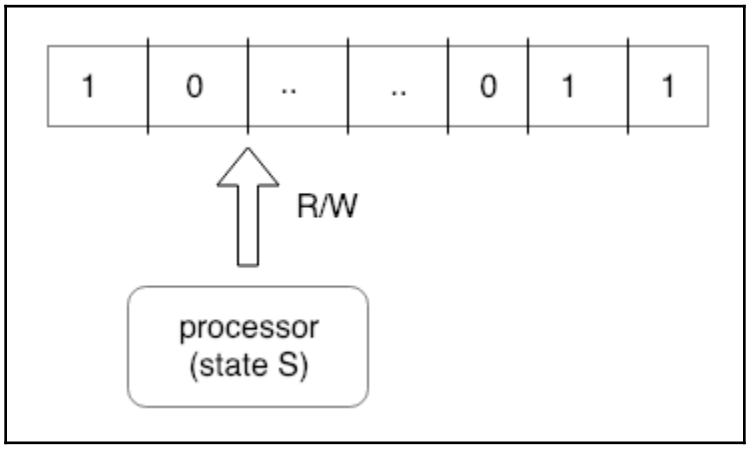
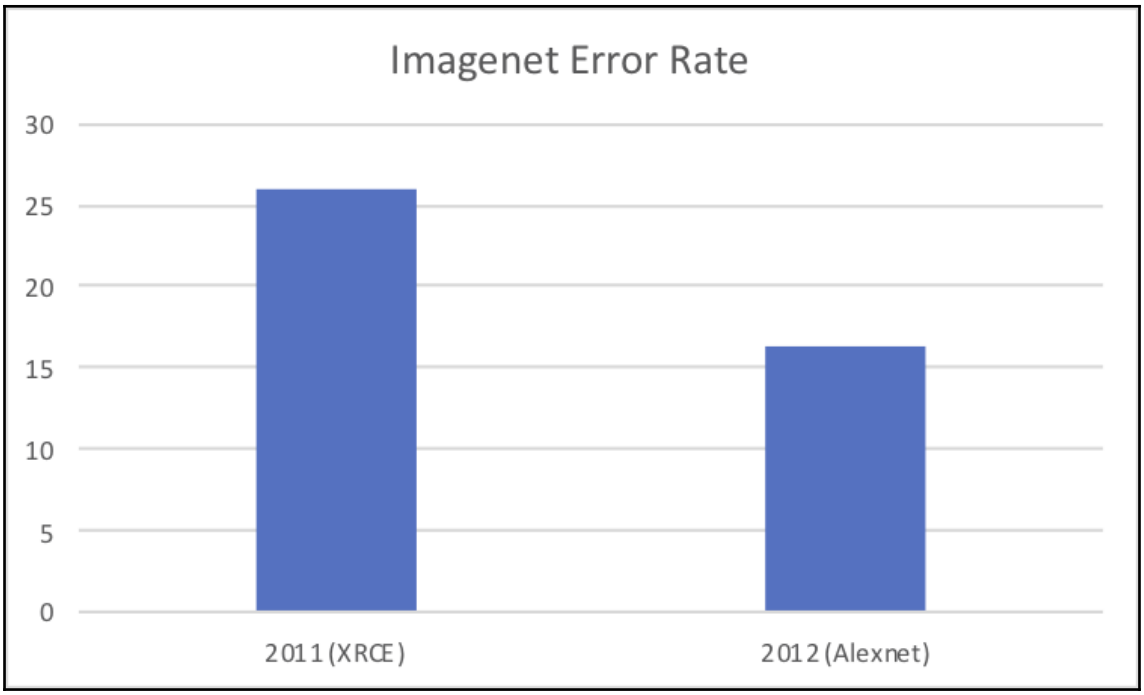
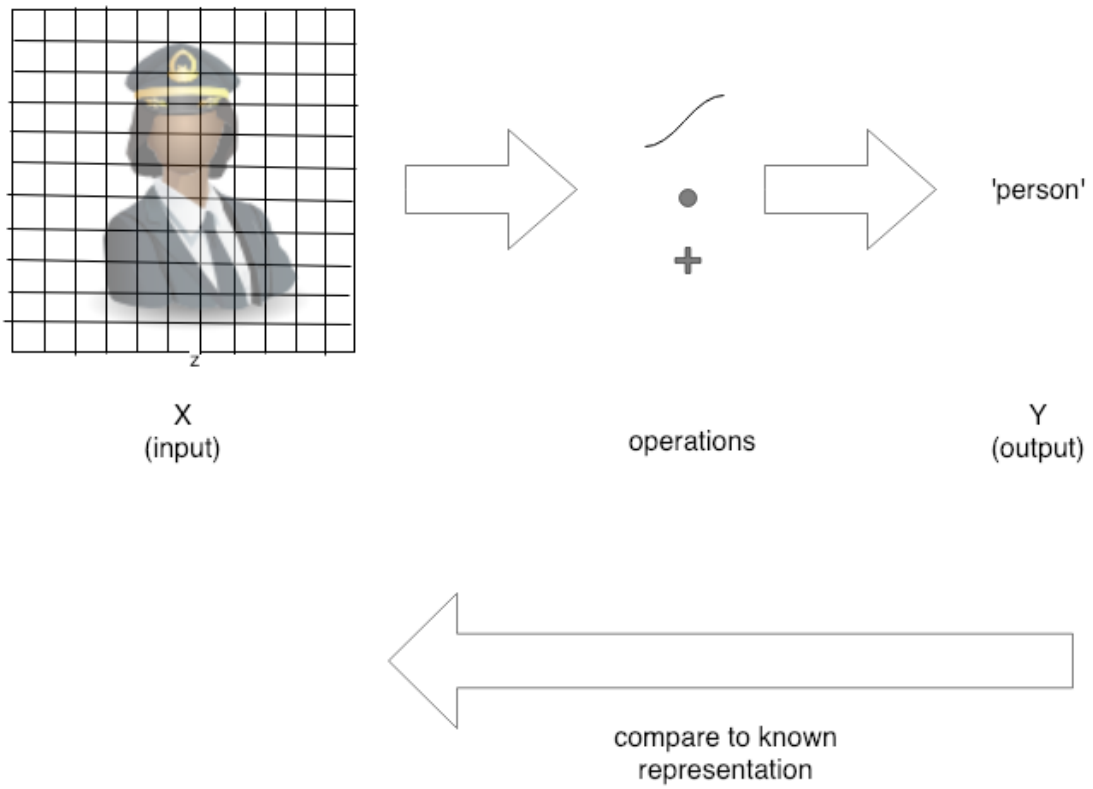
1

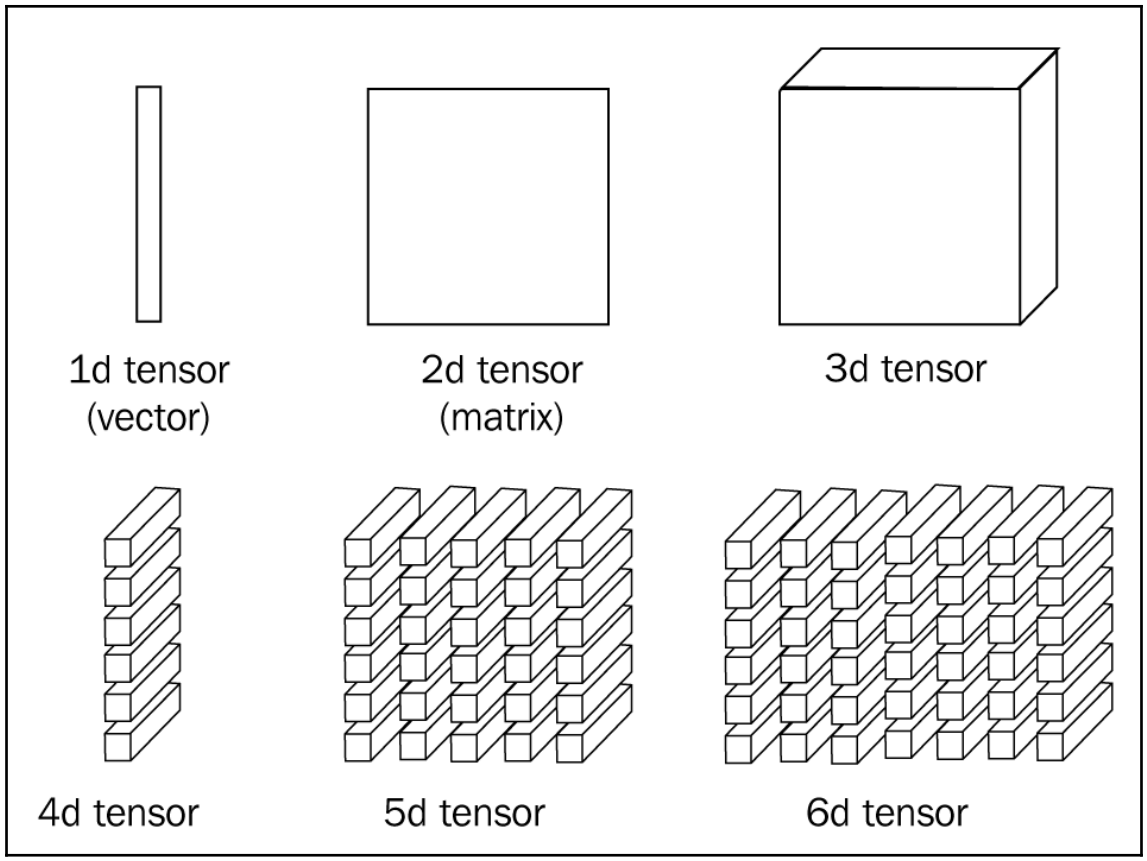
Chapter 1: Introduction to Deep Learning in Go

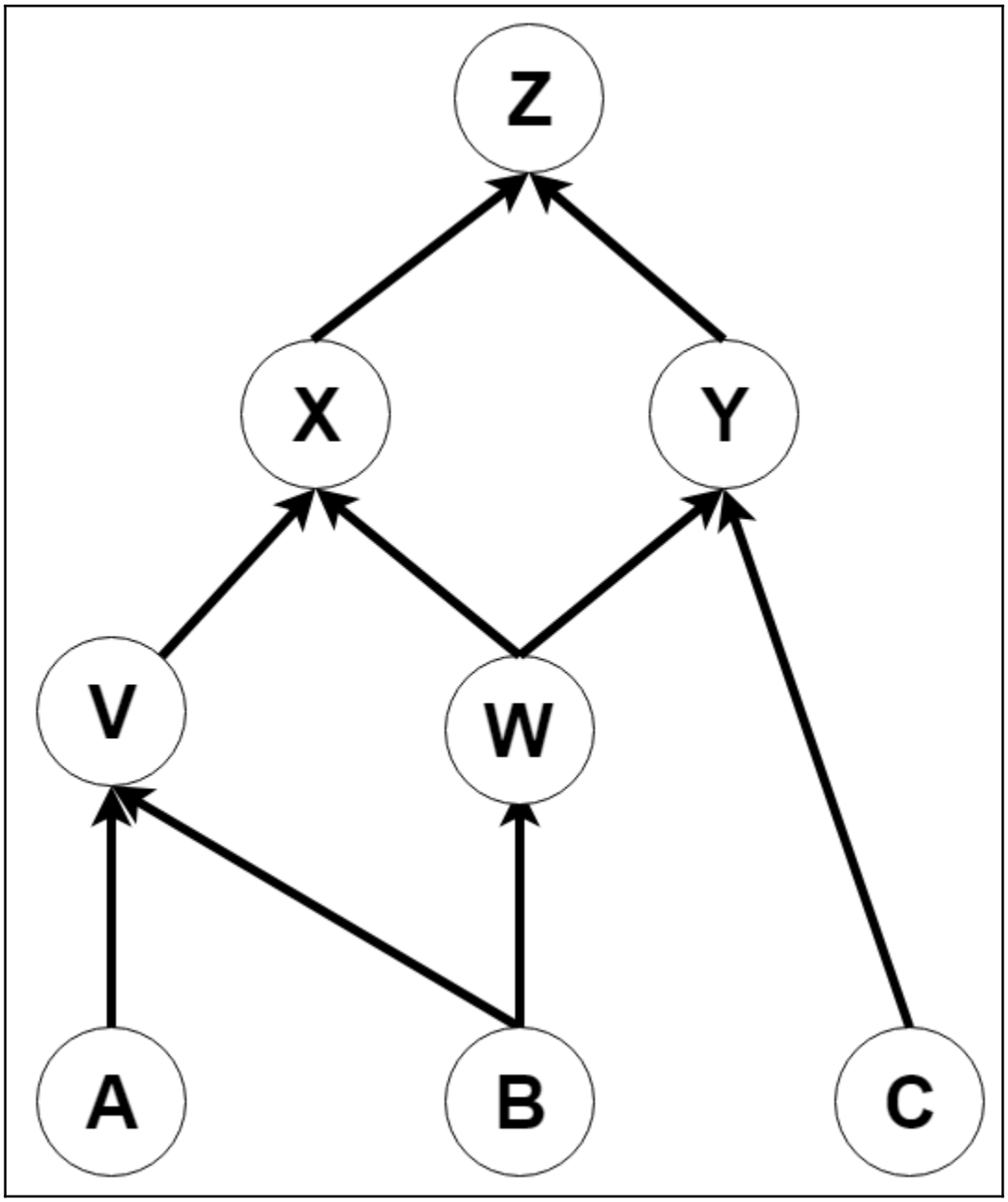


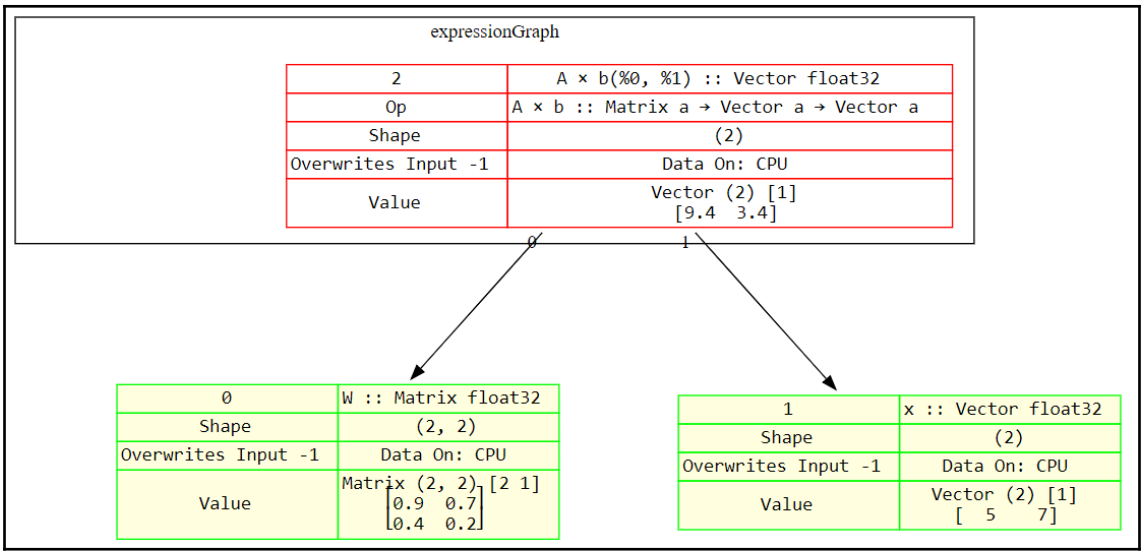

Imagenet Error Rate
30
25
20
15
10
5
0
2011 (XRCE)
2012 (Alexnet)

