

Introduction to Machine Learning

7 Jun 2020

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A few (not so, yet) recent quotes

- “A breakthrough in machine learning would be worth ten Microsofts”
(Bill Gates, Chairman, Microsoft)
- “Machine learning is the next Internet” (Tony Tether, Director, DARPA)
 - “Machine learning is today’s discontinuity” (Jerry Yang, ex-CEO, Yahoo)

What is Machine Learning?

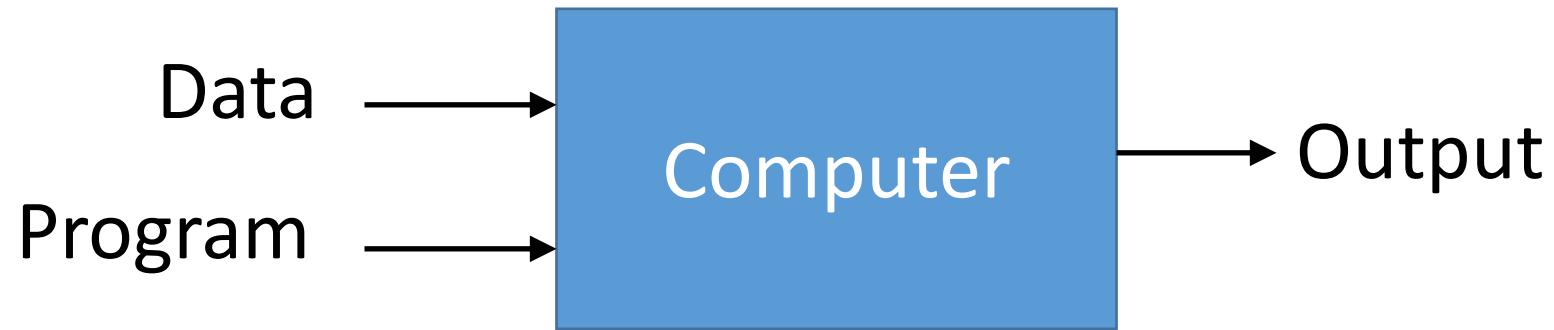


What is Machine Learning?

- Making predictions or decisions from data
- “Programming computers to optimize a performance criterion using example data or past experience” (Ethem Alpaydin, Machine Learning, 2010)
- “A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.” (Tom Mitchell, Machine Learning, 1997)
- “Learning general models from a data of particular examples”
- “Build a model that is *a good and useful approximation* to the data.”

Today

Traditional Programming



Machine Learning



Source: Domingos

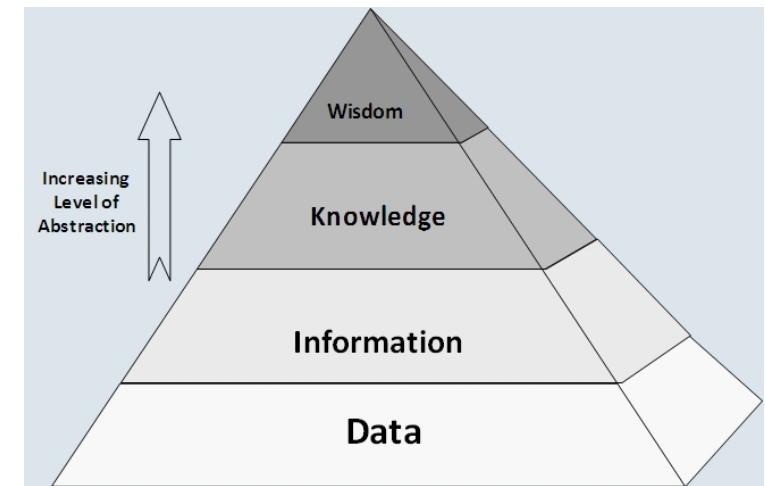
Related Terms

Machine Learning, Data Mining, Knowledge Discovery, Artificial Intelligence, Statistical Learning, Pattern Recognition, Computational Learning



When is Machine Learning Used?

- Human expertise does not exist
 - E.g. navigating on Mars
- Humans are unable to explain their expertise
 - E.g. speech recognition
- Solution changes in time
 - E.g. routing on a computer network
- Solution needs to be adapted to particular cases
 - E.g. user biometrics
- Data is cheap and abundant; knowledge is expensive and scarce



Applications of Machine Learning

From: cheapsales@buystufffromme.com
To: ang@cs.stanford.edu
Subject: Buy now!

Deal of the week! Buy now!
Rolex w4tchs - \$100
Med1cine (any kind) - \$50
Also low cost M0rgages available.

