STEVENS
INSTITUTE OF TECHNOLOGY
1870

Introduction to Machine Learning

FA690 Machine Learning in Finance

Dr. Zonghao Yang

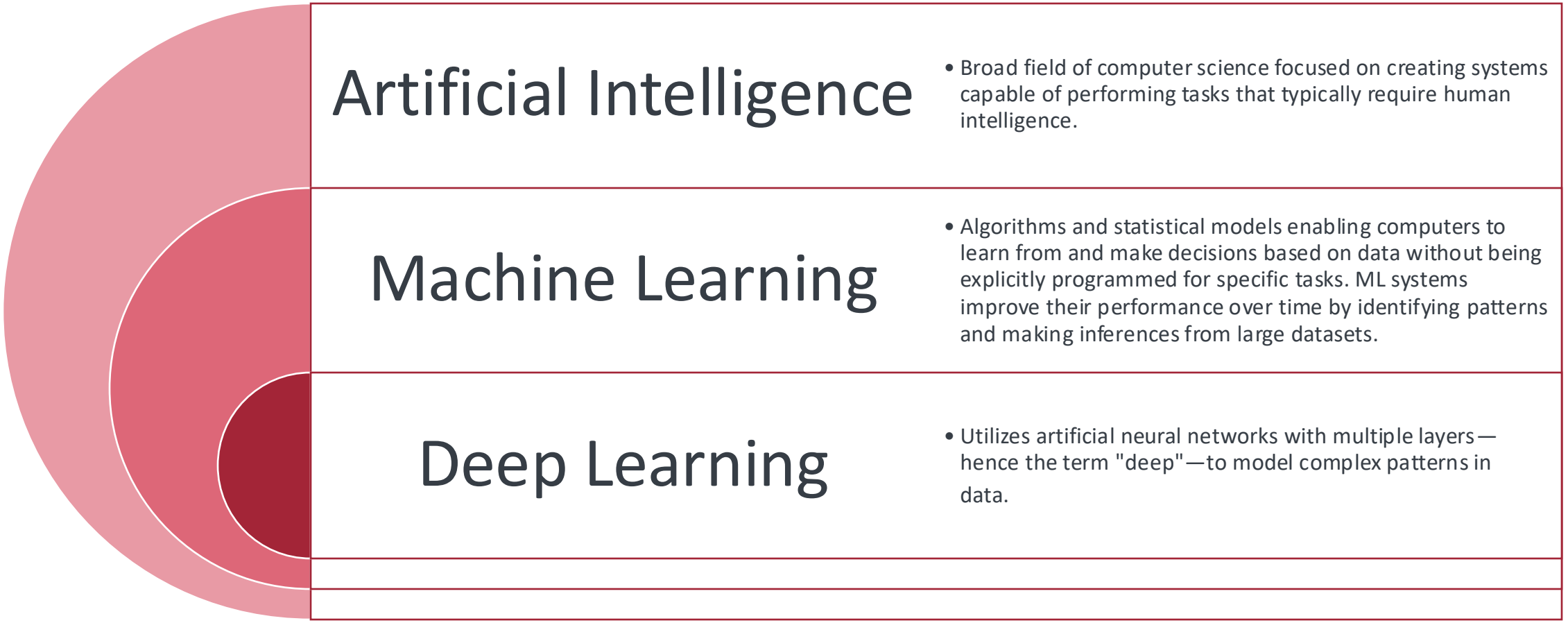
2025 Spring

Learning Objectives

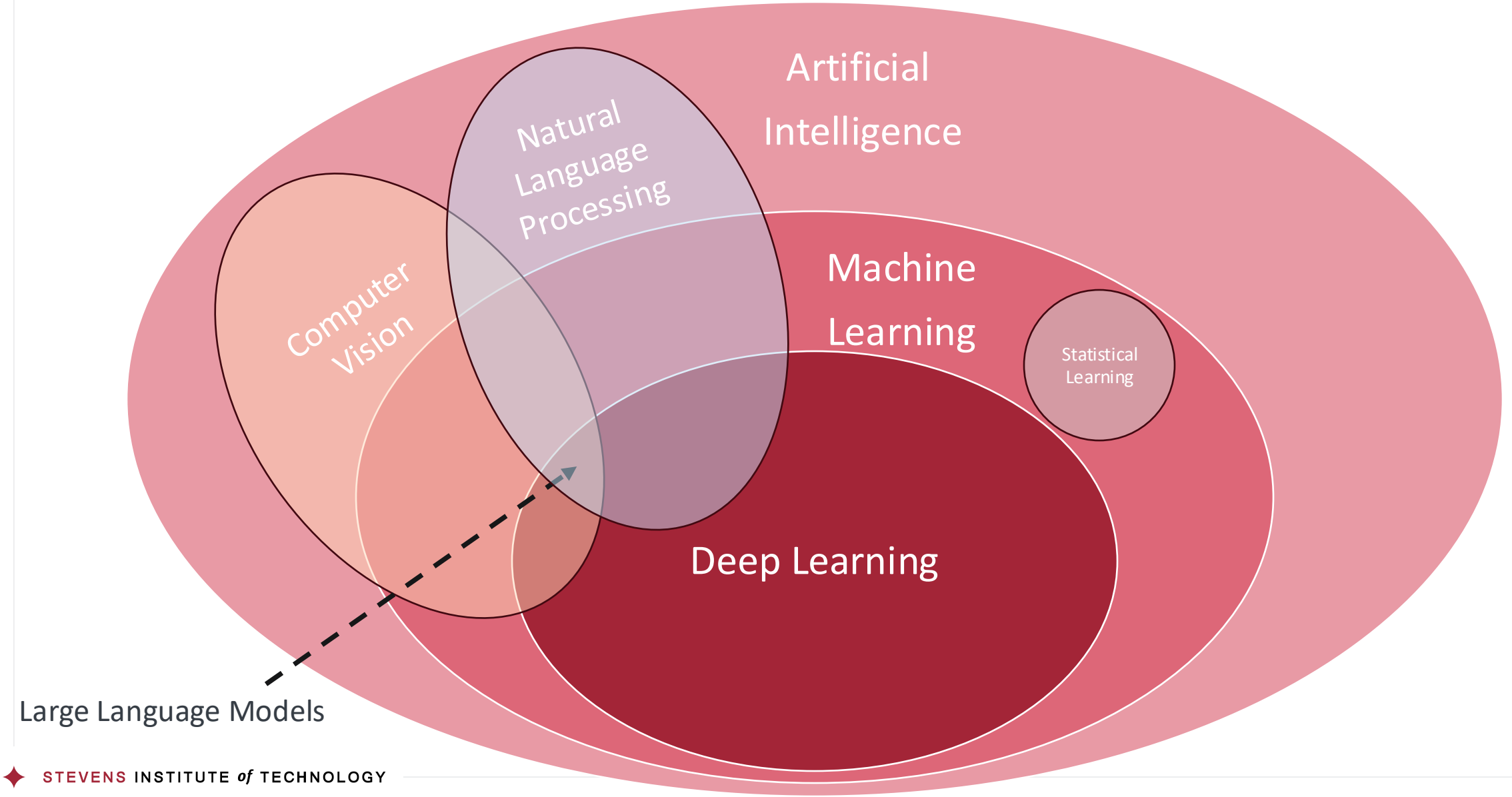
- Understand the relationship between Artificial Intelligence, Machine Learning, and Deep Learning, and recognize how recent technological advances (big data, hardware, software) have enabled their rapid development.
- Identify and understand the major branches of modern AI applications, including computer vision, natural language processing, and generative AI
- Recognize the transformative impact of AI across different domains through concrete examples in healthcare, environmental monitoring, business operations
- Preview how deep learning is beginning to transform finance and business, preparing students for deeper exploration of financial applications in subsequent lectures.