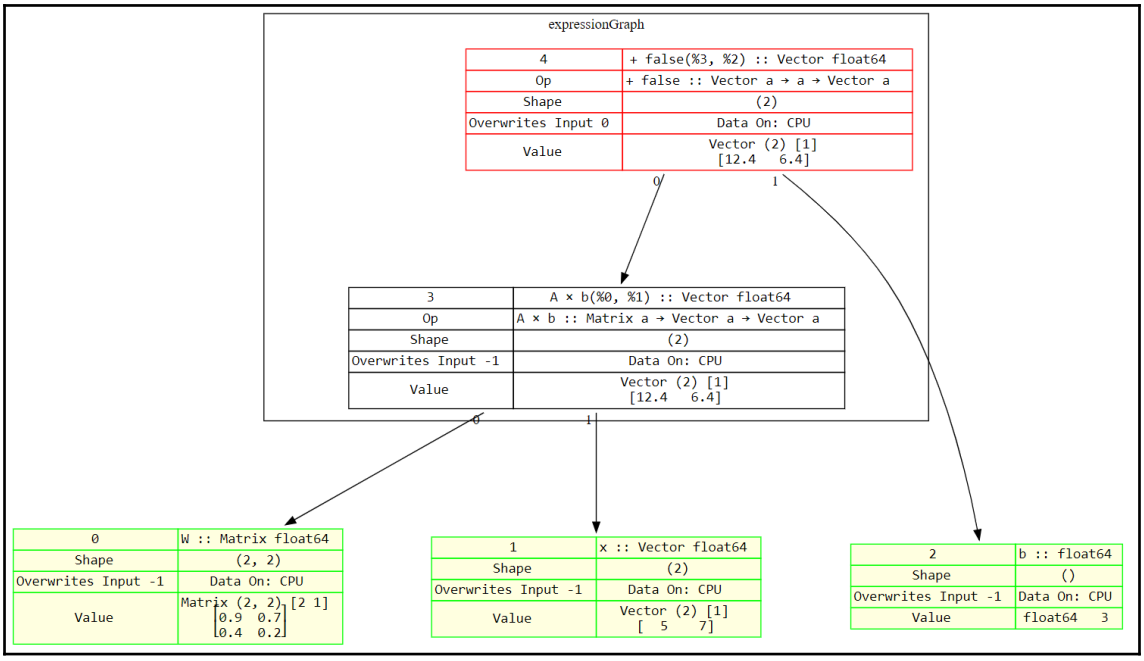

'person'
X
(input)
operations
Y
(output)
compare to known
representation


NIPS @NipsConference · Sep 5
#NIPS2018 The main conference sold out in 11 minutes 38 seconds
81
696
1.1K


1d tensor
(vector)
2d tensor
(matrix)
3d tensor
4d tensor
5d tensor
6d tensor


Z
X
Y
V
W
A
B
C


expressionGraph
2
A × b(%0, %1) :: Vector float32
Op
A × b :: Matrix a → Vector a → Vector a
Shape
(2)
Overwrites Input -1
Data On: CPU
Value
Vector (2) [1]
[9.4 3.4]
0
1
0
W :: Matrix float32
Shape
(2, 2)
Overwrites Input -1
Data On: CPU
Value
Matrix (2, 2) [2 1]
0.9 0.7
0.4 0.2
1
x :: Vector float32
Shape
(2)
Overwrites Input -1
Data On: CPU
Value
Vector (2) [1]
[5 7]


expressionGraph
4
+ false(%3, %2) :: Vector float64
Op
+ false :: Vector a → a → Vector a
Shape
(2)
Overwrites Input 0
Data On: CPU
Value
Vector (2) [1]
[12.4 6.4]
0
1
3
A × b(%0, %1) :: Vector float64
Op
A × b :: Matrix a → Vector a → Vector a
Shape
(2)
Overwrites Input -1
Data On: CPU
Value
Vector (2) [1]
[12.4 6.4]
0
1
0
W :: Matrix float64
Shape
(2, 2)
Overwrites Input -1
Data On: CPU
Value
Matrix (2, 2) [2 1]
0.9 0.7
0.4 0.2
1
x :: Vector float64
Shape
(2)
Overwrites Input -1
Data On: CPU
Value
Vector (2) [1]
[5 7]
2
b :: float64
Shape
()
Overwrites Input -1
Data On: CPU
Value
float64 3

Chapter 2: What Is a Neural Network and How Do I Train One?

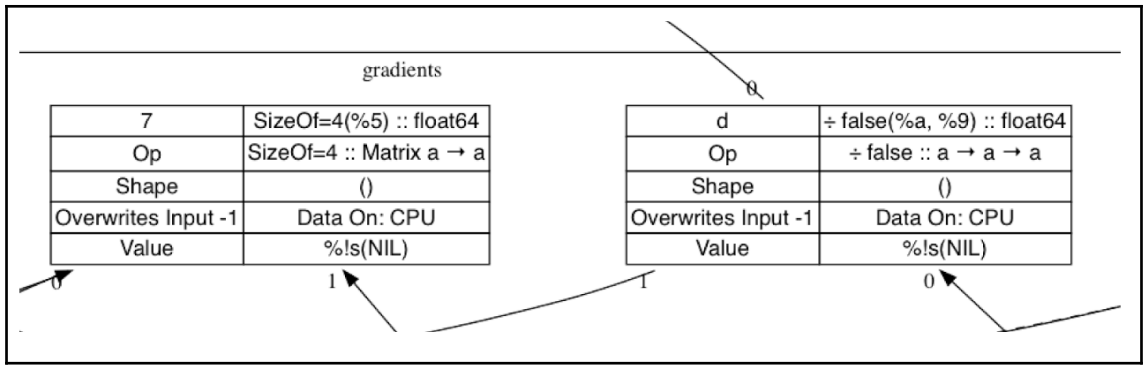
0	w :: Matrix float64
Shape	(3, 1)
Overwrites Input -1	Data On: CPU
Value	Vector (3, 1) [1 1] C[-0.168 0.441 -1]

0	w :: Matrix float64
Shape	(3, 1)
Overwrites Input -1	Data On: CPU
Value	Vector (3, 1) [1 1] C[-0.168 0.441 -1]

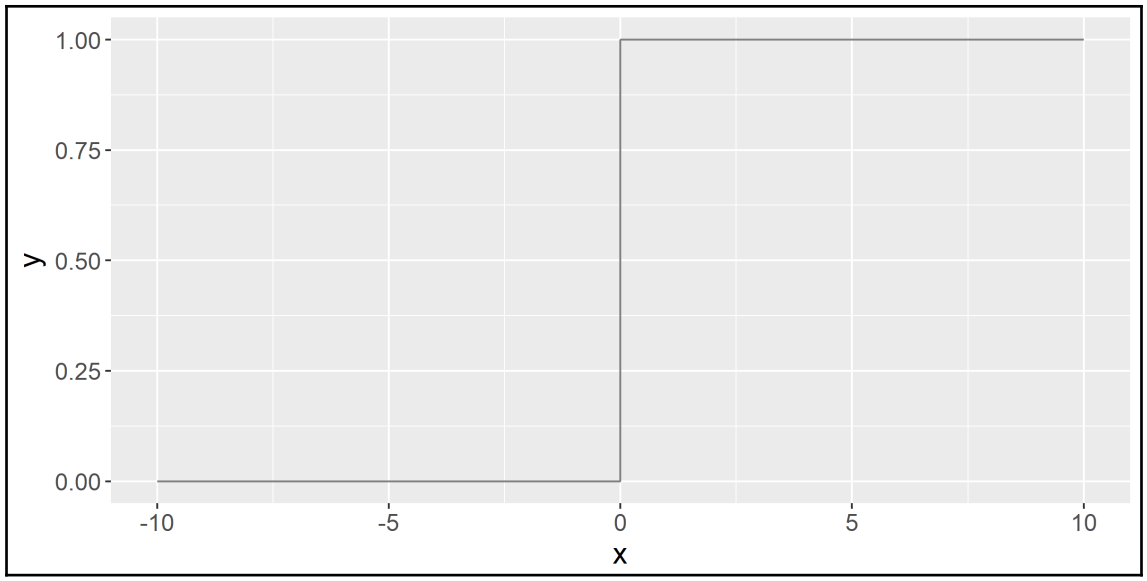
1	X :: Matrix float64
Shape	(4, 3)
Overwrites Input -1	Data On: CPU
Value	Matrix (4, 3) [3 1] ⎡ 0 0 1⎤ ⎢ 0 1 1⎥ ⎢ 1 0 1⎥ ⎣ 1 1 1⎦

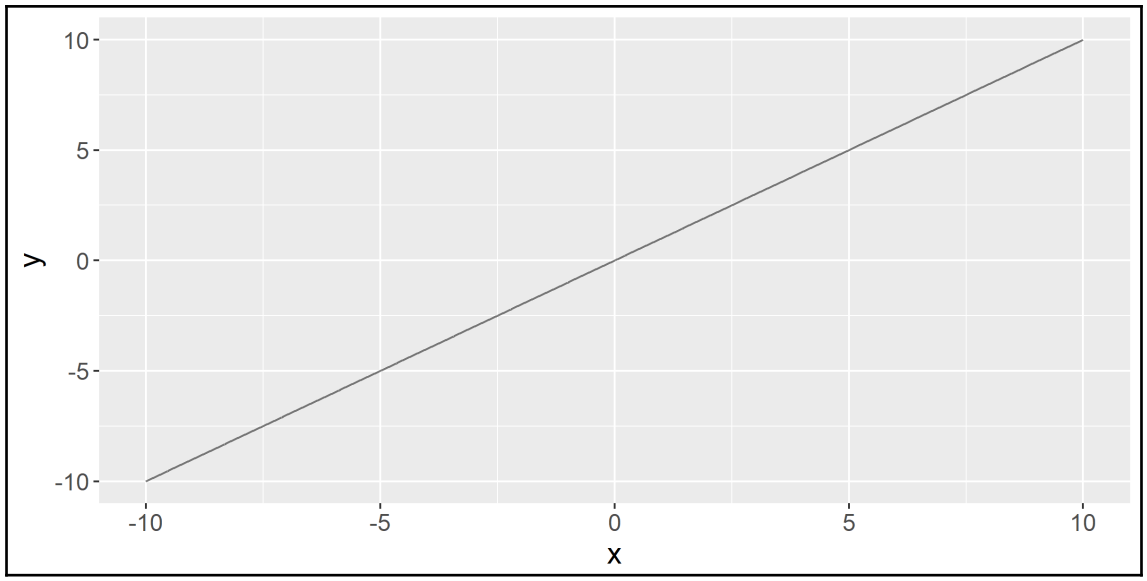
2	y :: Matrix float64
Shape	(4, 1)
Overwrites Input -1	Data On: CPU
Value	Vector (4, 1) [1 1] C[0 0 1 1]

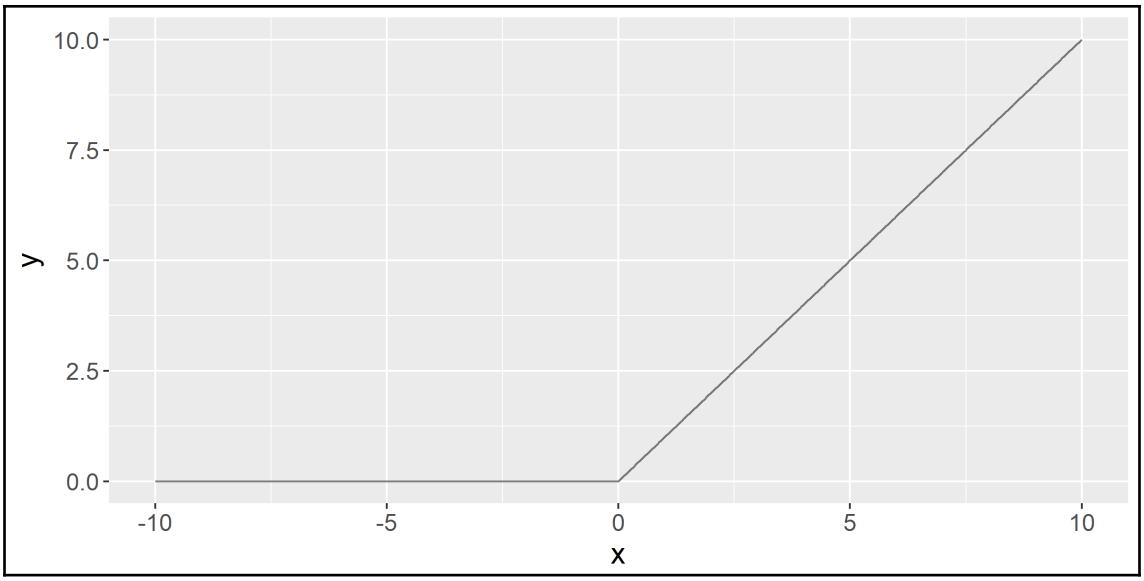
0	w :: Matrix float64
Shape	(3, 1)
Overwrites Input -1	Data On: CPU
Value	Grad
Vector (3, 1) [1 1] C[-0.168 0.441 -1]	%!s(NIL)
Ptr: 0x842351307104x	Ptr:

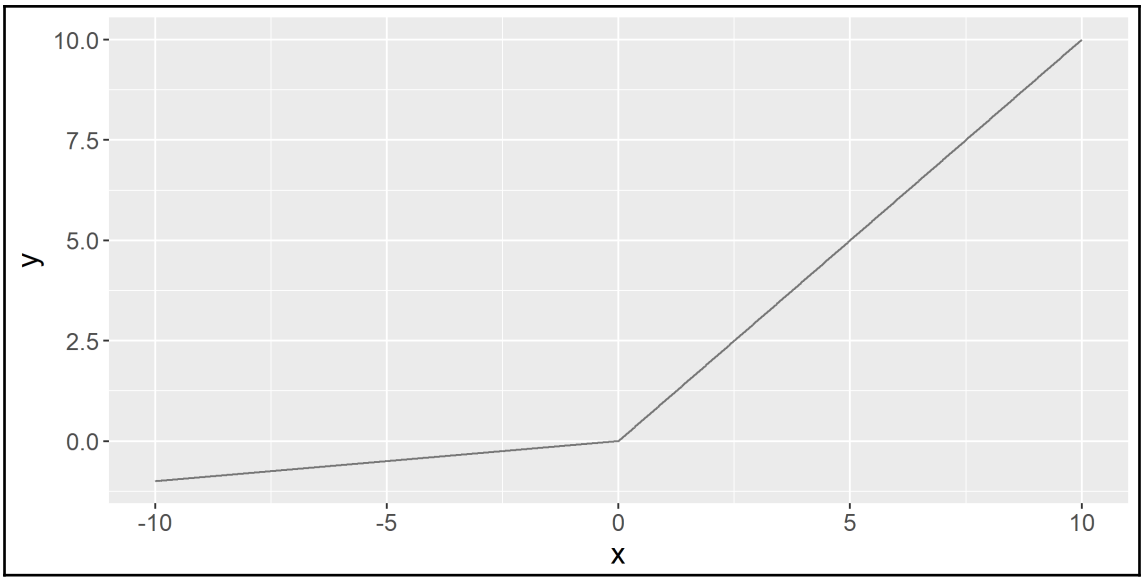


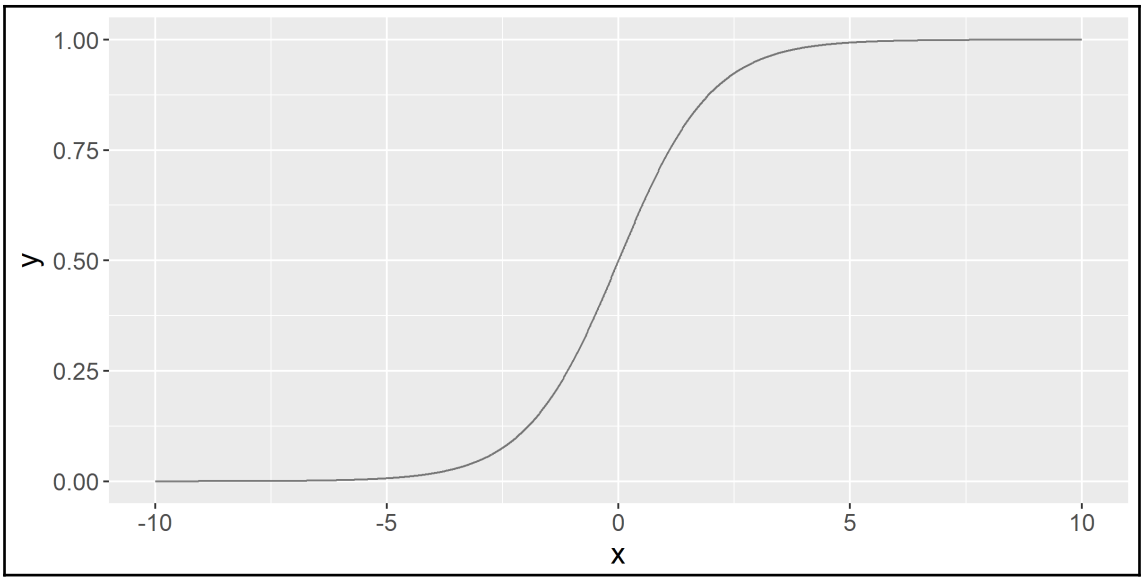
0	w :: Matrix float64
Shape	(3, 1)
Overwrites Input -1	Data On: CPU
Value	Grad
Vector (3, 1) [1 1] C[-0.168 0.441 -0.999]	Vector (3, 1) [1 1] C[0 0 0]
Ptr: 0x842350578400x	Ptr: 0xc42025b0c0

