Introduction to Machine Learning

Introduction

Varun Chandola

Computer Science & Engineering
State University of New York at Buffalo
Buffalo, NY, USA
chandola@buffalo.edu

University at Buffalo
Department of Computer Science and Engineering
School of Engeering and Applied Sciences

Outline

Making Intelligent Machines

Human Learning

Definition of Machine Learning

- Why Machine Learning?

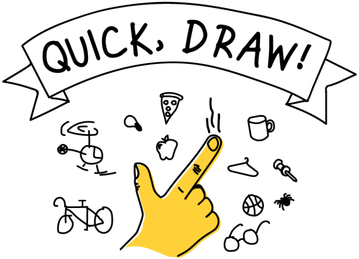
Learning from (Past) Data

Overview of ML

Supervised Learning

What is Machine Learning?

https://quickdraw.withgoogle.com/



Making Machines Intelligent

The world is woven from billions of lives, every strand crossing every other. What we call premonition is just movement of the web. If you could attenuate to every strand of quivering data, the future would be entirely calculable, as inevitable as mathematics.

Sherlock Holmes, 2017

What makes an artificial machine **intelligent**?

1. Talk. See. Hear.
   - Natural Language Processing, Computer Vision, Speech Recognition
2. Store. Access. Represent. (<u>Knowledge</u>)
   - Ontologies. Semantic Networks. Information Retrieval.
3. Reason.
   - Mathematical Logic. Bayesian Inference.
4. **Learn.**
   - Improve with Experience

What makes an artificial machine **intelligent**?

1. Talk. See. Hear.
   - Natural Language Processing, Computer Vision, Speech Recognition
2. Store. Access. Represent. (Knowledge)
   - Ontologies. Semantic Networks. Information Retrieval.
3. Reason.
   - Mathematical Logic. Bayesian Inference.
4. **Learn.**
   - Improve with Experience
     - Machine Learning

Human Learning?

- What do we learn?
  - Concepts (this is a chair, that is not a chair)
  - Distinguishing concepts (this is a chair, that is a table)
  - Other things (language, juggling, using a remote)
- How do we learn?
  1. Teaching (Passive).
  2. Experience (Active).
     2.1 Examples.
     2.2 Queries.
     2.3 Experimentation.

What is Machine Learning?

- Computers learn without being **explicitly programmed**.
  - Arthur Samuel (1959)
- A computer program learns from experience E with respect to some task T, if its performance P while performing task T improves over E.
  - Tom Mitchell (1989)

Why Machine Learning?

- Machines that know everything from the beginning?
  - Too bulky. Creator already knows everything. Fails with <u>new</u> experiences.
- Machines that <u>learn</u>?
  - Compact. Learn what is <u>necessary</u>.
  - Adapt.
  - Assumption: Future experiences are not too different from past experiences.
    - Have (structural) relationship.

Learning from (Past) Data

Deductive Logic

- All birds can fly
- Dodo is a bird
- $\Rightarrow$ Dodo can fly

Inductive Logic

- A stingray can swim
- Stingray is a fish
- $\Rightarrow$ All fish can swim

Learning from (Past) Data

Deductive Logic

- All birds can fly
- Dodo is a bird
- $\Rightarrow$ Dodo can fly

Inductive Logic

- A stingray can swim
- Stingray is a fish
- $\Rightarrow$ All fish can swim

Core Tenet

- ~~Deduce~~ Induce from past
- Generalize for future

Understanding the Machine Learning Landscape

- What do you want the ML algorithm to do?
  - ML tasks: classification, prediction, grouping, decision making
- How do you want to do it?
  - Supervised learning, unsupervised learning, and reinforcement learning

Machine Learning Problems

Supervised Learning

- Given a finite set of $\mathbf{x}$'s and corresponding y's, **learn** $f()$
- **Infer** y for a new $\mathbf{x}$
  - y - continuous (regression)
  - y - discrete (classification)

Unsupervised Learning

- Given only $\mathbf{x}$'s, infer structure in data
  - hidden (latent) relationships among the objects
- e.g., clustering, embedding, dimensionality reduction, etc.

Reinforcement Learning

- Find the best mapping of situations to actions to maximize a numerical reward
- Agent learns to behave in an environment

Supervised Learning - Machine Learning meet Mother Nature

- Data: A collection of data objects
  - A representation of the object of interest or the state of the target system, and/or
  - A label or a target value or a low-dimensional representation or an embedding or an action associated with the object/state
- Mother nature generates this data using an unknown generative process (secret recipe)
- ML problem - given part of the information, infer the other part

More Examples

Primary

- Given an individual's data (criminal and otherwise), predict risk of recidivism
- Given an email, determine if it is spam or normal
- Given an image, identify the object
- For a given day, predict the number of travelers that will pass through a subway station

Secondary

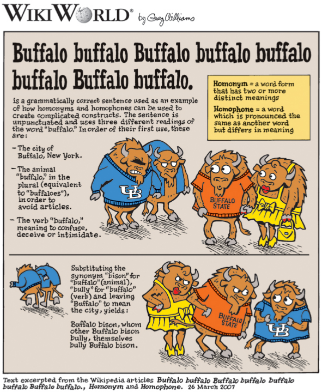
- Color a black and white image
- Translate English text to French
  - `translate.google.com`

True Test for Any Language System

- Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo.

True Test for Any Language System

- Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo.



- Buffalo buffalo, Buffalo buffalo buffalo, buffalo Buffalo buffalo.

Unsupervised Learning

- Learn hidden structure in the data
- No assumption of labels
- Examples
  1. Clustering (customers of Wegmans, set of magazine articles)
  2. Embedding any data into a metric space ($\Re^d$) (text, tweets, disease codes)
  3. Dimensionality reduction
  4. Factor analysis
  5. Dictionary learning

Isolating Music

`https://vimeo.com/348102769`

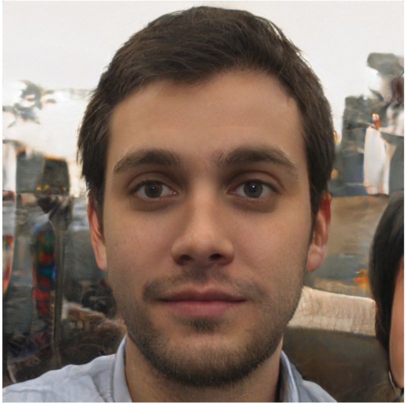
Reinforcement Learning

- An agent, operating in a changing environment, finds the best sequence of actions that maximize an end goal
- Key concepts: policy, reward, end-value, environment

- Examples
  1. Learning to play a game (Breakout, AlphaGo)
  2. A robotic vaccum cleaner figures out the best time to recharge
  3. Almost all robotic tasks
  4. Traffic light control

- https://www.youtube.com/v/V1eYniJ0Rnk

ML as a generator - faces



Generating faces

- https://thispersondoesnotexist.com
- https://www.whichfaceisreal.com

ML as a generator - text

You will rejoice to hear that no disaster has overtaken you. If your heart is grieved, and your joy is swallowed up, you have the LORD to thank.

You will rejoice to hear that no disaster has accompanied the commencement of an enterprise which you have regarded with such evil forebodings.

ML as a decision maker - criminal justice

References