# Introduction to Deep Learning with Python

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*PyCon Pakistan 16/12/2017* 



## Artificial intelligence, machine learning & deep learning

#### The Al universe



Goodfellow et. al., "Deep Learning." MIT Press (2016)

#### "What's the difference between AI and ML?"

#### "It's AI when you're raising money, it's ML when you're trying to hire people."

Data











Interest over time





Goodfellow et. al., "Deep Learning." MIT Press (2016)

#### Growing Use of Deep Learning at Google

*#* of directories containing model description files



Dean, "Large-Scale Deep Learning for Intelligent Computer Systems." WSDM (2016)

Across many

- 1. Bigger datasets
- 2. More computational power
- 3. Improvements in algorithms (due to 1 and 2)

## *"If big data is the new oil, deep learning is the new internal combustion engine."*

– Yann LeCun

(Director, Facebook AI Research)

"AI is the new electricity: Just as electricity transformed almost everything 100 years ago, today I actually have a hard time thinking of an industry that I don't think AI will transform in the next several years."

- Andrew Ng

(Founder, deeplearning.ai)

#### Neural networks

#### **Biological neuron** impulses carried toward cell body branches of axon dendrites axon axon nucleus terminals impulses carried away from cell body cell body

#### **Artificial neuron**



#### **Biological vs artificial neuron**





#### **Activation functions**



Sze et. al., "Efficient Processing of Deep Neural Networks: A Tutorial and Survey." arXiv (2017)

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#### **Activation functions**



LeCun et. al., "Deep Learning." Nature (2015)

#### A shallow neural network



#### A deep neural network



#### What we want





Goodfellow et. al., "Deep Learning." MIT Press (2016)

#### The need for depth



Goodfellow et. al., "Deep Learning." MIT Press (2016)

#### ... and even more depth



Szegedy et. al., "Going Deeper with Convolutions." CVPR (2015)

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#### Specialized architectures

Vision: Convolutional Neural Networks



#### Specialized architectures

Language: Recurrent Neural Networks



#### **Deep learning**

### The learning process

- 1. Pick a training example
- 2. Make a prediction for it
- 3. Compare your prediction with the truth (= error)
- 4. Modify your weights in order to minimize this error
- 5. Repeat until convergence

#### Minimizing the error



#### **Gradient descent**



#### Gradient descent in higher dimensions





#### Learning multiple layers


#### **Forward pass**











### Backpropagation algorithm in full



LeCun et. al., "Deep Learning." Nature (2015)

#### Applications

### **Object Detection**



Ren et. al., "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks." NIPS (2015)

#### **Scene segmentation**



Badrinarayanan et. al., "SegNet: A Deep Convolutional Encoder-Decoder Architecture..." PAMI (2016)

#### **Super resolution**

 $8 \times 8$  input  $32 \times 32$  samples ground truth

Dahl et. al., "Pixel Recursive Super Resolution." arXiv (2017)

#### Style transfer



Gatys et. al., "A Neural Algorithm of Artistic Style." arXiv (2015)

#### **Image translation**



Input sunny image

Al-generated rainy image



Liu et. al., "Unsupervised Image-to-Image Translation Networks." NIPS (2017)

#### Image generation



Karras et. al., "Progressive Growing of GANs for Improved Quality, Stability, and Variation." arXiv (2017)

#### Image generation



Karras et. al., "Progressive Growing of GANs for Improved Quality, Stability, and Variation." arXiv (2017)

#### Learning word representations



Mikolov et. al., "Efficient Estimation of Word Representations in Vector Space." arXiv (2013)

#### Learning sentiment representations

This is one of Crichton's best books. The characters of Karen Ross, Peter Elliot, Munro, and Amy are beautifully developed and their interactions are exciting, complex, and fast-paced throughout this impressive novel. And about 99.8 percent of that got lost in the film. Seriously, the screenplay AND the directing were horrendous and clearly done by people who could not fathom what was good about the novel. I can't fault the actors because frankly, they never had a chance to make this turkey live up to Crichton's original work. I know good novels, especially those with a science fiction edge, are hard to bring to the screen in a way that lives up to the original. But this may be the absolute worst disparity in quality between novel and screen adaptation ever. The book is really, really good. The movie is just dreadful.