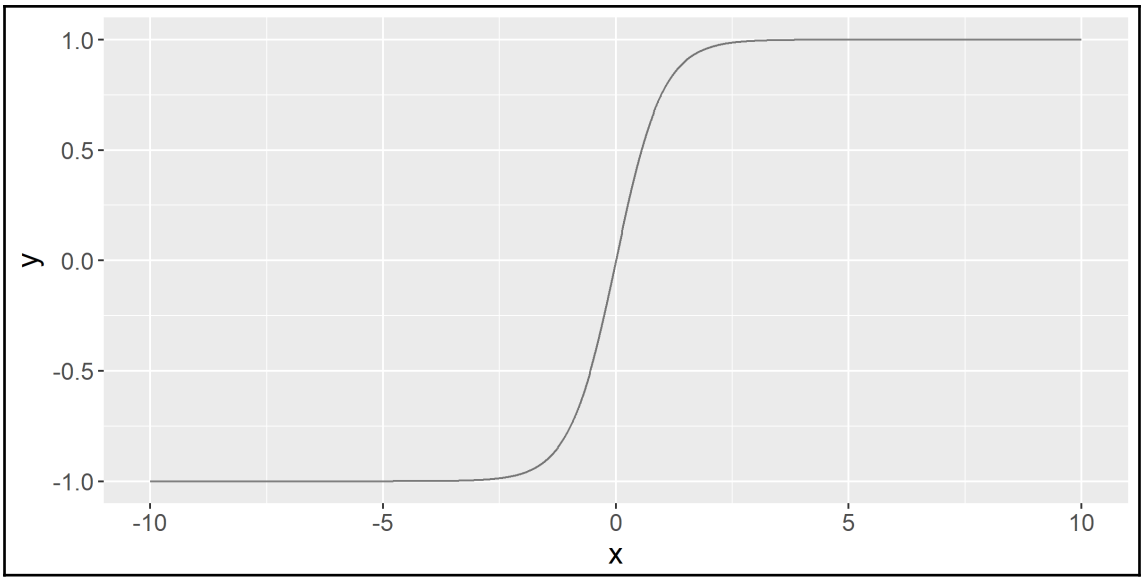

1.00
0.75
0.50
0.25
0.00
y
-10
-5
0
5
10
x

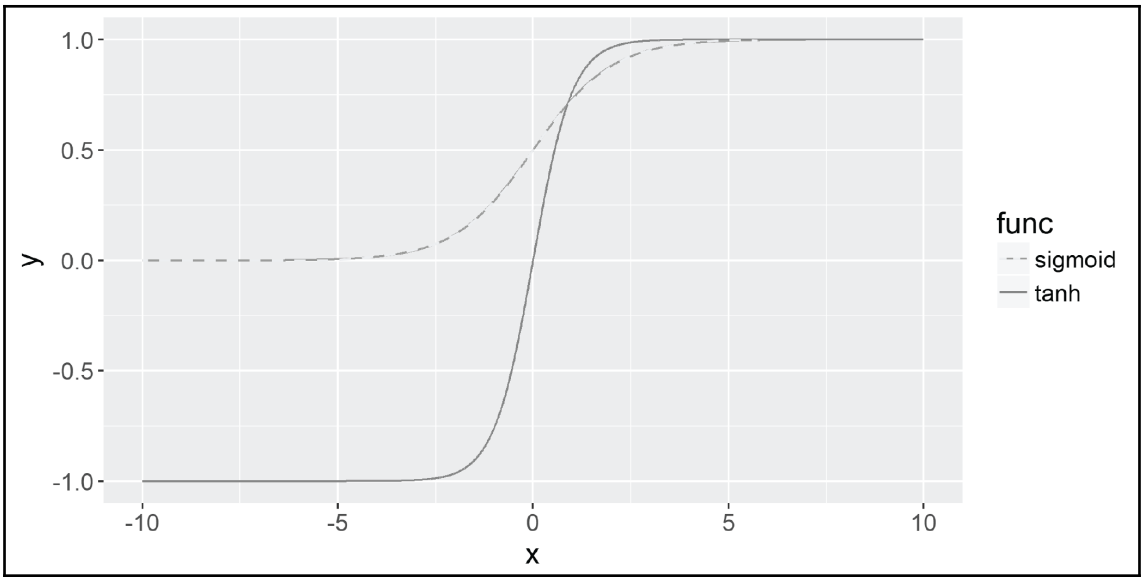

10
5
0
-5
-10
y
-10
-5
0
5
10
x

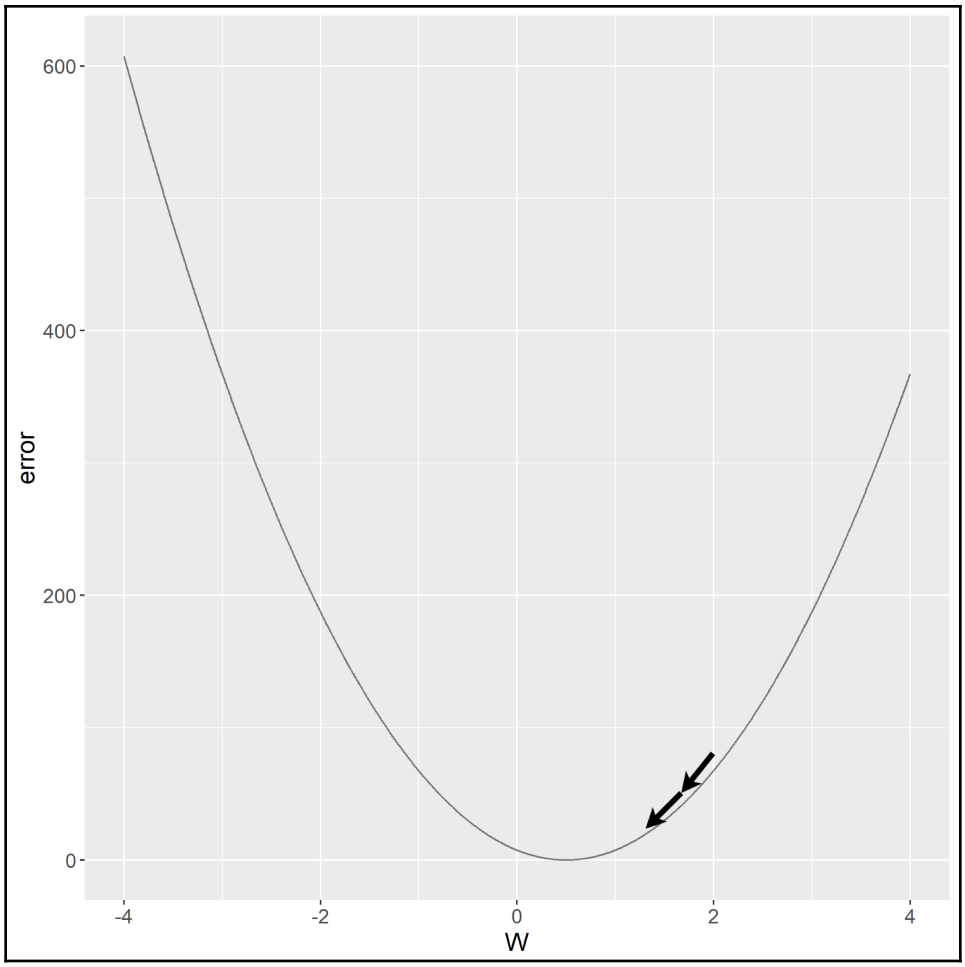

10.0
7.5
5.0
2.5
0.0
y
-10
-5
0
5
10
x

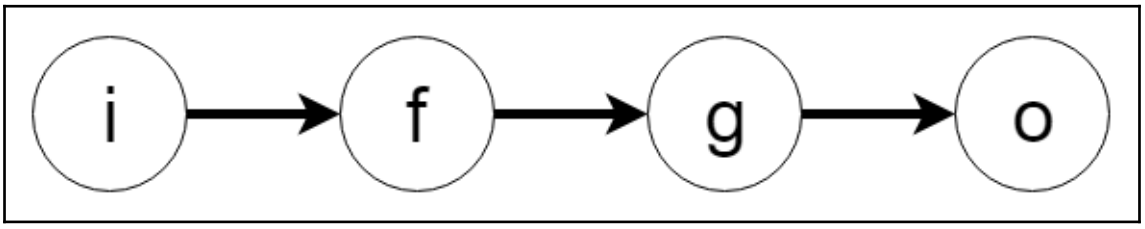

10.0
7.5
5.0
2.5
0.0
y
-10
-5
0
5
10
x


1.00
0.75
0.50
0.25
0.00
y
-10
-5
0
5
10
x

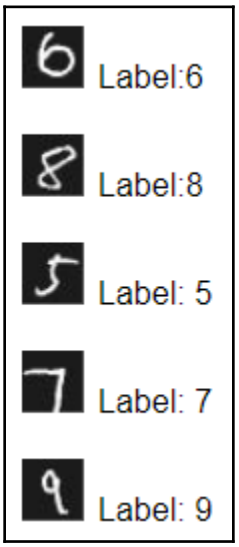

1.0
0.5
0.0
-0.5
-1.0
y
-10
-5
0
5
10
x

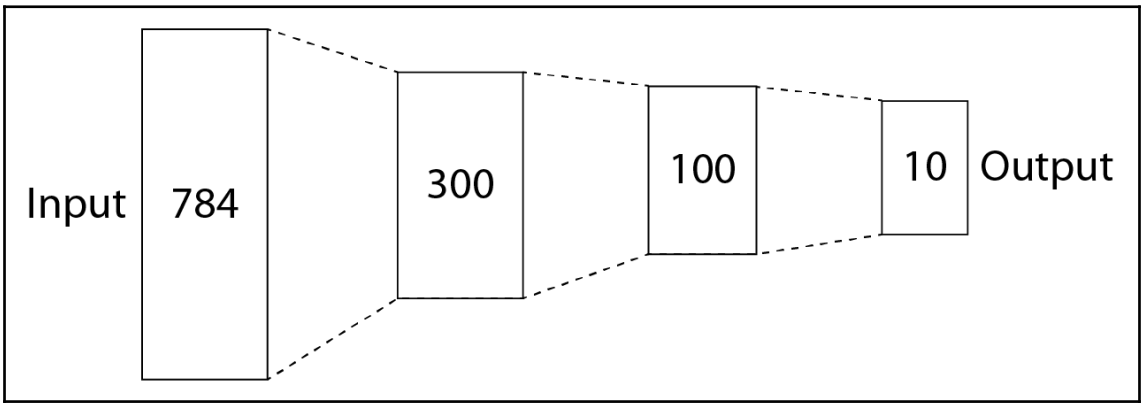

1.0
0.5
0.0
-0.5
-1.0
y
-10
-5
0
5
10
x
func
sigmoid
tanh


600
400
200
0
error
-4
-2
0
2
4
W

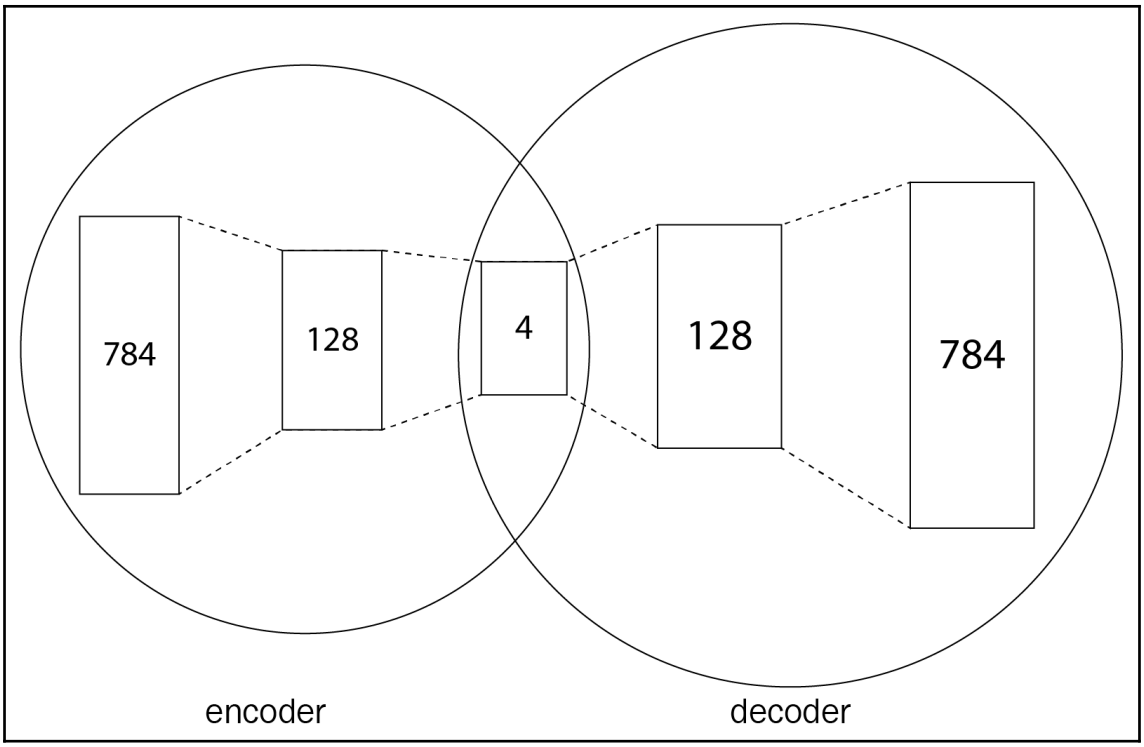

i
f
g
o

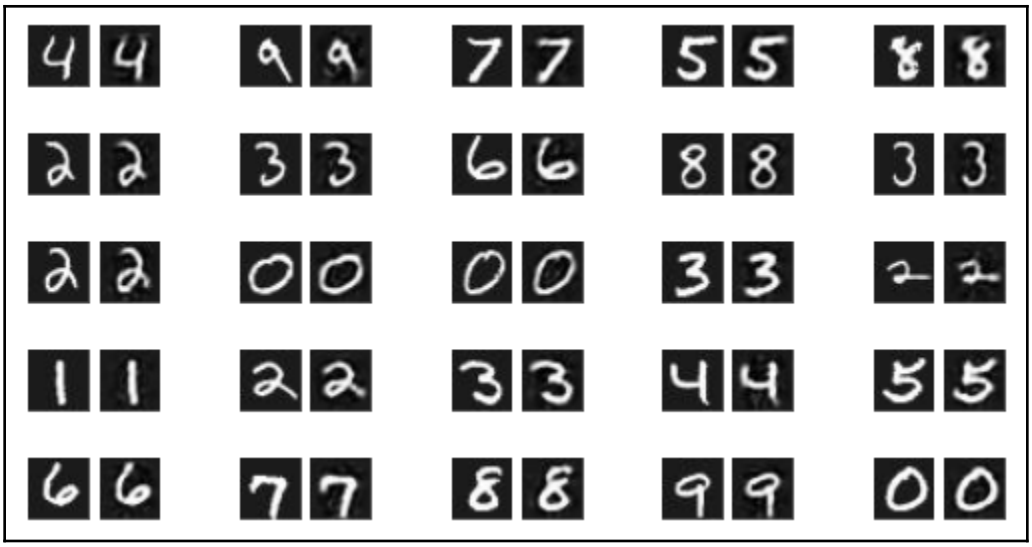
Chapter 3: Beyond Basic Neural Networks - Autoencoders and RBMs

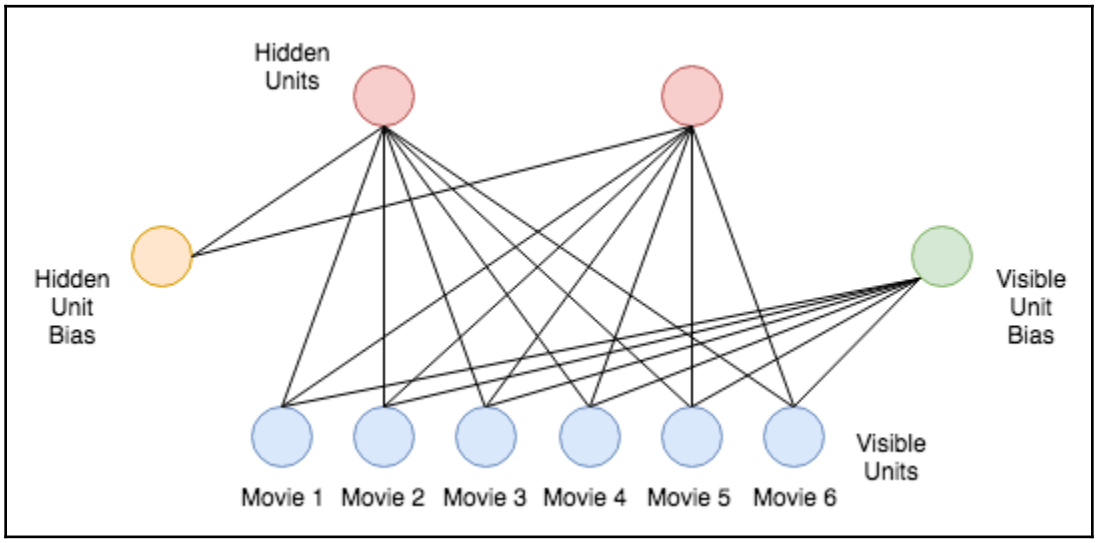


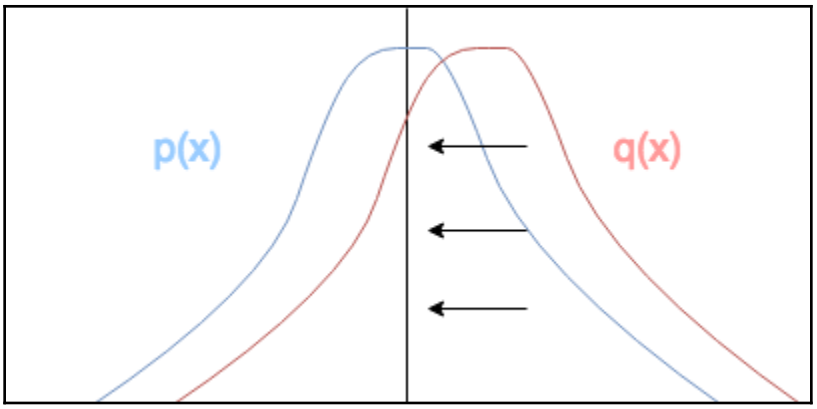



Label: 7, Guess: 7
Label: 1, Guess: 1
Label: 2, Guess: 3
Label:5, Guess 6
Label:3, Guess 3
Label:4, Guess 4
Label: 2, Guess: 3
Label: 7, Guess: 7


784
128
4
128
784
encoder
decoder



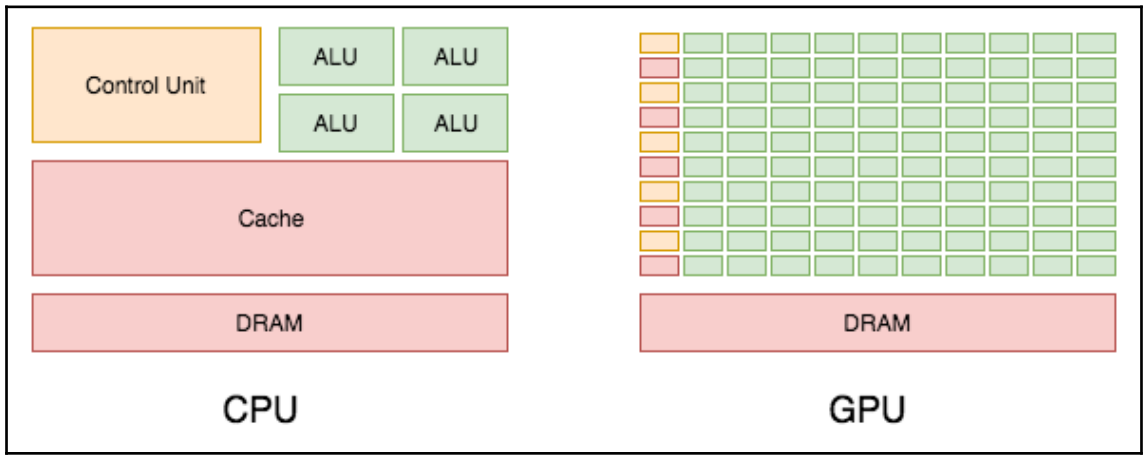

Hidden
Units
Hidden
Unit
Bias
Visible
Unit
Bias
Visible
Units
Movie 1
Movie 2
Movie 3
Movie 4
Movie 5
Movie 6

