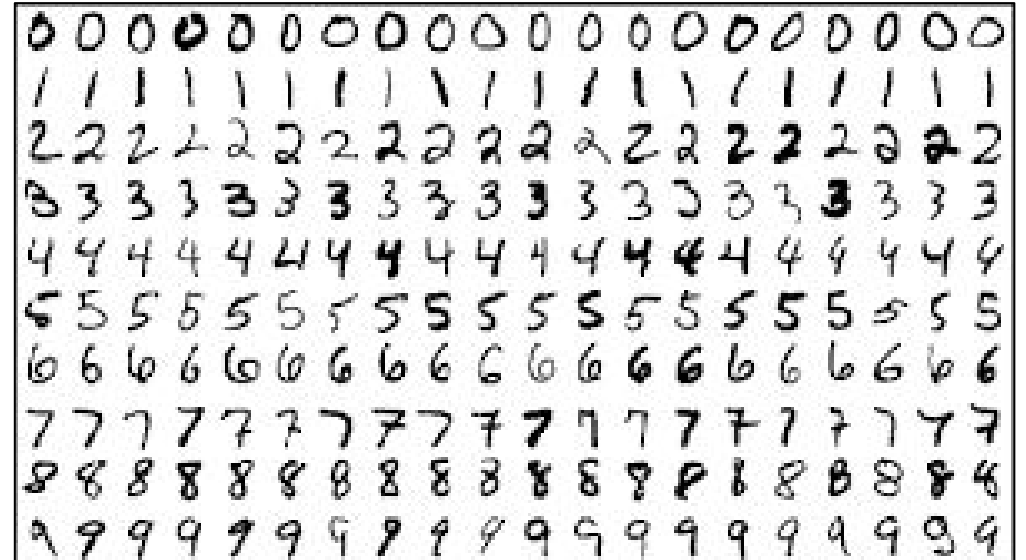
- Hyperparameters - parameters specified before training begins
 - Can influence the speed in which learning takes place
 - Can impact the accuracy of the model
 - Examples: Learning rate, decay rate, batch size
- Epoch - complete pass through the training dataset
- Activation functions - identifies active neurons
 - Examples: Sigmoid, Tanh, ReLU
- Pooling - Down-sampling technique
 - No parameters (weights) in pooling layer

HANDWRITTEN DIGIT RECOGNITION

HANDWRITTEN DIGIT RECOGNITION

HELLO WORLD of machine learning?

- MNIST data set of handwritten digits from Yann Lecun's website
- All images are 28x28 grayscale
 - Pixel values from 0 to 255
- 60K training examples / 10K test examples
- Input vector of size 784
 - $28 * 28 = 784$
- Output value is integer from 0-9



CAFFE

WHAT IS CAFFE?

An open framework for deep learning developed by the Berkeley Vision and Learning Center (BVLC)



- Pure C++/CUDA architecture
- Command line, Python, MATLAB interfaces
- Fast, well-tested code
- Pre-processing and deployment tools, reference models and examples
- Image data management
- Seamless GPU acceleration
- Large community of contributors to the open-source project

caffe.berkeleyvision.org
<http://github.com/BVLC/caffe>

CAFFE FEATURES

Deep Learning model definition

Protobuf model format

- Strongly typed format
- Human readable
- Auto-generates and checks Caffe code
- Developed by Google
- Used to define network architecture and training parameters
- No coding required!

```
name: "conv1"  
type: "Convolution"  
bottom: "data"  
top: "conv1"  
convolution_param {  
    num_output: 20  
    kernel_size: 5  
    stride: 1  
    weight_filler {  
        type: "xavier"  
    }  
}
```


NVIDIA'S DIGITS

NVIDIA'S DIGITS

Interactive Deep Learning GPU Training System

- Simplifies common deep learning tasks such as:
 - Managing data
 - Designing and training neural networks on multi-GPU systems
 - Monitoring performance in real time with advanced visualizations
- Completely interactive so data scientists can focus on designing and training networks rather than programming and debugging
- Open source

DIGITS - HOME

The screenshot shows the DIGITS Home interface. At the top, a dark navigation bar contains the 'DIGITS' logo on the left and 'ckillam (Logout)', 'Info', and 'About' on the right. Below the navigation bar, the word 'Home' is displayed in a large font. To the right of 'Home', the text '1/1 GPU available' is shown. The main content area features a status indicator 'No Jobs Running' and a set of tabs: 'Datasets (0)', 'Models (0)', 'Pretrained Models (0)', and a 'Rectangular Snip' button. Below the tabs, there is a 'Group Jobs' section with a checked checkbox and buttons for 'Delete' and 'Group'. A table below this section shows 'No Models' and has columns for 'name', 'framework', 'status', 'elapsed', and 'submitted'. On the right side of the page, there is a 'New Model' button with a dropdown menu currently showing 'Images'. Green circles and arrows highlight these key elements: the 'DIGITS' logo, the 'Home' text, the 'Datasets (0)' and 'Models (0)' tabs, the 'Group Jobs' checkbox, and the 'New Model' dropdown.

Clicking DIGITS will bring you to this Home screen

Click here to see a list of existing datasets or models

Clicking here will present different options for model and dataset creation

DIGITS - DATASET

New Object Detection Dataset

Object Detection Dataset Options

Images can be stored in any of the supported file formats (.png, .jpg, .jpeg, .bmp, .ppm).

Training image folder

Label files are expected to have the .txt extension. For example if an image file is named foo.png the corresponding label file should be foo.txt.