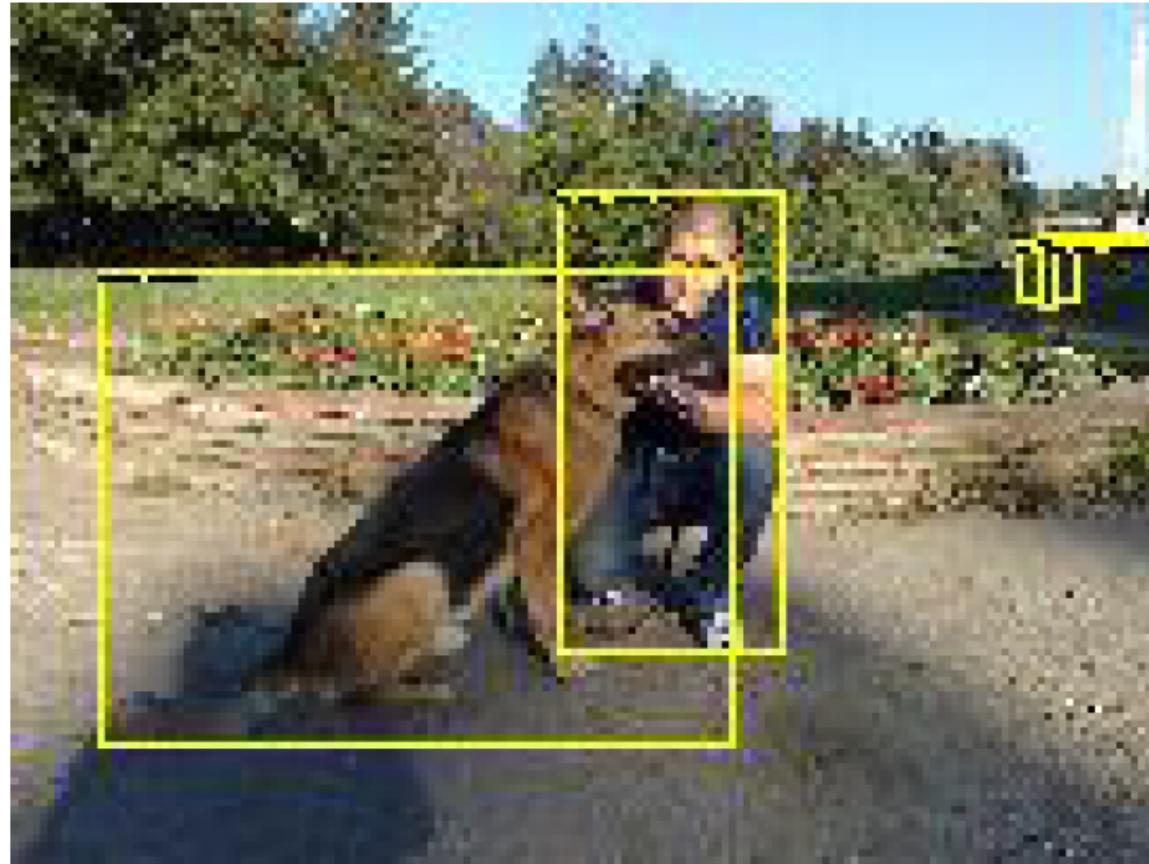
Spam

From: Alfred Ng
To: ang@cs.stanford.edu
Subject: Christmas dates?

Hey Andrew,
Was talking to Mom about plans for Xmas. When do you get off work. Meet Dec 22?
Alf

Non-spam

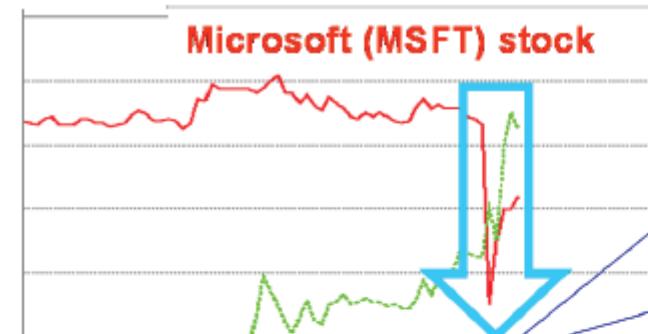
Applications of Machine Learning



Applications of Machine Learning

CCAGCTGCATCACAGGAGGCCAGCGAGCAGGTCTGTTCCAAGGGCCTCGAGCCAGTCTG EI
GAGGTGAAGGACGTCTCCCCAGGAGCCGGTGAGAAGCGCAGTCGGGGCACGGGGATG EI
TAAATTCTCTGTTAACACCTTCAGACTTATGTGTATGAAGGAGTAGAACCCAAA IE
AAACTAAAGAATTATTCTTACATTCAGTTCTGATCATGAAAACGCCAACAAAA IE
AAAGCAGATCAGCTGTATAAACAGAAAATTATTCGTGGTTCTGTCACTGTGTGATGGT N
TTGCCCTCAGCATCACCATGAACGGAGAGGCCATGCCCTGCGCTGAGGGCTGCCAGGCCA N

Applications of Machine Learning



Software giant Microsoft saw its shares dip a few percentage points this morning after U.S. District Judge Thomas Penfield Jackson issued his "findings of fact" in the government's ongoing antitrust case against the Seattle wealth-creation machine...

News:



Words like **Jackson** and **antitrust** are more likely in the stories preceding the plunge.

$P(\text{shares}) = 0.074$
 $P(\text{antitrust}) = 0.009$
 $P(\text{judge}) = 0.006$
 $P(\text{trading}) = 0.032$
 $P(\text{against}) = 0.025$
 $P(\text{Jackson}) = 0.001$

$P(\text{shares} \mid \text{MSFT}\downarrow) = 0.071$
 $P(\text{antitrust} \mid \text{MSFT}\downarrow) = 0.044$
 $P(\text{judge} \mid \text{MSFT}\downarrow) = 0.039$
 $P(\text{trading} \mid \text{MSFT}\downarrow) = 0.029$
 $P(\text{against} \mid \text{MSFT}\downarrow) = 0.027$
 $P(\text{Jackson} \mid \text{MSFT}\downarrow) = 0.025$



$$P(\text{MSFT}\downarrow \mid \text{Jackson}) = P(\text{Jackson} \mid \text{MSFT}\downarrow) P(\text{MSFT}\downarrow) / P(\text{Jackson})$$