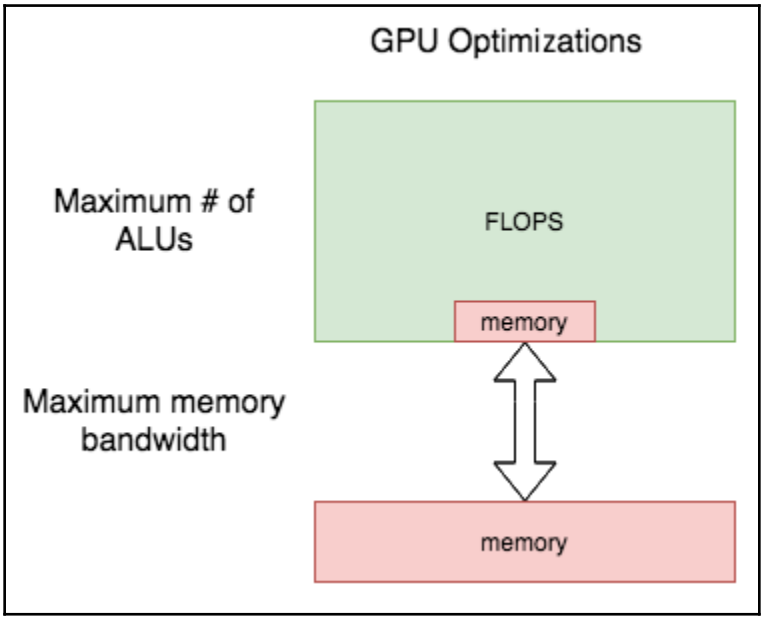


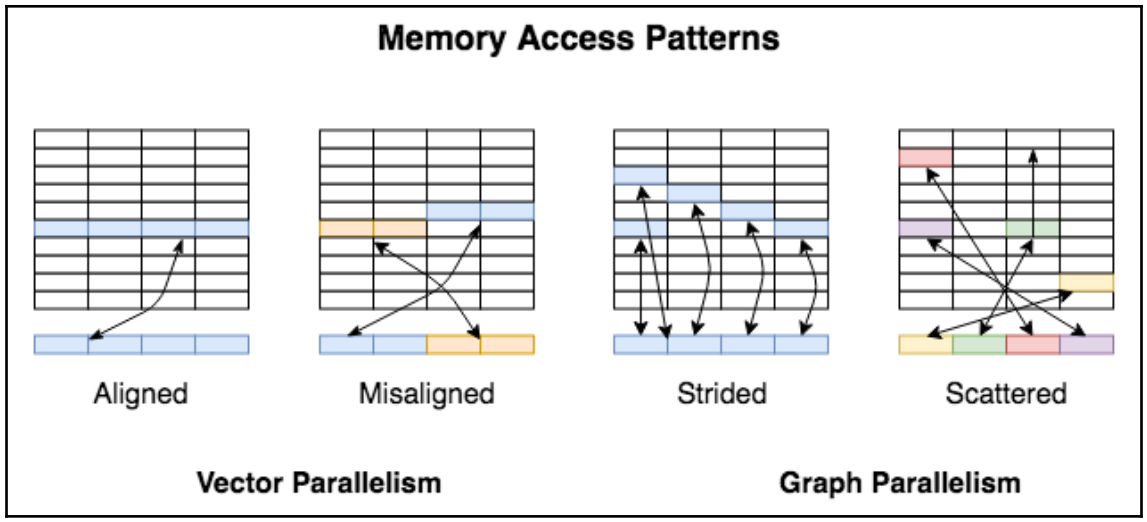

```
Loading Movielens data
Building movie index
Loading and converting per-user ratings
Processing rating 100000 of 1000209
Processing rating 200000 of 1000209
Processing rating 300000 of 1000209
Processing rating 400000 of 1000209
Processing rating 500000 of 1000209
Processing rating 600000 of 1000209
Processing rating 700000 of 1000209
Processing rating 800000 of 1000209
Processing rating 900000 of 1000209
Number of unique users:  6040
Number of unique movies:  3706
3883 movies pruned to index of 3706 unique titles
Testing movie lookup:  Erin Brockovich (2000)
```

```
Training RBM...
Training iteration: 1
Training iteration: 101
Training iteration: 201
Training iteration: 301
Training iteration: 401
Training iteration: 501
Training iteration: 601
Training iteration: 701
Training iteration: 801
Training iteration: 901
Generating sample recomendation...
3408 Grumpier Old Men (1995)
594 Tom and Huck (1995)
2398 Dracula: Dead and Loving It (1995)
2321 Money Train (1995)
745 City of Lost Children The (1995)
1022 Across the Sea of Time (1995)
1357 Lamerica (1994)
3108 Big Bully (1996)
292 Juror The (1996)
3256 Journey of August King The (1995)
```

Chapter 4: CUDA - GPU-Accelerated Training







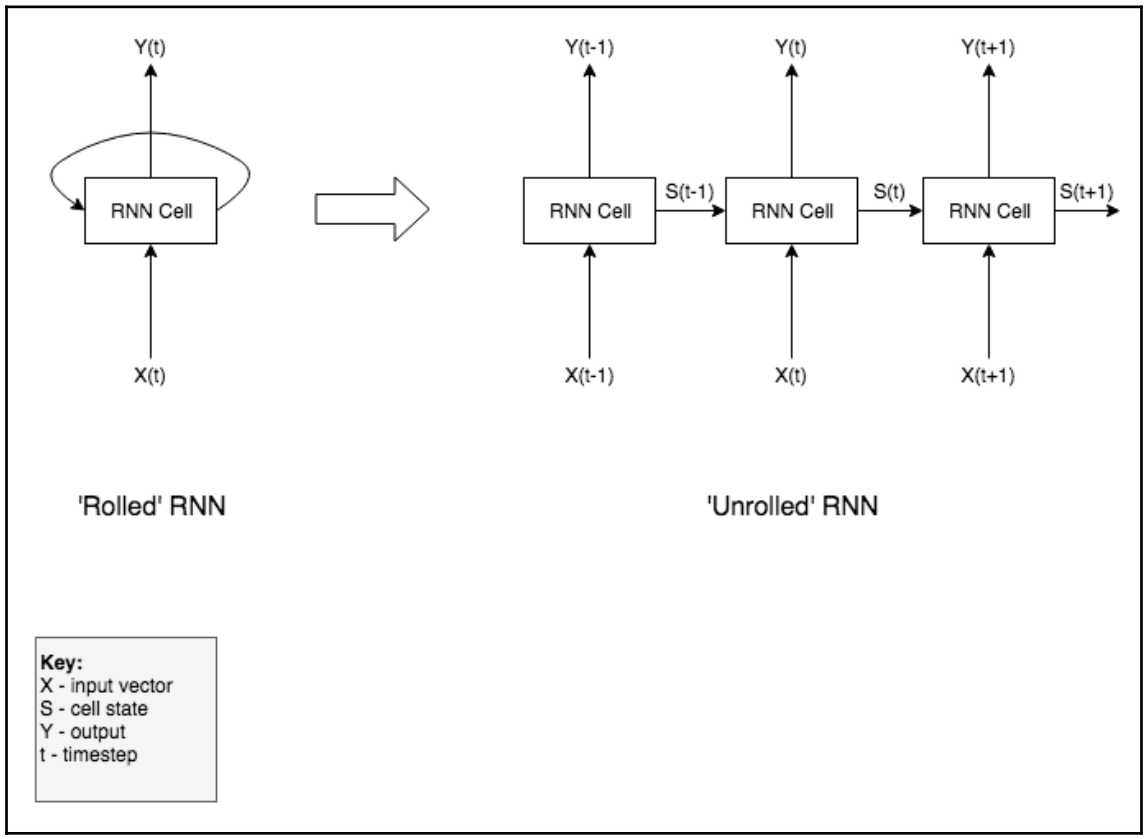

```
> nvidia-smi
Sun Jul 15 09:57:05 2018
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 390.59                 Driver Version: 390.59                    |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Vol
```

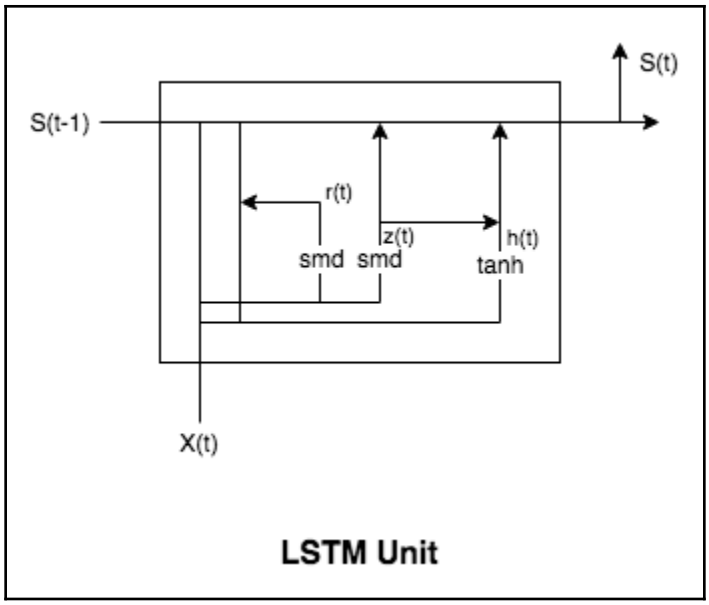
```
> nvcc --version
nvcc: NVIDIA (R) Cuda compiler driver
Copyright (c) 2005-2017 NVIDIA Corporation
Built on Fri_Nov__3_21:07:56_CDT_2017
Cuda compilation tools, release 9.1, V9.1.85
```

```
Jul  9 21:34 elembinop.ptx
Jul  9 21:34 elemunaryop.ptx
Jul  9 21:34 sigmoid32.ptx
Jul  9 21:34 sigmoid64.ptx
```

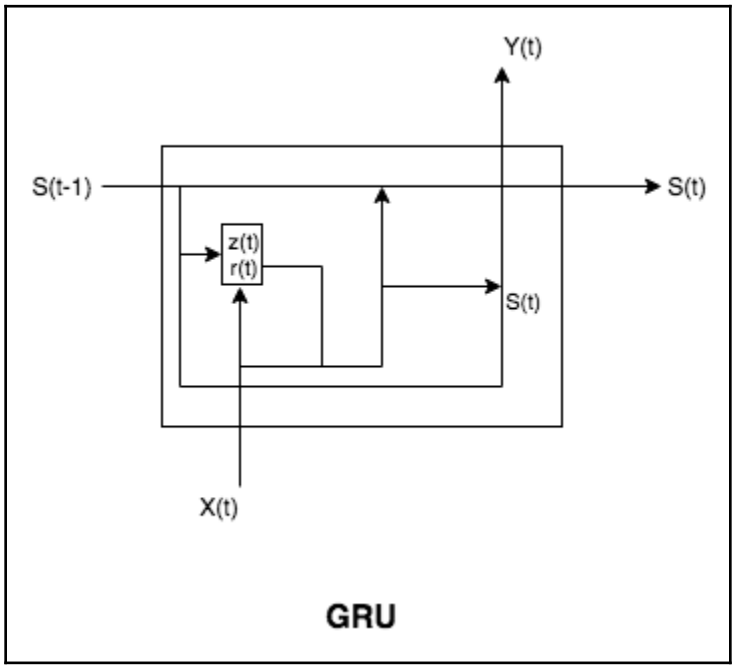
```
> go run main.go
CUDA version: 9010
CUDA devices: 1
Device 0
========
Name       :     "GeForce GTX 1060 6GB"
Clock Rate:      1784500 kHz
Memory     :     6370295808 bytes
Compute    :     6.1
```

Chapter 5: Next Word Prediction with Recurrent Neural Networks

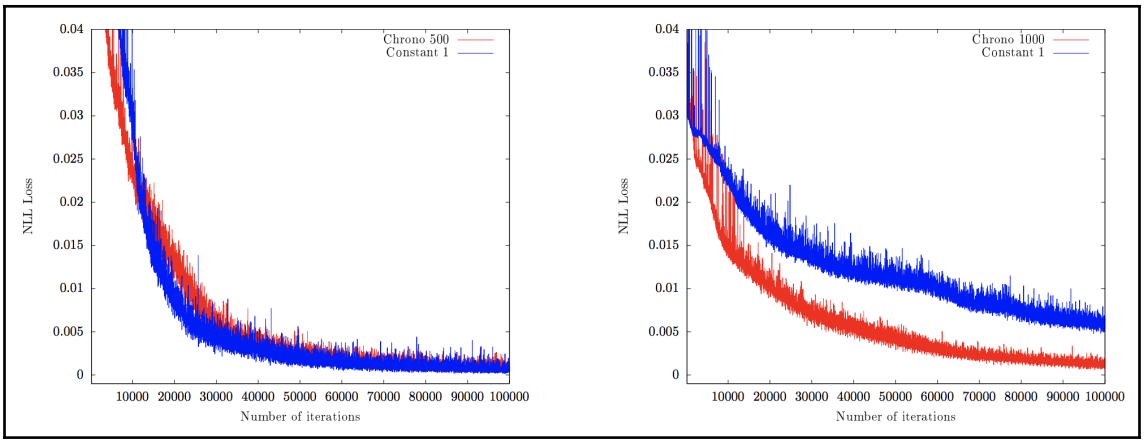




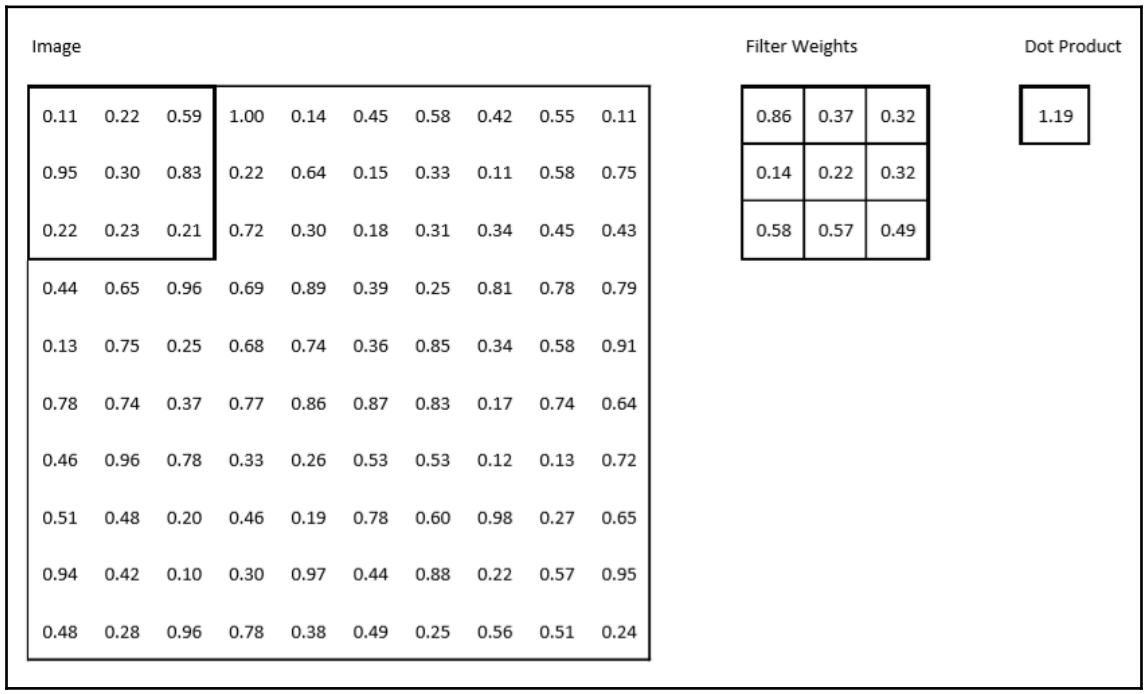
LSTM Unit



GRU


Chrono 500
Constant 1
NLL Loss
Number of iterations
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10000 20000 30000 40000 50000 60000 70000 80000 90000 100000
Chrono 1000
Constant 1
NLL Loss
Number of iterations

