

Demystifying Artificial Intelligence Sorcery

(Part 3: Deep Learning)^a

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^aAvailable @ <https://github.com/a-mhamdi/jlai/>



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ROADMAP

1. An overview
2. CNN, VAE, GAN & NLP
3. Transfer Learning
4. Reinforcement Learning
5. Responsible AI
6. Quizzes
7. Azure AI Fundamentals

An overview

- CNNs** (*Convolutional Neural Networks*) are used for image classification and other computer vision tasks because they are able to automatically learn features from raw data. This is useful for tasks where manual feature engineering is difficult or impractical.
- VAEs** (*Variational Autoencoders*) are used for tasks such as image generation and anomaly detection because they are able to learn a compact representation of a dataset and generate new samples from this representation.
- GANs** (*Generative Adversarial Networks*) are used for tasks such as image generation and data augmentation because they are able to generate new data samples that are similar to a given dataset.
- NLP** (*Natural Language Processing*) is important for tasks such as language translation, text classification, and language generation because it allows computers to process and understand human language.

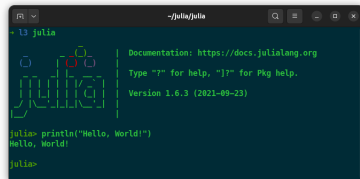


REMINDER

PROGRAMMING LANGUAGE



juliaang.org/



DEVELOPMENT ENVIRONMENTS



Pluto.jl



▲ \$ docker compose up

▼ \$ docker compose down



JULIA IN A NUTSHELL

- ▲ Fast
- ▲ Dynamic
- ▲ Reproducible
- ▲ Composable
- ▲ General
- ▲ Open Source



JULIA MICRO-BENCHMARKS (1/2)



<https://julialang.org/benchmarks>



JULIA MICRO-BENCHMARKS (2/2)

Geometric Means of Micro-Benchmarks by Language

1	C	1.0
2	Julia	1.17006
3	LuaJIT	1.02931
4	Rust	1.0999
5	Go	1.49917
6	Fortran	1.67022
7	Java	3.46773
8	JavaScript	4.79602
9	Matlab	9.57235
10	Mathematica	14.6387
11	Python	16.9262
12	R	48.5796
13	Octave	338.704





SOURCE CONTROL MANAGEMENT (SCM)

The screenshot displays the GitHub repository page for `a-mhamdi/jlali`. The repository is public and has 2 stars and 3 forks. The main branch is `main` with 1 branch and 0 tags. The repository contains a file named `README.md` with the title `Fuzzy Logic, Machine Learning and Deep Learning with Julia`. The commit history shows a series of commits, with the most recent being `fde8fca` yesterday, which updated the `docker-image.yml` file. The repository is described as `An Introduction to Artificial Intelligence with Julia` and includes tags for `flux`, `machine-learning`, `docker-image`, `fuzzy-logic`, `julialang`, and `mjl`. The repository also has a `Readme`, `MIT license`, `2 stars`, `2 watching`, and `3 forks`. The `Languages` section shows the following distribution: `Julia` 94.3%, `Dockerfile` 3.4%, `Batchfile` 2.1%, and `TeX` 0.2%.

<https://github.com/a-mhamdi/jlali>



CONTINUOUS INTEGRATION (CI)

The screenshot shows a web browser window displaying the Docker Hub repository for 'abmhamdi/jlai'. The browser's address bar shows 'hub.docker.com/r/abmhamdi/jlai'. The Docker Hub interface includes a search bar, navigation links for 'Explore', 'Repositories', 'Organizations', and 'Help', and a user profile for 'abmhamdi'. The repository page features a blue cube icon, the name 'abmhamdi/jlai' with a star, and a 'Manage Repository' button. It indicates the repository was updated 21 hours ago by 'abmhamdi' and is associated with 'Artificial Intelligence Labs @ ISETBZ'. The 'Overview' tab is selected, showing a description: 'Fuzzy Logic, Machine Learning and Deep Learning with Julia'. It states that the repository contains slides, labs, and code examples for using Julia to implement artificial intelligence algorithms, running on a Docker image for a consistent and reproducible environment. A status bar shows 'jlai-ci' as 'passing', with 'latest' as the current version, 22 Docker pulls, and 0 Docker stars. A 'Docker Pull Command' box displays the command 'docker pull abmhamdi/jlai'. At the bottom, a note states: 'To run the code, you will need to first pull the Docker image by running the following command:'.

