Machine Learning: An Introduction

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ML: From Rules to Data

Example: Activity Recognition




Example: Activity Recognition

```
0101001010100101010
1001010101001011101
0100101010010101001
0101001010100101010
```

Label = WALKING

```
1010100101001010101
0101010010010010001
0010011111010101111
1010100100111101011
```

Label = RUNNING

```
1001010011111010101
1101010111010101110
1010101111010101011
1111110001111010101
```

Label = BIKING

```
1111111111010011101
0011111010111110101
0101110101010101110
1010101010100111110
```

Label = GOLFING

Training and Testing

Training Phase

What is ML?

- Term “Machine Learning” coined by Arthur Samuel in 1959.
  - Samuel Checkers-playing Program
- Common definition (by Tom Mitchell)
  - Machine Learning is the study of computer algorithms that improve automatically through experience

More details

- Study of algorithms that
  - improve their performance P
  - at some task T
  - with experience E

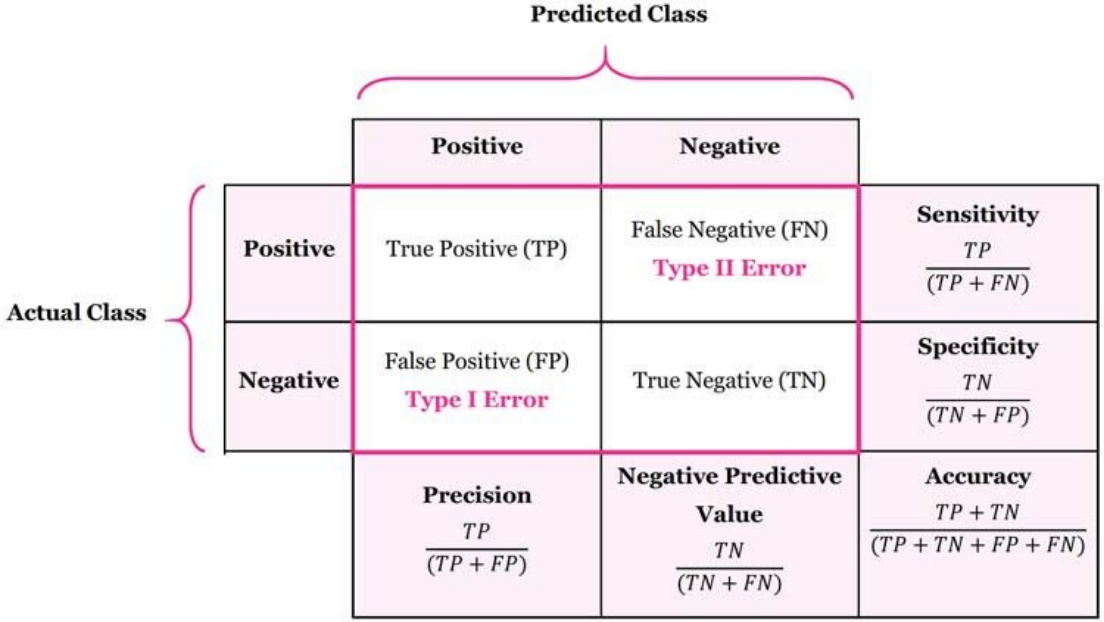
- Well-defined learning task: <P,T,E>

Task (T)

- Classification or Pattern Recognition
- Regression or Prediction
- Clustering
- Synthesis or Sampling
- Ranking
- Recommendation Systems
- Anomaly Detection
- Data Mining etc.

Performance (P)

- A quantitative measure to evaluate performance
  - Usually Task specific
- Classification
  -
  -



Performance (P)

- Regression
  - Error measure such as ‘mean squared error’

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2.$$

Experience (E)

- Supervised Learning
  - Labelled data – (Data, target value)
  - Target value could be category/class labels, real value, real vector, etc.
  - Classification, Regression
- Unsupervised Learning
  - Only data, no labels
  - Dimensionality Reduction, ICA, Clustering
- Reinforcement Learning
  - No examples, but a reward function
  - Payoff based on actions

An Incomplete History of Learning

- Turing Test (1950)
  - Machines do very poorly
- Rosenblatt's Perceptron (1960's)
  - Kick started the mathematical analysis of the learning process
  - Key idea behind Support Vector Machines (SVMs) and Neural Networks
- Construction of Fundamentals of Learning Theory (1960-70's)
  - Focus on generalization capability of learning machines
    - Performance on unseen data
  - Regularization for ill-posed problems
    - e.g., linear equations for ill-conditioned matrices

- Neural Networks (1980's)
  - Connectionism
  - Back-propagation [LeCun, `86]
  - CNNs, RNNs

- SVMs (1990's)
  - Margin Maximization
  - Kernel Methods to handle non-linearity

- Deep Learning (>2006)
  - Hinton, Bengio, LeCun at forefront
  - Abstract Representations

- (>2012) Craziness!!

Most Amazing Milestones So Far

- 1997 – Deep Blue defeats world chess champion Garry Kasparov

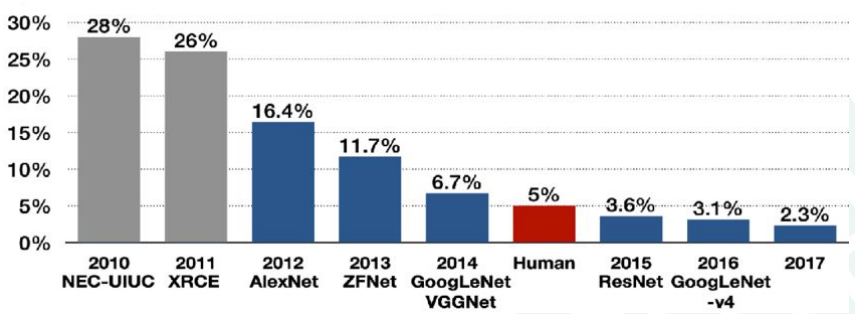
- 2005 – The DARPA Grand Challenge
- A $2 million prized race for autonomous vehicles across 100+ kms off-road terrain in the desert.