Applications of Machine Learning

The screenshot shows the Netflix homepage with a red header. At the top, there are four navigation tabs: "Start Your 1 Month Free Trial", "How It Works", "Browse Selection", and "1 Month Free Trial Info". On the right side of the header is a "Member Sign In" button. Below the header, a main headline reads: "Unlimited TV episodes & movies instantly over the Internet plus unlimited DVDs by mail!". The page is divided into three main sections:

- On your TV:** Shows icons for Wii, PS3, and XBOX360, each with a "Learn more >" button. A large arrow points from these devices to a television screen displaying a movie interface. Below this, text says "Watch as often as you want, anytime you want."
- On your computer:** Shows a laptop icon with a "PLAY" button and a "Learn more >" button. To its right is a large "AND" connector.
- DVDs by mail:** Shows a black mailbox with a red Netflix envelope inside, with a red arrow pointing to it. Below this, text says "Exchange as often as you want. No late fees - ever!"

At the bottom left, there's a "FAQs" section with links to various questions like "How does Netflix work?", "What is the selection like?", etc. To the right of this is a "How does Netflix work?" section with a detailed explanation of the service's features. On the far right, there's a "Start Your 1 Month Free Trial" form with fields for Email, Confirm Email, Password, and Confirm Password.

More ML Applications

- Science (Astronomy, neuroscience, medical imaging, bio-informatics)
- Environment (energy, climate, weather, resources)
- Retail (Intelligent stock control, demographic store placement)
- Manufacturing (Intelligent control, automated monitoring, detection methods)
- Security (Intelligent smoke alarms, fraud detection)
- Marketing (promotions, ...)
- Management (Scheduling, timetabling)
- Finance (credit scoring, risk analysis...)
- Web data (information retrieval, information extraction, ...)

More Recent ML Applications

- AlphaGo!
- Automating Employee Access Control
- Identifying whales in ocean based on audio recordings
- Predict wait times for patients in emergency rooms
- Extract heart failure diagnosis criteria from free-text physician notes
- Predicting hospital readmissions
- Is (s)he a psychopath?

Source: <http://www.forbes.com/sites/85broads/2014/01/06/six-novel-machine-learning-applications/#6b6f9a9e67bf>



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Introduction to Machine Learning

14

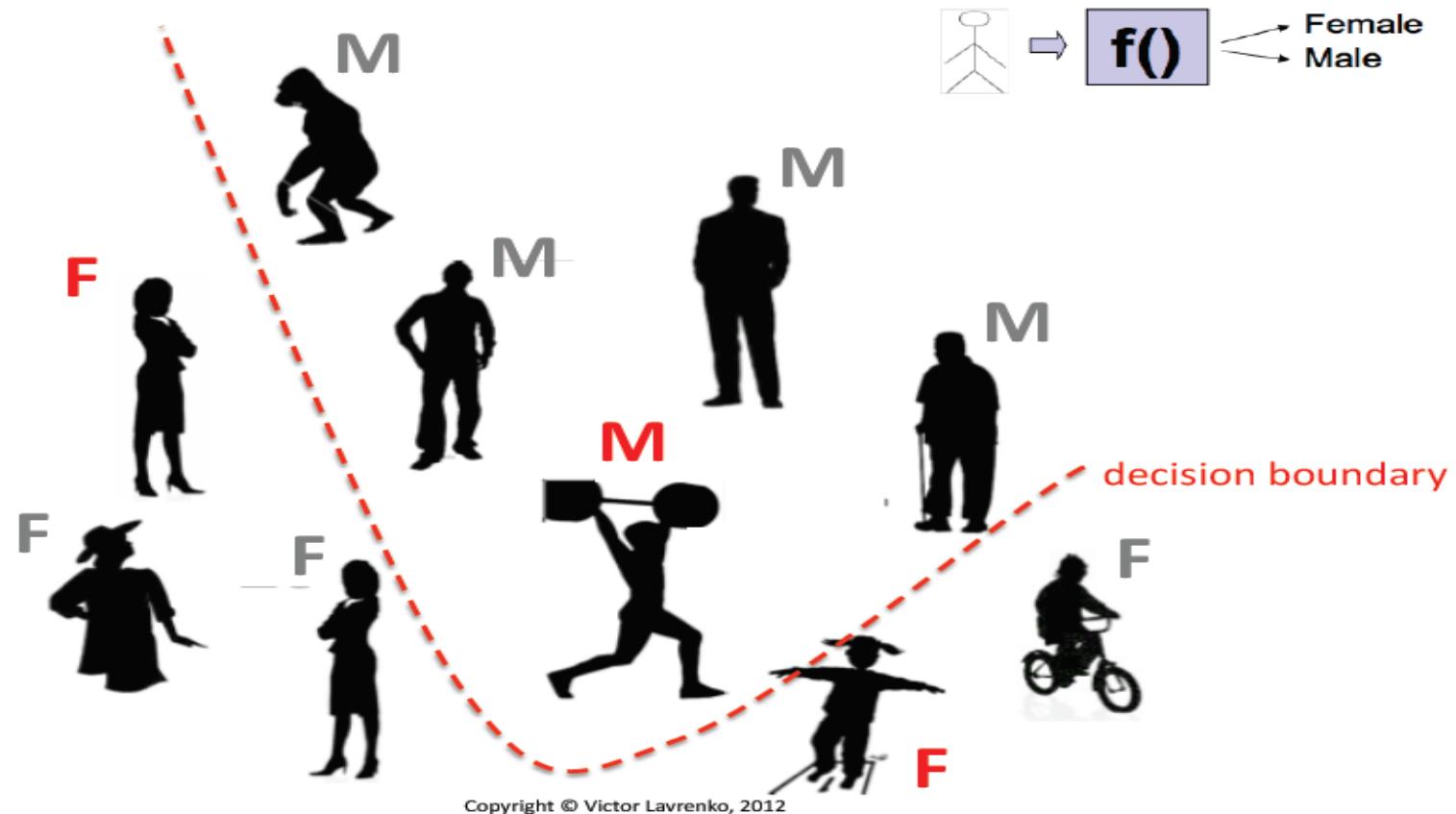
When are ML algorithms not needed?