Radford et. al., "Learning to Generate Reviews and Discovering Sentiment." *arXiv (2017)* 

#### Image captioning



A woman is throwing a frisbee in a park.



A dog is standing on a hardwood floor.



A **stop** sign is on a road with a mountain in the background



A little girl sitting on a bed with a teddy bear. A group of **people** sitting on a boat in the water.

A giraffe standing in a forest with trees in the background.

Vinyals et. al., "Show and Tell: A Neural Image Caption Generator." CVPR (2015)

#### Visual question answering

What are pulling a man on a wagon down on dirt road? Answer: horses Prediction: horses What is the color of the box ? Answer: red Prediction: red



What next to the large umbrella attached to a table? Answer: trees Prediction: tree

How many people are going up the mountain with walking sticks? Answer: four Prediction: four



Yang et. al., "Stacked Attention Networks for Image Question Answering." CVPR (2016)

### Playing games



Silver et. al., "Mastering the Game of Go with Deep Neural Networks and Tree Search." Nature (2016)

#### **Building better neural networks**



Zoph et. al., "Neural Architecture Search with Reinforcement Learning." ICLR (2017)

### **Building better software**



(b) Learned Hash-Map



Kraska et. al., "The Case for Learned Index Structures." arXiv (2017)

# What you need to get started with deep learning

#### These, pretty much



#### ... plus a handful of other stuff



https://medium.com/towards-data-science/building-your-own-deep-learning-box-47b918aea1eb

### Building a deep learning rig

Component		Selection	Base	Promo	Shipping T	ax Price	Where	
СРИ		Intel - Core i7-7700K 4.2GHz Quad-Core Processor	\$318.69			\$318.69	OutletPC	Buy
CPU Cooler		Cooler Master - Hyper 212 EVO 82.9 CFM Sleeve Bearing CPU Cooler	\$29.99	-\$10.00	FREE	\$19.99	Newegg	Buy
Motherboard		MSI - Z270-A PRO ATX LGA1151 Motherboard	\$114.88	-\$10.00		\$104.88	OutletPC	Buy
Memory	-	Corsair - Vengeance LPX 32GB (2 x 16GB) DDR4-3200 Memory	\$366.59		FREE	\$366.59	Newegg Marketplace	Buy
Storage		Samsung - 850 EVO-Series 500GB 2.5" Solid State Drive	\$149.89			\$149.89	OutletPC	Buy
Video Card		Zotac - GeForce GTX 1080 8GB AMP! Edition Video Card	\$564.75			\$564.75	OutletPC	Buy
Case		NZXT - S340 (White) ATX Mid Tower Case	\$69.99	-\$10.00	FREE	\$59.99	Newegg	Buy
Power Supply	•	EVGA - SuperNOVA G2 750W 80+ Gold Certified Fully-Modular ATX Power Supply	\$99.99	-\$20.00	\$5.99	\$85.98	Newegg	Buy
					Base Tota	al: \$1714.77		
				Ma	il-in Rebate	s: -\$50.00		
					Shippin	g: \$5.99		
					Tota	l: \$1670.76		

https://pcpartpicker.com/list/FRp8XH

#### An alternative

# amazon webservices

#### **Amazon Web Services**

#### Amazon EC2 P2 Instances

#### Powerful, Scalable GPU instances for high-performance computing

Amazon EC2 P2 Instances are powerful, scalable instances that provide GPU-based parallel compute capabilities. For customers with graphics requirements, see G2 instances for more information.