Stanford Racing Team's leader Sebastian Thrun

Most Amazing Milestones So Far

- 2011 – IBM Watson's Jeopardy! Victory
- The final tally was $77,147 to Mr. Jennings's $24,000 and Mr. Rutter's $21,600.

- 2015 – Machines "see" better than humans
- Largescale image recognition contest for classifying 50,000 high-resolution color images into 1,000 categories.
- The model is considered to have classified a given image correctly if the target label is one of the model's top 5 predictions.



Most Amazing Milestones So Far

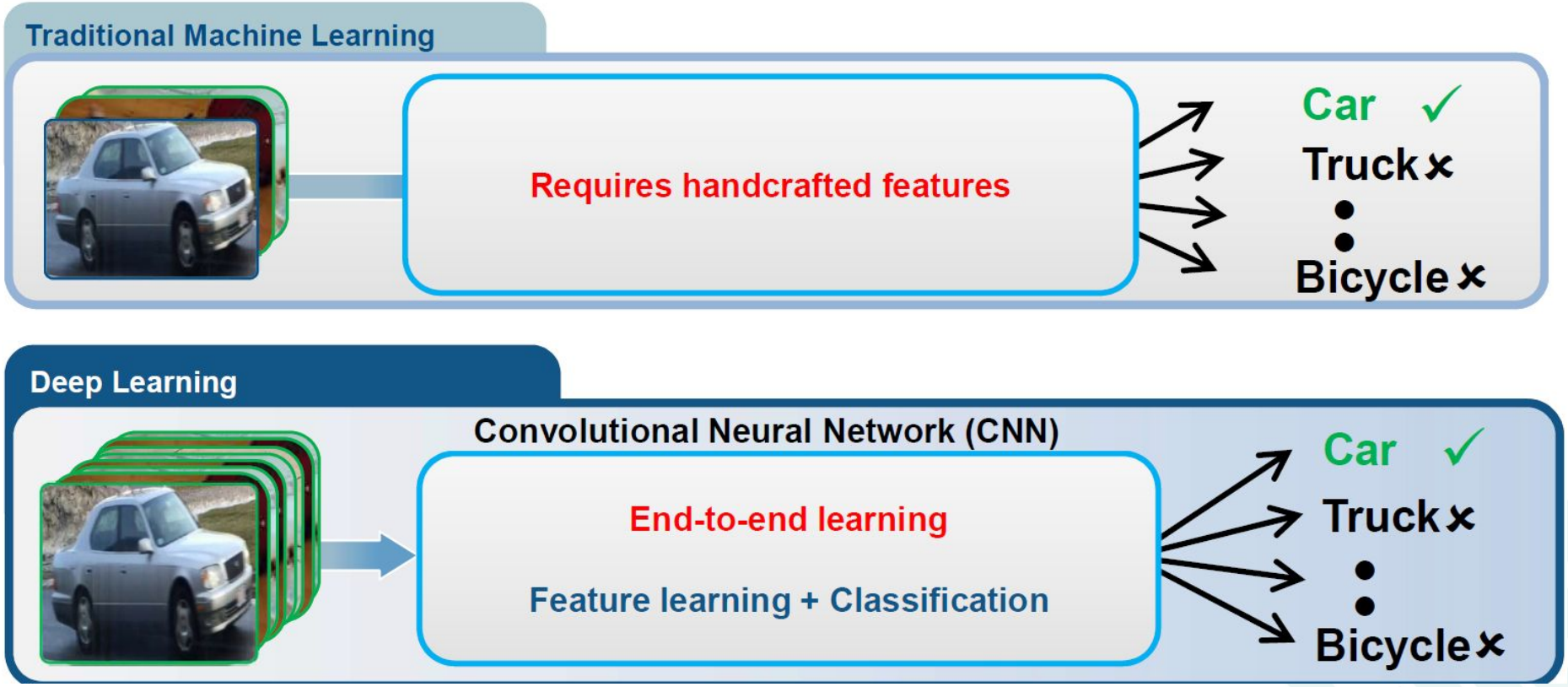
- 2016 – AlphaGo created by Deep Mind (now a Google subsidiary) defeated world Go champion Lee Sedol over five matches.

- There are over 100,000 possible opening moves in Go, compared to 400 in Chess, make the brute force approach impractical.

Recent Progress

- Google Search
- Computer Vision / Image Recognition
  - ImageNet
  - Convolutional Neural Networks
- Autonomous driving
- Speech Recognition
- Voice assistants
  - Apple's Siri, Microsoft's Cortana, Amazon's Echo
- Language Translation
  - Google Translate
  - Unsupervised Translation
- Game Playing / Deep Reinforcement Learning
  - AlphaGo

ML vs DL


Traditional Machine Learning
Requires handcrafted features
Car ✓
Truck ×
Bicycle ×
Deep Learning
Convolutional Neural Network (CNN)
End-to-end learning
Feature learning + Classification
Car ✓
Truck ×
Bicycle ×

Next Class

- Learning Problems and the Empirical Risk Minimization Framework
- Loss Functions for Classification and Regression
- Evaluation Metrics for Classification

References

1. Introduction to TensorFlow for Artificial Intelligence, Machine Learning, and Deep Learning: DeepLearning.AI