- When the relationships between all system variables (input, output, and hidden) is completely understood!
- This is NOT the case for almost any real system!

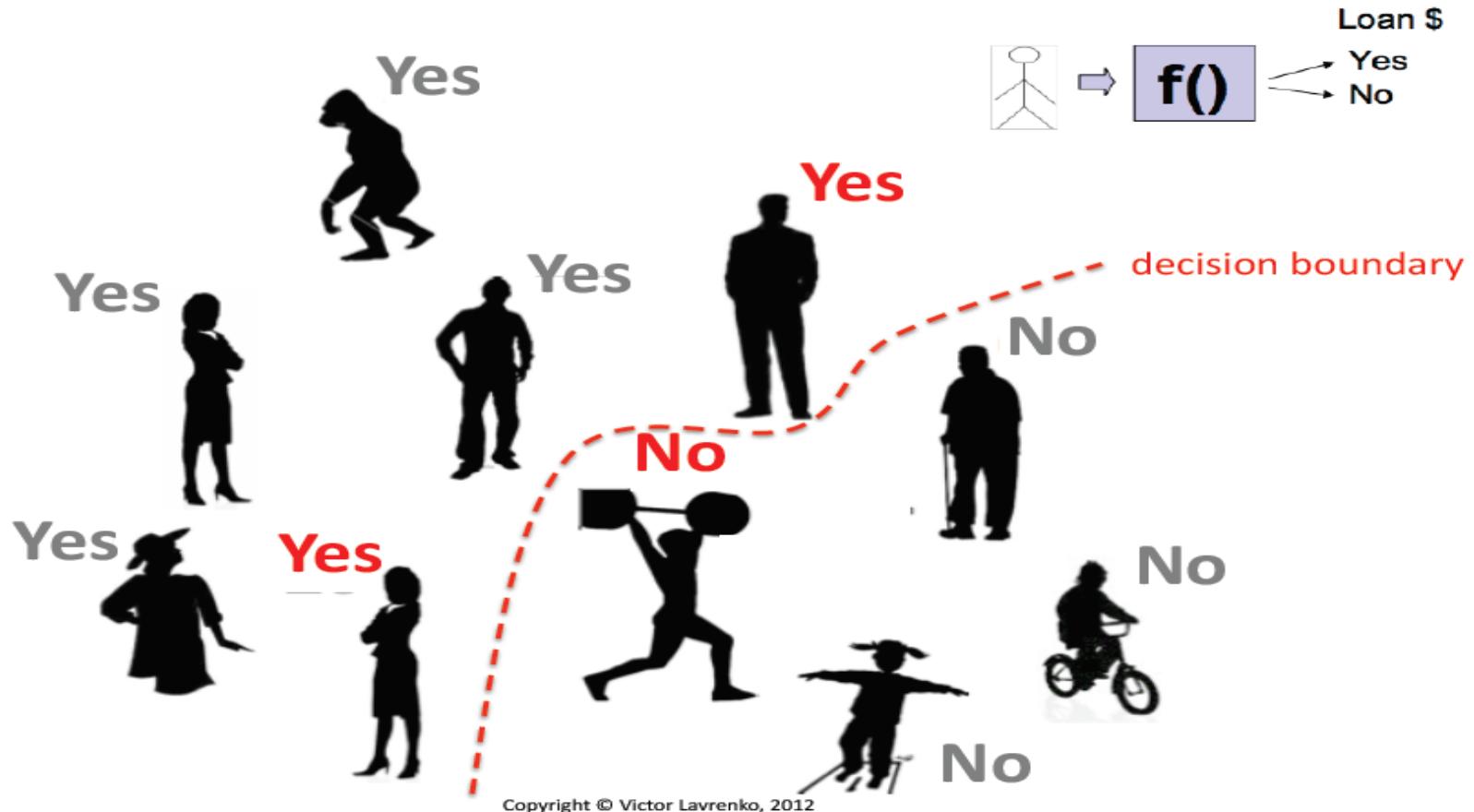
Overview of ML

- Supervised learning
 - Predict an output y when given an input x
 - For categorical y : classification.
 - For real-valued y : regression.
- Unsupervised learning
 - Create an internal representation of the input, e.g. clustering, dimensionality
 - This is important in machine learning as getting labels is often difficult and expensive
- Other settings of ML
 - Reinforcement learning (learning from “rewards”)
 - Semi-supervised learning (combines supervised + unsupervised)
 - Active learning, Transfer learning, Structured prediction

