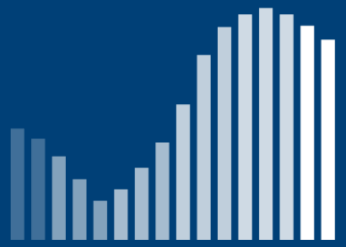
Wharton
University of Pennsylvania

Principles of Artificial Intelligence & Machine Learning

September 2017



Wharton Analytics Fellows

Today's Objectives

- **Define Artificial Intelligence (AI)** and describe its applications in business
- **Dive into Machine Learning (ML)** to highlight best practices and decode buzzwords such as "deep learning" and "cognitive computing"
- **Discuss major drivers and influencers** that are shaping the future of AI / ML

Introduction to

Artificial Intelligence

Defining Artificial Intelligence (AI)

Artificial Intelligence is the automation of activities we normally attribute to human thinking and rationality, such as problem-solving, decision-making, and learning

- **Philosophy**: Where does knowledge come from?
- **Linguistics**: How does language relate to thought?
- **Neuroscience**: How do our brains process information?
- **Behavioral Economics**: How do you make decisions to maximize utility?
- **Mathematics**: What can be computed?
- **Computer Science**: How can we build an efficient computer?

Source: Artificial Intelligence: A Modern Approach (2nd Edition) by Stuart J. Russell, Peter Norvig, and Ernest Davis

Motivations for Artificial Intelligence in Business

Artificial Intelligence is sure to impact your professional career path, regardless of your role within the business community

- **$27B+ was spent on AI** in 2016, with ~$9B coming from VC / PE
- **300% increase in AI-related private investments** from 2013 to 2016
- Machine learning startups accounted for **44% of all venture funding** in 2016

- Proactive AI adopters have **3% to 15% higher self-reported margins**
- **75% of executives** said that AI would be “actively implemented” within 3 years
- Early adopters are expected to **grow operating margins by >5%** over three years

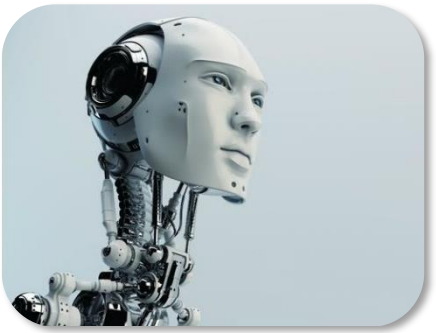
- Demand **for data scientists** is expected to **grow by 28%** between now and 2020
- **47% of jobs are at risk** of becoming irrelevant due to AI automation
- **40%+ of activities are automatable** in 51% of occupations

Sources: McKinsey Global Institute, Executive Office Report on AI, IBM Analytics Report, Venture Scanner

Societal Implications of Artificial Intelligence

Outside of the workplace, AI will also have far-reaching impact on our personal lives

Time to Impact

	Autonomous Weapons	Autonomous Industry	Autonomous Decision-Making	Artificial Superintelligence
				
⊕	**Save lives** and create a **military advantage** in the short term	Universal Basic Income could free people to **pursue their passions**	**Better, faster decisions** that underweight human biases	Ability to **solve** a wide range of **mysteries and maladies**
⊖	**High potential for misuse** by rogue or artificial agents	Rampant **unemployment**, **inequality**, and societal **unrest**	Introduction of **artificial biases** in infrastructure, recruiting, etc.	The **destruction of civilization** as we know it

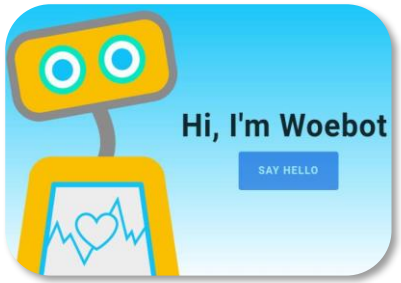
Modern Applications of AI Research

AI can be broken down into roughly five distinct research areas originating from the Total Turing test

Artificial Intelligence

- Machine Vision
- Natural Language Processing
- Machine Learning
- Robotics
- Expert Systems