P2 instances, designed for general-purpose GPU compute applications using CUDA and OpenCL, are ideally suited for machine learning, high performance databases, computational fluid dynamics, computational finance, seismic analysis, molecular modeling, genomics, rendering, and other server-side workloads requiring massive parallel floating point processing power.

Use the Amazon Linux AMI, pre-installed with popular deep learning frameworks such as Caffe and Mxnet, so you can get started quickly. You can also use the NVIDIA AMI with GPU driver and CUDA toolkit pre-installed for rapid onboarding.





AWS Free Tier includes 750 hours of both Linux and Windows t2.micro instances each month for one year for new AWS customers. To stay within the Free Tier, use only t2.micro instances.

View AWS Free Tier Details

#### **Amazon Web Services**

	vCPU	ECU	Memory (GiB)	Instance Storage (GB)	Linux/UNIX Usage
GPU Instances - Current Generation					
p2.xlarge	4	12	61	EBS Only	\$0.9 per Hour
p2.8xlarge	32	94	488	EBS Only	\$7.2 per Hour
p2.16xlarge	64	188	732	EBS Only	\$14.4 per Hour
g3.4xlarge	16	47	122	EBS Only	\$1.14 per Hour
g3.8xlarge	32	94	244	EBS Only	\$2.28 per Hour
g3.16xlarge	64	188	488	EBS Only	\$4.56 per Hour

#### **Amazon Web Services**

#### AWS AI Blog AWS Deep Learning AMI Now Supports PyTorch, Keras 2 and Latest Deep Learning Frameworks

by Cynthya Peranandam | on 18 OCT 2017 | in Artificial Intelligence, AWS Deep Learning AMIs | Permalink | 
Share Today, we're pleased to announce an update to the AWS Deep Learning AMI.

The AWS Deep Learning AMI, which lets you spin up a complete deep learning environment on AWS in a single click, now includes PyTorch, Keras 1.2 and 2.0 support, along with popular machine learning frameworks such as TensorFlow, Caffe2 and Apache MXNet.

#### Using PyTorch for fast prototyping

The AMI now includes PyTorch 0.2.0, allowing developers to create dynamic neural networks in Python, a good fit for dynamic inputs such as text and time series. Developers can get started quickly using these beginner and advanced tutorials, including setting up distributed training with PyTorch.

#### Improved Keras support

The AMI now supports the most recent version of Keras, v2.0.8. By default, your Keras code will run against TensorFlow as a backend; you can also swap to other supported backends such as Theano and CNTK. We've also included a modified version of Keras 1.2.2 which runs on the Apache MXNet backend with better training performance.

### Deep learning software ecosystem

	Aggr	egate po	pularity	<pre>(30•contrib + 20•issues + 3•forks + 1•stars)•1e-3</pre>
$\checkmark$	#1:	377.51		tensorflow/tensorflow
$\checkmark$	#2:	174.15		fchollet/keras
$\checkmark$	#3:	143.84		BVLC/caffe
$\checkmark$	#4:	128.26		dmlc/mxnet
$\checkmark$	#5:	72.85		Theano/Theano
$\checkmark$	#6:	69.32		Microsoft/CNTK
	#7:	67.30		<pre>deeplearning4j/deeplearning4j</pre>
$\checkmark$	#8:	61.54		baidu/paddle
$\checkmark$	#9:	54.07		pytorch/pytorch
$\checkmark$	#10:	29.65		pfnet/chainer
	#11:	29.35		torch/torch7
	#12:	29.33		NVIDIA/DIGITS
$\checkmark$	#13:	28.42		tflearn/tflearn
$\checkmark$	#14:	28.09		caffe2/caffe2
$\checkmark$	#15:	21.41		davisking/dlib
				https://twitter.com/fchollet/status/915366704401719296













### Deep learning in a day

- 1. Create an AWS account
- 2. Launch an EC2 instance
- 3. SSH into your instance
- 4. Launch a Jupyter Notebook
- 5. ???