<https://hub.docker.com/r/abmhamdi/jlai>

CNN, VAE, GAN & NLP

CNN

MOTIVATING FACTORS

- ▶ A **Convolutional Neural Network (CNN)** is a type of neural network that is particularly well-suited for image classification and object recognition tasks. It is designed to process data with a grid-like topology, such as an image,.
 - ▶ **CNNs** are composed of several types of layers, including convolutional layers, pooling layers, and fully connected layers.
- ❶ The **convolutional layers** apply filters to the input data, which are used to detect patterns and features in the data.
 - ❷ The **pooling layers** reduce the spatial dimensions of the data, which helps to reduce the complexity of the model and make it more robust to small translations of the input data.
 - ❸ The **fully connected layers** combine the features learned by the convolutional and pooling layers to make a prediction.

CNN

USE CASES

Image classification

Object detection

Image segmentation

Medical image analysis

Medical image analysis

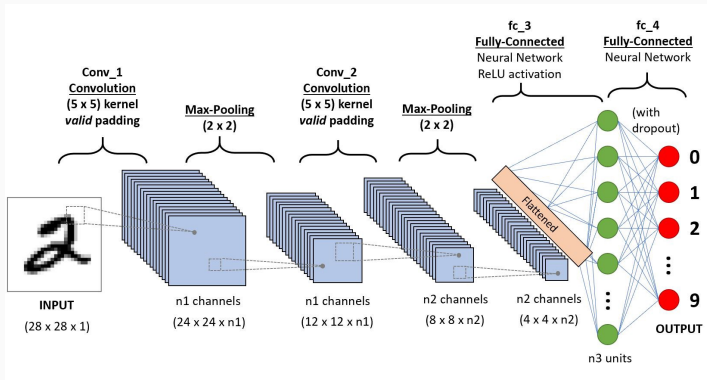
Self-driving cars

Robotics

Natural language processing

CNN

ARCHITECTURE



► Source

CNN

IMAGE KERNELS

Image Kernels explained · x +

setosa.io/ev/image-kernels/

By [Victor Powell](#)

An image kernel is a small matrix used to apply effects like the ones you might find in Photoshop or Gimp, such as blurring, sharpening, outlining or embossing. They're also used in machine learning for 'feature extraction', a technique for determining the most important portions of an image. In this context the process is referred to more generally as "convolution" (see: [convolutional neural networks](#).)

To see how they work, let's start by inspecting a black and white image. The matrix on the left contains numbers, between 0 and 255, which each correspond to the brightness of one pixel in a picture of a face. The large, granulated picture has been blown up to make it easier to see; the last image is the "real" size.

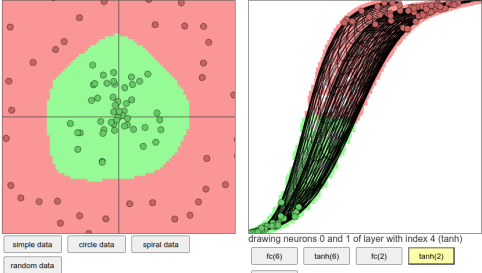
<https://setosa.io/ev/image-kernels/>

CNN

CONVNETJS DEMO

Feel free to change this, the text area above gets eval()'d when you hit the button and the network gets reloaded. Every 10th of a second, all points are fed to the network multiple times through the trainer class to train the network. The resulting predictions of the network are then "painted" under the data points to show you the generalization.