Chapter 6: Object Recognition with Convolutional Neural Networks



Image

0.11	0.22	0.59	1.00	0.14	0.45	0.58	0.42	0.55	0.11
0.95	0.30	0.83	0.22	0.64	0.15	0.33	0.11	0.58	0.75
0.22	0.23	0.21	0.72	0.30	0.18	0.31	0.34	0.45	0.43
0.44	0.65	0.96	0.69	0.89	0.39	0.25	0.81	0.78	0.79
0.13	0.75	0.25	0.68	0.74	0.36	0.85	0.34	0.58	0.91
0.78	0.74	0.37	0.77	0.86	0.87	0.83	0.17	0.74	0.64
0.46	0.96	0.78	0.33	0.26	0.53	0.53	0.12	0.13	0.72
0.51	0.48	0.20	0.46	0.19	0.78	0.60	0.98	0.27	0.65
0.94	0.42	0.10	0.30	0.97	0.44	0.88	0.22	0.57	0.95
0.48	0.28	0.96	0.78	0.38	0.49	0.25	0.56	0.51	0.24

Filter Weights

0.86	0.37	0.32
0.14	0.22	0.32
0.58	0.57	0.49

Dot Product

1.19	0.83

Input

0.96	0.28	0.80	0.14	0.10	0.86	0.64	0.11	0.73	0.28
0.92	0.20	0.29	0.53	0.45	0.33	0.54	0.11	0.34	0.59
0.97	0.64	0.34	0.53	0.74	0.20	0.47	0.52	0.42	0.53
0.50	0.52	0.65	0.72	0.98	0.11	0.44	0.44	0.10	0.43
0.69	0.96	0.40	0.56	0.91	0.95	0.98	0.34	0.82	0.82
0.22	0.95	0.35	0.13	0.43	0.93	0.16	0.37	0.62	0.14
0.81	0.74	0.46	0.86	0.56	0.57	0.29	0.20	0.45	0.65
0.68	0.90	0.97	0.94	0.61	0.96	0.52	0.61	0.73	0.23
0.97	0.91	0.88	0.22	0.46	0.56	0.40	0.12	0.75	0.87
0.52	0.64	0.96	0.35	0.63	0.35	0.22	0.42	0.93	0.43

MaxPool

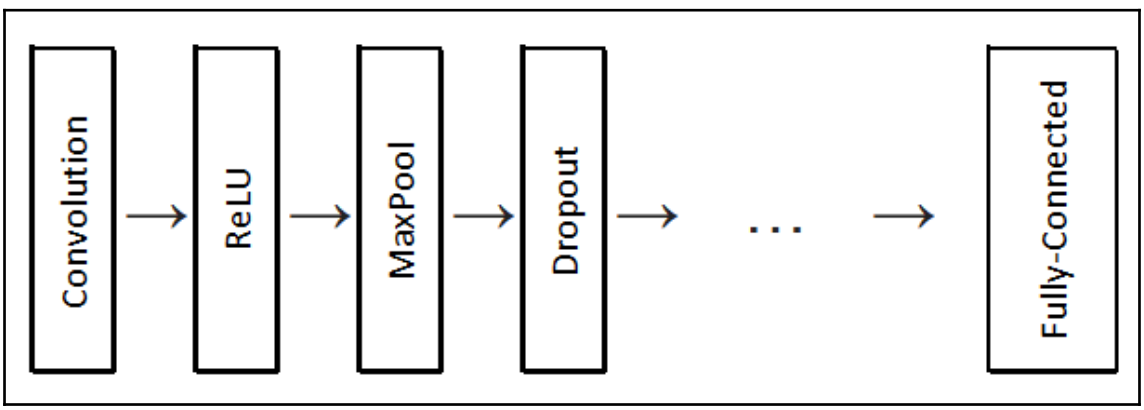
0.96

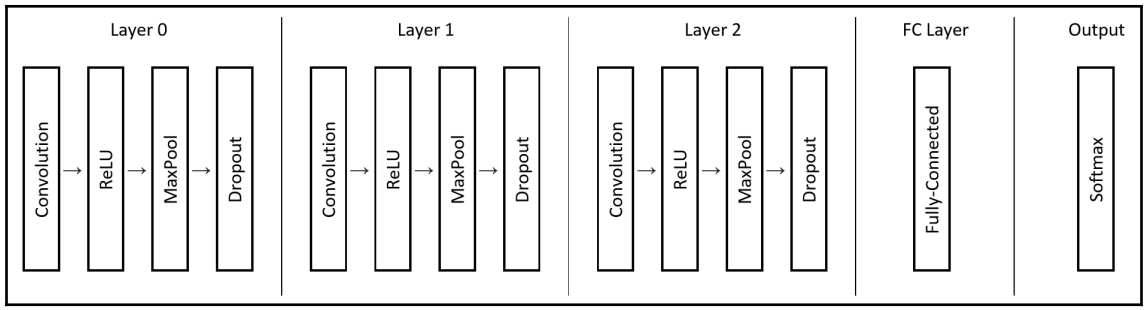
Input

0.96	0.28	0.80	0.14	0.10	0.86	0.64	0.11	0.73	0.28
0.92	0.20	0.29	0.53	0.45	0.33	0.54	0.11	0.34	0.59
0.97	0.64	0.34	0.53	0.74	0.20	0.47	0.52	0.42	0.53
0.50	0.52	0.65	0.72	0.98	0.11	0.44	0.44	0.10	0.43
0.69	0.96	0.40	0.56	0.91	0.95	0.98	0.34	0.82	0.82
0.22	0.95	0.35	0.13	0.43	0.93	0.16	0.37	0.62	0.14
0.81	0.74	0.46	0.86	0.56	0.57	0.29	0.20	0.45	0.65
0.68	0.90	0.97	0.94	0.61	0.96	0.52	0.61	0.73	0.23
0.97	0.91	0.88	0.22	0.46	0.56	0.40	0.12	0.75	0.87
0.52	0.64	0.96	0.35	0.63	0.35	0.22	0.42	0.93	0.43

MaxPool

0.96	0.80




Layer 0
Convolution
ReLU
MaxPool
Dropout
Layer 1
Convolution
ReLU
MaxPool
Dropout
Layer 2
Convolution
ReLU
MaxPool
Dropout
FC Layer
Fully-Connected
Output
Softmax


0 - airplane
1 - automobile
2 - bird
3 - cat
4 - deer
5 - dog
6 - frog
7 - horse
8 - ship
9 - truck

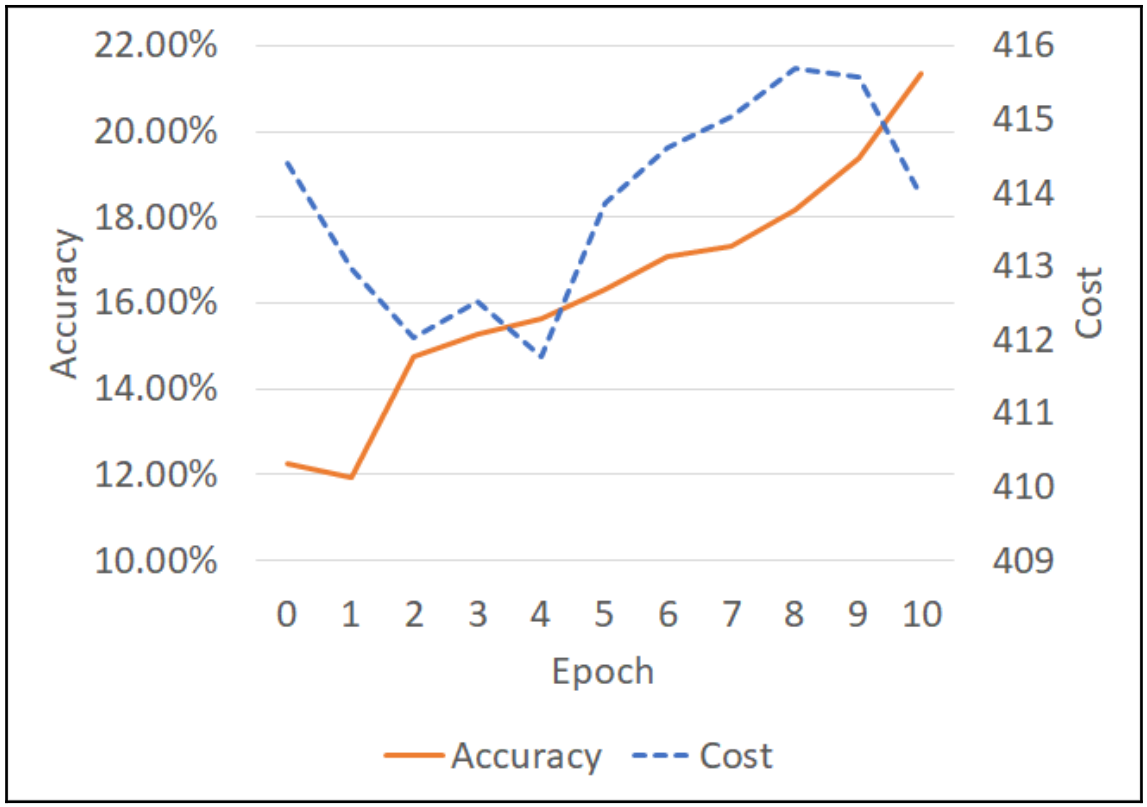

22.00%
20.00%
18.00%
16.00%
14.00%
12.00%
10.00%
Accuracy
416
415
414
413
412
411
410
409
Cost
0 1 2 3 4 5 6 7 8 9 10
Epoch
Accuracy
Cost

Image	Classification
	horse
	frog
	automobile
	airplane
	truck
	cat
	cat
	cat
	cat
	cat

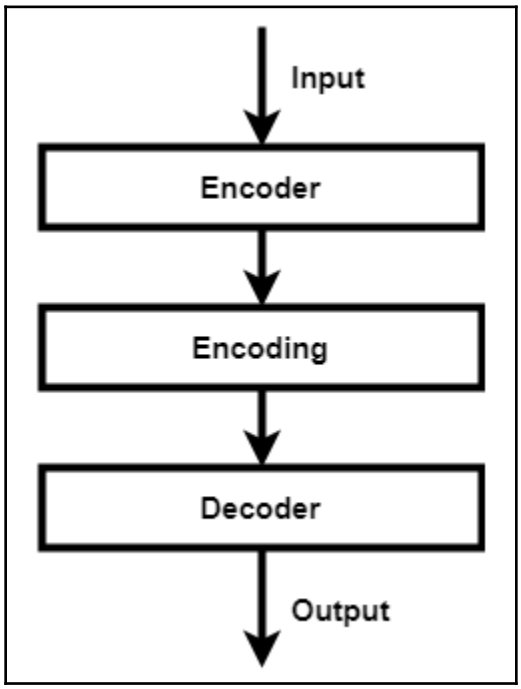
```
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 417.35       Driver Version: 417.35       CUDA Version: 10.0     |
|-------------------------------+----------------------+----------------------+
| GPU  Name            TCC/WDDM | Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|===============================+======================+======================|
|   0  GeForce GTX 1080   WDDM  | 00000000:01:00.0  On |                  N/A |
| 18%   49C    P8    14W / 200W |    788MiB /  8192MiB |      0%      Default |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                       GPU Memory |
|  GPU       PID   Type   Process name                             Usage      |
|=============================================================================|
|    0      1144    C+G   Insufficient Permissions                       N/A  |
|    0      5040    C+G   ...6)\Google\Chrome\Application\chrome.exe N/A  |
|    0      7832    C+G   C:\Windows\explorer.exe                       N/A  |
|    0      8576    C+G   ...t_cw5n1h2txyewy\ShellExperienceHost.exe N/A  |
|    0      9080    C+G   ...dows.Cortana_cw5n1h2txyewy\SearchUI.exe N/A  |
|    0     14448    C+G   ...mmersiveControlPanel\SystemSettings.exe N/A  |
|    0     14544    C+G   ...2.0_x64__8wekyb3d8bbwe\WinStore.App.exe N/A  |
|    0     16132    C+G   ...sktop App\AcWebBrowser\acwebbrowser.exe N/A  |
|    0     18252    C+G   ...cal\mattermost\app-4.1.2\Mattermost.exe N/A  |
|    0     56948    C+G   ...rogram Files\Microsoft VS Code\Code.exe N/A  |
+-----------------------------------------------------------------------------+
```

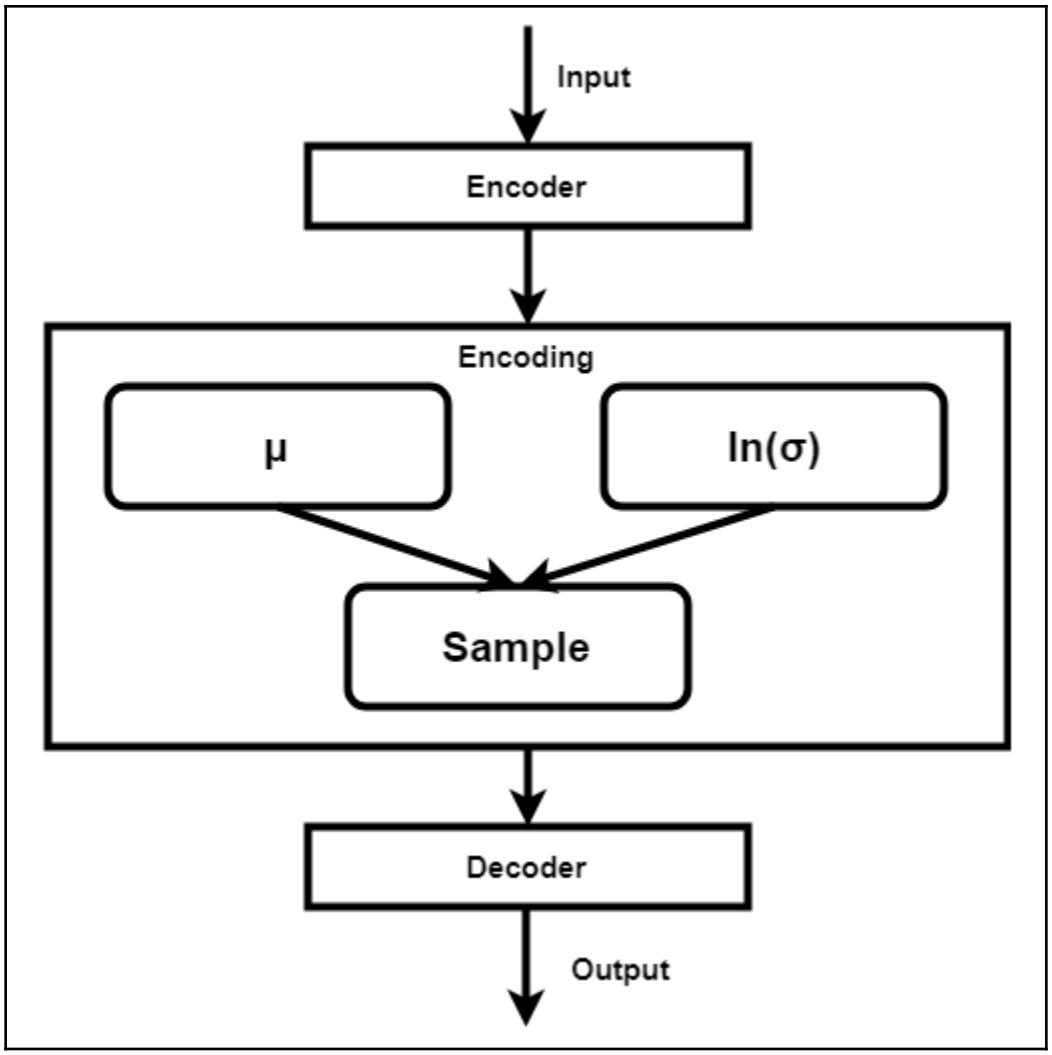
Chapter 7: Maze Solving with Deep Q-Networks