FarmTech
Prospera



Therapist Chatbots
Woebot

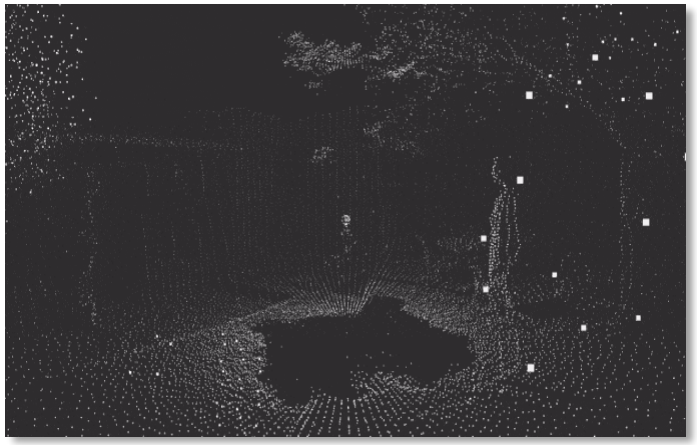
Pro Gaming
OpenAI

Robot Bankers
Commonwealth Bank of Australia

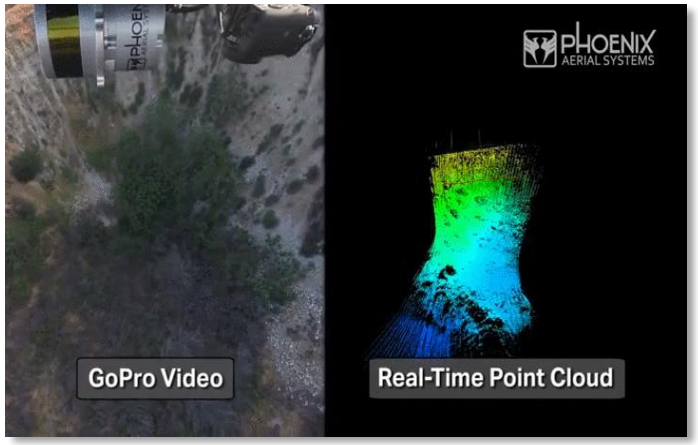
Warehouse Ops
Amazon

Machine Vision – How Robots See

Onboard automotive sensors are pushing the boundaries of perception, and doing so cheaper than ever



Scanse's 3D Environment



Phoenix Aerial Systems Mapping Drone

Autonomous Truck on Top Gear

Applications

- Geological mapping / imaging to monitor erosion or other changes
- Doing survey work for construction projects
- Making accurate volumetric estimates of landfills

Companies

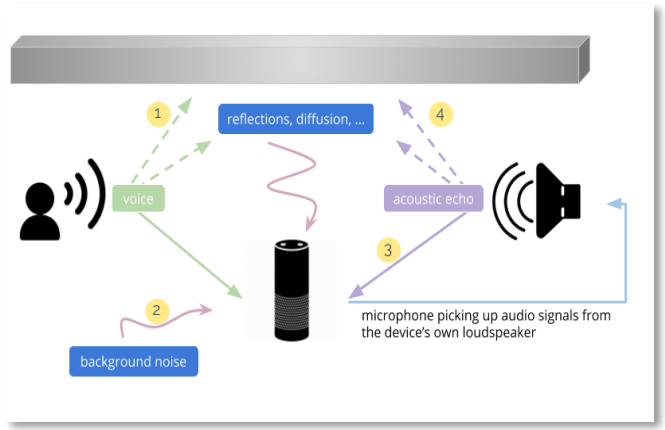
- **Velodyne** - Combines up to 64 emitter/receiver pairs in a single sensor that can provide 360 degree horizontal view
- **Scanse** - Inexpensive scanning Lidar a la Velodyne
- **Quanergy** - Inexpensive solid-state Lidar. Uses non-mechanical "phased array optics" to move laser

Natural Language Processing – How Robots Hear

In our quest to optimize for speed, efficiency and convenience, we are moving to a world where we primarily speak to machines before reading and listening to their responses

Adaptive Beamforming

Enables noise reduction, automatic speech recognition, and speaker separation



Voice Print Identification

Enables personalization, user identification, and biometric authentication

Speech Synthesis

Enables mimicry of any person's voice with predefined emotion or intonation

*"**AI is the new electricity**. Just as 100 years ago electricity **transformed industry after industry**, AI will now do the same."*

- Andrew Ng

"If I were to guess what our **biggest existential threat** is, it's probably [AI]… With artificial intelligence, we are **summoning the demon**."

- Elon Musk

Artificial Intelligence

Drivers & Influencers

Rise of Big Data

Though “big data” is everyone’s least favorite buzzword, AI and ML have both benefited significantly from the world’s ever-increasing volume, variety, and velocity of data

Volume: Quantity of data available for analysis

- Gigabytes
- Terabytes
- Petabytes

Variety: Types of data available for analysis

- Structured (financial metrics, demographic data, etc.)
- Unstructured (conversational transcripts, social media, etc.)

Velocity: How quickly data is available for analysis

- Real Time
- Near-Real Time
- Batch

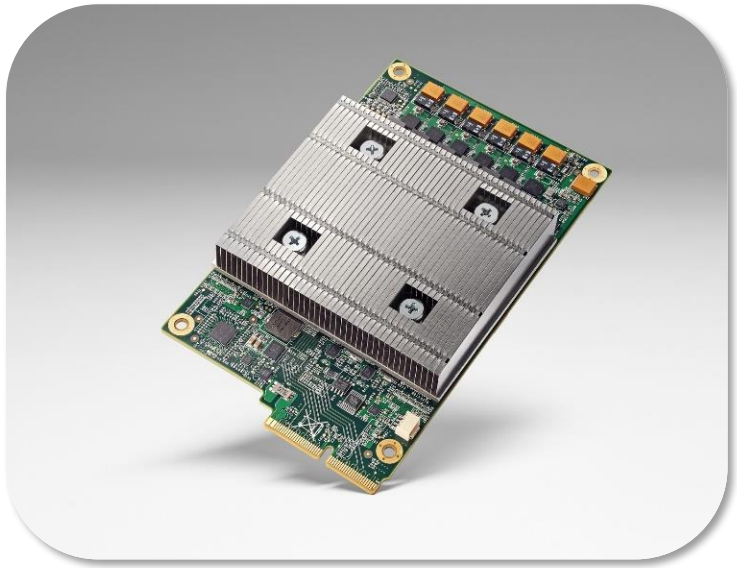
Improvements in Software & Hardware

Both software and hardware have made significant improvements over the past several years, enabling data scientists to develop increasingly-complex neural architectures