Training label folder

Validation image folder

Validation label folder

Pad image (Width x Height)

 x

Resize image (Width x Height)

 x

Channel conversion

Minimum box size (in pixels) for validation set

Custom classes

New Image Classification Dataset

Image Type

Image size (Width x Height)

 x

Resize Transformation

[See example](#)

Use Image Folder Use Text Files

Training Images

Minimum samples per class

Maximum samples per class

% for validation

% for testing

Separate validation images folder

Separate test images folder

DB backend

Image Encoding

Group Name

Dataset Name

[Create](#)

Different options will be presented based upon the task

DIGITS - MODEL

New Object Detection Model

Select Dataset

Python Layers

Server-side file

Use client-side file

Solver Options

Training epochs: 30

Snapshot interval (in epochs): 1

Validation interval (in epochs): 1

Random seed: [none]

Batch size: [network defaults] (multiples allowed)

Batch Accumulation

Solver type: Stochastic gradient descent (SGD)

Base Learning Rate: 0.01 (multiples allowed)

Show advanced learning rate options

Data Transformations

Subtract Mean: image

Crop Size: none

New Image Classification Model

Select Dataset

Python Layers

Server-side file

Use client-side file

Solver Options

Training epochs: 30

Snapshot interval (in epochs): 1

Validation interval (in epochs): 1

Random seed: [none]

Batch size: [network defaults] (multiples allowed)

Batch Accumulation

Solver type: Stochastic gradient descent (SGD)

Base Learning Rate: 0.01 (multiples allowed)

Show advanced learning rate options

Data Transformations

Subtract Mean: image

Crop Size: none

Define custom layers with Python

Can anneal the learning rate

Standard Networks Previous Networks Pretrained Networks Custom Network

Network	Details	Intended image size
LeNet	Original paper [1998]	28x28 (gray)

Standard Networks Previous Networks Pretrained Networks Custom Network

Network	Details	Intended image size
LeNet	Original paper [1998]	28x28 (gray)

Differences may exist between model tasks

DIGITS - TRAINING



Loss function and accuracy during training

Annealed learning rate

DIGITS - VISUALIZATION

Once training is complete DIGITS provides an easy way to visualize what happened

Trained Models

Select Model

Epoch #5

Download Model

Make Pretrained Model

Select Visualization Method

Image Segmentation

Visualization Options

Display segmented image.

Colormap

From dataset

Inference Options

Do not resize input image(s)

Test an image

Image file

image file

Test

Test a record from validation set

Record from validation set

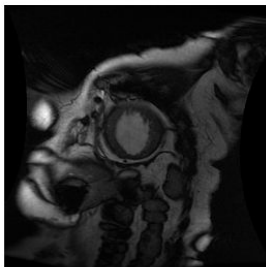
SC-HF-NI-3

Show visualizations and statistics

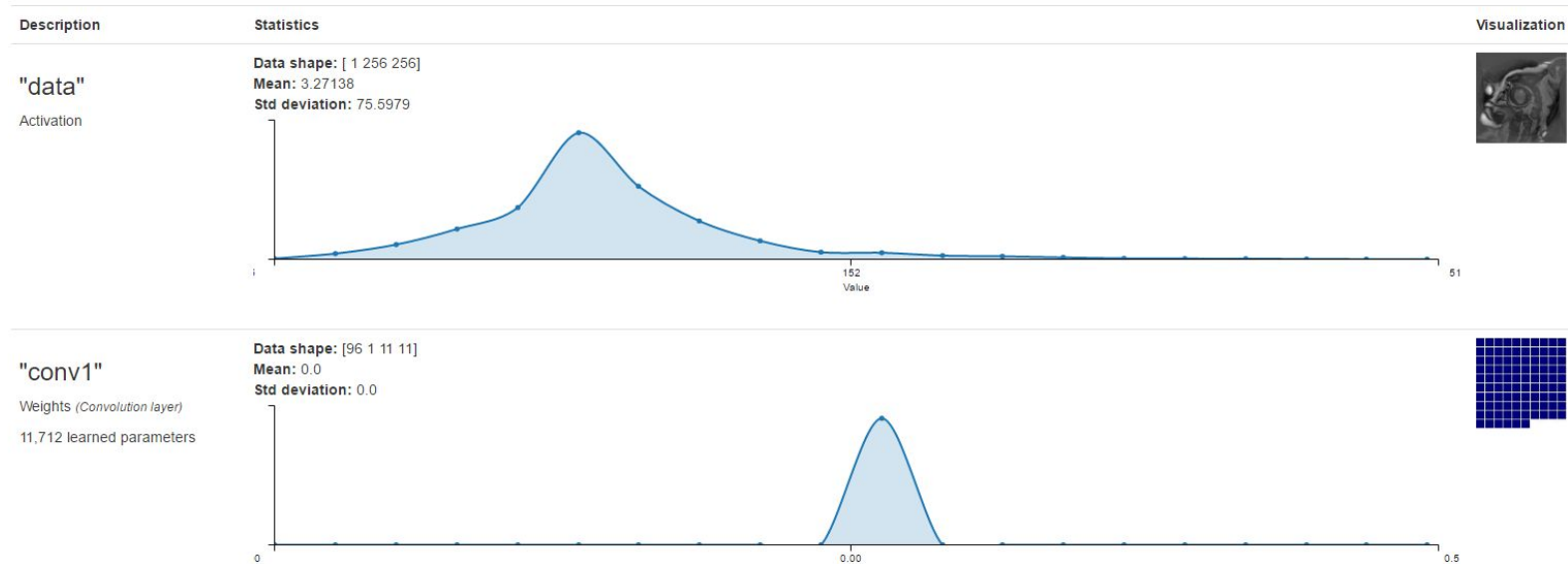
DIGITS - VISUALIZATION RESULTS

Summary

Output visualizations



Layer visualizations



LAB DISCUSSION / OVERVIEW

LAB OVERVIEW

- Learn about the workflow of Deep Learning
 - Create dataset
 - Create model
 - Evaluate model results
 - Try different techniques to improve initial results
- Train your own Convolutional Neural Network using Caffe and DIGITS to identify handwritten characters

