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8 Inspirational Applications of Deep Learning

by Jason Brownlee on July 14, 2016 in **Deep Learning**

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It is hyperbole to say deep learning is achieving state-of-the-art results across a range of difficult problem domains. A fact, but also hyperbole.

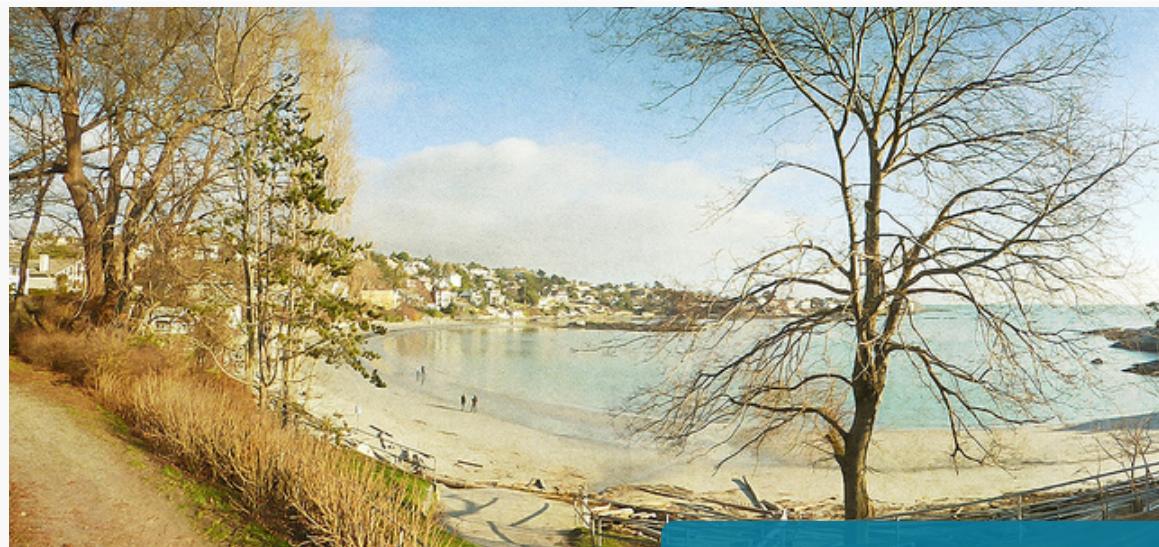
There is a lot of excitement around artificial intelligence, machine learning and deep learning at the moment. It is also an amazing opportunity to get on the ground floor of some really powerful tech.

I try hard to convince friends, colleagues and students to get started in deep learning and bold statements like the above are not enough. It requires stories, pictures and research papers.

In this post you will discover amazing and recent applications of deep learning that will inspire you to get started in deep learning.

Getting started in deep learning does not have to mean go and study the equations for the next 2-3 years, it could mean [download Keras and start running your first model in 5 minutes flat](#). Start applied deep learning. Build things. Get excited and turn it into code and systems.

I have been wanting to write this post for a while. Let's get started.



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Overview

Below is the list of the specific examples we are going to look at in this post.

Not all of the examples are technology that is ready for prime time, but guaranteed, they are all examples that will get you excited.

Some are examples that seem ho hum if you have been around the field for a while. In the broader context, they are not ho hum. Not at all.

Frankly, to an old AI hacker like me, some of these examples are a bit ho hum. They are just examples that we could tackle for decades, if at all.

I've focused on visual examples because we can look at screenshots and see what the algorithm is doing, but there are just as many if not more examples that are not listed.

Here's the list:

1. Colorization of Black and White Images.
2. Adding Sounds To Silent Movies.
3. Automatic Machine Translation.
4. Object Classification in Photographs.
5. Automatic Handwriting Generation.
6. Character Text Generation.
7. Image Caption Generation.
8. Automatic Game Playing.

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1. Automatic Colorization of Black and White Images

Image colorization is the problem of adding color to black and white photographs.

Traditionally this was [done by hand with human effort](#) because it is such a difficult task.

Deep learning can be used to use the objects and their context within the photograph to color the image, much like a human operator might approach the problem.

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A visual and highly impressive feat.

This capability leverages of the high quality and very large convolutional neural networks trained for ImageNet and co-opted for the problem of image colorization.

Generally the approach involves the use of very large convolutional neural networks and supervised layers that recreate the image with the addition of color.