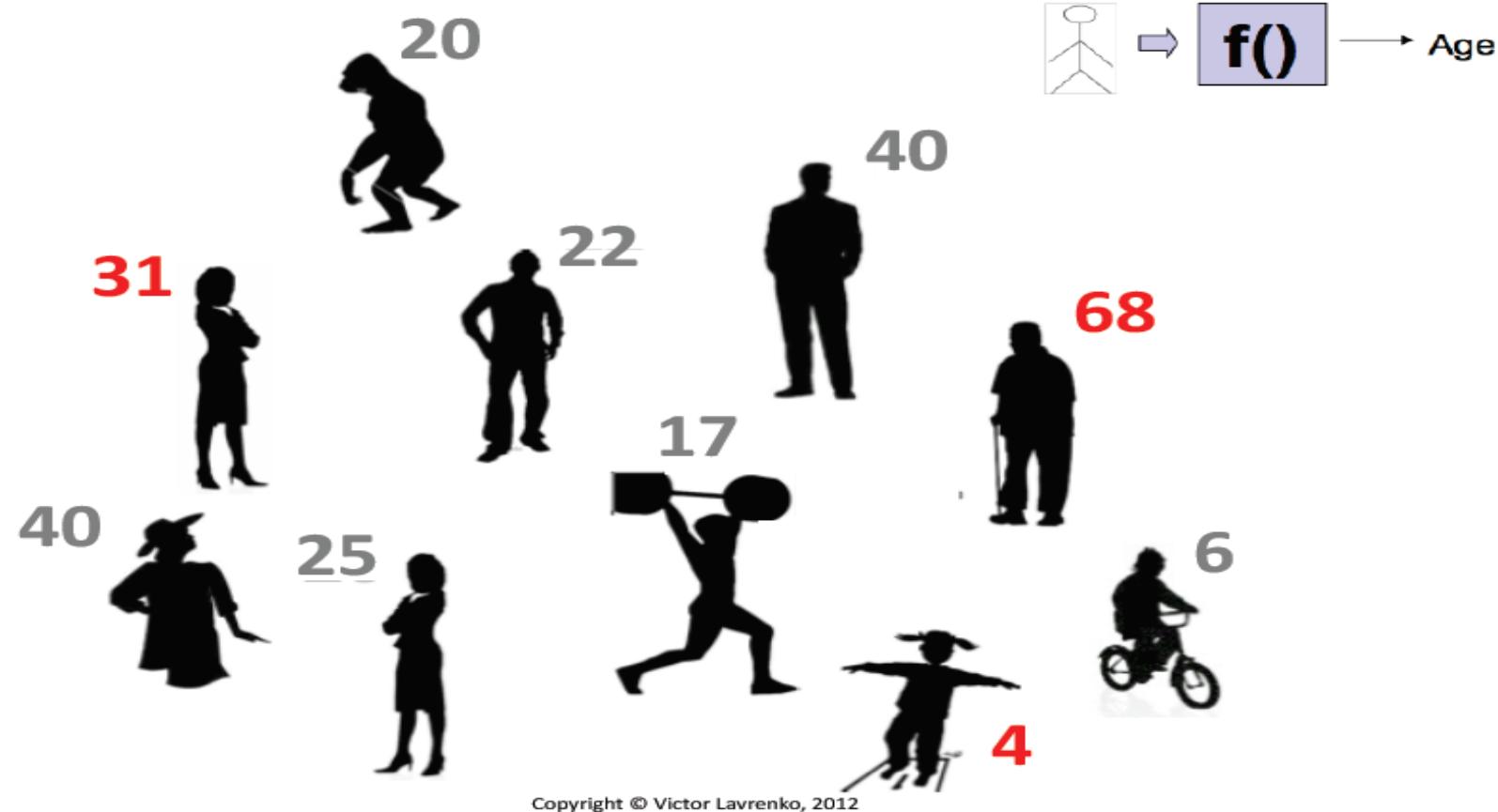
Classification (Supervised Learning)