Landscape of Artificial Intelligence

Introduction to Artificial Intelligence



Introduction to Artificial Intelligence

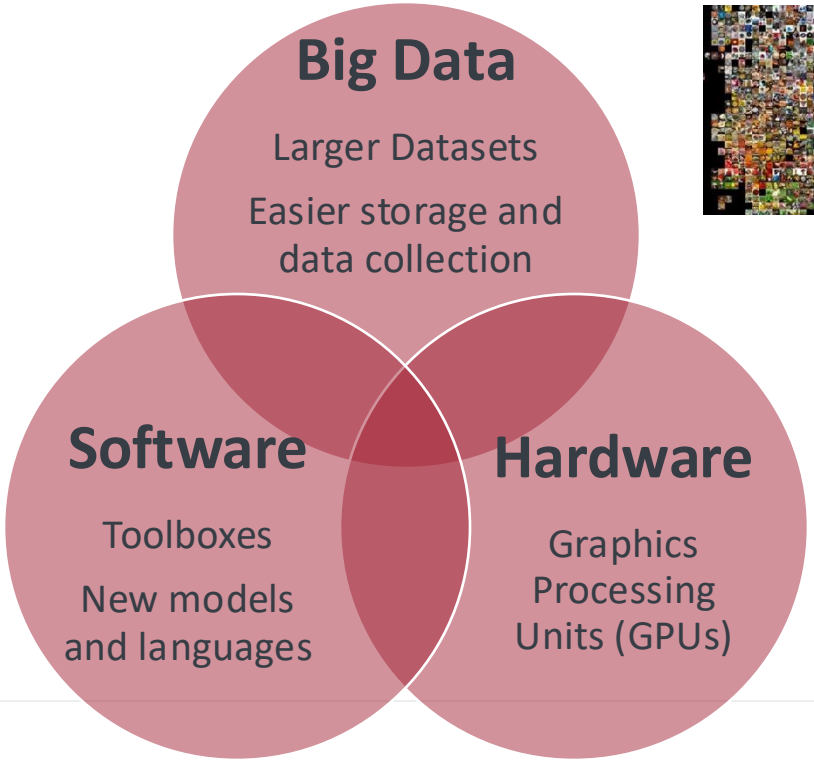


Introduction to Artificial Intelligence

- AI is not new

1952 Stochastic Gradient Descent → 1958 Perceptron → 1986 Backpropagation → 1995 Deep Convolutional Neural Networks → 2012 ImageNet Competition → 2019 Turning Award for Deep Learning → 2024 Nobel Prize in Physics and Chemistry