CREATE DATASET IN DIGITS

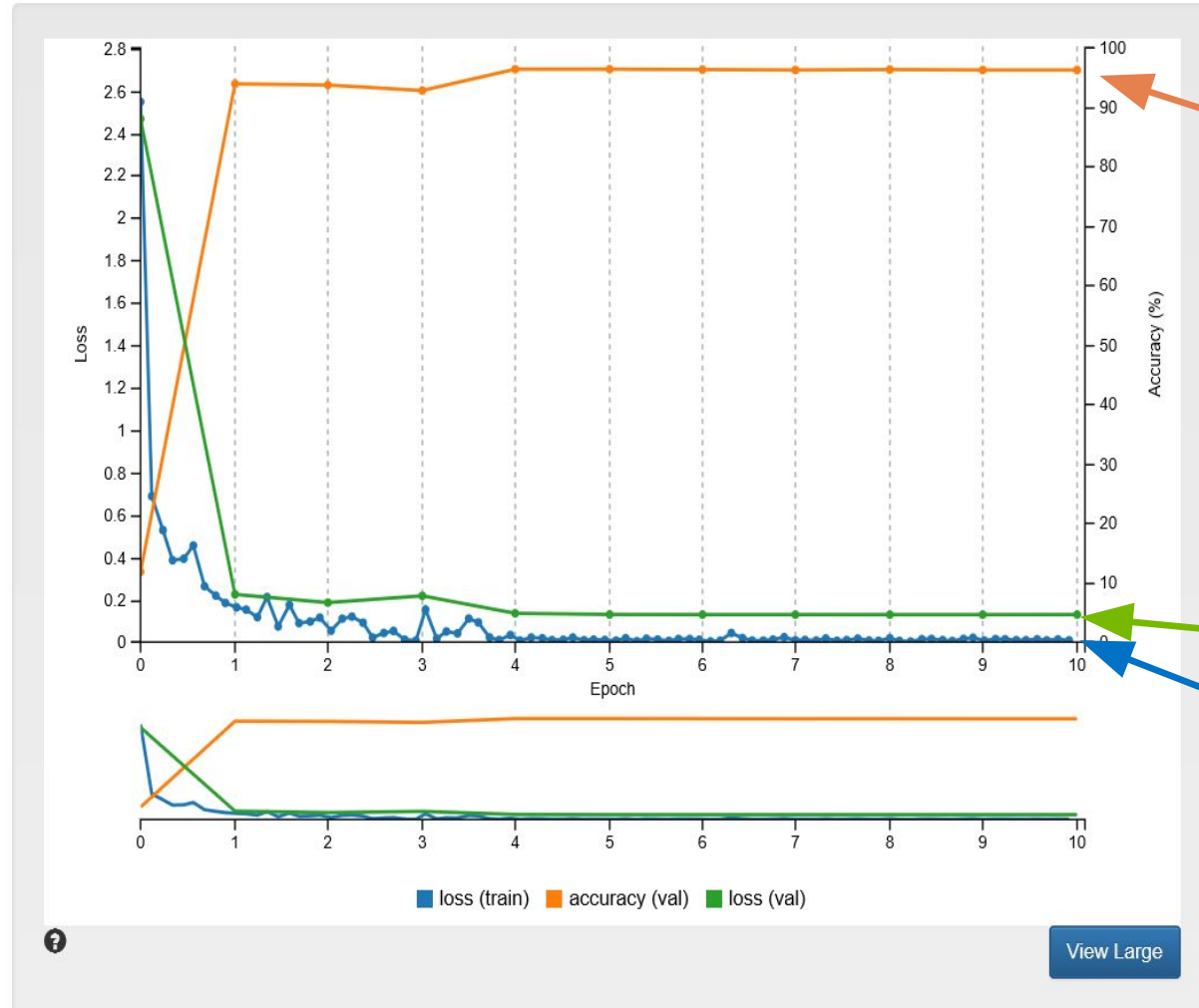
- Dataset settings
 - Image Type: Grayscale
 - Image Size: 28 x 28
 - Training Images: `/home/ubuntu/data/train_small`
 - Select **“Separate test images folder”** checkbox
 - Test Images: `/home/ubuntu/data/test_small`
 - Dataset Name: MNIST Small

CREATE MODEL

- Select the “**MNIST small**” dataset
- Set the number of “**Training Epochs**” to 10
- Set the framework to “**Caffe**”
- Set the model to “**LeNet**”
- Set the name of the model to “**MNIST small**”
- When training done, Classify One :

`/home/ubuntu/data/test_small/2/img_4415.png`

EVALUATE THE MODEL



Accuracy
obtained from
validation dataset

Loss function
(Validation)

Loss function
(Training)