Advancements in the way data is processed…

1. **Distributed Processing** → Splitting workloads between computers (nodes) in a network
2. **Parallel Processing** → Sharing individual jobs between nodes within a network
3. **In-Memory Processing** → Processing data using RAM instead of disk storage

… continue to shape the future of hardware

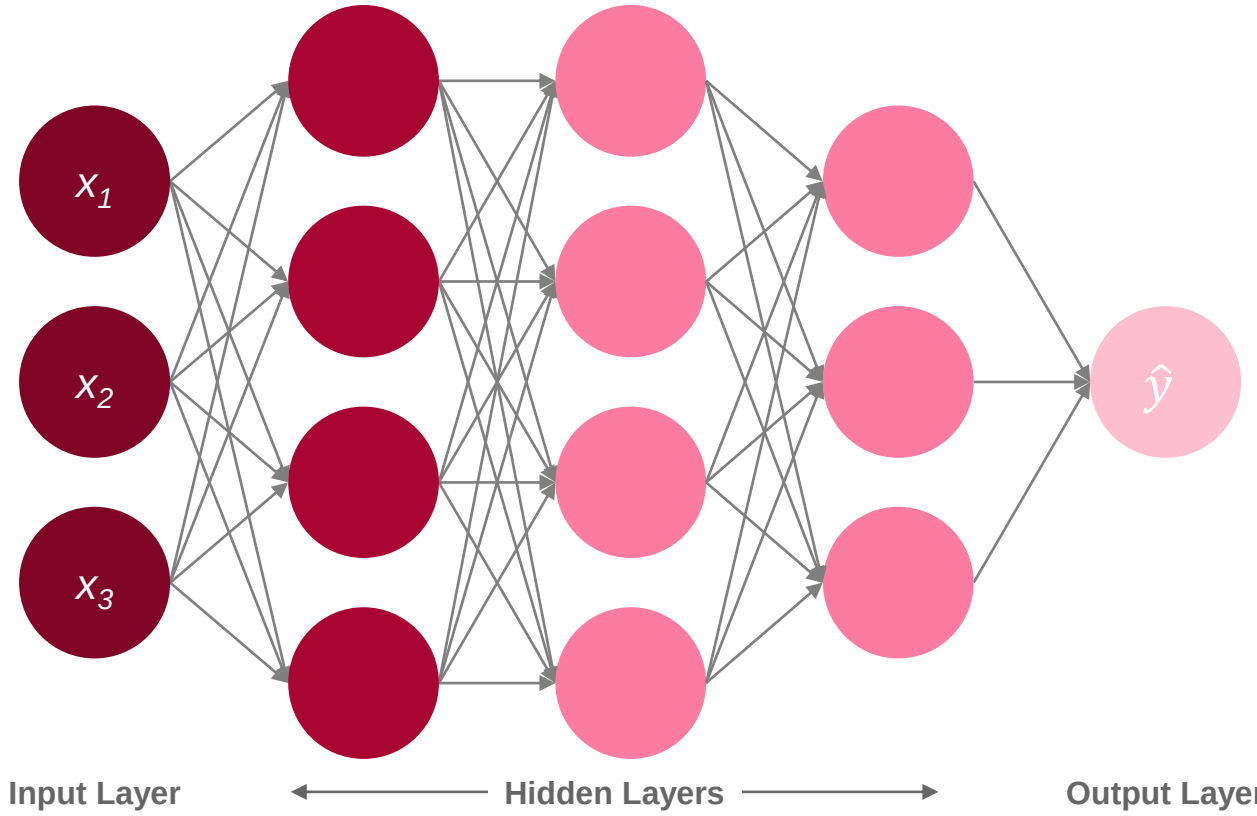


Google's Tensor Processing Unit

Evolution of Analytical Techniques

Though today's ML techniques are much more advanced than those used in the past, the data science community has built a number of sophisticated tools and resources to guide the next generation