On the right we visualize the transformed representation of all grid points in the original space and the data, for a given layer and only for 2 neurons at a time. The number in the bracket shows the total number of neurons at that level of representation. If the number is more than 2, you will only see the two visualized but you can cycle through all of them with the cycle button.



simple data circle data spiral data random data

Controls:
CLICK: Add red data point
SHIFT+CLICK: Add green data point
CTRL+CLICK: Remove closest data point

Go [back to ConvNetJS](https://cs.stanford.edu/people/karpathy/convnetjs/)

drawing neurons 0 and 1 of layer with index 4 (tanh)

fc(6) tanh(6) fc(2) **tanh(2)**

fc(2)

cycle through visualized neurons at selected layer (if more than 2)

<https://cs.stanford.edu/people/karpathy/convnetjs/demo/classify2d.html>



Code is available at <https://github.com/a-mhamdi/jlai/>

→ *Codes* → *Julia* → *Part-3* → *cnn.jl*



VAE

MOTIVATING FACTORS

- ▶ A **Variational Autoencoder (VAE)** is a type of deep learning model that is used to learn latent representations of data. It is a generative model, which means that it can generate new samples of data that are similar to the training data.
- ▶ **VAEs** are trained to encode the data into a low-dimensional latent space and then decode the latent representation back into the original data space. During training, the **VAE** learns to reconstruct the input data, while also trying to enforce a constraint on the latent space that encourages it to represent the data in a meaningful way.
- ▶ The constraint that is used in a **VAE** is called the variational lower bound. This lower bound is maximized during training, which encourages the latent space to be structured in a way that is useful for generating samples that are similar to the training data.