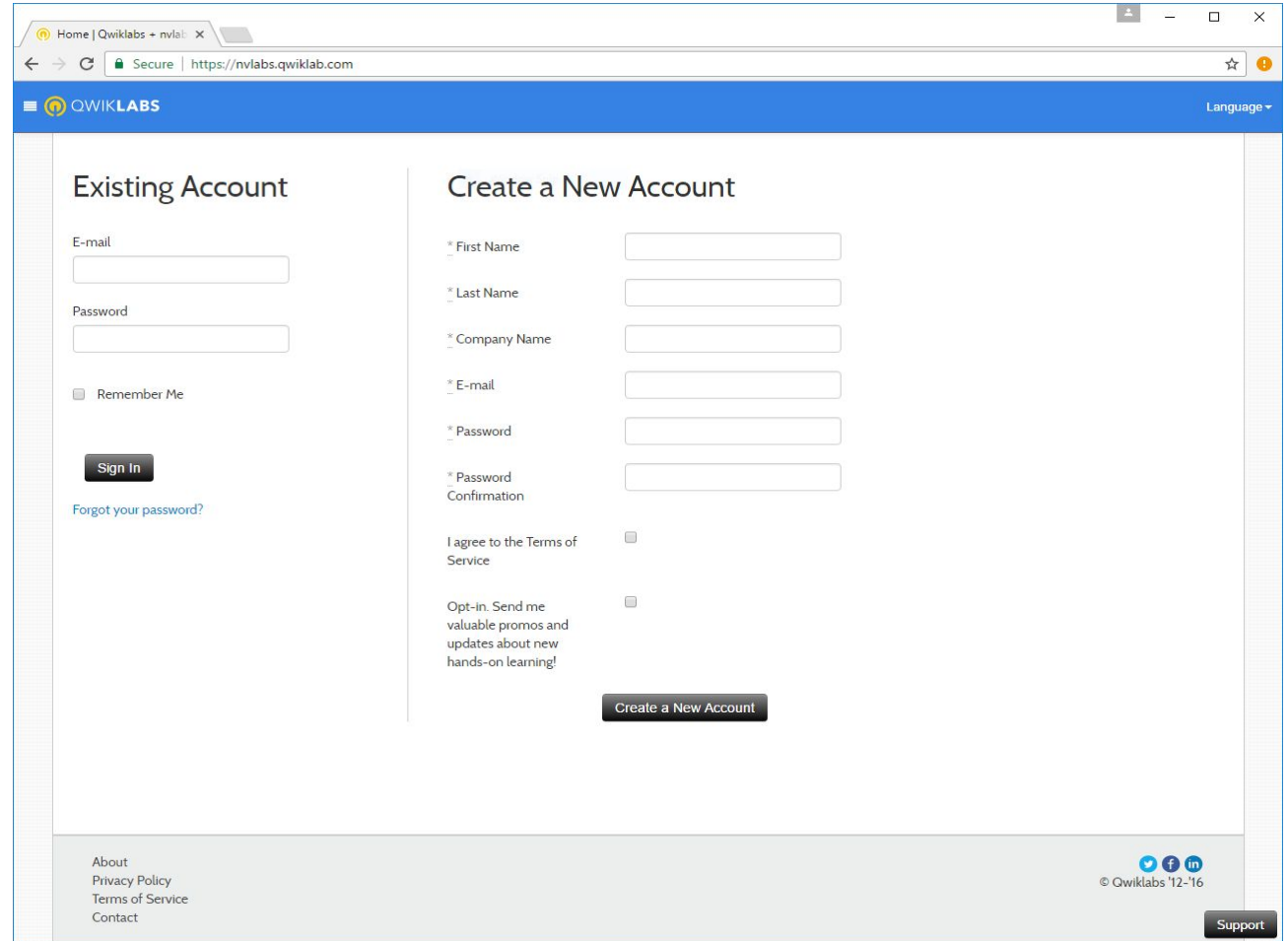
ADDITIONAL TECHNIQUES TO IMPROVE MODEL

- More training data
- Data augmentation
- Modify the network

LAUNCHING THE LAB ENVIRONMENT

NAVIGATING TO QWIKLABS

1. Navigate to:
<https://nvlabs.qwiklab.com>
2. Login or create a new account



The screenshot shows a web browser window with the URL <https://nvlabs.qwiklab.com>. The page features a blue header with the Qwiklabs logo and a "Language" dropdown. The main content area is divided into two columns: "Existing Account" and "Create a New Account".

Existing Account:

- E-mail:
- Password:
- Remember Me
-
- [Forgot your password?](#)

Create a New Account:

- * First Name:
- * Last Name:
- * Company Name:
- * E-mail:
- * Password:
- * Password Confirmation:
- I agree to the Terms of Service
- Opt-in. Send me valuable promos and updates about new hands-on learning!
-

Footer:

- Links: About, Privacy Policy, Terms of Service, Contact
- Social media icons: Twitter, Facebook, LinkedIn
- Copyright: © Qwiklabs '12-'16
-

ACCESSING LAB ENVIRONMENT

3. Select the event specific In-Session Class in the upper left

4. Click the “Image Classification with DIGITS” Class from the list

The screenshot displays the NVIDIA DIGITS interface. At the top, there is a header bar with a dropdown menu for 'In-Session Class' set to 'GTC2017'. To the right of the dropdown, there are statistics: a clock icon followed by '125.3 Total Hours', a green circle icon followed by '68 Completed Labs', and a hamburger menu icon followed by '8 Classes Taken'. Below the header is a 'Class Details' section with a vertical list of classes. The class 'Image Classification with DIGITS' is highlighted in green. To the right of this list is a detailed view for the selected class, including a description, duration (90 min.), access time (115 min.), setup time (5 min.), and level (Beginner). A 'Select' button is visible in the top right corner of the detailed view.

In-Session Class: GTC2017

125.3 Total Hours

68 Completed Labs

8 Classes Taken

Class Details

- Deep Learning for Image Segmentation
- Neural Network Deployment with DIGITS and TensorRT
- Image Classification with DIGITS**
- Medical Image Segmentation Using DIGITS
- Object Detection with DIGITS
- Photo Editing with Generative Adversarial Networks in Tensorflow and DIGITS
- Accelerating Applications with CUDA C/C++

nVIDIA Image Classification with DIGITS [Select](#)

Deep learning is giving machines near human levels of visual recognition capabilities and disrupting many applications by replacing hand-coded software with predictive models learned directly from data. This lab introduces the machine learning workflow and provides hands-on experience with using deep neural networks (DNN) to solve a real-world image classification problem. You will walk through the process of data preparation, model definition, model training and troubleshooting, validation testing and strategies for improving model performance. You will also see the benefits of GPU acceleration in the model training process. On completion of this lab you will have the knowledge to use NVIDIA DIGITS to train a DNN on your own image classification dataset.

Duration:	90 min.
Access Time:	115 min.
Setup Time:	5 min.
Level:	Beginner

LAUNCHING THE LAB ENVIRONMENT

The screenshot shows the NVIDIA DIGITS interface. At the top, there is a header with 'In-Session Class: GTC2017', a clock icon, '125.3 Total Hours', '68 Completed Labs', and '8 Classes Taken'. Below this is a 'Class Details' section with a list of labs. The lab 'Image Classification with DIGITS' is highlighted in green. To the right of this lab, there is a 'Select' button. A green arrow points from the text '5. Click on the Select button to launch the lab environment' to this button. The lab details for 'Image Classification with DIGITS' are shown on the right, including a description, duration (90 min), access time (115 min), setup time (5 min), and level (Beginner).

In-Session Class: GTC2017

125.3 Total Hours

68 Completed Labs

8 Classes Taken

Class Details

- Deep Learning for Image Segmentation
- Neural Network Deployment with DIGITS and TensorRT
- Image Classification with DIGITS**
- Medical Image Segmentation Using DIGITS
- Object Detection with DIGITS
- Photo Editing with Generative Adversarial Networks in Tensorflow and DIGITS
- Accelerating Applications with CUDA C/C++

nvidia Image Classification with DIGITS **Select**

Deep learning is giving machines near human levels of visual recognition capabilities and disrupting many applications by replacing hand-coded software with predictive models learned directly from data. This lab introduces the machine learning workflow and provides hands-on experience with using deep neural networks (DNN) to solve a real-world image classification problem. You will walk through the process of data preparation, model definition, model training and troubleshooting, validation testing and strategies for improving model performance. You will also see the benefits of GPU acceleration in the model training process. On completion of this lab you will have the knowledge to use NVIDIA DIGITS to train a DNN on your own image classification dataset.