- Its recent success is a combination of 3 main factors

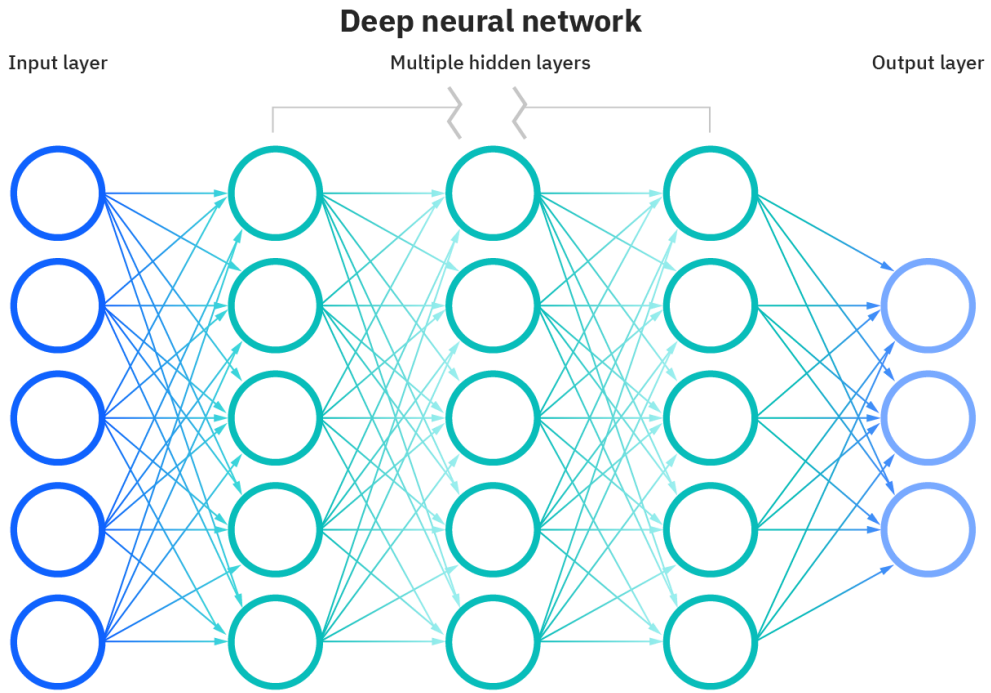


TensorFlow

PyTorch

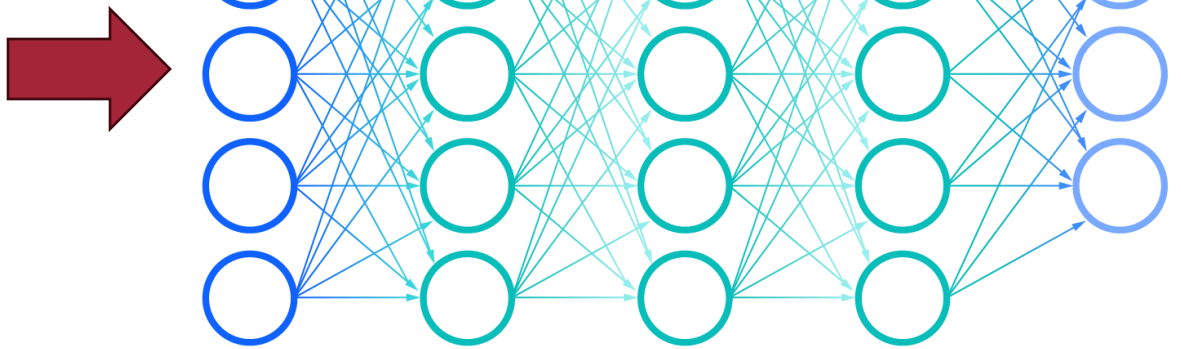
The Building Block of Deep Learning