ML has become both increasingly more complicated…



… and significantly more accessible

python

INSIGHT

kaggle

coursera

R

alteryx

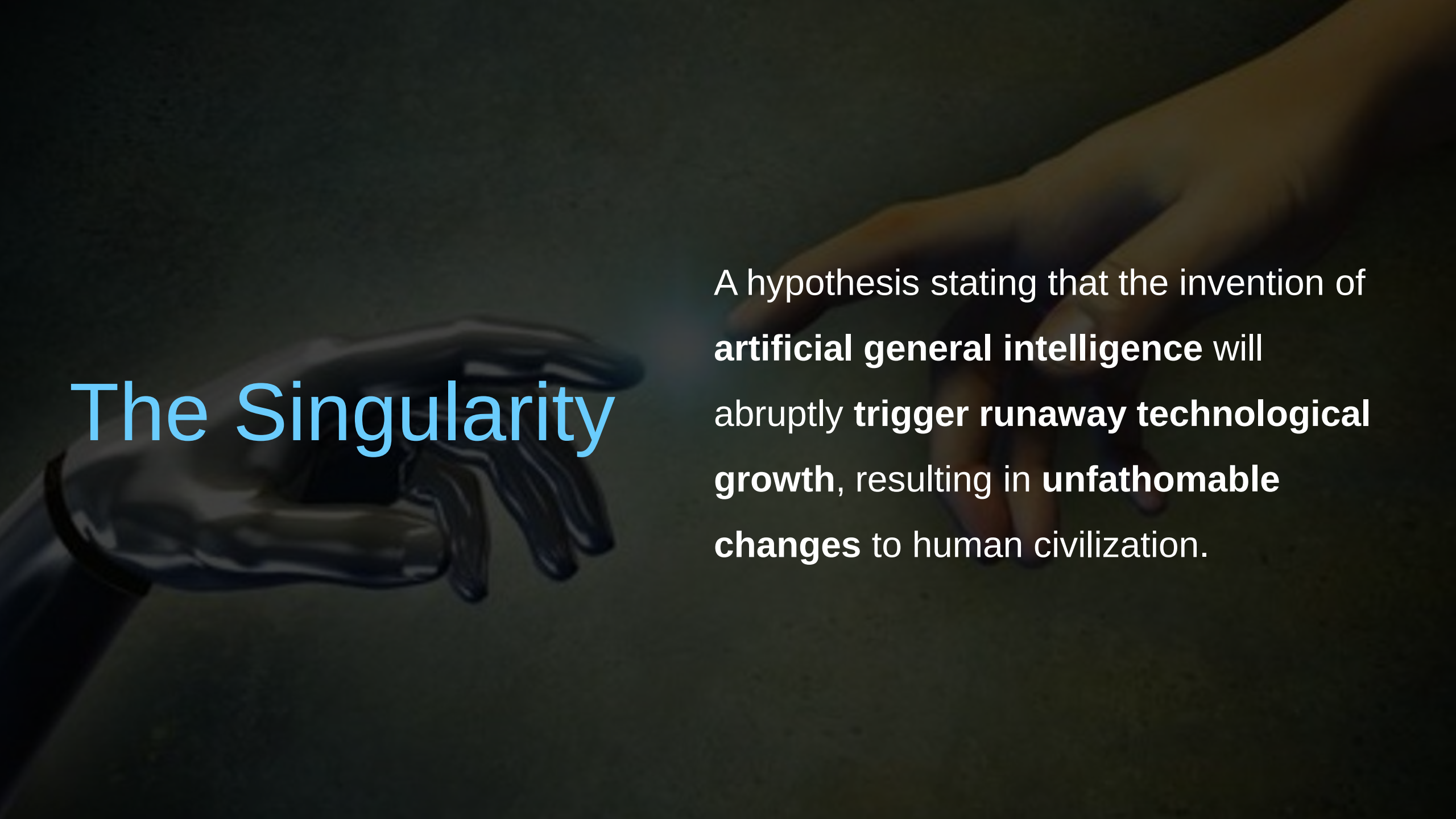
DataCamp

Building to General Intelligence

While artificial agents have historically been limited to ‘narrow intelligence’, recent advancements in cognitive computing are leading some to speculate that we’ll reach the Singularity within our lifetime

Machine Vision	Natural Language Processing	Machine Learning	Robotics	Expert Systems
Pattern Recognition	Translation	Supervised	Humanoid	Process Control
Image Processing	Topic Modeling	Semi-Supervised	Mobile	Monitoring
3D Modeling	Sentiment Analysis	Unsupervised	Manipulators	Diagnoses
Augmented Reality	Speech to Text	Reinforcement		Design
Virtual Reality	Text to Speech			Planning

As we **blend these five capabilities together** to enable increasingly complex use cases, **we inch closer to the Holy Grail of AI: artificial general intelligence**



The Singularity

A hypothesis stating that the invention of **artificial general intelligence** will abruptly **trigger runaway technological growth**, resulting in **unfathomable changes** to human civilization.

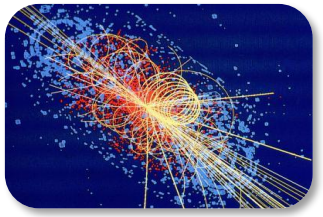
Diving into

Machine Learning

Introduction to Machine Learning

Whether you realize it or not, you are impacted by machine learning every single day

1. Machine learning algorithms are responsible for many **scientific and business model innovations**

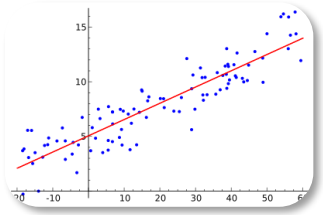


Discovery of Higgs boson

2. **Deep learning** architectures (e.g., recurrent, convolutional neural networks) are **to thank for a variety of modern technologies**

Siri, Alexa, and Cortana

3. Contrary to popular belief, **not all ML algorithms are obscure and overly-complex**



Linear Regression

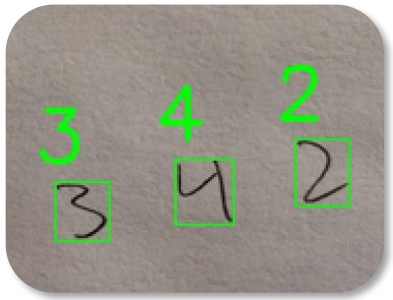
Four Types of Machine Learning

There are four types of problems that we aim to solve with ML, and each requires a different approach to learning and deployment

Machine Learning

Supervised

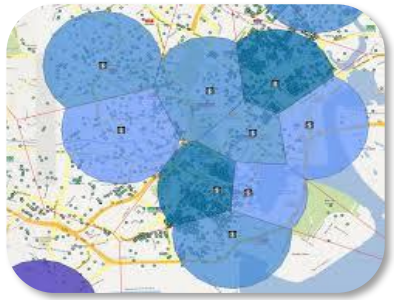
Generate predictions by training on **labeled datasets**