Duration: 90 min.

Access Time: 115 min.

Setup Time: 5 min.

Level: Beginner

5. Click on the Select button to launch the lab environment

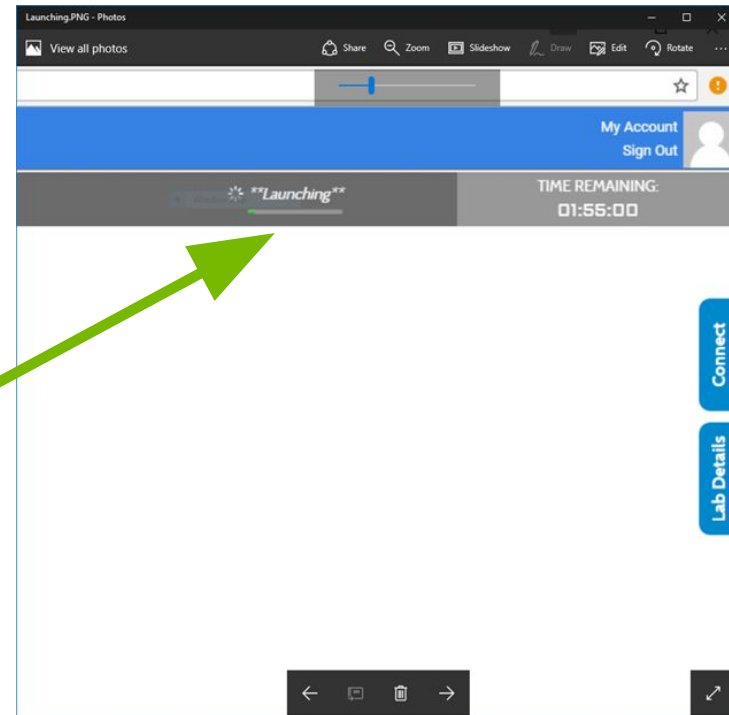
- After a short wait, lab Connection information will be shown
- Please ask Lab Assistants for help!

LAUNCHING THE LAB ENVIRONMENT



6. Click on the Start Lab button

You should see that the lab environment is “launching” towards the upper-right corner



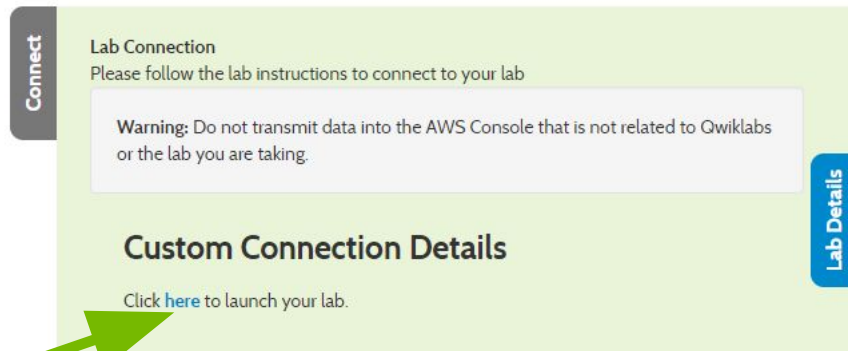
CONNECTING TO THE LAB ENVIRONMENT

Image Classification with DIGITS

End

TIME REMAINING:
01:54:50

Goto:
gravatar.com/en



The screenshot shows a 'Lab Connection' panel with a 'Connect' tab on the left and a 'Lab Details' tab on the right. The main content area contains a warning message and a section titled 'Custom Connection Details'. A green arrow points from the text 'Click here' in the 'Custom Connection Details' section to the word 'here'.

Connect

Lab Connection
Please follow the lab instructions to connect to your lab

Warning: Do not transmit data into the AWS Console that is not related to Qwiklabs or the lab you are taking.

Custom Connection Details

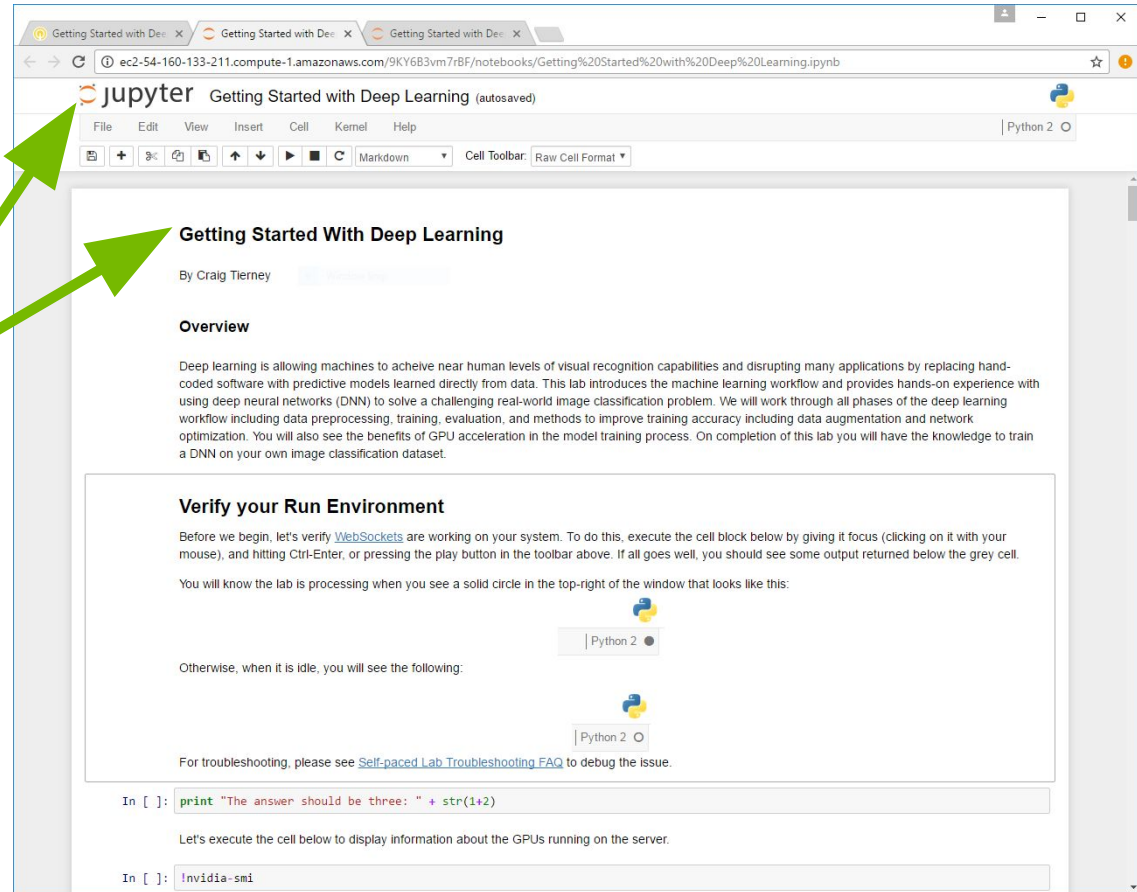
Click [here](#) to launch your lab.