State-of-the-art AI is often based on deep neural networks



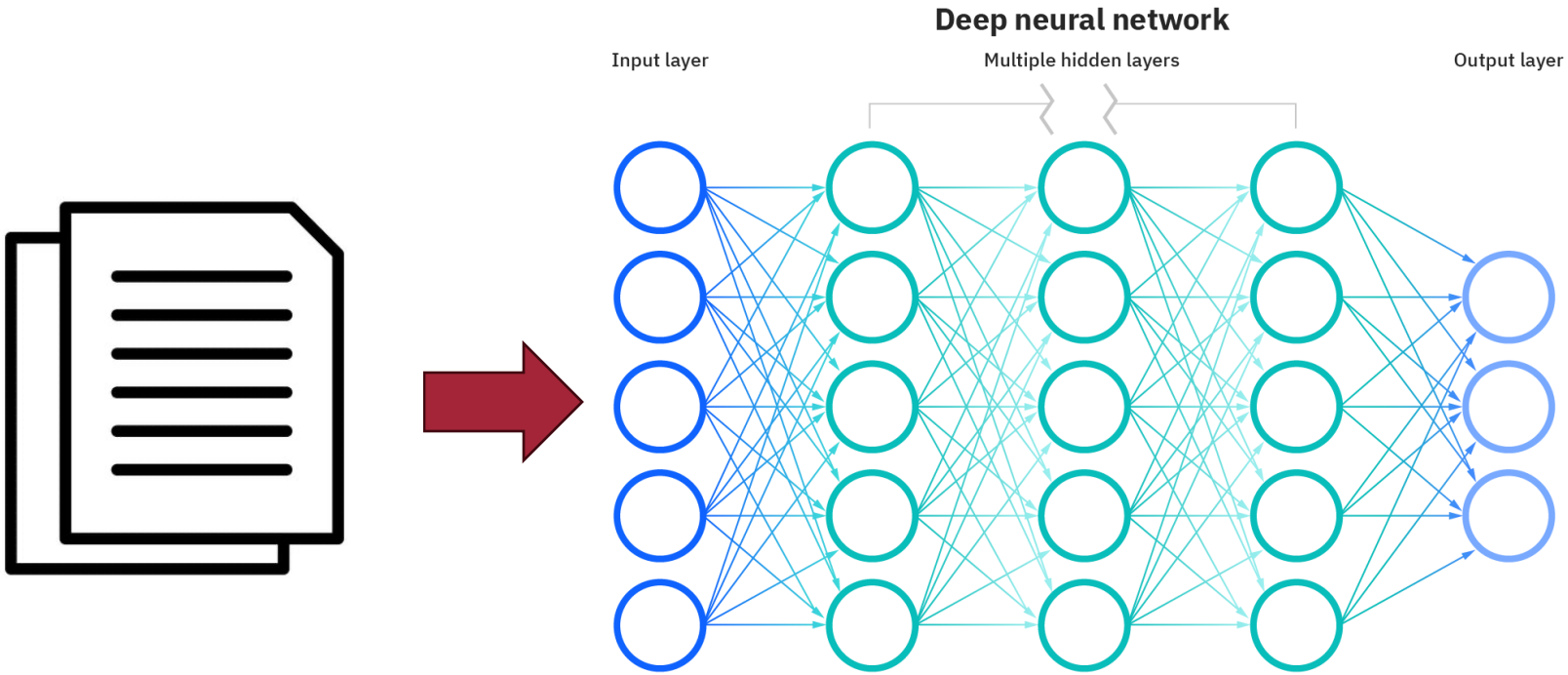
The Building Block of Deep Learning

Computer Vision

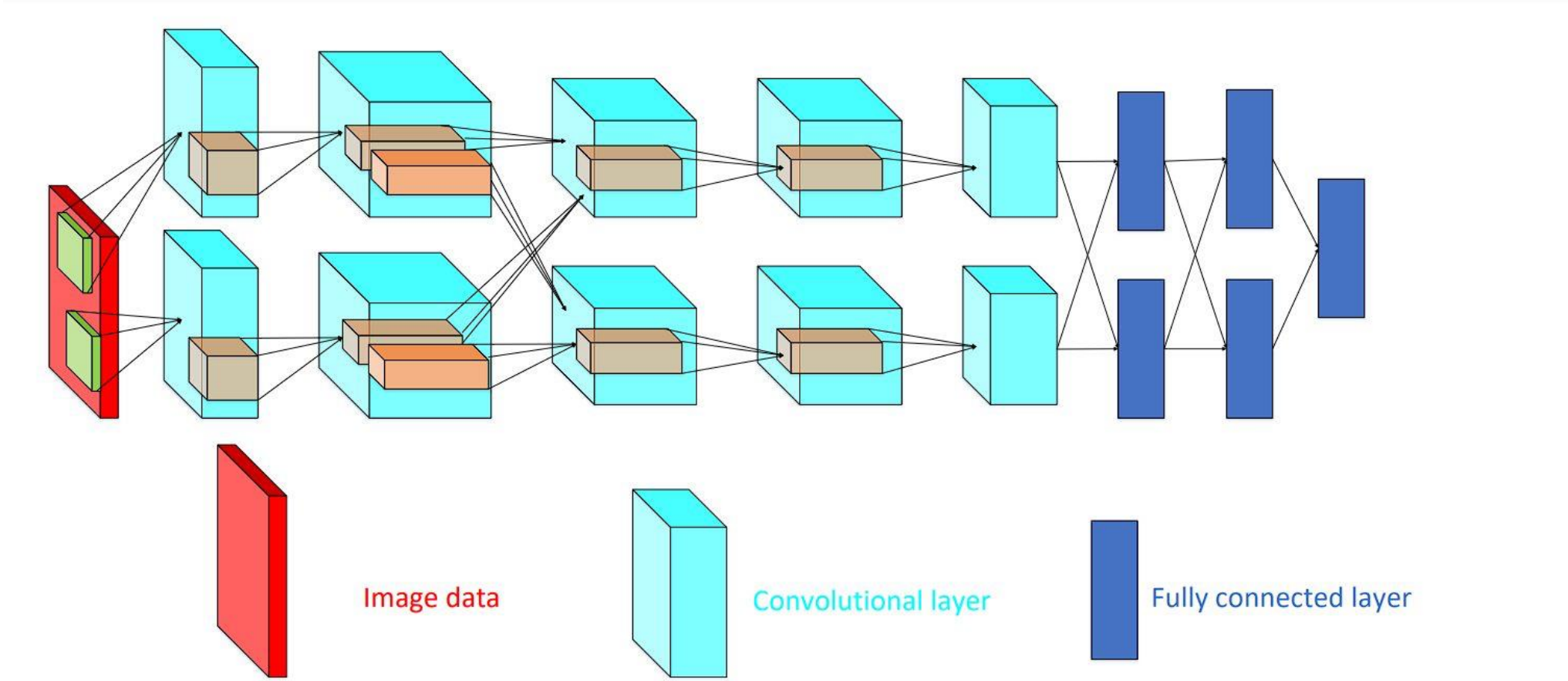