#### 6. Profit!

aws	Services	🗸 🗸 Resource Groups 🗸 🚯			$\Diamond$	Samar Haider 👻 Oregon 👻 Support 👻		
EC2 Dashboard	<b>^</b>	Resources			୯	Account Attributes	i	
Events	•	You are using the following Amazon EC2 resources in the US	t (Oregon) region:		Supported Platforms			
Tags		0 Running Instances		0 Elastic IPs		VPC		
Reports		0 Dedicated Hosts		0 Snapshots		Default VPC		
Limits		0 Volumes		0 Load Balancers		vpc-9e94a5fb		
INSTANCES		1 Key Pairs		3 Security Groups		Resource ID length management		
Instances		0 Placement Groups				Resource IS longer management		
Launch Templates					Additional Information			
Spot Requests		Create Instance				- Getting Started Guide		
Reserved Instances	s	To start using Amazon EC2 you will want to launch a virtual ser	start using Amazon EC2 you will want to launch a virtual server, known as an Amazon EC2 instance.			Documentation		
Dedicated Hosts		Launch Instance				All EC2 Resources		
Scheduled Instance	es					Forums		
IMAGES     Note: Your instances will launch in the US West (Oregon) region						Pricing		
AMIs		Service Health C Scheduled Events		Scheduled Events	C	Contact Us		
Bundle Tasks		Service Status:		US West (Oregon):		AWS Marketplace		
ELASTIC BLOCK STORE		US West (Oregon):     No events		No events				
		This service is operating normally				Find free software trial products in the AWS		
Snapshots		Availability Zone Status:		Or try these popular AMIs:				
E NETWORK & SECURITY		<ul> <li>us-west-2a:</li> <li>Availability zone is operating normally</li> </ul>			Barracuda NextGen Firewall F-Series - PAYG			
Security Groups		👩 us-west-2b:				Provided by Barracuda Networks, Inc.		
Elastic IPs		Availability zone is operating normally				Rating ****		
Placement Groups		ø us-west-2c:				Starting from \$0.60/hr or from \$4,599/yr		
Key Pairs	-	Availability zone is operating normally				fees		
🗨 Feedback 🔇	) English	(US)		© 2008 - 2017, Amazon Web Services,	Inc. or its affiliate	es. All rights reserved. Privacy Policy Terms of U	s	

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aws	Services	✓ Resource Groups	¥ 🛠			¢	Samar Haider 👻	Oregon 👻	Support	•	
EC2 Dashboard Events		Launch Instance 🔻	Connect	Actions *					Ð	¢	0
Tags		Q Filter by tags and attributed	ites or search	by keyword			0	K < No	ne found	> :	>
Reports Limits INSTANCES					You do not have any running instances in this region. First time using EC2? Check out the Getting Started Guide. Click the Launch Instance button to start your own server.						
Launch Templates Spot Requests Reserved Instances	5				Launch Instance						
Scheduled Instance	es	Select an instance above			0.0.0						
<ul> <li>IMAGES</li> <li>AMIS</li> <li>Bundle Tasks</li> <li>ELASTIC BLOCK STORE</li> <li>Volumes</li> <li>Snapshots</li> </ul>											
<ul> <li>NETWORK &amp; SECURITY</li> <li>Security Groups</li> <li>Elastic IPs</li> <li>Placement Groups</li> <li>Key Pairs</li> </ul>	Ŧ										





#### Step 2: Choose an Instance Type

Amazon EC2 provides a wide selection of instance types optimized to fit different use cases. Instances are virtual servers that can run applications. They have varying combinations of CPU, memory, storage, and networking capacity, and give you the flexibility to choose the appropriate mix of resources for your applications. Learn more about instance types and how they can meet your computing needs.