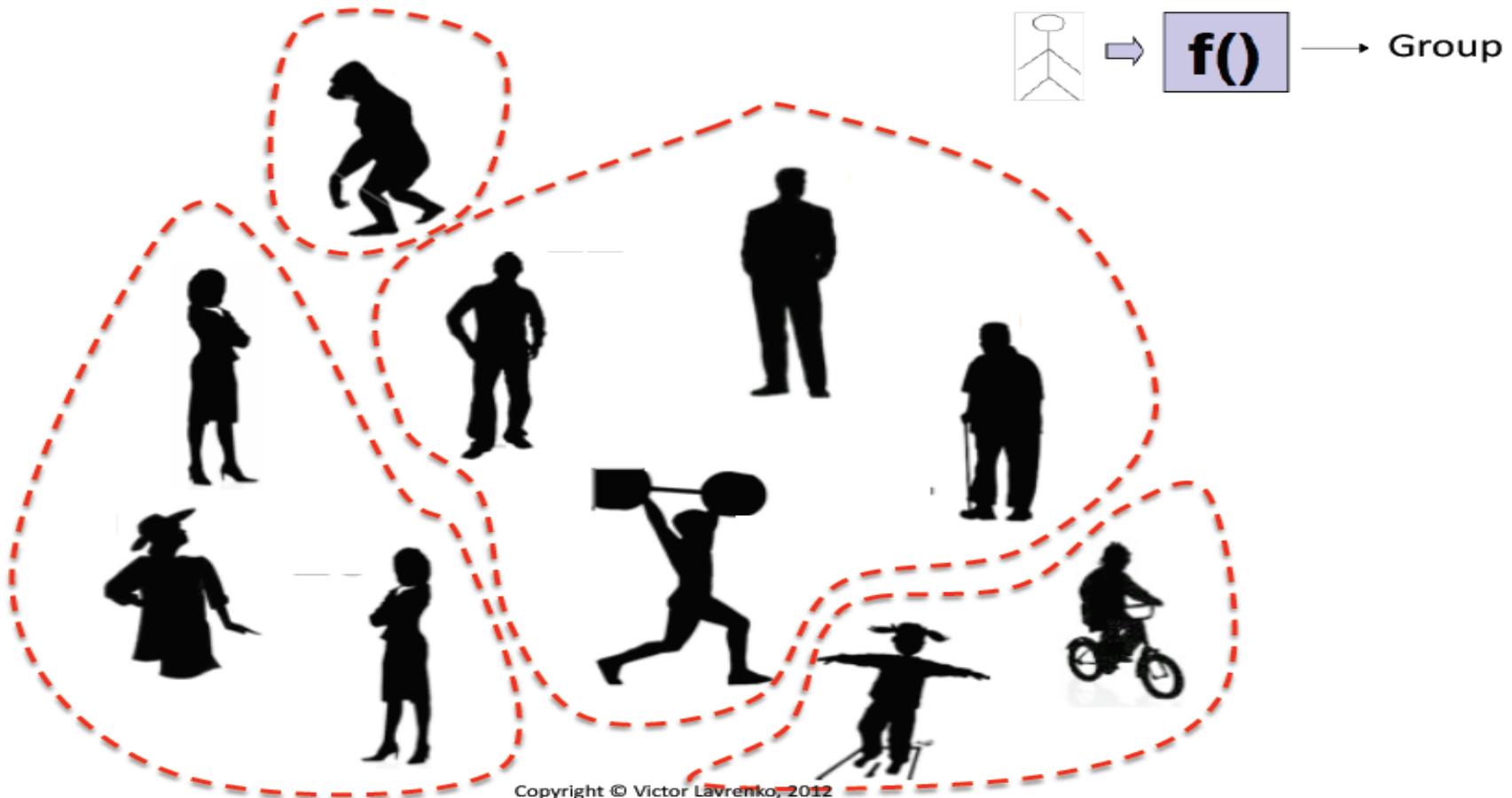
Classification (Supervised Learning)



Regression (Supervised Learning)

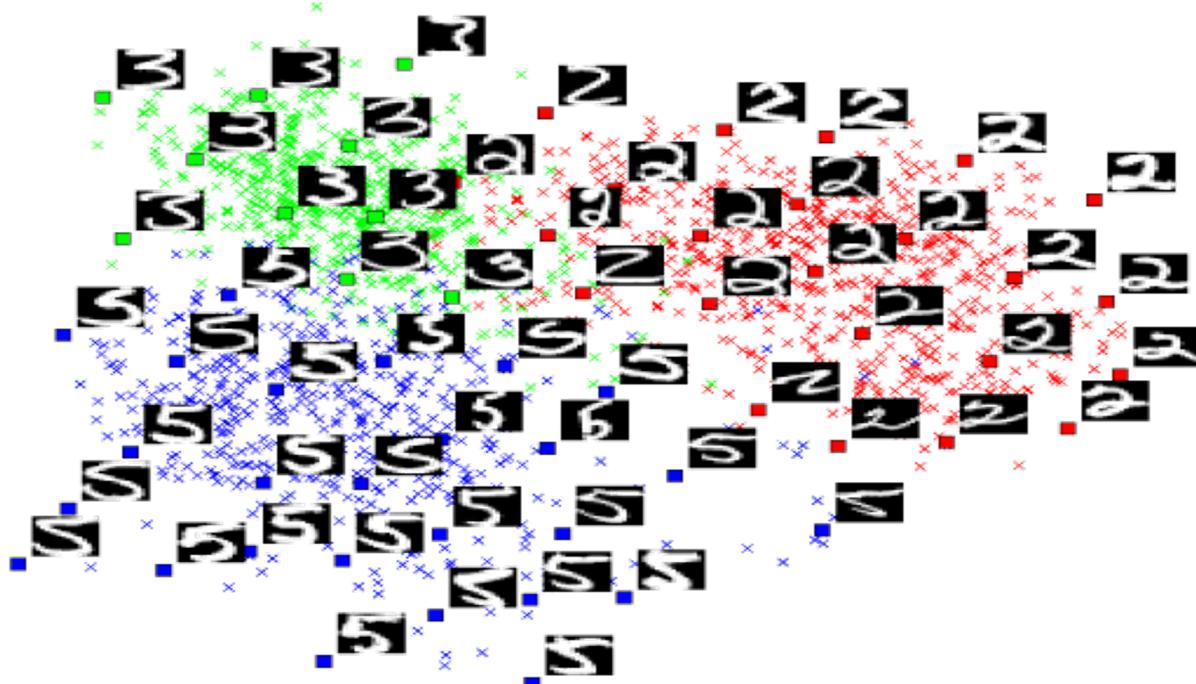


Clustering (Unsupervised Learning)



Dimensionality Reduction (Unsupervised Learning)

- Large sample size is required for high-dimensional data
- Query accuracy and efficiency degrade rapidly as the dimension increases
- Strategies
 - Feature reduction
 - Feature selection
 - Manifold learning
 - Kernel learning



Other Settings: Ranking (Supervised Learning)