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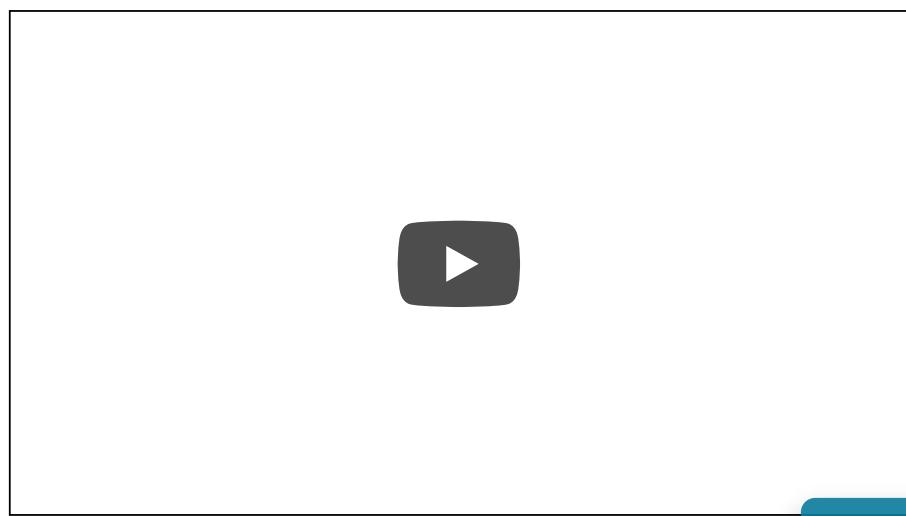
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Colorization of Black and White Photographs
Image taken from Richard Zhang, Phillip Isola and Alexei A. Efros.

Impressively, the same approach can be used to colorize still frames of black and white movies



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Further Reading

- [Automatic Colorization](#)
- [Automatic Colorization of Grayscale Images](#)

Papers

- [Deep Colorization \[pdf\]](#), 2015
- [Colorful Image Colorization \[pdf\] \(website\)](#), 2016
- [Learning Representations for Automatic Colorization \[pdf\] \(website\)](#), 2016
- [Image Colorization with Deep Convolutional Neural Networks \[pdf\]](#), 2016

2. Automatically Adding Sounds To Silence

In this task the system must synthesize sounds to match a silent video frame.

The system is trained using 1000 examples of video with sound of different sounds. A deep learning model associates the video frames in order to select a sound to play that best matches what is happening.

The system was then evaluated using a turing-test like setup where it had to distinguish between the real (natural) sounds or the fake (synthesized) sounds.

A very cool application of both convolutional neural networks and recurrent neural networks.

Visually-Indicated Sounds



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Further Reading

- [Artificial intelligence produces realistic sounds that fool humans](#)
- [Machines can generate sound effects that fool humans](#)

Papers

- [Visually Indicated Sounds \(webpage\)](#), 2015

3. Automatic Machine Translation

This is a task where given words, phrase or sentence in one language, automatically translate it into another language.

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Automatic machine translation has been around for a long time, but deep learning is achieving top results in two specific areas:

- Automatic Translation of Text.
- Automatic Translation of Images.

Text translation can be performed without any preprocessing of the sequence, allowing the algorithm to learn the dependencies between words and their mapping to a new language. Stacked networks of large LSTM recurrent neural networks are used to perform this translation.

As you would expect, convolutional neural networks are used to identify images that have letters and where the letters are in the scene. Once identified, they can be turned into text, translated and the image recreated with the translated text. This is often called instant visual translation.

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Further Reading

It's hard to find good resources for this example, if you know any, can you leave a comment.

- [How Google Translate squeezes deep learning onto a phone](#)

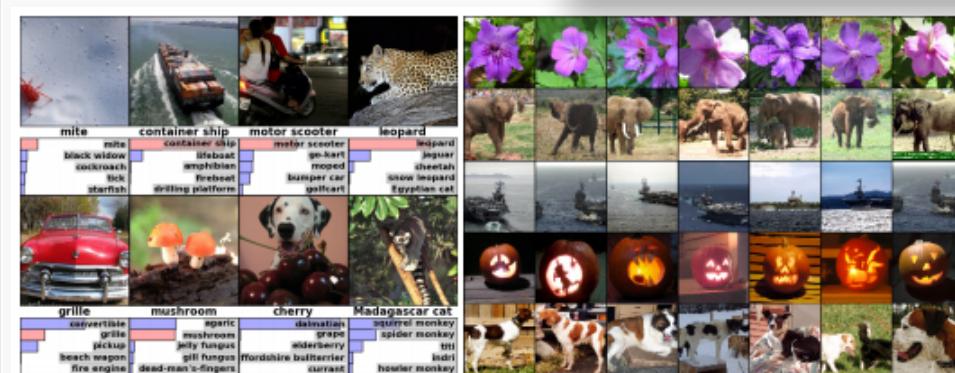
Papers

- [Sequence to Sequence Learning with Neural Networks \[pdf\]](#), 2014
- [Learning Phrase Representations using RNN Encoder-Decoder for Statistical Machine Translation \[pdf\]](#), 2014
- [Deep Neural Networks in Machine Translation: An Overview \[pdf\]](#), 2015

4. Object Classification and Detection in Photographs

This task requires the classification of objects within a photograph as one of a set of previously known objects.