Filter by: GPU compute 💌

Current generation

Currently selected: p2.xlarge (11.75 ECUs, 4 vCPUs, 2.7 GHz, E5-2686v4, 61 GiB memory, EBS only)

Show/Hide Columns

Family -	Туре 👻	vCPUs (j) 👻	Memory (GiB) 👻	Instance Storage (GB) (i) -	EBS-Optimized Available (i)	Network Performance (i) -	IPv6 Support ⊸ (j)
GPU compute	p2.xlarge	4	61	EBS only	Yes	High	Yes
GPU compute	p2.8xlarge	32	488	EBS only	Yes	10 Gigabit	Yes
GPU compute	p2.16xlarge	64	732	EBS only	Yes	25 Gigabit	Yes
GPU compute	p3.2xlarge	8	61	EBS only	Yes	Up to 10 Gigabit	Yes
GPU compute	p3.8xlarge	32	244	EBS only	Yes	10 Gigabit	Yes
GPU compute	p3.16xlarge	64	488	EBS only	Yes	25 Gigabit	Yes

Cancel Previous Review and Launch Next: Configure Instance Details



#### Step 7: Review Instance Launch

Please review your instance launch details. You can go back to edit changes for each section. Click Launch to assign a key pair to your instance and complete the launch process.

▼ AMI De	tails	Edit AMI
	Deep Learning AMI (Ubuntu) Version 2.0 - ami-3b6bce43	
0	Deep Learning AMI with Conda-based virtual environments for Apache MXNet, TensorFlow, Caffe2, PyTorch, Theano, CNTK and Keras	
	Root Device Type: ebs Virtualization type: hvm	

#### ▼ Instance Type

Edit instance type

Edit security groups

\*

Instance Type	ECUs	ECUs vCPUs Memor		Instance Storage (GB)	EBS-Optimized Available	Network Performance
p2.xlarge	11.75	4	61	EBS only	Yes	High

#### Security Groups

►

Security group name Description	launch-wizard-3 launch-wizard-3 created 2017-12-15	Γ23:16:49.904+05:00										
Type (j)	Protocol (j)	Port Range (j)	Source (i)	Description (j)								
	This security group has no rules											
Instance Details				Edit instance details								
				Cancel Previous Launch								



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#### Step 7: Review Instance Launch

Please review your instance launch details. You can go back to edit changes for each section. Click Launch to assign a key pair to your instance and complete the launch process.

▼ AMI De	tails		Edit AMI
6	Deep Learning AMI (Ubuntu	Select an existing key pair or create a new key pair ×	
✓ Instance	Deep Learning AMI with Conda-b Root Device Type: ebs Virtualization	A key pair consists of a <b>public key</b> that AWS stores, and a <b>private key file</b> that you store. Together, they allow you to connect to your instance securely. For Windows AMIs, the private key file is required to obtain the password used to log into your instance. For Linux AMIs, the private key file allows you to securely SSH into your instance.	Edit instance type
Instand	ce Type ECUs	Note: The selected key pair will be added to the set of keys authorized for this instance. Learn more	Network Performance
p2.xlarg	ge 11.75	about removing existing key pairs from a public AMI.	High
▼ Security	y Groups	Choose an existing key pair     •       Select a key pair     •       aws-key     •	Edit security groups
Security Descript	group name launch-wiz tion launch-wiz	■ I acknowledge that I have access to the selected private key file (aws-key.pem), and that without this file, I won't be able to log into my instance.	
Туре	1	Pr Cancel Launch Instances	Description (i)
		This security group has no rules	
▶ Instanc	e Details		Edit instance details
			Cancel Previous Launch
<b>Q</b> Feedba	ck 🔇 English (US)	© 2008 - 2017, Amazon Web Services, Inc. or its affiliates	a. All rights reserved. Privacy Policy Terms of Use

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	Placement Groups			Sched	uled events	No schedu	uled events			VPC ID	vpc-9	e94a5fb					
	Key Pairs	-			AMI ID	Deep Lear	rning AMI (Ubun	tu) Version 2.0		Subnet ID	subne	et-d3adf5a4					-