Lab Details

7. Click on “here” to access your lab environment / Jupyter notebook

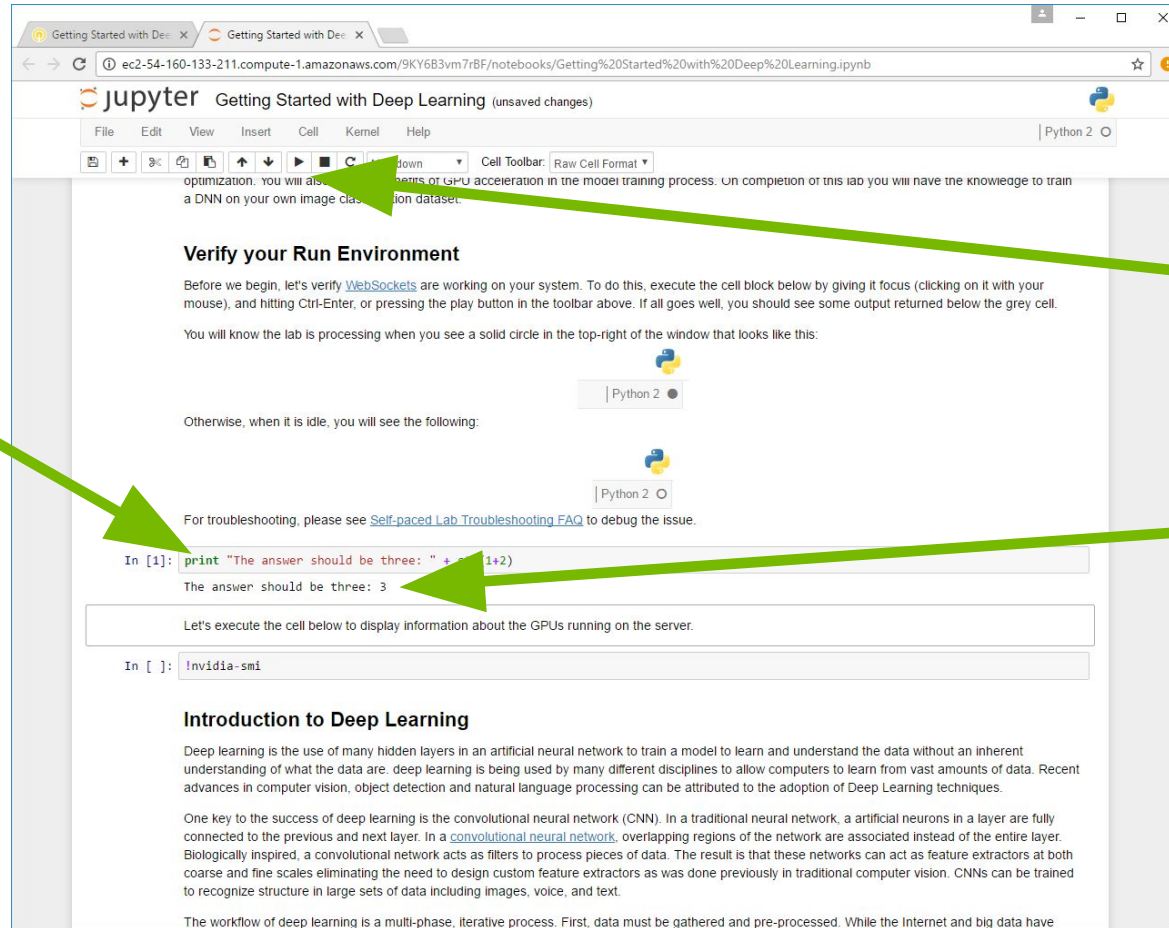
CONNECTING TO THE LAB ENVIRONMENT

You should see your
“Getting Started With
Deep Learning” Jupyter
notebook



The screenshot displays a web browser window with the JupyterLab interface. The browser's address bar shows the URL: `ec2-54-160-133-211.compute-1.amazonaws.com/9KY6B3vm7rBF/notebooks/Getting%20Started%20with%20Deep%20Learning.ipynb`. The JupyterLab header includes the title "Getting Started With Deep Learning (autosaved)" and a menu bar with options: File, Edit, View, Insert, Cell, Kernel, and Help. Below the menu is a toolbar with icons for file operations and a "Cell Toolbar" set to "Raw Cell Format". The main content area shows the notebook's title "Getting Started With Deep Learning" by Craig Tierney. The "Overview" section describes deep learning and the lab's purpose. A section titled "Verify your Run Environment" provides instructions on how to check if the lab is processing or idle, accompanied by two Python 2 kernel status icons. At the bottom, there are two code input cells: the first contains `print "The answer should be three: " + str(1+2)` and the second contains `!nvidia-smi`.