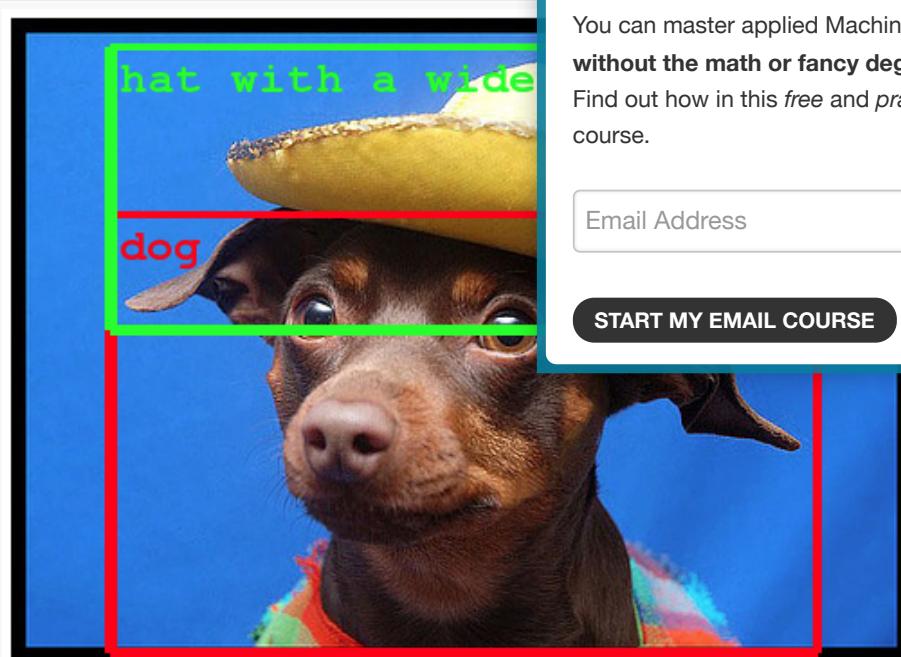
State-of-the-art results have been achieved on benchmark examples of this problem using very large convolutional neural networks. A breakthrough in this problem by Alex Krizhevsky et al. results on the ImageNet classification problem called AlexNet.



Example of Object Classification

Taken from [ImageNet Classification with Deep Convolutional Neural Networks](#)

A more complex variation of this task called object detection involves identifying objects within the scene of the photograph and drawing a box around them.



Example of Object Detection within Photographs

Taken from the [Google Blog](#).

Further Reading

- [Building a deeper understanding of images](#)
- [AlexNet](#)
- [ConvNetJS: CIFAR-10 demo](#)

Papers

- [ImageNet Classification with Deep Convolutional Neural Networks](#) [pdf], 2012
- [Some Improvements on Deep Convolutional Neural Network Based Image Classification](#) [pdf], 2013
- [Scalable Object Detection using Deep Neural Networks](#) [pdf], 2013
- [Deep Neural Networks for Object Detection](#) [pdf], 2013