## \$ssh -i ./aws-key.pem ubuntu@ec2-34-211-139-121.us-west-2.compute.amazonaws.com

# \$jupyter notebook

\$ ssh -i ./aws-key.pem ubuntu@ec2-34-211-139-121.us-west-2.compute.amazonaws.com The authenticity of host 'ec2-34-211-139-121.us-west-2.compute.amazonaws.com (34 .211.139.121)' can't be established. ECDSA key fingerprint is SHA256:kHrJKN1SjbiW2Igs1S8oPEyv6aFdpOAYd64vvV3fmpw. Are you sure you want to continue connecting (yes/no)? yes Warning: Permanently added 'ec2-34-211-139-121.us-west-2.compute.amazonaws.com,3 4.211.139.121' (ECDSA) to the list of known hosts. Welcome to Ubuntu 16.04.1 LTS (GNU/Linux 4.4.0-36-generic x86\_64)

- \* Documentation: https://help.ubuntu.com
- \* Management: https://landscape.canonical.com
- \* Support: https://ubuntu.com/advantage
- Get cloud support with Ubuntu Advantage Cloud Guest: http://www.ubuntu.com/business/services/cloud

469 packages can be updated.

192 updates are security updates.

Last login: Sun Oct 16 02:04:33 2016 from 124.110.152.24 ubuntu@ip-172-31-38-216:~\$ nvidia-smi

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File Edit View Insert Cell Kernel Widgets Help	Python [default] C	C
$\bullet$		
In [1]: "Hello World"		
Out[1]: 'Hello World'		
In [2]: 1 + 1		
Out[2]: 2		

```
import keras
from keras.models import Sequential
```

```
model = Sequential()
model.add(Dense(512, activation='relu', input_shape=(784,)))
model.add(Dense(512, activation='relu'))
model.add(Dense(10, activation='softmax'))
```

```
model.compile(loss='categorical_crossentropy', optimizer='sgd')
model.fit(x_train, y_train, epochs=5, batch_size=32)
```

```
classes = model.predict(x_test, batch_size=128)
score = model.evaluate(x_test, y_test)
```

## Where to learn more

## Courses

# fast.ai by Jeremy Howard



HOME ABOUT GETTING STARTED LESSONS - PART 2 CONTACT BLOG

Welcome to fast.ai's 7 week course, **Practical Deep Learning For Coders, Part 1**, taught by Jeremy Howard (Kaggle's #1 competitor 2 years running, and founder of Enlitic). Learn how to build state of the art models without needing graduate-level math—but also without dumbing anything down. Oh and one other thing... it's totally free!

When you're done here, head over to part 2, Cutting Edge Deep Learning for Coders, to continue your learning.

"fast.ai... can actually get smart, motivated students to the point of being able to create industrial-grade ML deployments"



Harvard Business Review The Business of Artificial Intelligence





# deeplearning.ai by Andrew Ng



# Books

## Goodfellow Bengio & Courville

computer science/machine learning DEEP LEARNING Ian Goodfellow, Yoshua Bengio, and Aaron Courville

> Deep learning is a form of machine learning that enables computers to learn from experience and understand the world in terms of a hierarchy of concepts. Because the computer gathers knowledge from experience, there is no need for a human computer operator to formally specify all the knowledge that the computer needs. The hierarchy of concepts allows the computer to learn complicated concepts by building them out of simpler ones; a graph of these hierarchies would be many layers deep. This book introduces a broad range of topics in deep learning.

> The text offers mathematical and conceptual background, covering relevant concepts in linear algebra, probability theory and information theory, numerical computation, and machine learning. It describes deep learning techniques used by practitioners in industry, including deep feedforward networks, regularization, optimization algorithms, convolutional networks, sequence modeling, and practical methodology and it surveys such applications as natural language processing, speech recognition, computer vision, online recommendation systems, bioinformatics, and video games. Finally, the book offers research perspectives, covering such theoretical topics as linear factor models, autoencoders, representation learning, structured probabilistic models. Monte Carlo methods, the partition function, approximate inference, and deep generative models.