The Building Block of Deep Learning

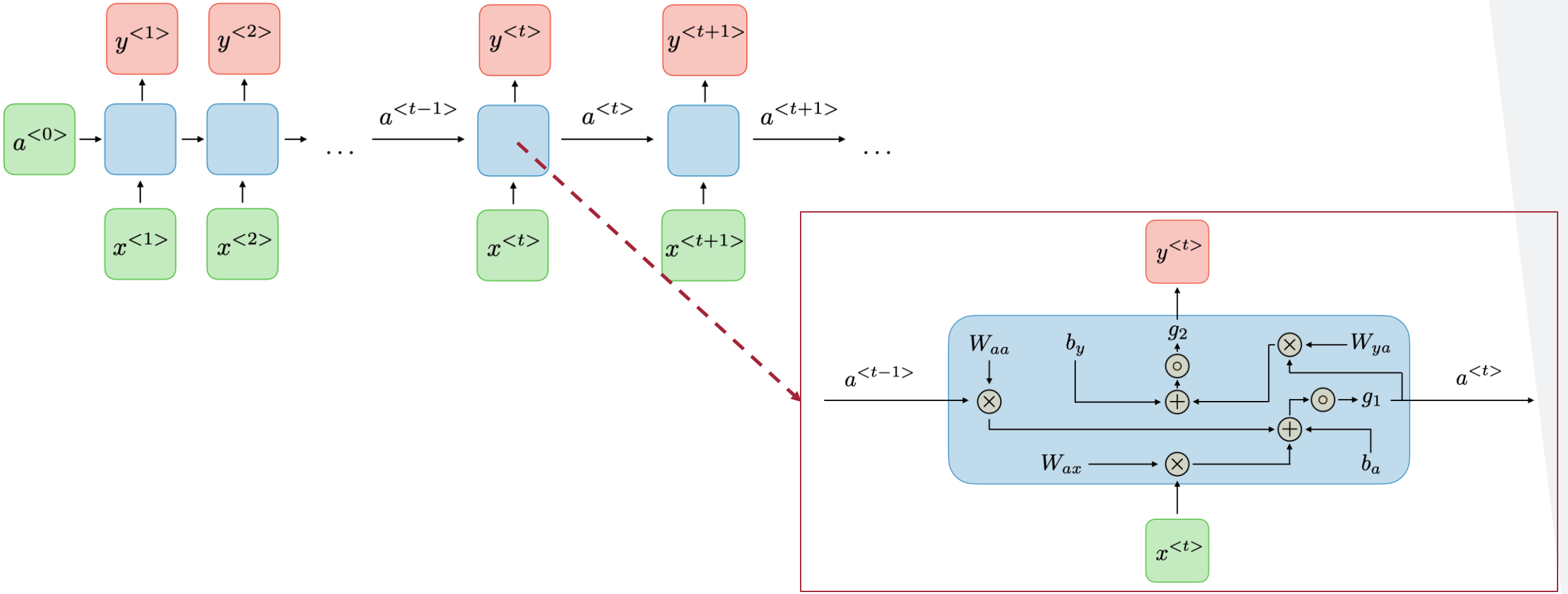
Natural Language Processing



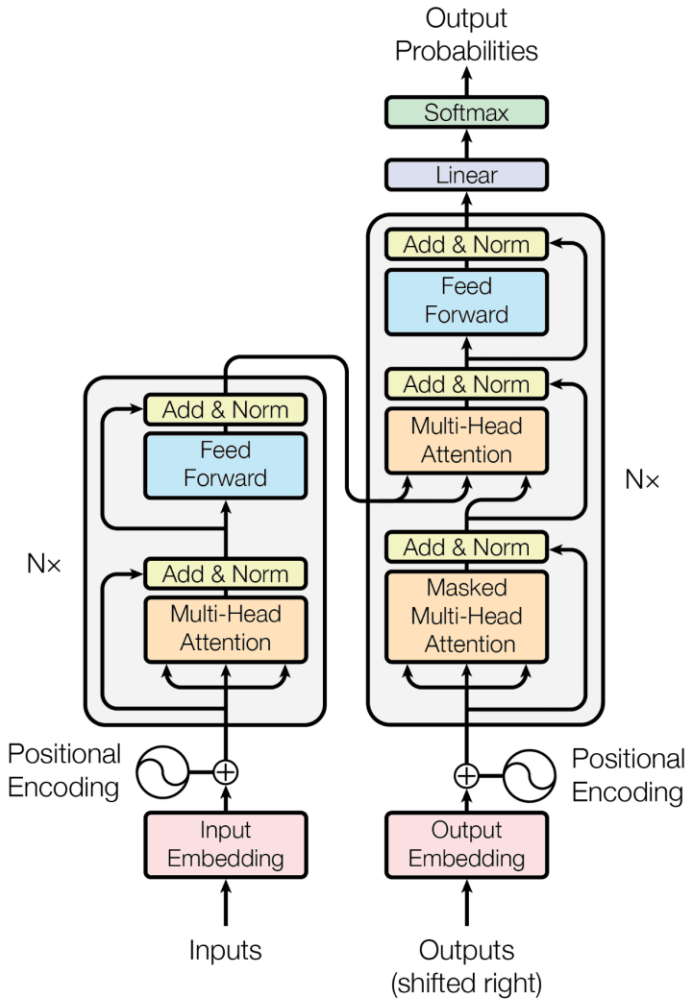