Handwriting Recognition

Unsupervised

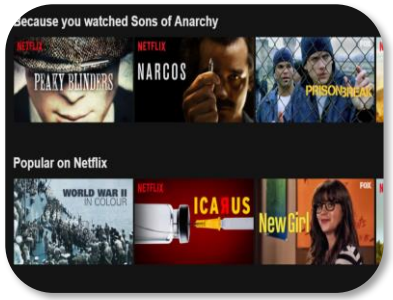
Expose and **visualize** hidden relationships and anomalies in **unlabeled datasets**



Geospatial Market Segmentation

Semi-Supervised

Generate predictions using a **small amount of labeled data** within a larger pool of unlabeled data



Interactive Recommendations

Reinforcement

Create an agent capable of taking environmental actions to **maximize utility** over time

Self-Driving Vehicles

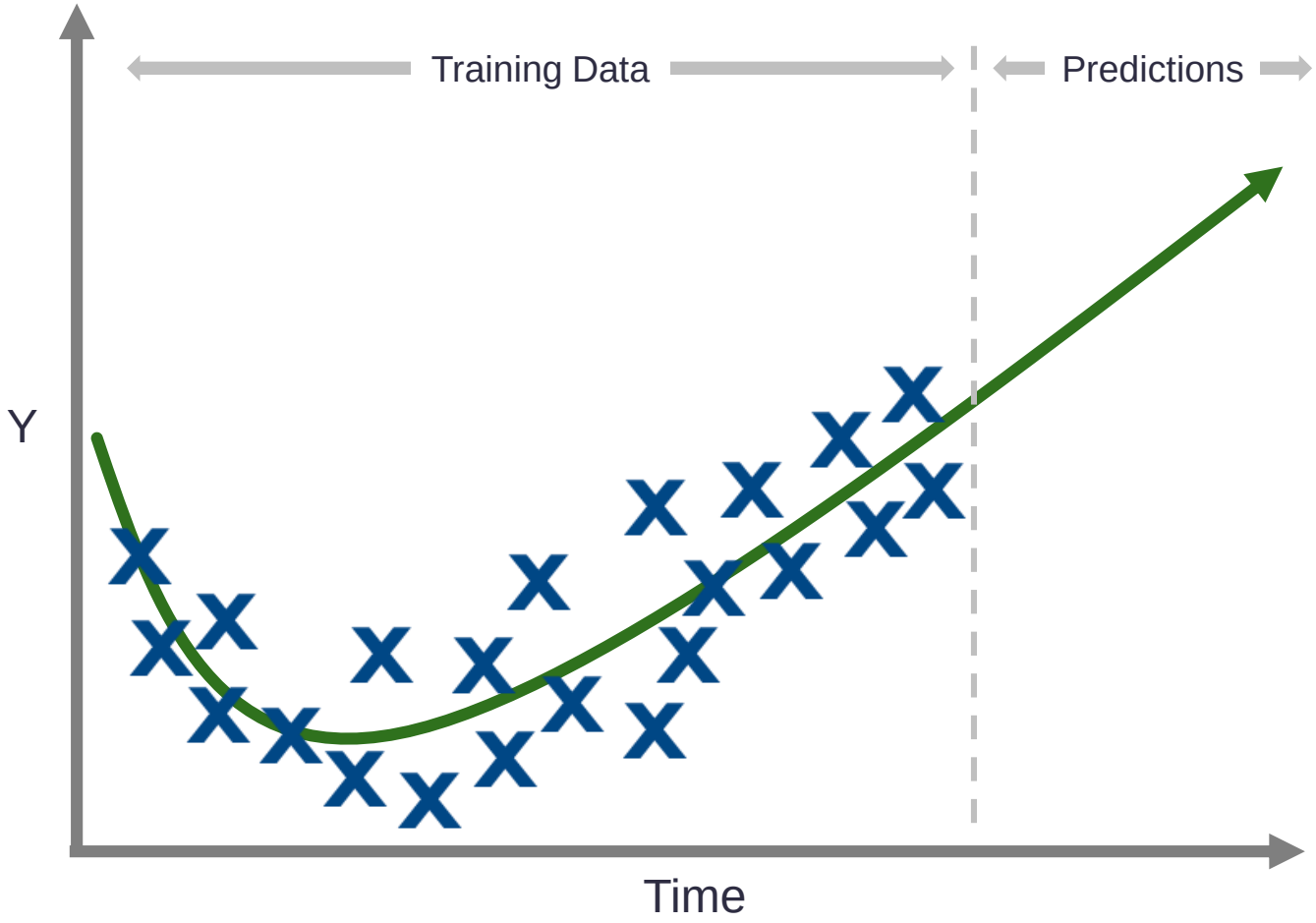
Principles of

Machine Learning

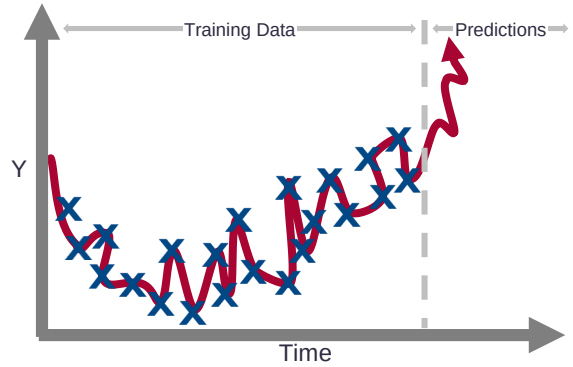
Principle #1: Generalization

When we train a machine to think, we are mostly concerned with how well it can predict the future. This often means that we need to restrain the complexity of our model to improve its ability to generalize