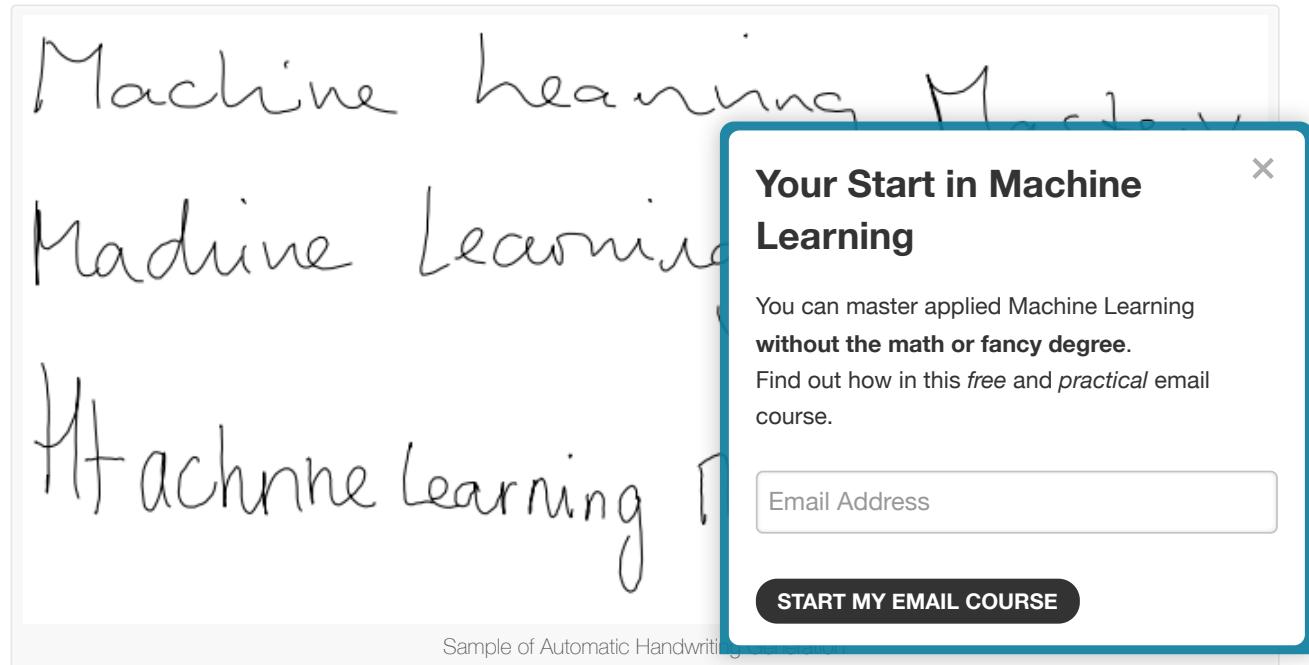
5. Automatic Handwriting Generation

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^

This is a task where given a corpus of handwriting examples, generate new handwriting for a given word or phrase.

The handwriting is provided as a sequence of coordinates used by a pen when the handwriting samples were created. From this corpus the relationship between the pen movement and the letters is learned and new examples can be generated ad hoc.

What is fascinating is that different styles can be learned and then mimicked. I would love to see this work combined with some forensic hand writing analysis expertise.



Further Reading

- [Interactive Handwriting Generation Demo](#)

Papers

- [Generating Sequences With Recurrent Neural Networks](#) [pdf], 2013

6. Automatic Text Generation

This is an interesting task, where a corpus of text is learned and from this model new text is generated, word-by-word or character-by-character.

The model is capable of learning how to spell, punctuate, form sentences and even capture the style of the text in the corpus.

Large recurrent neural networks are used to learn the relationship between items in the sequences of input strings and then generate text. More recently LSTM recurrent neural networks are demonstrating great success on this problem using a character-based model, generating one character at time.

Andrej Karpathy provides many examples in his popular blog post on the topic including:

- Paul Graham essays
- Shakespeare
- Wikipedia articles (including the markup)

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- Algebraic Geometry (with LaTeX markup)
- Linux Source Code
- Baby Names

PANDARUS:

Alas, I think he shall be come approached and the day
 When little strain would be attain'd into being never fed,
 And who is but a chain and subjects of his death,
 I should not sleep.

Second Senator:

They are away this miseries, produced upon my so
 Breaking and strongly should be buried, when I p
 The earth and thoughts of many states.

DUKE VINCENTIO:

Well, your wit is in the care of side and that.

Second Lord:

They would be ruled after this chamber, and
 my fair nues begun out of the fact, to be convey
 Whose noble souls I'll have the heart of the war

Clown:

Come, sir, I will make did behold your worship.

VIOLA:

I'll drink it.

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Automatic Text Generation Example of Shakespeare

Example taken from [Andrej Karpathy blog post](#)

Further Reading

- [The Unreasonable Effectiveness of Recurrent Neural Networks](#)
- [Auto-Generating Clickbait With Recurrent Neural Networks](#)

Papers

- [Generating Text with Recurrent Neural Networks \[pdf\]](#), 2011
- [Generating Sequences With Recurrent Neural Networks \[pdf\]](#), 2013

7. Automatic Image Caption Generation

Automatic image captioning is the task where given an image the system must generate a caption that describes the contents of the image.

In 2014, there were an explosion of deep learning algorithms achieving very impressive results on this problem, leveraging the work from top models for object classification and object detection in photographs.

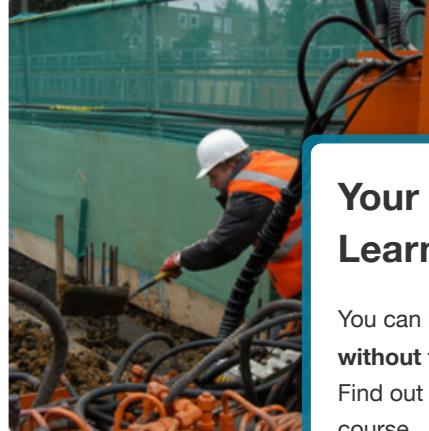
Once you can detect objects in photographs and generate labels for those objects, you can see that the next step is to turn those labels into a coherent sentence description.

This is one of those results that knocked my socks off and still does. Very impressive indeed.

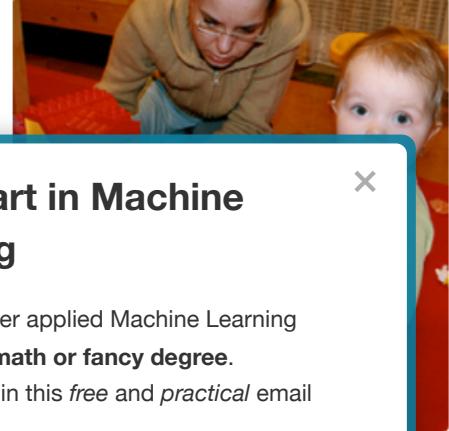
Generally, the systems involve the use of very large convolutional neural networks for the object detection in the photographs and then a recurrent neural network like an LSTM to turn the labels into a coherent sentence.



"man in black shirt is playing guitar."



