Machine Learning: Theory, Implementation and Practice

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Outline

- Introduction
- Machine Learning Algorithms: Discriminative vs Generative Models with Sample Code
- Machine Learning Algorithms: from Theories to Packages
- Machine Learning: Real World Practice
- Review

Outline

What is Machine Learning?

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  machine learning algorithms learn a *model* from *data*

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- Machine Learning is a kind of data summarization technique that human can specify statistical rules in to get results to help people while leaving the judgment of results to the people.
- It is not magic, we have to know something about the task.
- It is usually constrained by the reach of human knowledge.

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- **End-to-end programs** below: random article generator (generative) and an audio classifier (discriminative).

Random Article Generator – Task Definition

- From some article data, generate a new random article.
- Famous application: SCIgen by MIT.

Random Article Generator – Model

- First order hidden markov chain.
- Maintain a map keyed by word with its value as word-ratio pairs indicating how many times each word is next to the keyed word. (e.g. red $\rightarrow$ [(cat, 2), (dog, 3)])
- Beware of punctuations and special characters.
- Generation rule: given a word, randomly generate the next word weighed by word co-occurence.
- See `https://github.com/scan33scan33/easyml/blob/master/text_generation/article_generator.py` for 36 lines of code.

Audio Classification – Task Definition

- From some audio tracks some labeled positive and some labeled negative, train a model that tells positive ones from negative ones.
- Why? Audio format is something that is not semantically understandable. I want to write some simple programs to make it accessible.

Audio Classification – Model

- Record some audio tracks and do FFT.
- Use Perceptron to train a linear model.
- See `https://github.com/scan33scan33/easyml/blob/master/voice_recognition/voice_auth.py` for a few lines of code.

The Perceptron Algorithm

- Input: n training samples with labels $[(y_1, \mathbf{x}_1), (y_2, \mathbf{x}_2), \ldots, (y_n, \mathbf{x}_n)]$.
- Output: a linear weight vector $\mathbf{w}$.
- Algorithm Framework:
  1. Initialize an initial $\mathbf{w} = [0, \ldots, 0]$.
  2. For each sample, $\mathbf{w} \leftarrow \mathbf{w} - (y_i - \text{sign}(\mathbf{w}^T \mathbf{x}_i))\mathbf{x}_i$.

Outline

Some Theories

- Statistical Theory: studies how generalized a model is
- Learning Theory: explains how algorithms work
- Psychology: studies how computer can simulate human beings (neural networks)
- Optimization Theory: makes algorithms run faster

Cores of Statistical Theory

- Various statistical models (mostly on regression.)
- Each variable needs $k \geq 1$ samples to make it stable.

Cores of Learning Theory

- Extensive analysis on classification models.
- VC-dimension (for classification): complex models have poor generalizability
- Learning models for simple algorithms: online-learning, PAC-learning, SQ, etc.

Cores of Optimization Theory

- Hardness of the problem:
  $LP < QP < QCQP < SOCP < SDP$.
- CPU speed: x-GHz
- Memory access speed: DISK $\sim$ Network $<$ RAM $<$ Cache
- Example:

  3-GHz CPU, 100 clocks for 1kB memory access and in avg 100 clocks per meta-instruction, linear time algorithm, 2GB data points in memory: $\frac{2\times 100}{3} < 66(\times\text{convergence iterations})secs$

From Theories to Packages

- Consider computer architecture: embedded, multi-core or distributed?
- Consider what algorithms to support.
- Write docs (or build a discussion group) for target users!!!

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Let's see some example packages.

LIBSVM

- Optimized for multi-core architecture (using OPENMP).
- Linear to quadratic time algorithms to train non-linear models.
- Linear convergence: $O(1/\epsilon)$

LIBLINEAR

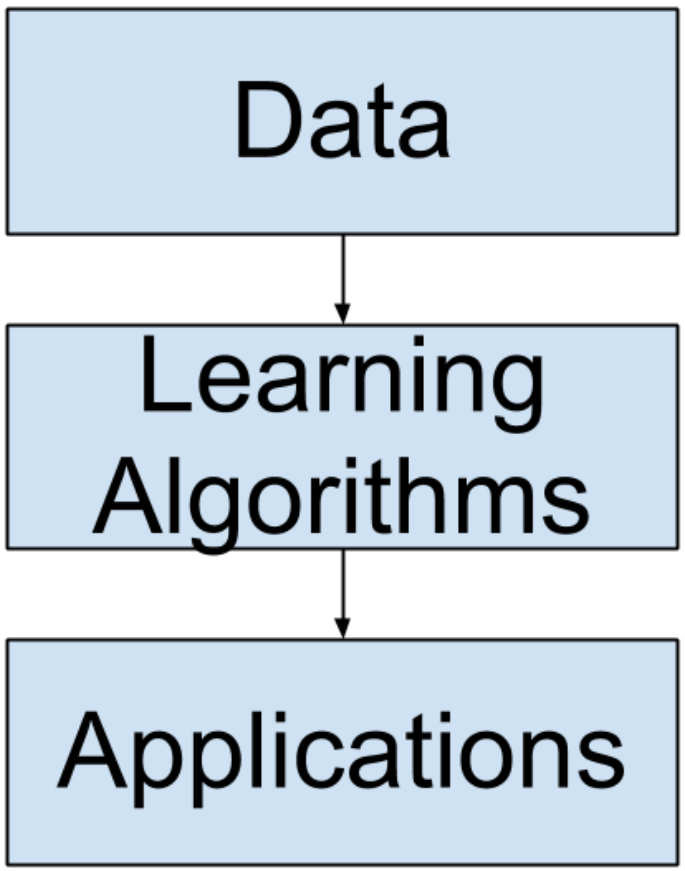
- Optimized for multi-core architecture (using OPENMP).
- Linear time algorithms to train linear models.
- Linear convergence: $O(1/\epsilon)$
- Application to text classification: LIBSHORTTEXT.