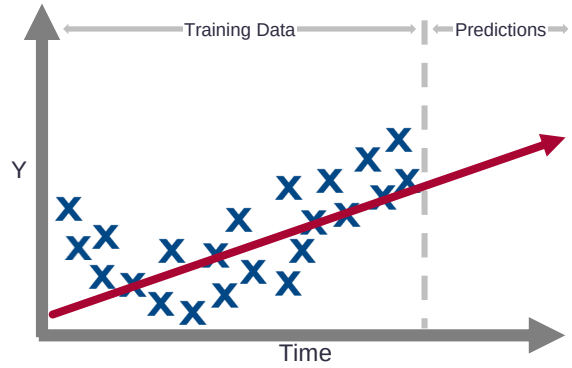
Strong Fit



Overfitting (High Variance)



Underfitting (High Bias)



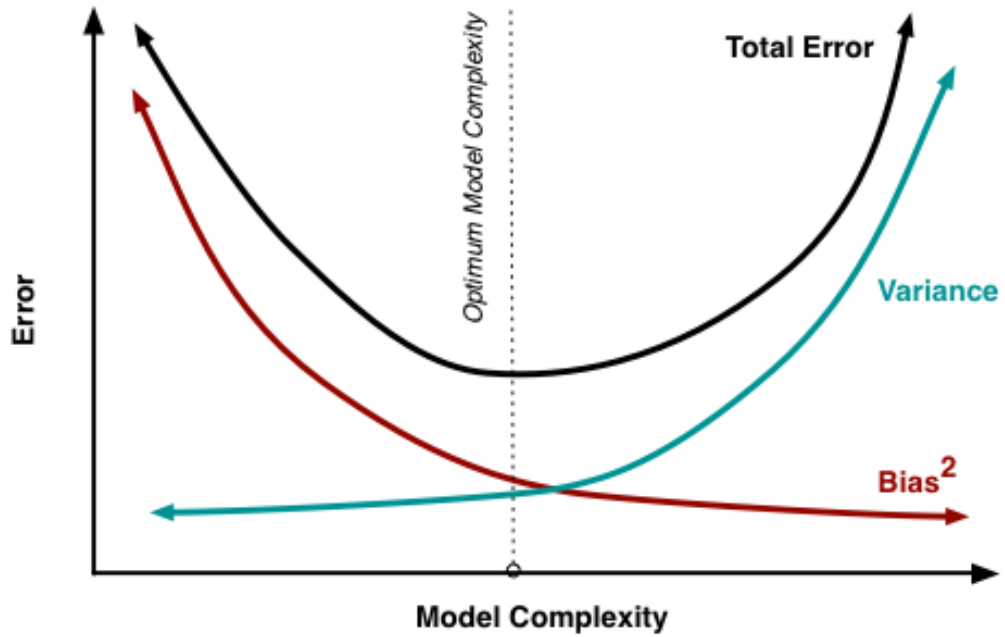
Principle #2: No Free Lunch

Unfortunately, there is no 'magical' algorithm that will solve all of our problems. Generating accurate predictions requires a thorough understanding of the underlying behaviors at play within our data

For a given problem, pick the right algorithms…

Supervised		Semi-Supervised
Regression	Classification	Clustering
Linear Regression	Logistic Regression	K-Nearest Neighbors
Multivariate Linear Reg.	Multinomial Logistic Reg.	HCA
Random Forests		PCA
Gradient Boosted Machines		LLE
Support Vector Machines		t-SNE
Multi-Layer Neural Networks		LDA
Recurrent Neural Networks		DBSCAN
Convolutional Neural Networks		Autoencoders
…		….