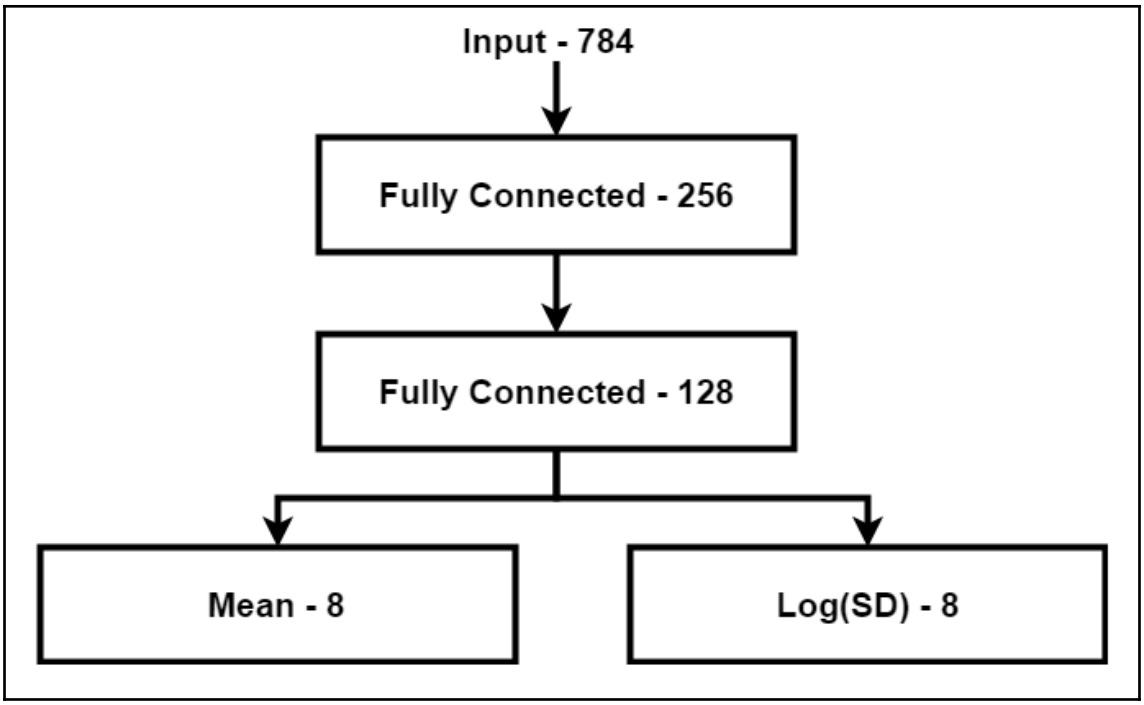
```
2019/06/17 22:29:33 width 21, height 11
Matrix (11, 21) [21 1]
⎡1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1⎤
⎢2  0  1  0  0  0  1  0  0  0  0  0  1  0  0  0  0  0  0  0  1⎥
⎢1  0  1  1  1  0  1  0  1  1  1  0  1  0  1  1  1  0  1  1  1⎥
⎢1  0  0  0  0  0  1  0  0  0  1  0  1  0  1  0  1  0  0  0  1⎥
⎢1  0  1  0  1  1  1  1  1  0  1  1  1  0  1  0  1  1  1  0  1⎥
⎢1  0  1  0  1  0  0  0  1  0  0  0  1  0  1  0  1  0  0  0  1⎥
⎢1  1  1  0  1  0  1  0  1  1  1  0  1  0  1  0  1  0  1  1  1⎥
⎢1  0  0  0  1  0  1  0  1  0  0  0  1  0  0  0  1  0  1  0  1⎥
⎢1  0  1  1  1  0  1  0  1  0  1  1  1  1  1  0  1  0  1  0  1⎥
⎢1  0  0  0  0  0  1  0  0  0  0  0  0  0  0  0  1  0  0  0  3⎥
⎣1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1⎦
{1 0} {9 20}
true
false
false
false
2019/06/17 22:29:33 episode 0, 1st loop
2019/06/17 22:29:44 episode 100, 1st loop
2019/06/17 22:29:55 episode 200, 1st loop
2019/06/17 22:30:07 episode 300, 1st loop
```

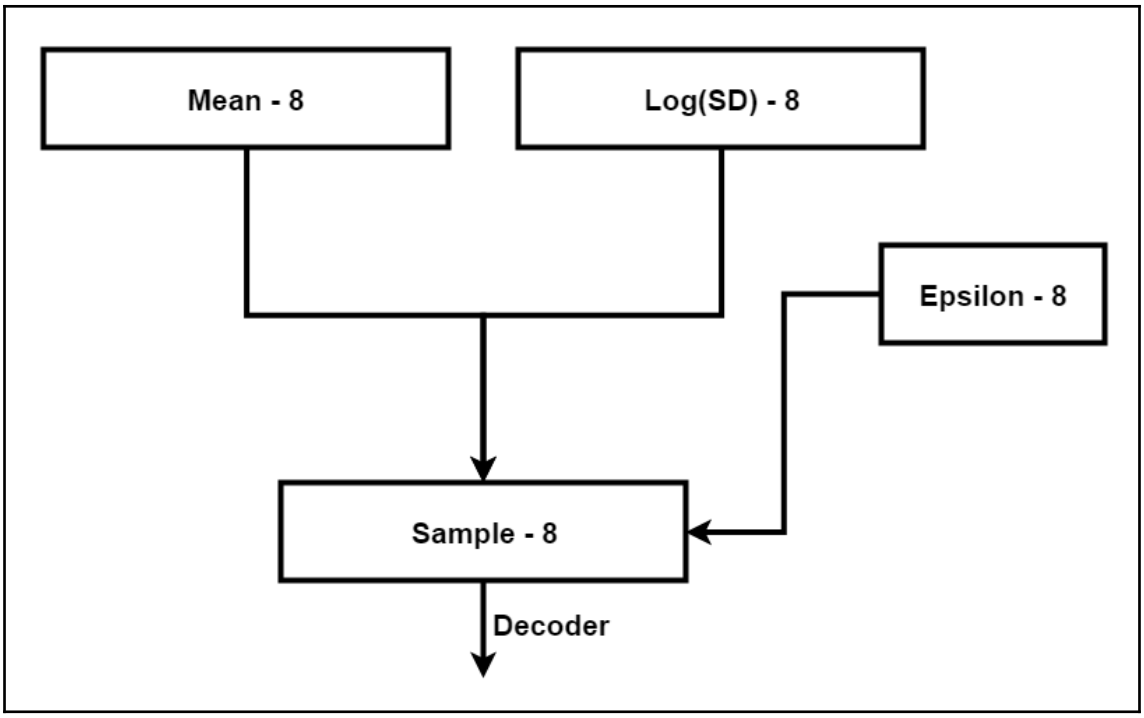
```
2019/06/17 23:11:26 player at: {2 7} best: {1 0}
2019/06/17 23:11:26 reward -1, done false
2019/06/17 23:11:26
┌1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1┐
|0  0  1  0  0  0  1  0  0  0  0  0  1  0  0  0  0  0  0  1|
|1  0  1  1  1  0  1  0  1  1  1  0  1  0  1  1  1  0  1  1  1|
|1  0  0  0  0  0  1  0  0  0  1  0  1  0  1  0  1  0  0  0  1|
|1  0  1  0  1  1  1  1  1  0  1  1  1  0  1  0  1  1  1  0  1|
|1  0  1  0  1  0  0  0  1  0  0  0  1  0  1  0  1  0  0  0  1|
|1  1  1  0  1  0  1  0  1  1  1  0  1  0  1  0  1  0  1  1  1|
|1  0  0  4  1  0  1  0  1  0  0  0  1  0  0  0  1  0  1  0  1|
|1  0  1  1  1  0  1  0  1  0  1  1  1  1  1  0  1  0  1  0  1|
|1  0  0  0  0  0  1  0  0  0  0  0  0  0  0  0  1  0  0  0  3|
└1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1┘
2019/06/17 23:11:26 player at: {3 7} best: {-1 0}
2019/06/17 23:11:26 reward 0, done false
```

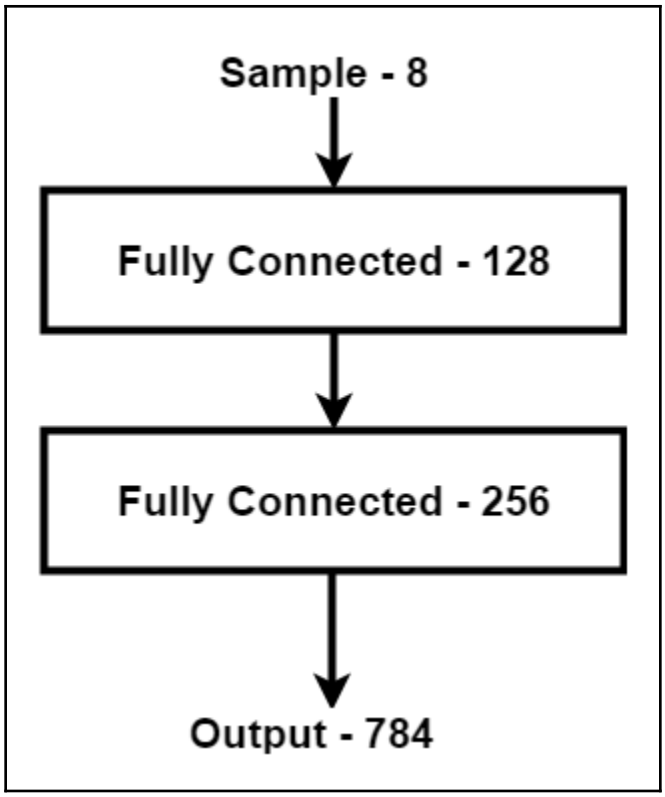
Chapter 8: Generative Models with Variational Autoencoders