VAE

USE CASES

Generative modeling

Anomaly detection

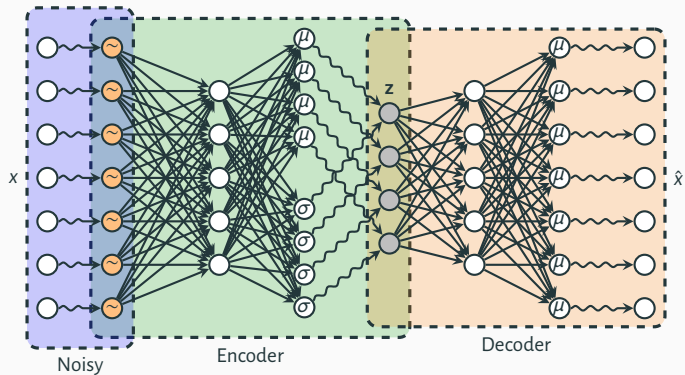
Data compression

Representation learning

Semi-supervised learning

VAE

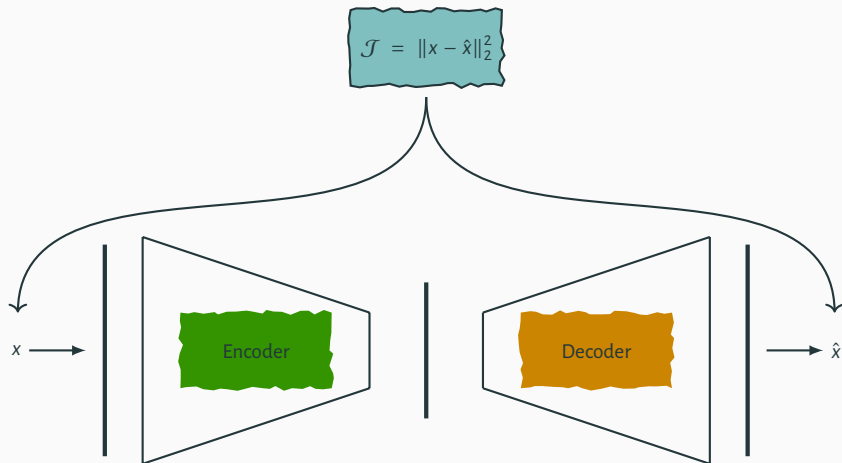
ARCHITECTURE OF VARIATIONAL AUTOENCODER



VAE

LOSS OF VANILLA AUTOENCODER

MINIMIZE SQUARED ERROR LOSS



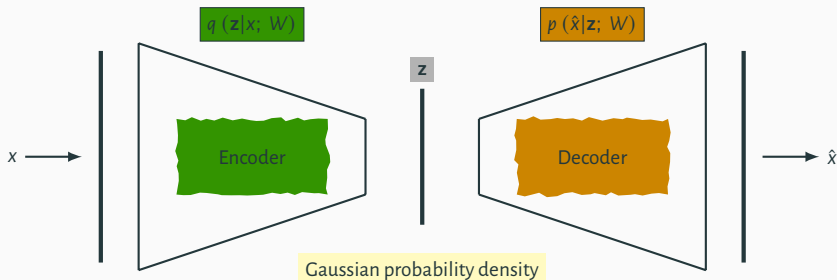
VAE

LOSS OF VARIATIONAL AUTOENCODER

$$\mathcal{J} = - \mathbb{E}_{\mathbf{z} \sim q(\mathbf{z}|\mathbf{x}^{(i)}; W)} \left[\log p(\hat{\mathbf{x}}^{(i)} | \mathbf{z}; W) \right] + \mathcal{KL} \left(q(\mathbf{z}|\mathbf{x}^{(i)}; W) \parallel p(\mathbf{z}) \right)$$

Expected negative log likelihood term wrt to encoder distribution

Kullback-Leiber divergence term where $p(\mathbf{z}) \sim \mathcal{N}(\mu = 0, \sigma^2 = 1)$



VAE

 \mathcal{KL} LOSS DERIVATION

In a VAE, the latent vector \mathbf{z} is calculated by:

$$\mathbf{z} = \boldsymbol{\mu} + \boldsymbol{\sigma} \odot \boldsymbol{\epsilon} \quad \text{where} \quad \boldsymbol{\epsilon} \sim \mathcal{N}(\mathbf{0}_z, \mathbb{1}_{z \times z})$$

$\boldsymbol{\mu}$ and $\boldsymbol{\sigma}$ denote respectively the mean and variances for the latent vector \mathbf{z} . The encoder learns to output the two vectors $\boldsymbol{\mu} \in \mathbb{R}^z$, and $\boldsymbol{\sigma} \in \mathbb{R}^z$. The encoder distribution is

$$q(\mathbf{z} | x^{(i)}) = \mathcal{N}(\mathbf{z} | \boldsymbol{\mu}(x^{(i)}), \boldsymbol{\Sigma}(x^{(i)})) \quad \text{where} \quad \boldsymbol{\Sigma} = \begin{bmatrix} \sigma_1^2 & 0 & 0 & \dots \\ 0 & \sigma_2^2 & 0 & \dots \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \sigma_l^2 \end{bmatrix}$$

The latent prior is given by

$$p(\mathbf{z}) = \mathcal{N}(\mathbf{0}_z, \mathbb{1}_{z \times z})$$

$$\mathcal{KL}(q(\mathbf{z} | x^{(i)}; W) \| p(\mathbf{z})) = \frac{1}{2} \left[- \sum_i (\log \sigma_i^2 + 1) + \sum_i \sigma_i^2 + \sum_i \mu_i^2 \right]$$

► Source

VAE

CODE SNIPPET



Code is available at <https://github.com/a-mhamdi/jlai/>

→ Codes → Julia → Part-3 → vae.jl



GAN

AN OVERVIEW

- ▶ A **Generative Adversarial Network (GAN)** is a type of deep learning model designed to generate new, synthetic samples of data. It consists of two networks: a **generator network** and a **discriminator network**. The **generator network** generates synthetic samples, while the **discriminator network** tries to distinguish between the synthetic samples and real samples of data.
- ▶ During training, the **generator and discriminator networks** are trained concurrently, with the **generator** trying to generate synthetic samples that are indistinguishable from real samples, and the **discriminator** trying to correctly classify the samples as either real or synthetic. The **generator** is trained to improve its synthetic samples based on the feedback from the **discriminator**, and the **discriminator** is trained to become more sensitive to synthetic samples.
- ▶ The goal of a **GAN** is to learn a generative model that can produce synthetic samples that are similar to the training data. **GANs** have been used for a variety of tasks, including image generation, audio synthesis, and natural language processing.

GAN

USE CASES

Image generation

Image style transfer

Text-to-image synthesis

Video prediction

Text-to-speech synthesis

Super-resolution

Data augmentation

Domain adaptation

GAN

CODE SNIPPET



Code is available at <https://github.com/a-mhamdi/jlai/>

→ *Codes* → *Julia* → *Part-3* → *gan.jl*



NLP

PURPOSE OF NLP

- ▶ **Natural Language Processing (NLP)** is a field of artificial intelligence and computer science that focuses on the interaction between computers and humans using natural language.
- ▶ **NLP** involves the development of algorithms and models that can understand, interpret, and generate human language.
- ▶ **NLP** is used in a wide range of applications, including machine translation, question answering, text summarization, text classification, and sentiment analysis.