Convolutional Neural Networks: AlexNet



Recurrent Neural Networks

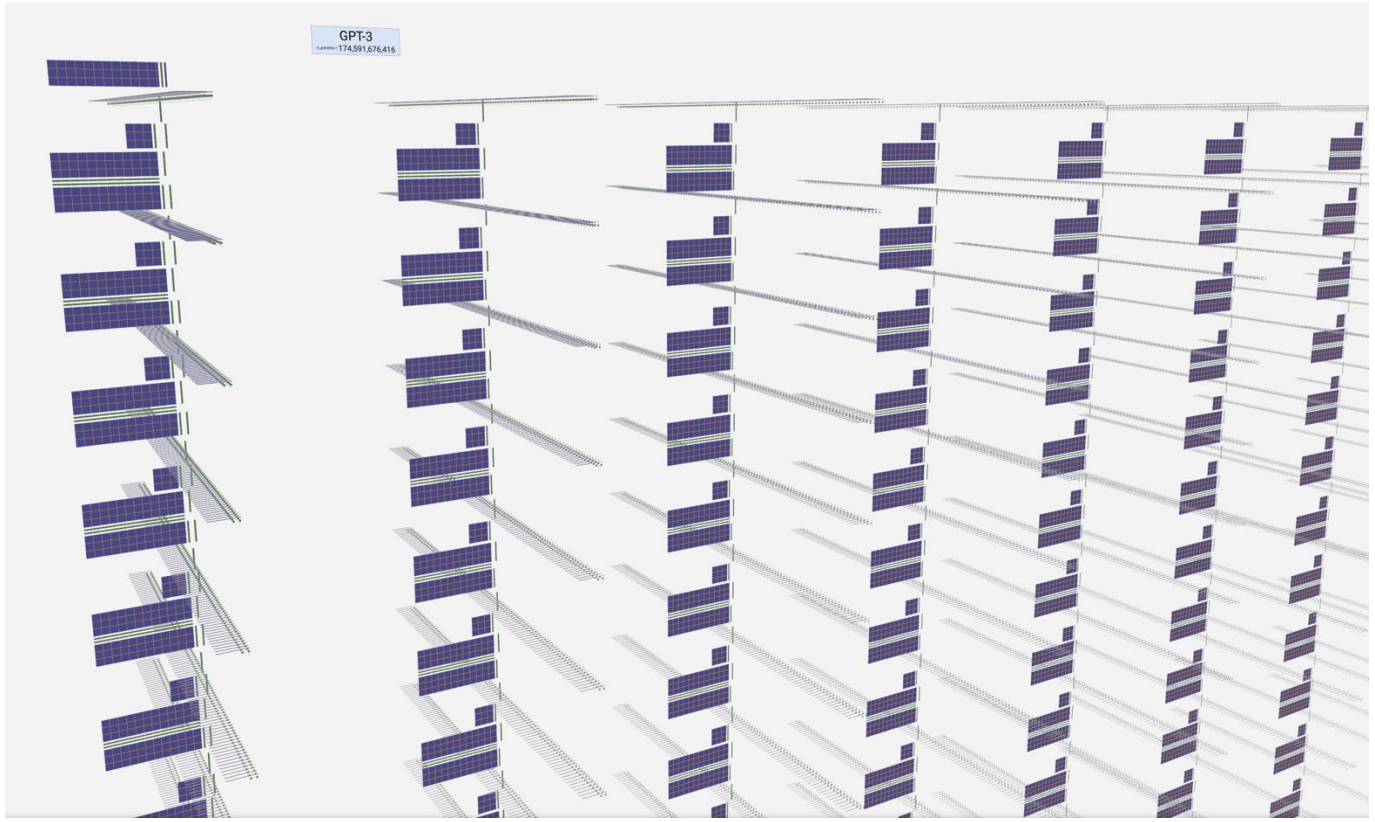


Transformer



Large Language Models

GPT-3 has 174,591,676,416 parameters.