Input
Encoder
Encoding
μ
ln(σ)
Sample
Decoder
Output

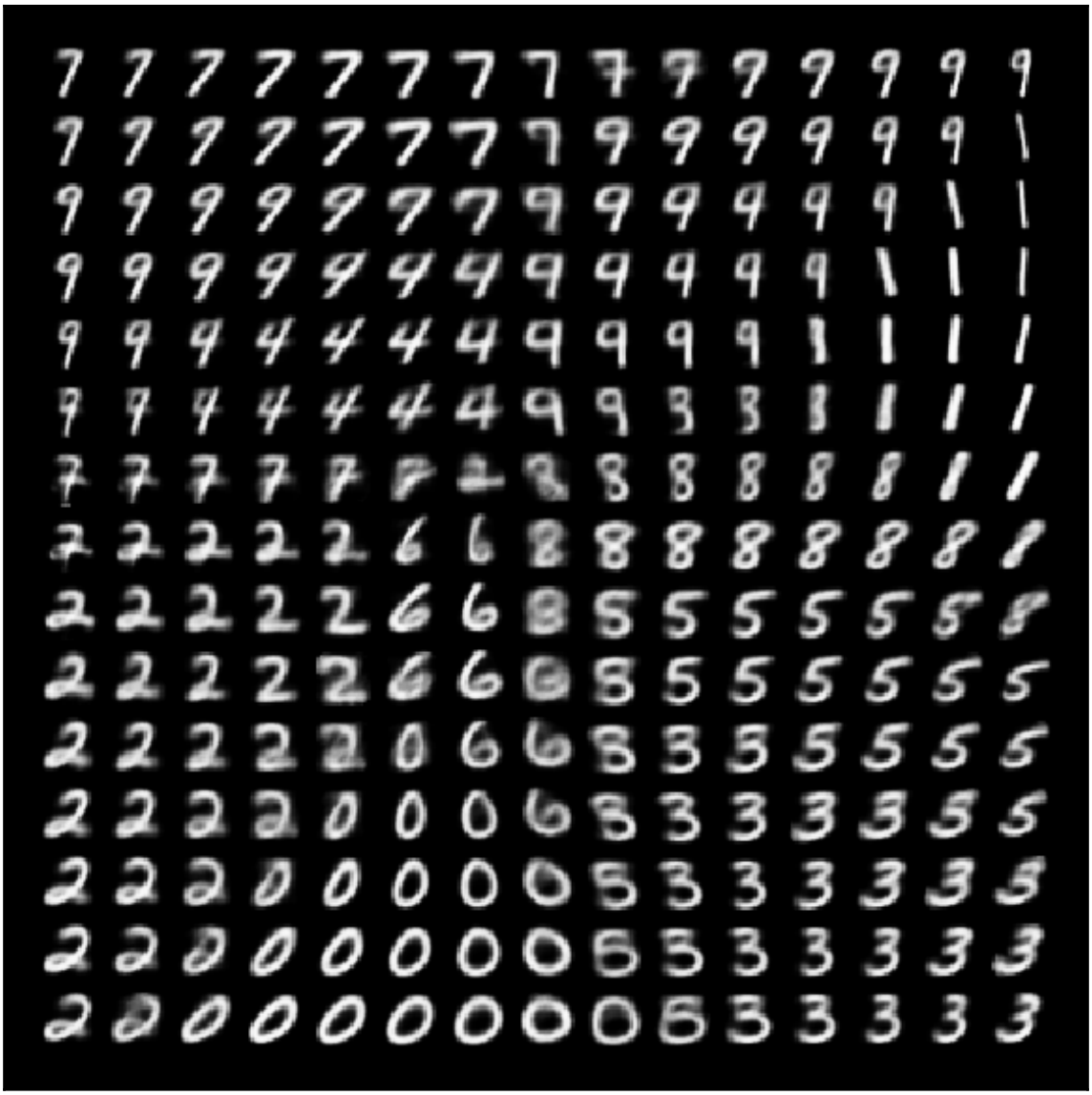

Input - 784
Fully Connected - 256
Fully Connected - 128
Mean - 8
Log(SD) - 8

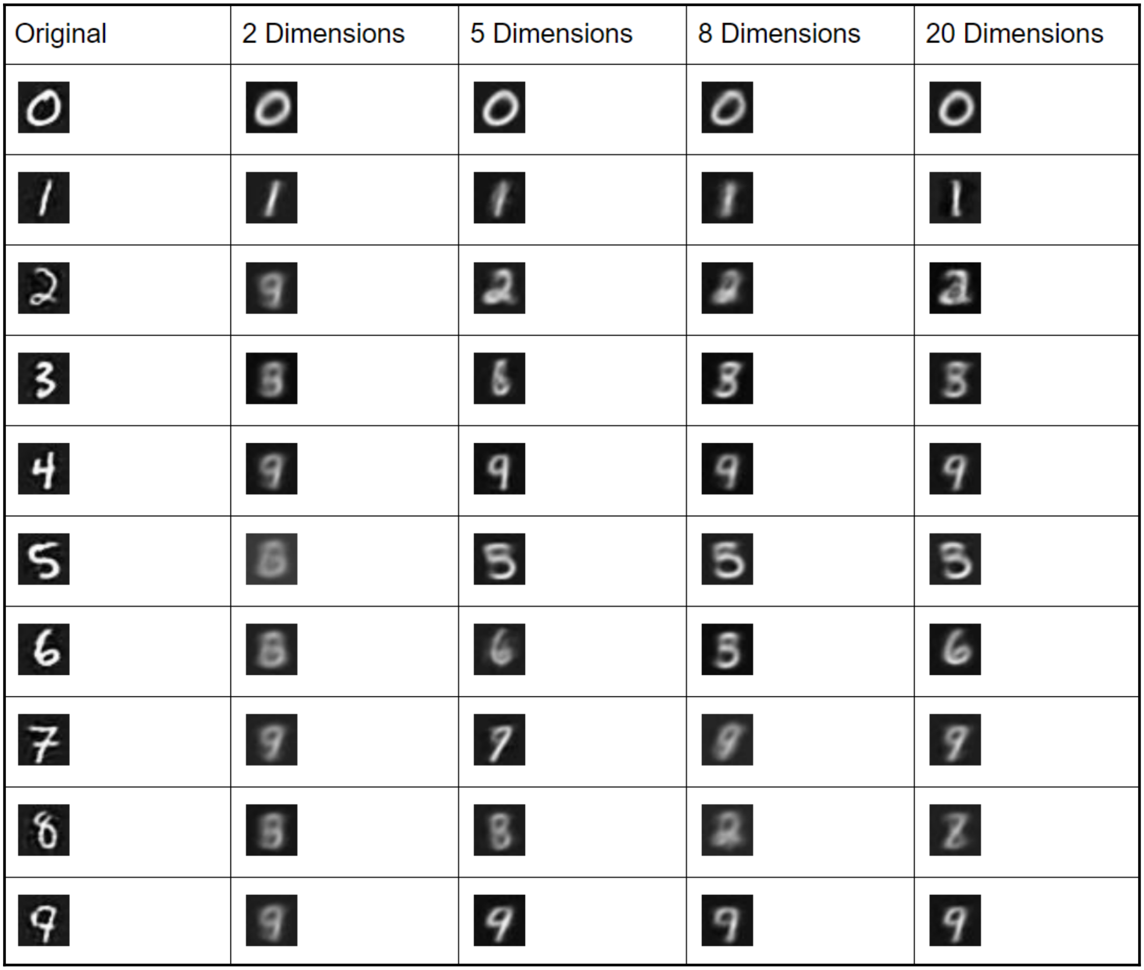

Mean - 8
Log(SD) - 8
Epsilon - 8
Sample - 8
Decoder


Sample - 8
Fully Connected - 128
Fully Connected - 256
Output - 784

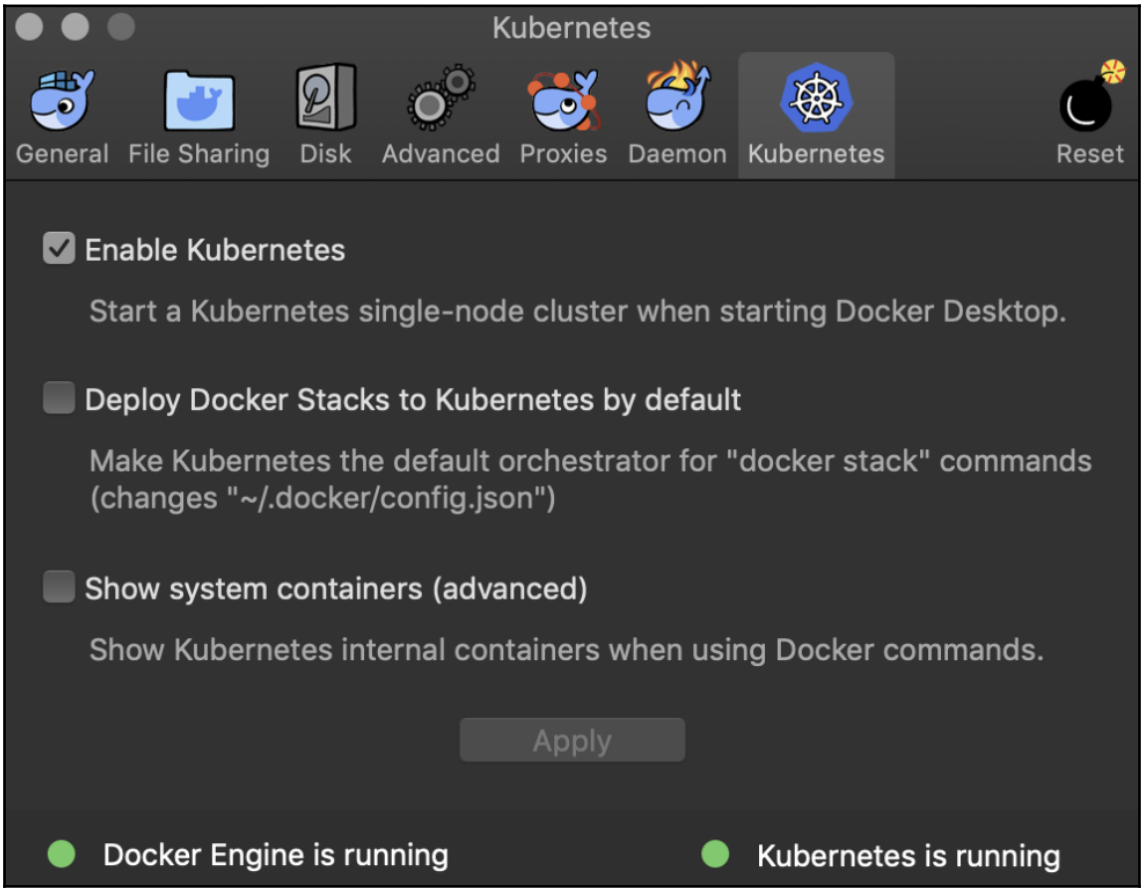
Epoch	Standard Autoencoder	Variational Autoencoder
10		
20		
30		
40		
50		

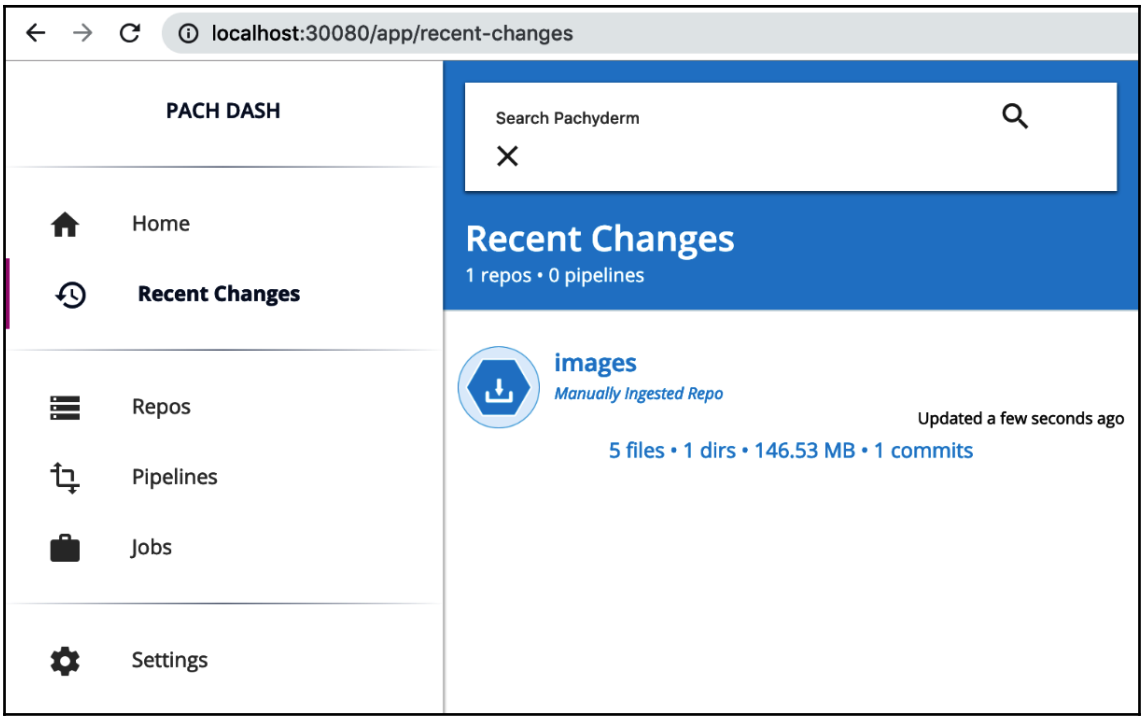
Epoch	Standard Autoencoder	Variational Autoencoder
10		
20		
30		
40		
50		

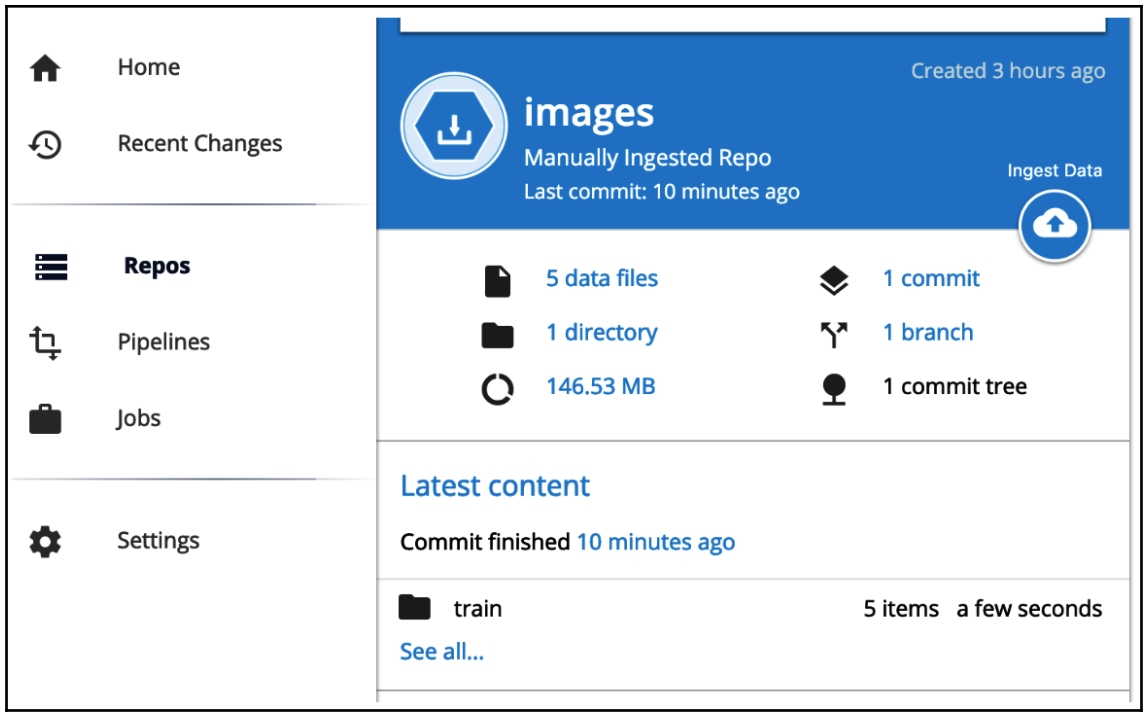



Original
2 Dimensions
5 Dimensions
8 Dimensions
20 Dimensions

Chapter 9: Building a Deep Learning Pipeline




localhost:30080/app/recent-changes
PACH DASH
Home
Recent Changes
Repos
Pipelines
Jobs
Settings
Search Pachyderm
Recent Changes
1 repos • 0 pipelines
images
Manually Ingested Repo
Updated a few seconds ago
5 files • 1 dirs • 146.53 MB • 1 commits


Home
Recent Changes
Repos
Pipelines
Jobs
Settings
Created 3 hours ago
images
Manually Ingested Repo
Last commit: 10 minutes ago
Ingest Data
5 data files
1 directory
146.53 MB
1 commit
1 branch
1 commit tree
Latest content
Commit finished 10 minutes ago
train
5 items a few seconds
See all...