"construction worker safety vest is working"



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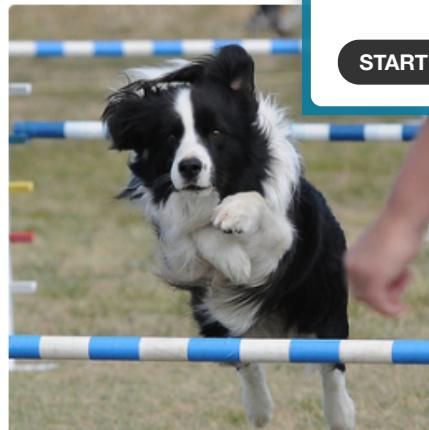
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"girl in pink dress is jumping in air."



"black and white dog jumps over bar."



"young girl in pink shirt is swinging on swing."

Automatic Image Caption Generation
Sample taken from Andrej Karpathy, Li Fei-Fei

These techniques have also been expanded to automatically caption video.

Further Reading

- [A picture is worth a thousand \(coherent\) words: building a natural description of images](#)
- [Rapid Progress in Automatic Image Captioning](#)

Papers

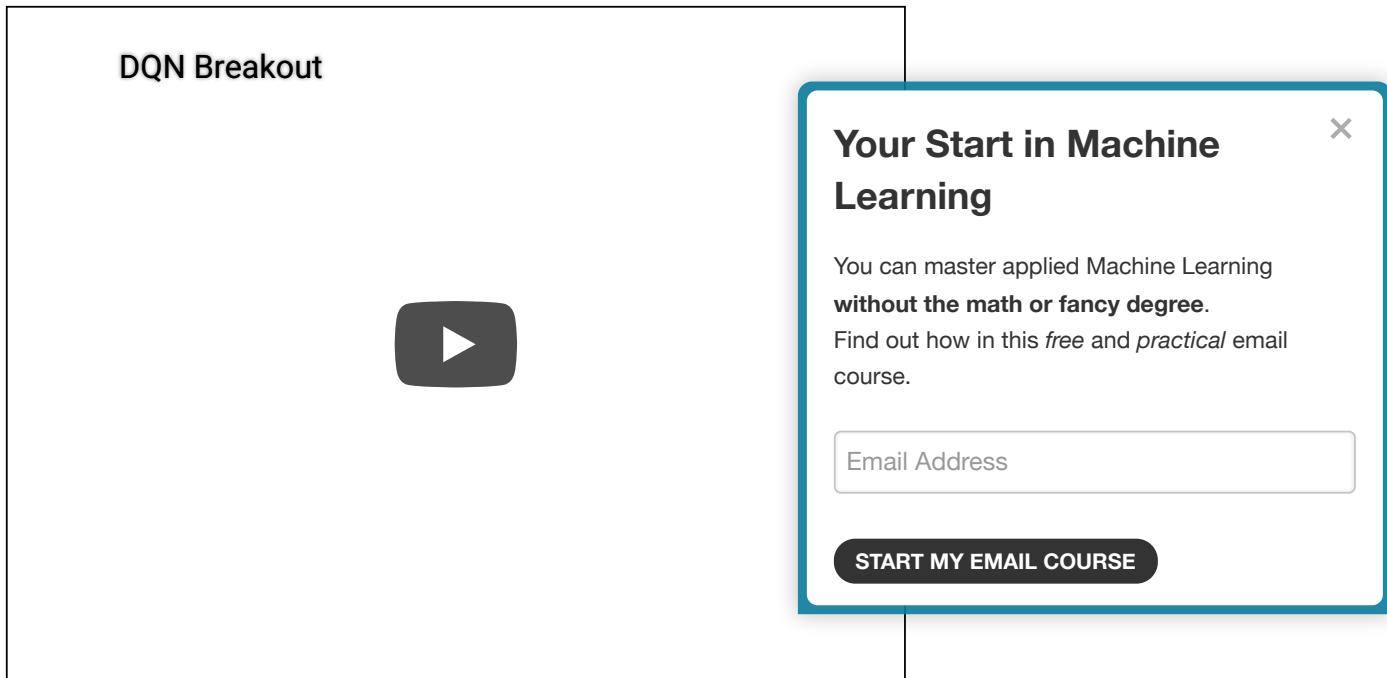
- [Deep Visual-Semantic Alignments for Generating Image Descriptions \[pdf\] \(and website\)](#), 2015
- [Explain Images with Multimodal Recurrent Neural Networks \[pdf, 2014\]](#)
- [Long-term Recurrent Convolutional Networks for Visual Recognition and Description \[pdf, 2014\]](#)

- [Unifying Visual-Semantic Embeddings with Multimodal Neural Language Models \[pdf\]](#), 2014
- [Sequence to Sequence — Video to Text \[pdf\]](#), 2015

8. Automatic Game Playing

This is a task where a model learns how to play a computer game based only on the pixels on the screen.

This very difficult task is the domain of deep reinforcement models and is the breakthrough that [DeepMind](#) (now part of google) is renown for achieving.