> Deep Learning can be used by undergraduate or graduate students planning careers in either industry or research, and by software engineers who want to begin using deep learning in their products or platforms. A website offers supplementary material for both readers and instructors.

> Ian Goodfellow is Research Scientist at OpenAI, Yoshua Bengio is Professor of Computer Science at the Université de Montréal. Aaron Courville is Assistant Professor of Computer Science at the Université de Montréal.

Adaptive Computation and Machine Learning series

"Written by three experts in the field, Deep Learning is the only comprehensive book on the subject. It provides much-needed broad perspective and mathematical proliminaries for software engineers and students entering the field, and serves as a reference for authorities." —Elon Musk, cochair of OpenAI; cofounder and CEO of Tesla and SpaceX

"This is the definitive textbook on deep learning. Written by major contributors to the field, it is clear, comprehensive, and authoritative. If you want to know where deep learning came from, what it is good for, and where it is going, read this book."

-Geoffrey Hinton FRS, Emeritus Professor, University of Toronto; Distinguished Research Scientist, Google

"Deep learning has taken the world of technology by storm since the beginning of the decade. There was a need for a textbook for students, practitioners, and instructors that includes basic concepts, practical aspects, and advanced research topics. This is the first comprehensive textbook on the subject, written by some of the most innovative and prolific researchers in the field. This will be a reference for years to come."

-Yann LeCun, Director of Al Research, Facebook; Silver Professor of Computer Science, Data Science, and Neuroscience, New York University

Cover image: Central Park Azake Wak Dreamscape by Daniel Ambrosi (danielambrosi.com) Daniel Ambrosis': "Dreamscapes" are created by applying a version of Google's DeepDream open source software modified by Joseph Smarr (Google) and Chris Lamb (NVIDIA) to operate successfully on Ambrosi's multi-lhundred megapixel panoramic image.

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# Books

### Michael Nielsen

#### **Neural Networks and Deep Learning**

*Neural Networks and Deep Learning* is a free online book. The book will teach you about:

- Neural networks, a beautiful biologically-inspired programming paradigm which enables a computer to learn from observational data
- Deep learning, a powerful set of techniques for learning in neural networks

Neural networks and deep learning currently provide the best solutions to many problems in image recognition, speech recognition, and natural language processing. This book will teach you many of the core concepts behind neural networks and deep learning.

For more details about the approach taken in the book, see here. Or you can jump directly to Chapter 1 and get started. Neural Networks and Deep Learning What this book is about

- On the exercises and problems
- Using neural nets to recognize handwritten digits
- How the backpropagation algorithm works
- Improving the way neural networks learn
- A visual proof that neural nets can compute any function
- Why are deep neural networks hard to train?
- Deep learning

Appendix: Is there a *simple* algorithm for intelligence? Acknowledgements Frequently Asked Questions

If you benefit from the book, please make a small donation. I suggest \$5, but you can choose the amount.





★ Yann LeCun, Yoshua Bengio, and Geoffrey Hinton, "Deep Learning." *Nature (2015)* 

### **Most Cited Deep Learning Papers**

https://github.com/terryum/awesome-deep-learning-papers

### Deep Learning Papers Reading Roadmap

https://github.com/songrotek/Deep-Learning-Papers-Reading-Roadmap

## Demos

### **TensorFlow Playground**

https://playground.tensorflow.org/

### ConvNetJS

https://cs.stanford.edu/people/karpathy/convnetjs/

## Quick, Draw!

https://quickdraw.withgoogle.com/

## "Software is eating the world, but AI is going to eat software."

– Jensen Huang (CEO, Nvidia)



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