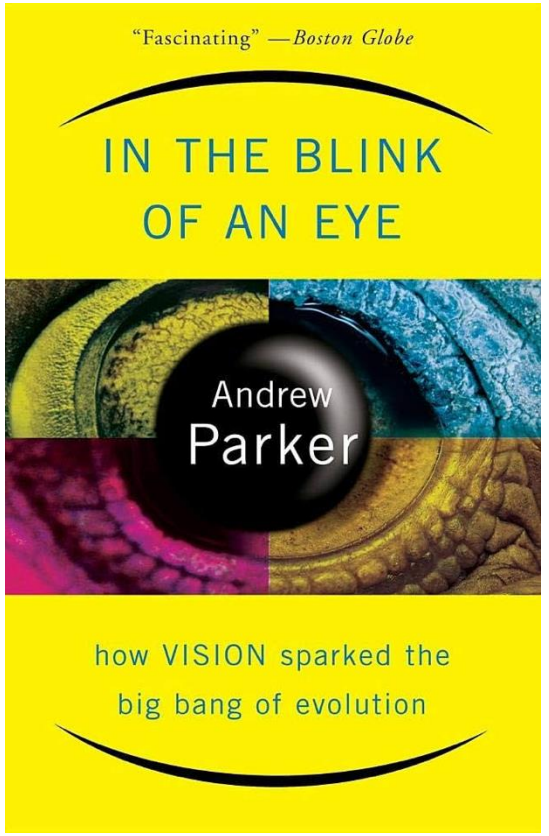
Computer Vision

Discover from images what is present in the world, where things are, what actions are taking place, to predict and anticipate events in the world.