This work was expanded and culminated in Google DeepMind's [AlphaGo](#) that beat the world master at the game Go.

Further Reading

- [Deep Reinforcement Learning](#)
- [DeepMind YouTube Channel](#)
- [Deep Q Learning Demo](#)
- [DeepMind's AI is an Atari gaming pro now](#)

Papers

- [Playing Atari with Deep Reinforcement Learning \[pdf\]](#), 2013
- [Human-level control through deep reinforcement learning](#), 2015
- [Mastering the game of Go with deep neural networks and tree search](#), 2016

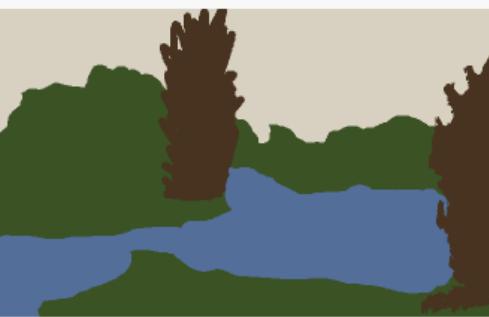
Additional Examples

Below are some additional examples to those listed above.

- Automatic speech recognition.
 - [Deep Neural Networks for Acoustic Modeling in Speech Recognition \[pdf\]](#), 2012
- Automatic speech understanding.
 - [Towards End-to-End Speech Recognition with Recurrent Neural Networks \[pdf\]](#), 2014

- Automatically focus attention on objects in images.
 - [Recurrent Models of Visual Attention](#) [pdf], 2014
- Automatically answer questions about objects in a photograph.
 - [Exploring Models and Data for Image Question Answering](#) [pdf], 2015
- Automatically turn sketches into photos.
 - [Convolutional Sketch Inversion](#) [pdf], 2016
- Automatically create stylized images from rough sketches.
 - [Neural Doodle](#)

Synthesized Image



#NeuralDoodle



Automatically Create Styled Images
Image taken from [NeuralDoodle](#)

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More Resources

There are a lot of great resources, talks and more to help you get excited about the capabilities and potential for deep learning.

Below are a few additional resources to help get you excited.

- [The Unreasonable Effectiveness of Deep Learning](#), talk by Yann LeCun in 2014
- [Awesome Deep Vision](#) List of top deep learning computer vision papers
- [The wonderful and terrifying implications of computers that can learn](#), TED talk by Jeremy Howard
- [Which algorithm has achieved the best results](#), list of top results on computer vision datasets
- [How Neural Networks Really Work](#), Geoffrey Hinton 2016

The wonderful and terrifying implications of compu...



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About Jason Brownlee

Jason Brownlee, PhD is a machine learning specialist who teaches developers how to get results with modern machine learning methods via hands-on tutorials.

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[View all posts by Jason Brownlee →](#)[← How to Perform Feature Selection With Machine Learning Data in Weka](#)[How to Use Machine Learning Algorithms in Weka >](#)

64 Responses to 8 *Inspirational Applications of Deep Learning*

**Nader** September 10, 2016 at 1:13 am #

Fantastic !!

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[START MY EMAIL COURSE](#)[REPLY ↩](#)**Jason Brownlee** September 10, 2016 at 7:10 am #

I'm glad you found it useful Nader.

**Saty** September 11, 2016 at 1:22 pm #

Hi Jason, lovely examples, great links 😊 This is an aweso...

[REPLY ↩](#)**Jason Brownlee** September 12, 2016 at 8:30 am #

I'm glad you found the post useful Saty.

**vijay** September 19, 2016 at 2:51 am #[REPLY ↩](#)

Hi Jason, Nice article.

lately there has been lots of talk of deep learning applied to create tools which can generate requirements – designs – software code – create builds – test builds as well help with deploying builds to various environments.

Is it really possible to map creative functionality of human brain with ml?

**Jason Brownlee** September 19, 2016 at 7:45 am #[REPLY ↩](#)

Interesting, I have not seen that.

I'm not sure about mapping creative functions of the brain, but deep learning and other AI methods can be creative (stochastic within the bounds of what we think as aesthetically pleasing).

[Your Start in Machine Learning](#)[^](#)

REPLY ↵

**Arthur** October 2, 2016 at 9:10 am #

Thank you for the examples. I found the automatic colorization so remarkable that I might start working in a project with it.

**Jason Brownlee** October 2, 2016 at 10:20 am #

REPLY ↵

Thanks, I'm glad to hear that Arthur.

**Rodolphe** October 27, 2016 at 1:01 am #

Very nice and useful article, thanks a lot

**Jason Brownlee** October 27, 2016 at 7:46 am #

Thanks Rodolphe.