… to optimize the bias-variance trade-off

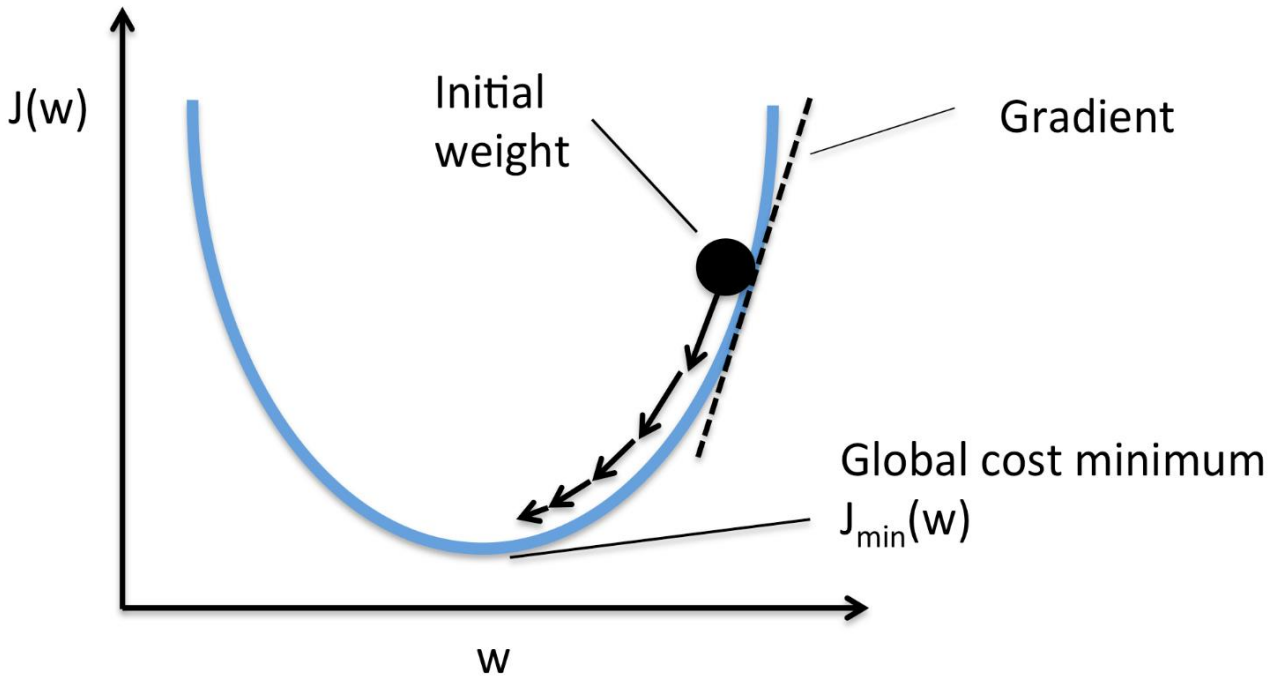


Graphic Source: Scott Fortmann-Roe

Principle #3: Occam's Razor

When two algorithms present similar results, there are many reasons why we should prefer the simpler of the two

Gradient Descent 101



Advantages of Simplicity

1. **Significantly less costly to compute** due to their relatively simple cost functions, accelerating insight to action

2. **Less likely to encounter optimization issues** when working in lower-dimensional spaces

3. Final solutions are generally **easier to interpret**, **visualize**, and **understand**

Graphic Source: Sebastian Raschka

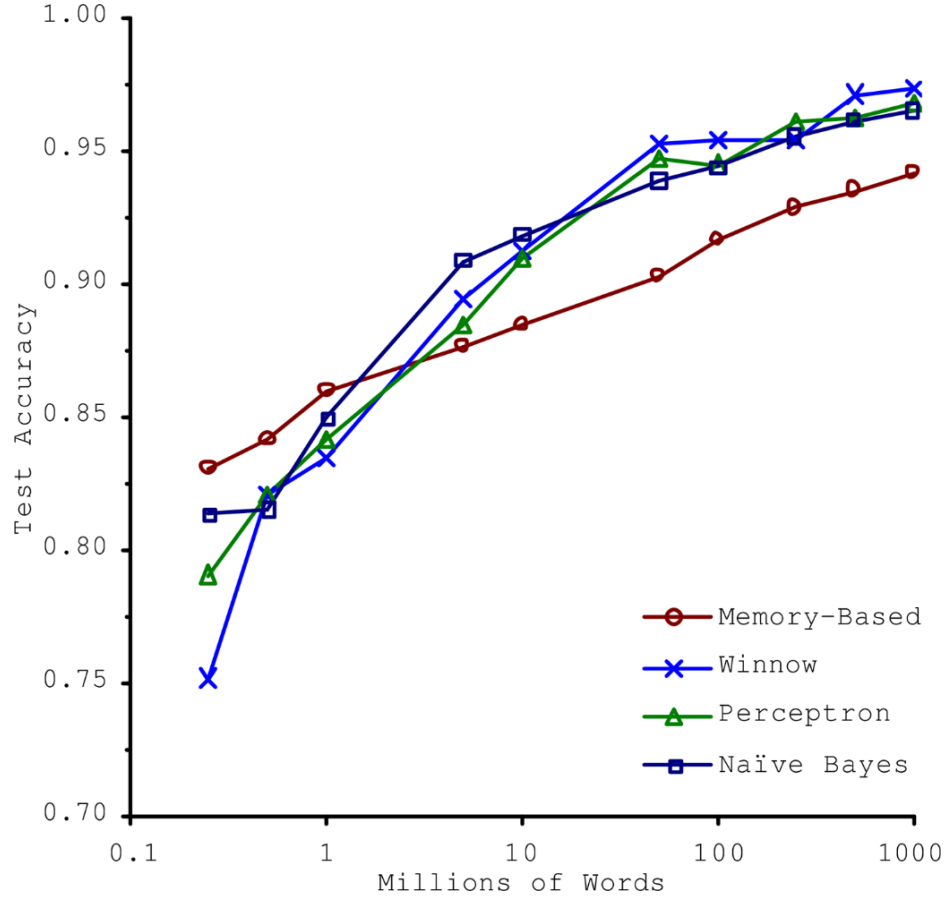
Principle #4: More Data > More Complex Algorithms

Using fancy algorithms is just one piece of the data science puzzle. Including new features or increasing the volume of data available for training will substantially improve your results.