JUPYTER NOTEBOOK



1. Place your cursor in the code

2. Click the "run cell" button

3. Confirm you receive the same result

STARTING DIGITS

Instruction in Jupyter notebook will link you to DIGITS

The screenshot shows a Jupyter notebook titled "Getting Started with Deep Learning (autosaved)". The browser address bar shows the URL: `ec2-54-160-133-211.compute-1.amazonaws.com/9KY6B3vm7rBF/notebooks/Getting%20Started%20with%20Deep%20Learning.ipynb`. The notebook interface includes a menu bar (File, Edit, View, Insert, Cell, Kernel, Help) and a toolbar with various icons. A "New Dataset" menu is open, showing options: "Classification", "Object Detection", and "Other". Below the menu, there is a table with columns: "framework", "status", "elapsed", and "s".

To start DIGITS, [click here](#).

Task - Create a Database

First, we want to create a database from the MNIST data. To create a database, select **Classification** from the **New Dataset** menu. At this point you may need to enter a username. If requested, just enter any name in lower-case.

In the **New Dataset** window, you want to set the following fields to the values specified:

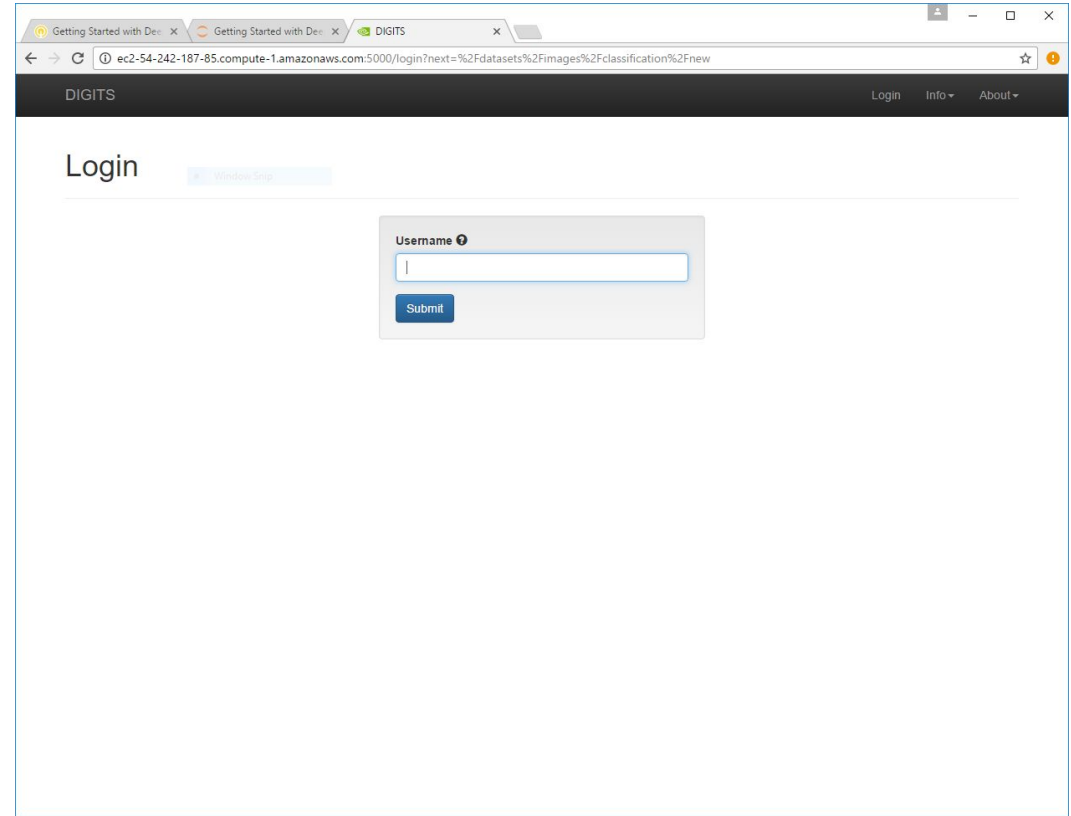
- Image Type : Grayscale
- Image Size : 28 x 28
- Training Images: /home/ubuntu/data/train_small
- Select **Separate test images folder** checkbox
- Test Images : /home/ubuntu/data/test_small
- Dataset Name : MNIST Small

Your screen should look like the image below.

DIGITS New Dataset mebersole (Logout) Info About

ACCESSING DIGITS

- Will be prompted to enter a username to access DIGITS
 - Can enter any username
 - Use lower case letters










LAB REVIEW

FIRST RESULTS

Small dataset (10 epochs)

- 96% of accuracy achieved
- Training is done within one minute

	SMALL DATASET
	1 : 99.90 %
	2 : 69.03 %
	8 : 71.37 %
	8 : 85.07 %
	0 : 99.00 %
	8 : 99.69 %
	8 : 54.75 %

FULL DATASET








6x larger dataset

- Dataset
 - Training Images: /home/ubuntu/data/train_full
 - Test Image: /home/ubuntu/data/test_full
 - Dataset Name: MNIST full
- Model
 - Clone “MNIST small”.
 - Give a new name “MNIST full” to push the create button

SECOND RESULTS

Full dataset (10 epochs)

- 99% of accuracy achieved
- No improvements in recognizing real-world images

	SMALL DATASET	FULL DATASET
	1 : 99.90 %	0 : 93.11 %
	2 : 69.03 %	2 : 87.23 %
	8 : 71.37 %	8 : 71.60 %
	8 : 85.07 %	8 : 79.72 %
	0 : 99.00 %	0 : 95.82 %
	8 : 99.69 %	8 : 100.0 %
	8 : 54.75 %	2 : 70.57 %

DATA AUGMENTATION

Adding Inverted Images

















DIGITS Image Classification Dataset smorino (Logout) Info

Exploring MNIST invert (train_db) images

Show all images or filter by class: 0 1 2 3 4 5 6 7 8 9

Items per page: 10 - **25** - 50 - 100





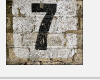

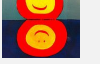
« 0 1 2 3 4 5 ... 3600 »

			
2	9	7	3
			
1	4	6	5
			
5	3	8	2
			
3	1	8	6

- $\text{Pixel}(\text{Inverted}) = 255 - \text{Pixel}(\text{original})$
- White letter with black background
 - Black letter with white background
- Training Images:
/home/ubuntu/data/train_invert
- Test Image:
/home/ubuntu/data/test_invert
- Dataset Name: MNIST invert