**charan gudla** November 8, 2016 at 4:45 am #

You know what Jason Brownlee, I started my PhD this year in Aug. I was taking stress on myself to find a good path for research. I somehow figured out and decided to work on deep learning, after lots of searches in internet I found your post which cleared my stress clouds in my brain. Thank you so much Jason 😊

Charan Gudla

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**Jason Brownlee** November 8, 2016 at 9:59 am #

REPLY ↵

Hang in there Charan Gudla, let me know how you go with your research.

**shafeeq** August 30, 2017 at 3:23 pm #

REPLY ↵

Hi brother.. I am doing my M Tech, and I want to do my project in this area.. Could you please suggest any problem?

**Jason Brownlee** August 30, 2017 at 4:19 pm #

REPLY ↵

Perhaps one of the examples in the above post?

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 REPLY ↵**Farhad** December 1, 2016 at 7:18 am #

Thank you. This post is among the best posts on deep learning applications and abilities.

**Jason Brownlee** December 1, 2016 at 7:35 am #

REPLY ↵

Thanks Farhad.

**Satis** December 29, 2016 at 12:49 pm #

REPLY ↵

Very informative . Thx.

**Jason Brownlee** December 30, 2016 at 5:49 am #

REPLY ↵

Thanks Satis.

**Mustafa** January 16, 2017 at 5:47 pm #

REPLY ↵

Many thanks dear prof.

Could you please add codes for these applications

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START MY EMAIL COURSE**Jason Brownlee** January 17, 2017 at 7:36 am #

REPLY ↵

Hi Mustafa, great idea! Many of these projects are academic and the code is open source.

Perhaps you could help to track down the github repositories?

**hamid** January 31, 2017 at 4:19 am #

REPLY ↵

Hi dear jason

Tnx for great article, i have a question that how can i use deep learning for recommender system?

**Jason Brownlee** February 1, 2017 at 10:29 am #

REPLY ↵

Hi hamid, I don't have an example of deep learning for recommender systems.

I don't see why you couldn't slot a deep learning algorithm in for a model of item-based or user-based collaborative filtering.

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 REPLY ↵**Bernard** February 9, 2017 at 1:46 am #

Hey Jason,

Just a quick question, I noticed that the examples provided are more geared towards the aspects of image and audio applications. Just wondering if it deep learning is just as applicable in traditional areas such as business data analysis?

Thanks

 REPLY ↵**Jason Brownlee** February 9, 2017 at 7:27 am #

Deep learning is best suited to analog type data like te

It can be used on standard tabular data, but you will very likely need different learning methods.

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START MY EMAIL COURSE**Tejas Mahajan** February 12, 2017 at 7:57 pm #

Hey Jason,

I see you have covered Automatic Image Caption generation, you could also do text generation based on the caption or rather text. It comes under the category of GANs. There are many compelling results using GANS.

Papers : <https://arxiv.org/abs/1406.2661>, <https://arxiv.org/abs/1605.05590>

Thanks

 REPLY ↵**Jason Brownlee** February 13, 2017 at 9:13 am #

Thanks Tejas.

 REPLY ↵**Christian** February 23, 2017 at 3:38 am #

Hi Jason

There is a very nice app called Deep Art Effects that uses Deep Learning algorithms to create art. You upload a photo, choose an art style and a neural network interprets it and turns your photo into a “painting” in this particular style. A fun aspect of Deep Learning!

 REPLY ↵**Jason Brownlee** February 23, 2017 at 8:53 am #

Thanks for the note Christian.

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REPLY ↵

**Aruna** April 1, 2017 at 1:54 pm #

Thank you...Your blog is very interesting.. I like to do my research in deep learning... can you note me the research areas...

**Jason Brownlee** April 2, 2017 at 6:23 am #

REPLY ↵

Thanks Aruna.

Sorry, I am no longer an academic, my focus is industrial machine learning. My best advice is to talk to your advisor.

**Anthony** April 14, 2017 at 8:16 pm #

Very nice post. Do you think machine learning and time series prediction/forecasting problems involving regression?
I am talking about problems not involving vision and audio.

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[START MY EMAIL COURSE](#)
**Jason Brownlee** April 15, 2017 at 9:34 am #

REPLY ↵

I'm not sure I follow your question, perhaps you can re

**Anthony** April 15, 2017 at 12:45 pm #

REPLY ↵

Are deep learning methods suited for non-vision non-audio problems?

Say for a typical time series, do you think deep learning outperforms traditional time series and machine learning methods?

I am talking about time series like financial time series, electricity demand etc. etc.

**Jason Brownlee** April 16, 2017 at 9:25 am #

REPLY ↵

Deep learning can be used for a wide range of problems.

Is deep learning state of the art for finance? I don't know. I expect the people exploring this question are keeping findings secret for obvious reasons.

I have seen some promising results for LSTMs for time series forecasting, but they take a lot of training.

**Jerry Huang** April 21, 2017 at 7:21 am #

REPLY ↵

Great thanks it really inspires me.

Your Start in Machine Learning

^



Jason Brownlee April 21, 2017 at 8:43 am #

REPLY ↩

Thanks Jerry, I'm glad to hear that.