*"**We don't have better algorithms** than anyone else; we just **have more data**"*

- Peter Norvig, Google

"The Unreasonable Effectiveness of Data"



Principle #5: Cross-Validation

In the same way that we cannot determine a drug's effectiveness by only testing it on a single patient, we need to examine our model using multiple data samples (called 'folds') to evaluate performance

Cross-Validation 101

k-fold Cross-Validation Error

Used to evaluate how well each model generalizes an independent data set

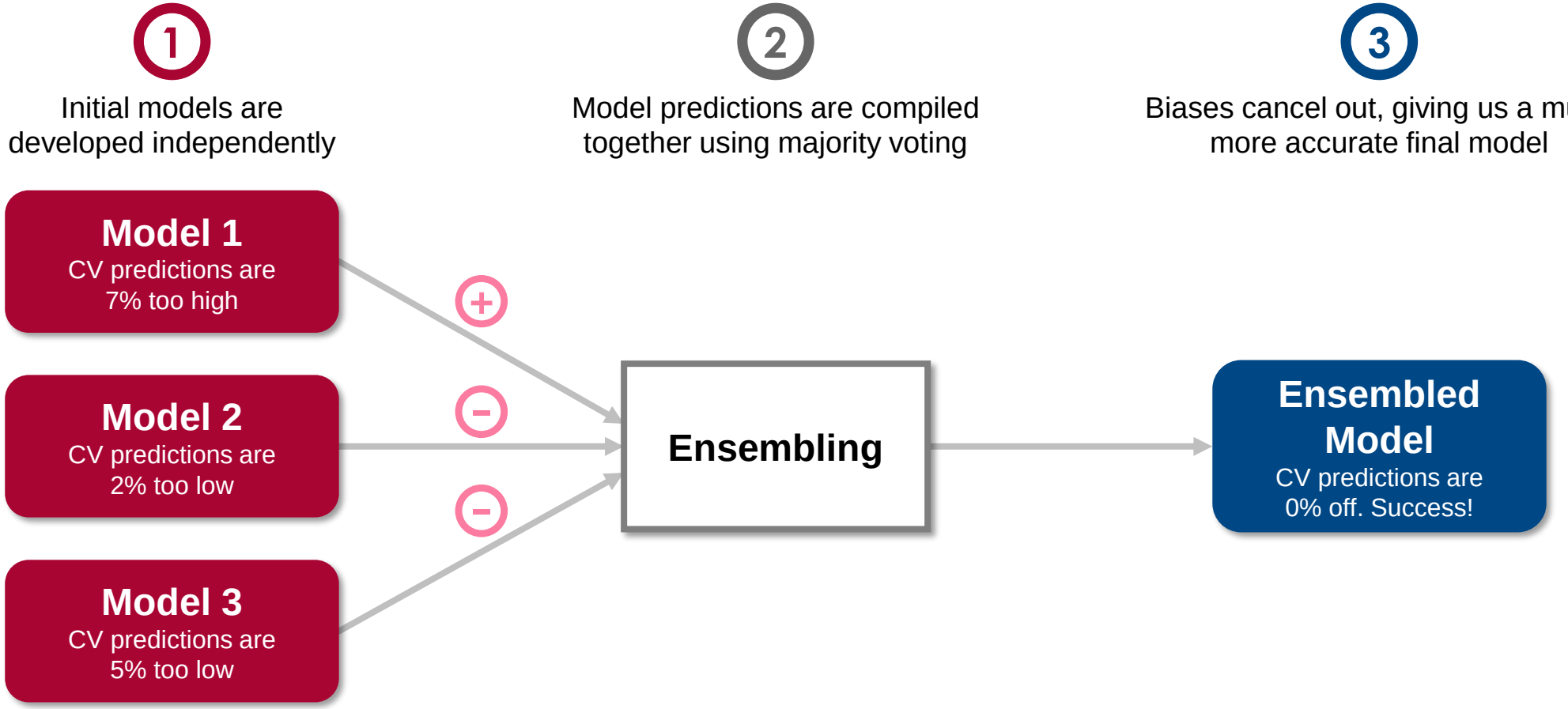
$$E = \frac{1}{10}\sum_{i=1}^{10} E_i$$

Graphic Source: Karl Rosaen

Principle #6: Algorithmic Diversity

Algorithmic diversity is key to predictive success; the combination of many simple models ("weak learners") can outperform much more complex algorithms ("strong learners")

Ensembling 101



Wrapping-Up

Key Take-Aways

- We must be able to decipher the signal from the noise with regards to AI / ML
- AI will have profound practical and ethical implications for our society
- Getting started is not as difficult as you might think

Wharton Analytics Fellows Overview

The Wharton Analytics Fellows program creates opportunities for MBAs, PhDs, and undergraduates to gain hands-on experience in data science and analytical consulting

HOW IT WORKS

- Selected students are divided into teams (2 MBAs / PhDs and 4 undergraduates per client)
- Participants receive specialized training in analytics, problem solving, and project management
- Each team commits ~5 hours per week during the Fall to test hypotheses and collaborate with their client
- Teams share key insights during a final, on-site client presentation

WHAT YOU'LL ACHIEVE

- Solve real-world problems for the world's leading organizations
- Build interview stories of leadership, drive, and analytical ability
- Develop your analytical skills and consulting toolkit
- Grow your network within the Penn ecosystem while cultivating relationships with potential employers
- Prepare for your career in Data Science, Consulting, People Analytics, FinTech, or General Management

OUR CLIENTS – FALL 2017

L'ORÉAL

Identify drivers of employee attrition and provide recommendations to improve corporate diversity

U.S. SECURITIES AND EXCHANGE COMMISSION · MCMXXXIV

Leverage performance data to unlock career path insights and kickstart the SEC's People Analytics practice

citi VENTURES

Collaborate with Citi's MD of Data Science to predict sovereign default using machine learning

TradeStation

Develop a scoring system that can measure and improve customer engagement for a digital equity trading platform

VISTAR MEDIA

Create a revenue forecasting model for a large digital advertiser by predicting media owner behavior

Thank you for your time

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