Take-home Message

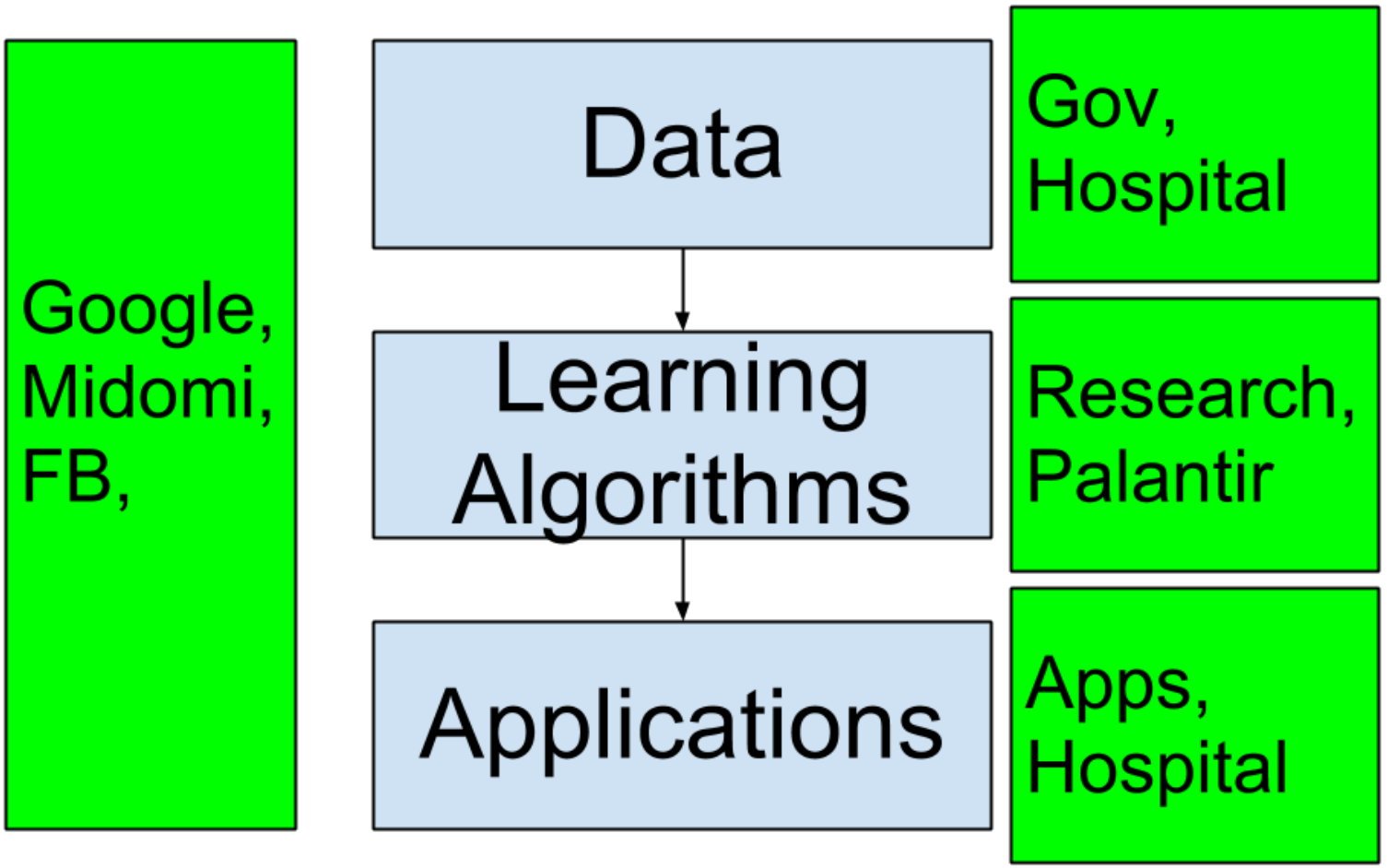
- Theories are mostly only for reference...
- Good implementation can overcome theoretical difficulties...
- But theoretical mindset is important.

Outline

A Real World Machine Learning System



A Real World Machine Learning System with Industries



Challenges of Data Storage

- Format: how to make other people access if needed
- Fast data access: No-SQL, SQL vs files on disk...
- Privacy concerns

Challenges of Model Complexity

- Simple model: fast training/prediction time, accountable, saving computational power
- Complex model: higher accuracy

Good Models in Practice

- Use meaningful features only
- Not sensitive to changes

Outline

Review

- Machine learning: learning from data
- Give example codes for generative models and discriminative models
- Introduces some theories and how they are used in practice
- Connect all these to the industry needs

Code to infinity and beyond! Thanks!

Thanks! The most update-to-date code and slides are at `https://github.com/scan33scan33/easyml`.