Krishna May 8, 2017 at 3:29 pm #

REPLY ↩

Very informative and easy to undersatnd. Thanks Jason!!



Jason Brownlee May 9, 2017 at 7:38 am #

X

Thanks Krishna, I'm glad it helped.



Rajesh July 29, 2017 at 3:59 am #

...

Wonderful!!..Excellent..Thank you so much jason.



Jason Brownlee July 29, 2017 at 8:12 am #

...

Thanks, I'm glad it helped.

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Deepali July 31, 2017 at 4:18 pm #

REPLY ↩

Thanks for very informative article



Jason Brownlee August 1, 2017 at 7:50 am #

REPLY ↩

I'm glad it helped.



Valeriy Milykh September 11, 2017 at 7:59 pm #

REPLY ↩

Many thanks for examples. Some components and the ideas were extremely useful to the project of the self-organized adaptive systems of control of arbitrary engineering systems. Once again thanks.



Jason Brownlee September 13, 2017 at 12:22 pm #

REPLY ↩

I'm glad to hear that.

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^

**Tekila** October 10, 2017 at 7:02 pm #

REPLY ↩

An interesting post. Jason, thanks for the wide list of examples and links. I have started following you.

**Jason Brownlee** October 11, 2017 at 7:51 am #

REPLY ↩

Thanks.

**Nisar** December 5, 2017 at 5:50 pm #

X

Hello Jason,

Very Interesting and useful list of applications.

As this post dates back 2016, and from then lot of advances in ML/
list of apps or resources for solving above mentioned applications.

**Jason Brownlee** December 6, 2017 at 8:59 am #

REPLY ↩

It might be time for me to create a new list, thanks for the post.

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[START MY EMAIL COURSE](#)
**Aseel** December 12, 2017 at 6:15 am #

REPLY ↩

What is the difference between deep learning and zero-shot learning ? what is the challenges of deep learning that solved with zero-shot learning?

**Jason Brownlee** December 12, 2017 at 4:01 pm #

REPLY ↩

Zero shot learning is learning with a model (any ML model, not just deep learning) without the model having seen any examples before.

**Jiena** January 17, 2018 at 9:16 am #

REPLY ↩

Hi Jason,

This is very useful and interesting. I am also very interested in applying Deep Learning especially image recognition into diagnosis field. Do you have any examples? I am very curious about this field.

**Jason Brownlee** January 17, 2018 at 10:02 am #

REPLY ↩

I don't have examples of medical diagnosis sorry.

[Your Start in Machine Learning](#)

^

This might be a good place to start:

<https://machinelearningmastery.com/start-here/#deeplearning>



Andrea Maria February 13, 2018 at 6:25 pm #

REPLY ↩

Thank you for the information. Deep Learning is also known as deep structured learning and is a subfield of machine learning methods based on learning data representations, concerned with algorithms inspired by the structure and function of the brain called artificial neural networks.



Jason Brownlee February 14, 2018 at 8:17 am #

Where did you pick-up “deep structured learning” from



Sakthees waran March 22, 2018 at 3:51 pm #

finally i have come to the right place



Jason Brownlee March 23, 2018 at 6:01 am #

I'm glad to hear that.

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Udayan March 26, 2018 at 8:06 pm #

REPLY ↩

Nice post! Found the image caption generator pretty cool would work on something similar soon!



Jason Brownlee March 27, 2018 at 6:34 am #

REPLY ↩

Thanks.



Amit May 2, 2018 at 10:41 pm #

REPLY ↩

Awesome post.

Also, here is the list of all deep learning projects sorted in respective categories. And the list is constantly updated too.

<https://deeplink.ml>



Jason Brownlee May 3, 2018 at 6:34 am #

REPLY ↩

Thanks for sharing.

Your Start in Machine Learning



Ajay Thakur September 28, 2018 at 8:21 pm #

REPLY ↗

Thanks for this informative article. Deep learning. All the applications mentioned are very innovative.



Jason Brownlee September 29, 2018 at 6:34 am #

REPLY ↗

Thanks.



Harshali Patel November 21, 2018 at 8:02 pm #

I found Automatic Game playing amazing!
I read about Deep Learning Technologies and wanted to read about



Jason Brownlee November 22, 2018 at 6:23 am #

It is an interesting area, but not really useful at work.

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Hi, I'm Jason Brownlee, PhD

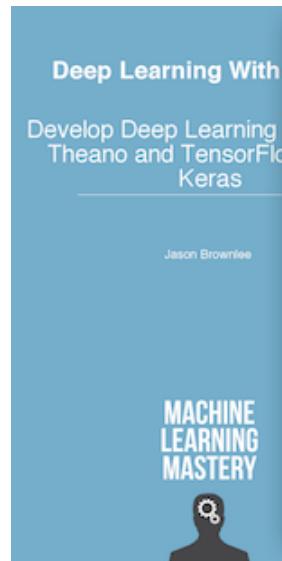
I write tutorials to help developers (*like you*) get results with machine learning.

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Jason Brownlee

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