NLP

USE CASES

Part-of-speech tagging

Named entity recognition

Sentiment analysis

Machine translation

Text summarization

NLP

GENERAL PROCESS IN JULIA

1. Preprocess the text data by lowercasing, removing punctuation, and splitting the text into individual tokens (*e.g.*, words or subwords).
2. Build a vocabulary of the most common tokens in the text data.
3. Encode the text data as a sequence of integers using the vocabulary.
4. Pad the encoded sequences to the same length to make them suitable for input to a model.
5. Define the **NLP** model using a library such as `Flux.jl` or `Knet.jl`.
6. Train the model using gradient descent and a suitable loss function.
7. Use the trained model to make predictions on new data.

NLP

CODE SNIPPET



Code is available at <https://github.com/a-mhamdi/jlai/>

→ *Codes* → *Julia* → *Part-3* → *nlp.jl*



Transfer Learning

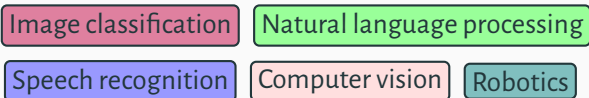
TRANSFER LEARNING

DRIVING FORCES

- ▶ **Transfer Learning** is a machine learning technique in which a model that has been trained on one task is re-purposed on a second related task. **Transfer Learning** can be used to improve the performance of the second task by leveraging the knowledge learned from the first task.
- ▶ One common use of **Transfer Learning** is to fine-tune a pre-trained model on a new dataset. For example, a pre-trained image classification model that has been trained on a large dataset such as ImageNet can be fine-tuned on a smaller dataset of a different but related task, such as detecting objects in medical images. Fine-tuning the pre-trained model on the new dataset can lead to improved performance compared to training a model from scratch on the smaller dataset.
- ▶ **Transfer Learning** is useful because it allows a machine learning model to learn from a large amount of data, even if the data is not directly related to the task at hand. It can also be used to speed up the training process, since the model does not need to be trained from scratch.

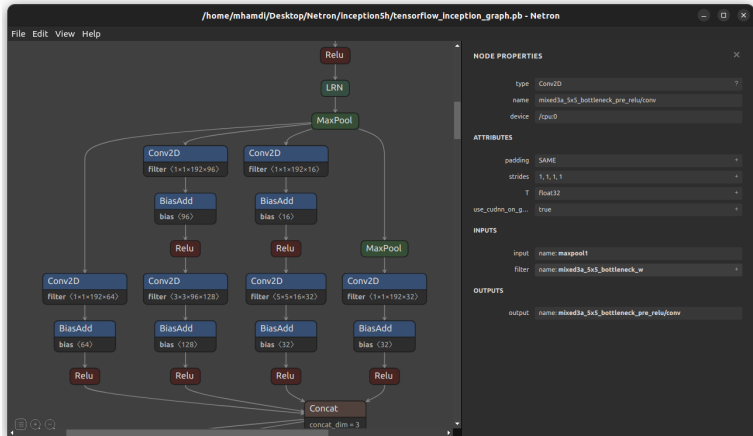
TRANSFER LEARNING

USE CASES



TRANSFER LEARNING

NETRON



<https://github.com/lutzroeder/netron>

TRANSFER LEARNING

GENERAL PROCESS IN JULIA

1. Load the pre-trained model (*e.g.*, a convolutional neural network trained on ImageNet).
2. Replace the final layer (or layers) of the pre-trained model with a new, untrained layer (or layers) that is suitable for your target task.
3. Freeze the weights of the pre-trained layers to prevent them from being updated during training.
4. Load your dataset and split it into training and validation sets.
5. Use the training set to fine-tune the weights of the new layer (or layers) using gradient descent and a suitable loss function.
6. Monitor the performance of the model on the validation set and adjust the hyperparameters (*e.g.*, *learning rate*) as needed.
7. When you're satisfied with the performance of the model on the validation set, you can use it to make predictions on the test set or on new data.