Given a query and a set of web pages, rank them according to relevance

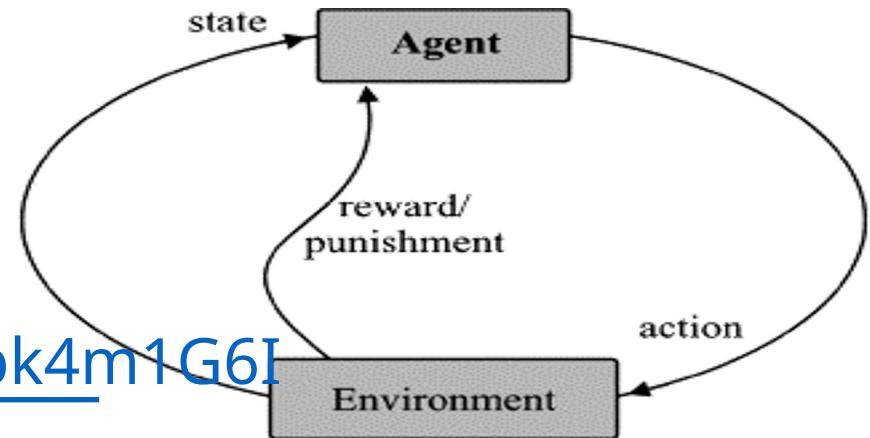
Google search results for "machine learning":

- Machine learning - Wikipedia, the free encyclopedia**
en.wikipedia.org/wiki/Machine_learning ▾
Machine learning, a branch of artificial intelligence, concerns the construction and study of systems that can learn from data. For example, a machine learning ...
Artificial intelligence - Supervised learning - List of machine learning ... - Weka
Franck Demontcourt +1'd this
- CS 229: Machine Learning**
cs229.stanford.edu/ ▾
Check out this year's awesome projects at Fall 2012 Projects. Come check out the cool new projects during the CS229 Poster Session this Thursday December ...
You've visited this page 2 times. Last visit: 8/14/13
- Machine Learning | Coursera**
https://www.coursera.org/course/ml ▾
Machine learning is the science of getting computers to act without being explicitly programmed. In the past decade, machine learning has given us self-driving ...
Franck Demontcourt and 3 other people +1'd this
- Machine Learning Department - Carnegie Mellon University**
www.ml.cmu.edu/ ▾
Large group with projects in robot learning, data mining for manufacturing and in multimedia databases, causal inference, and disclosure limitation.
- Machine Learning - MIT OpenCourseWare**
ocw.mit.edu › Courses › Electrical Engineering and Computer Science ▾
6.867 is an introductory course on machine learning which gives an overview of many concepts, techniques, and algorithms in machine learning, beginning with ...

- Other applications
 - User preference, e.g. Netflix “My List” -- movie queue ranking
 - Flight search (search in general)
 - ...

Other Settings: Reinforcement Learning

- Learning a policy: A **sequence** of outputs
- No supervised output but delayed reward
 - E.g. Game playing
 - E.g. Robot in a maze
- Multiple agents, partial observability, ...
- Example (Simple Demo):
 - <https://www.youtube.com/watch?v=DCjbk4m1G6I>



