

An Introduction to Machine Learning using TensorFlow

With Examples from the MNIST dataset.

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Machine Learning

What is Machine Learning?

Definition Machine Learning¹

- ▶ 3 attributes
 - ▶ Experience E
 - ▶ Task T
 - ▶ Performance Measure P

A computer program is said to learn if its performance at tasks in T as measured by P improves with experience in E .

¹Tom Mitchell

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It is very hard to write a program to recognize an object in an image.

- ▶ We do not know how to perform this computation.
- ▶ A number of intuitive rules in our day-to-day decision making.

¹Tom Mitchell

Types of Machine Learning Problems

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A Brief
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► Supervised Learning

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- ▶ Supervised Learning
- ▶ Unsupervised Learning

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- ▶ Supervised Learning
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- ▶ Semi-supervised Learning

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- ▶ Supervised Learning
- ▶ Unsupervised Learning
- ▶ Semi-supervised Learning
- ▶ Reinforcement Learning.

Types of Machine Learning Problems

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- Classification: Data belongs to discrete categories or classes.

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- ▶ Classification: Data belongs to discrete categories or classes.
- ▶ Regression: The output variable is usually a real value.

Standard Example of Machine Learning

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- ▶ A lot of genetics is done on fruit flies (Hinton)
 - ▶ They breed fast, a lot is known about them.

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- ▶ MNIST: a database of handwritten digits. ML equivalent of fruit flies.
- ▶ Easy to understand and compare algorithms.
- ▶ Textbook Example of ML.

MNIST dataset

- ▶ Medium sized dataset: Training set: 60,000 samples
Test set: 10,000 samples.

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- ▶ Medium sized dataset: Training set: 60,000 samples
Test set: 10,000 samples.
- ▶ Sample: 28×28 pixels, Each pixel is a 0 or 1
- ▶ Vector size per sample: 785 ($28 \times 28 + 1$)
- ▶ First real success story in ML.

Tensorflow: Framework for Numerical Computation

- ▶ One of several frameworks: Theano, Caffe, MxNet, CNTK, Keras, Torch, Spark, Flux (Julia), KNet (Julia).

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- ▶ Library for efficient multidimensional array processing.

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- ▶ Library for efficient multidimensional array processing.
- ▶ Advantages of using TF:
 - ▶ Primitives for defining functions on tensors.
 - ▶ Parallelize operations.
 - ▶ Automatic differentiation.

Tensors

What is a tensor?

- ▶ Multi-dimensional array

What is a tensor?

- ▶ Multi-dimensional array
- ▶ A multidimensional version of a vector.

0-dimensional	scalar
1 -dimensional	vector
2-dimensional	matrix
3-dimensional	3-tensor

Example:

- ▶ Black and White image: 2D tensor (1 channel: $H \times W$)
- ▶ RGB color image: 3D tensor (3 channels: $H \times W \times 3$)

In the style of functional programming, think of a tensor as a mapping from a multidimensional array to a real valued scalar.

Computation Graphs

Workflow in TF

- Build the CG.

Computation Graphs

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- ▶ Start new session to evaluate the graph.

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- ▶ Python based: can build models using Jupyter notebooks.
- ▶ One can build wrappers around TF and call it from other languages.

Types of Neural Network

► FeedForward Network

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- ▶ FeedForward Network
- ▶ Convolutional Network:
 - ▶ Assumes some kind of spatial structure in its input.
 - ▶ Inputs that are close to each other are related.
 - ▶ Sparse weight matrix.
 - ▶ Weights are shared (i.e. patterns are repeated across regions of the image.)

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- ▶ Recurrent Network:
 - ▶ Used to model sequences of data. e.g. Temporal pattern like text, music etc.

Digit Recognition Model

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- ▶ Each input: $28 \times 28 \times 1$ matrix

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- ▶ Each input: $28 \times 28 \times 1$ matrix B & W : Therefore 1 channel.

Digit Recognition Model

- ▶ Each input: $28 \times 28 \times 1$ matrix B & W: Therefore 1 channel. RGB color input: 3 channels.
- ▶ Simple Convolutional Architecture This has two iterations of
 - ▶ Convolution
 - ▶ ReLU: Rectified Linear Unit $\max(input, 0)$. Other possibilities are sigmoid, tanh.
 - ▶ MaxPool
- ▶ At the end, we have a dense layer that converts into a softmax probability output.
- ▶ Softmax function: Allows us to map a real number into multiple categories.
- ▶ One hot encoding: Allows us to model categorical data.
e.g. $1 = [1 \ 0 \ 0]$, $2 = [0 \ 1 \ 0]$, $3 = [0 \ 0 \ 1]$