TRANSFER LEARNING

CODE SNIPPET



Code is available at <https://github.com/a-mhamdi/jlai/>

→ Codes → Julia → Part-3 → transfer-learning-*.jl



Reinforcement Learning

REINFORCEMENT LEARNING

SYNOPSIS

- ▶ **Reinforcement Learning** is a type of machine learning in which an agent learns to interact with its environment in order to maximize a reward. It involves learning to map situations (called states) to actions that will maximize a reward. The agent receives feedback in the form of rewards and penalties for its actions, which it uses to adjust its behavior accordingly.
- ▶ In **reinforcement Learning**, the goal is to learn a policy that maximizes the cumulative reward over time. The agent learns this policy through **trial and error**, by exploring different actions in different states and receiving feedback in the form of rewards or penalties.
- ▶ **Reinforcement Learning** is used in a variety of applications, including control systems, game playing, and natural language processing. It has been successful in a number of tasks, including teaching a computer to play chess and Go at a high level.

REINFORCEMENT LEARNING

CODE SNIPPET

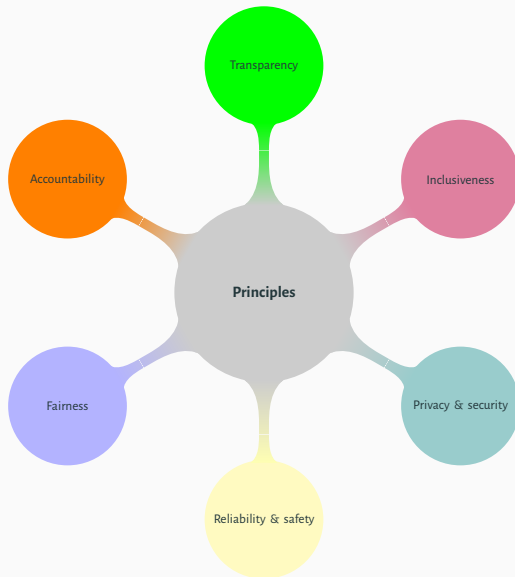


Code is available at <https://github.com/a-mhamdi/jlai/>

→ Codes → Julia → Part-3 → reinforcement-learning.jl



Responsible AI



Quizzes

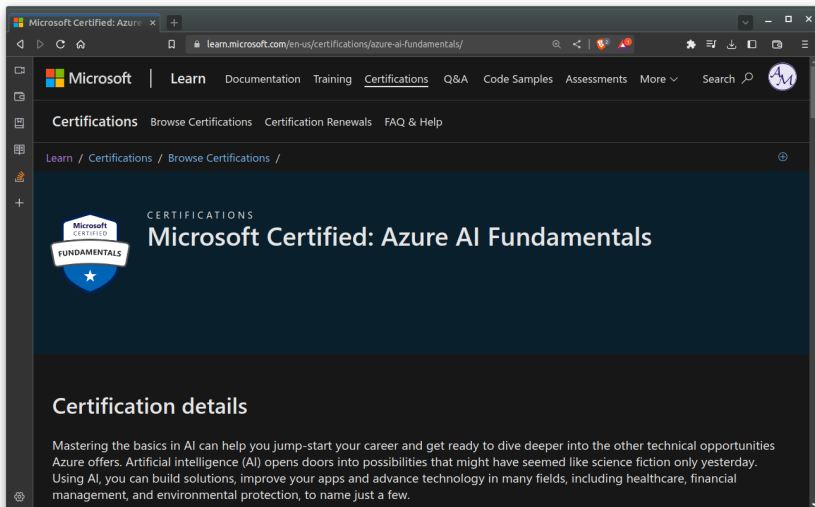
KNOWLEDGE CHECK



<https://app.wooclap.com/RAIAS3>

Azure AI Fundamentals

EXAM PREP AI-900



<https://learn.microsoft.com/en-us/certifications/azure-ai-fundamentals/>

LINK BUNDLE

<https://karpathy.ai/>

<https://colah.github.io/posts/2014-03-NN-Manifolds-Topology/>

<http://yann.lecun.com/>

<https://www.ibm.com/downloads/cas/GB8ZMQZ3>

<https://www.hackingnote.com/>

<https://stanford.edu/shervine/teaching/>

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FURTHER READING (1/2)

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