DATA AUGMENTATION

Adding inverted images (10 epochs)

	SMALL DATASET	FULL DATASET	+INVERTED
	1 : 99.90 %	0 : 93.11 %	1 : 90.84 %
	2 : 69.03 %	2 : 87.23 %	2 : 89.44 %
	8 : 71.37 %	8 : 71.60 %	3 : 100.0 %
	8 : 85.07 %	8 : 79.72 %	4 : 100.0 %
	0 : 99.00 %	0 : 95.82 %	7 : 82.84 %
	8 : 99.69 %	8 : 100.0 %	8 : 100.0 %
	8 : 54.75 %	2 : 70.57 %	2 : 96.27 %

MODIFY THE NETWORK

Adding filters and ReLU layer

```
layer {
  name: "pool1"
  type: "Pooling"
  ...
}
```

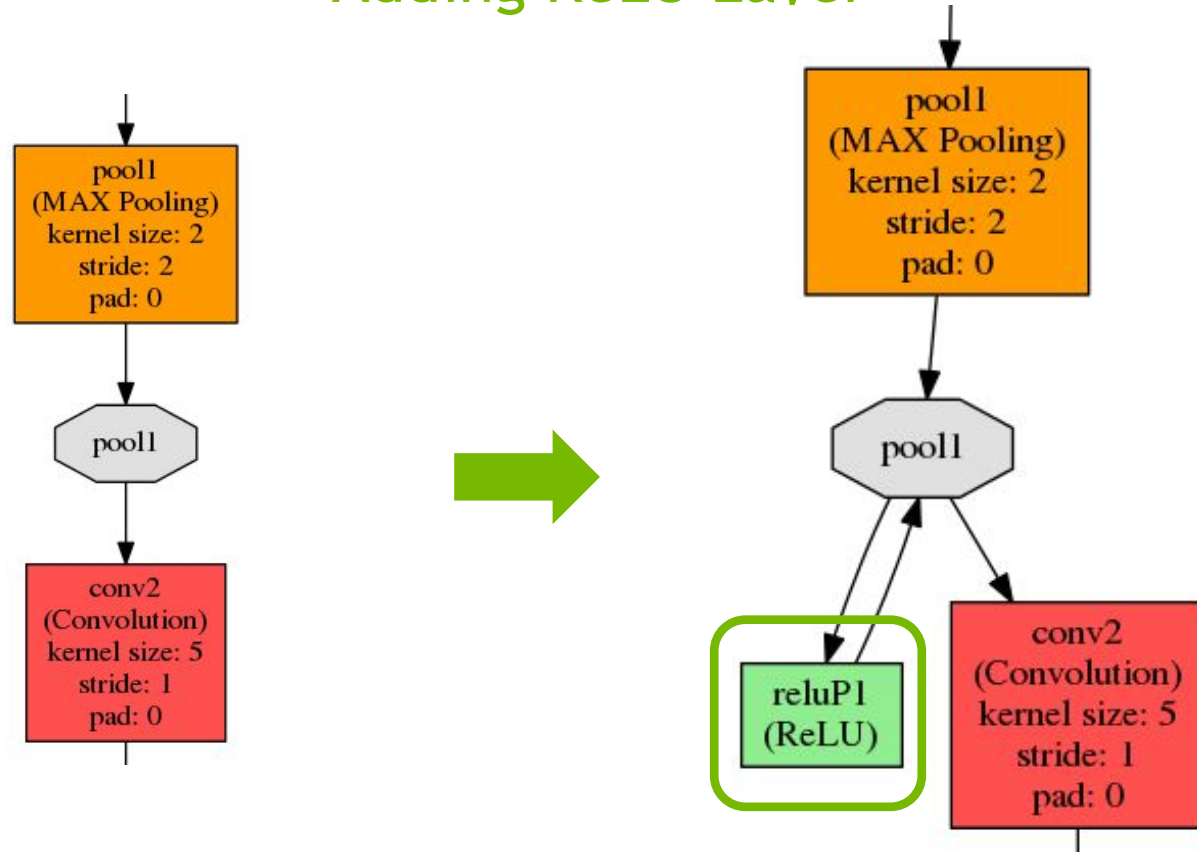
```
layer {
  name: "reluP1"
  type: "ReLU"
  bottom: "pool1"
  top: "pool1"
}
```

```
layer {
  name: "reluP1"
```

```
layer {
  name: "conv1"
  type: "Convolution"
  ...
  convolution_param {
    num_output: 75
  }
  ...
  layer {
    name: "conv2"
    type: "Convolution"
    ...
    convolution_param {
      num_output: 100
    }
    ...
  }
}
```





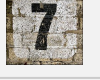

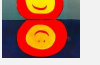
MODIFY THE NETWORK

Adding ReLU Layer



MODIFIED NETWORK

Adding filters and ReLU layer (10 epochs)

	SMALL DATASET	FULL DATASET	+INVERTED	ADDING LAYER
	1 : 99.90 %	0 : 93.11 %	1 : 90.84 %	1 : 59.18 %
	2 : 69.03 %	2 : 87.23 %	2 : 89.44 %	2 : 93.39 %
	8 : 71.37 %	8 : 71.60 %	3 : 100.0 %	3 : 100.0 %
	8 : 85.07 %	8 : 79.72 %	4 : 100.0 %	4 : 100.0 %
	0 : 99.00 %	0 : 95.82 %	7 : 82.84 %	2 : 62.52 %
	8 : 99.69 %	8 : 100.0 %	8 : 100.0 %	8 : 100.0 %
	8 : 54.75 %	2 : 70.57 %	2 : 96.27 %	8 : 70.83 %

WHAT'S NEXT

- Use / practice what you learned
- Discuss with peers practical applications of DNN
- Reach out to NVIDIA and the Deep Learning Institute

WHAT'S NEXT

TAKE SURVEY

...for the chance to win an NVIDIA SHIELD TV.

Check your email for a link.

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Check your email for details to access more DLI training online.

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Instructor: Charles Killam, LP.D.



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