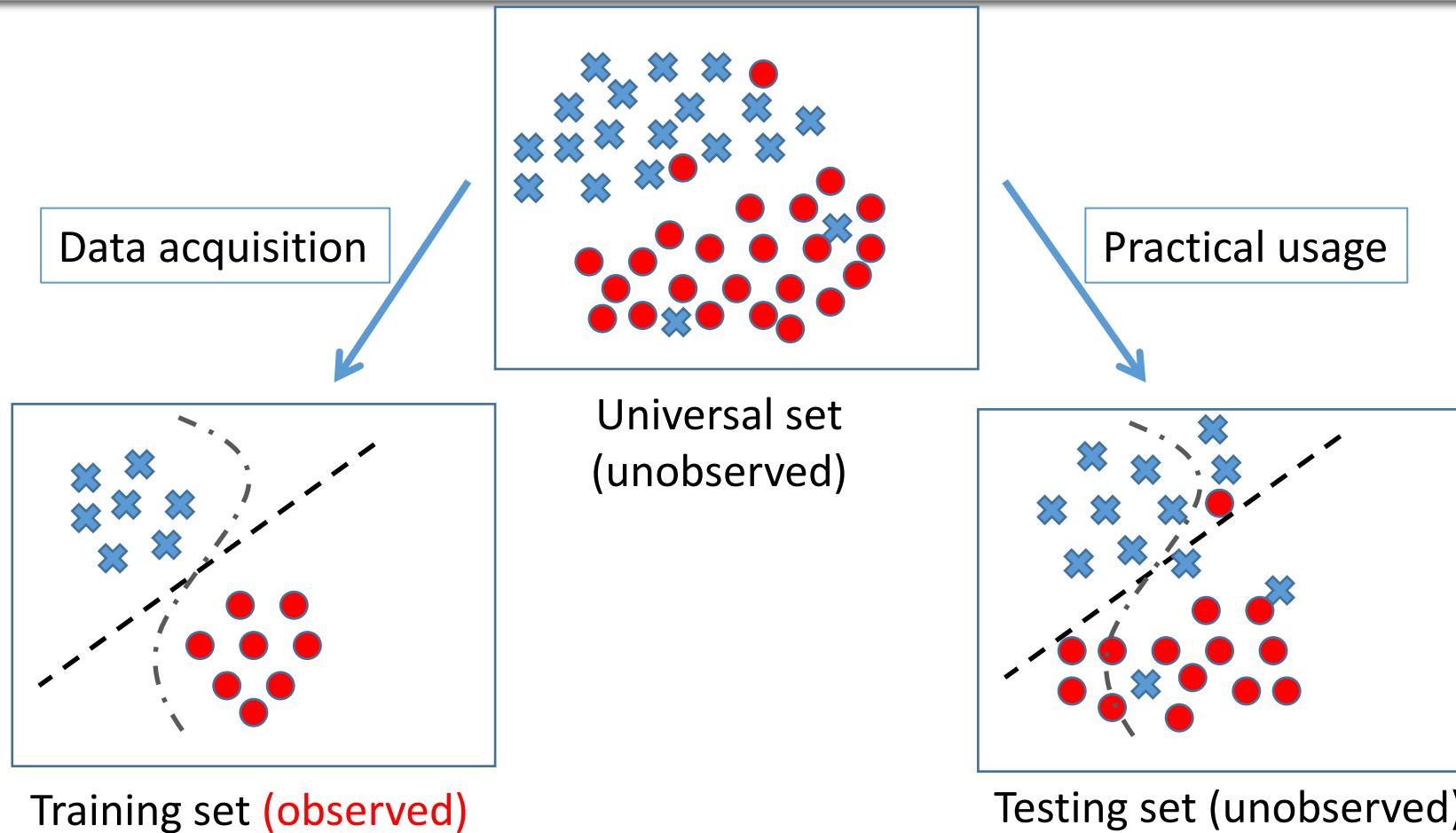
ML Problems

	<i>Supervised Learning</i>	<i>Unsupervised Learning</i>
<i>Discrete</i>	classification or categorization	clustering
<i>Continuous</i>	regression	dimensionality reduction

ML in Practice

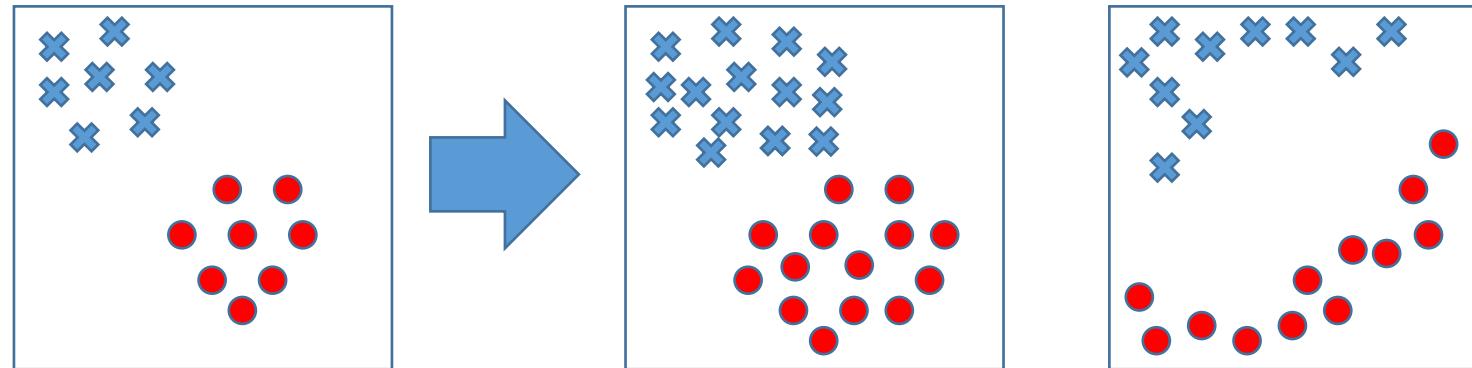
- Understanding domain, prior knowledge, and goals
- Data integration, selection, cleaning, pre-processing, etc.
- Learning models
- Interpreting results
- Consolidating and deploying discovered knowledge
- Loop

Training and Testing ML Models



Training and Testing ML Models

- Training is the process of making the system able to learn.
- **No free lunch** rule:
 - Training set and testing set may not come from the same distribution
 - Need to make some assumptions or bias



ML Datasets

- UCI Repository:
<http://www.ics.uci.edu/~mlearn/MLRepository.html>
- Statlib: <http://lib.stat.cmu.edu/>
- Kaggle
- Many more...

ML Resources

- MOOCs
 - Coursera, EdX, Udacity
- Conferences/Journals
 - JMLR, Machine Learning, IEEE Transactions on Neural Networks and Learning Systems, IEEE Transactions on Pattern Analysis and Machine Intelligence, Annals of Statistics
 - ICML, NIPS, KDD, IJCAI, AAAI, ICDM

Mathematical Basis

- Functions, Logarithms and Exponentials
- Vectors, Dot Products, Orthogonality
- Matrices, Matrix Operations, Linear Transformations, Eigendecomposition
- Calculus, Differentiation, Integration
- Probability and Statistics
- Functional Analysis, Hilbert Spaces

Programming

- Python
 - Numpy, Scipy – numerical/scientific computing, linear algebra
 - Matplotlib – for plotting
 - Scikitlearn – for machine learning

Foundational Reading/Follow-up

- Math
 - Part 1 of Deep Learning book: <http://www.deeplearningbook.org/>
 - Essence of linear algebra: <http://youtu.be/kjBOesZCoqc>
 - Essence of calculus: <https://goo.gl/Hnk1jA>
- Programming
 - Practice Python
 - <https://try.jupyter.org/>
 - <https://docs.python.org/3/tutorial/>
 - Video Tutorials: <https://www.youtube.com/watch?v=cpPG0bKHYKc>
 - Play with Numpy, Matplotlib, scikitlearn