Vision

"The Cambrian Explosion is triggered by the sudden evolution of **vision**, which set off an evolutionary arms race where animals either **evolved** or **died**." Andrew Parker

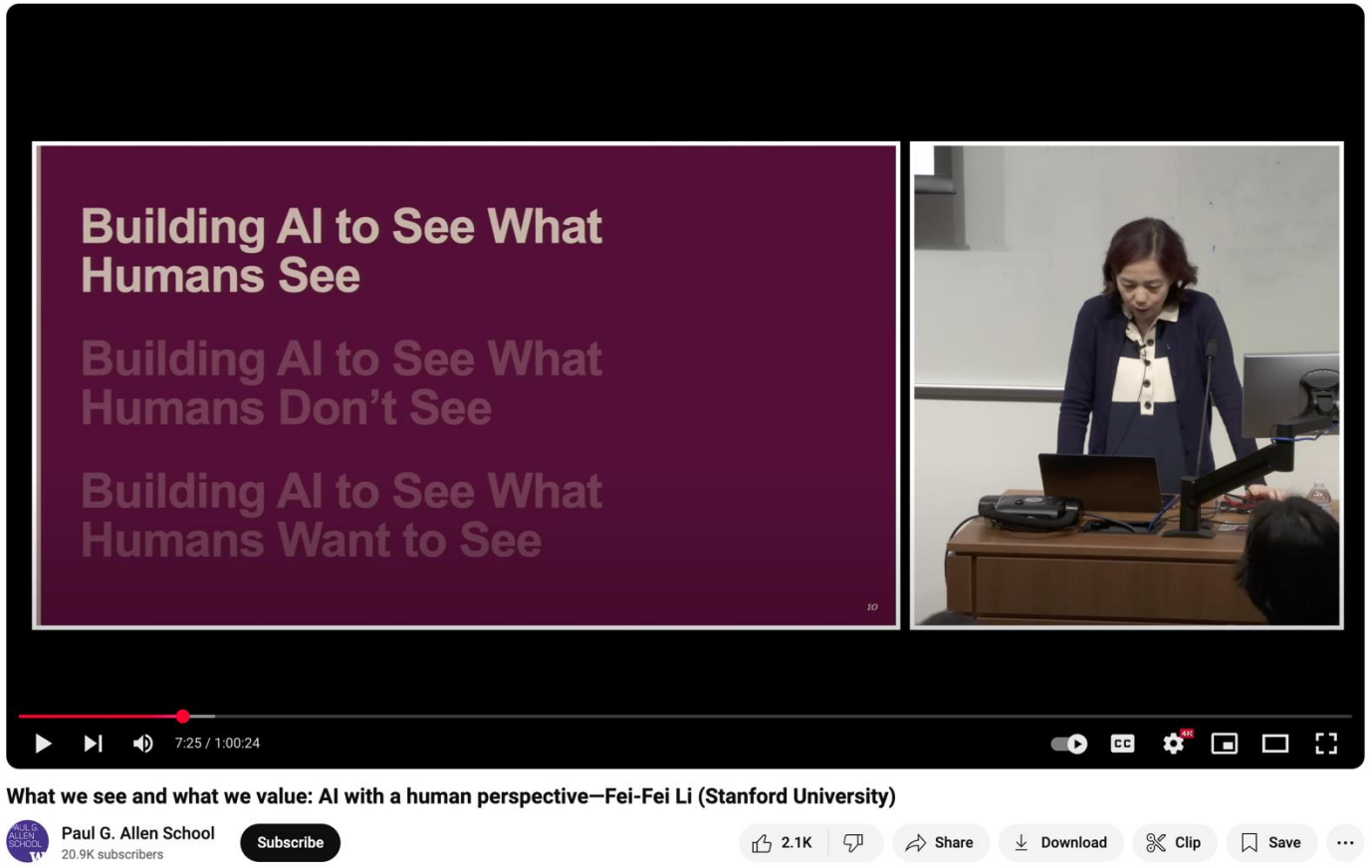
- The Cambrian explosion was a period of rapid evolution that occurred around 540 million years ago



Vision

Humans are amazingly good at seeing objects

- Seminar on “What we see and what we value: AI with a human perspective” Fei-Fei Li, January 2024 [YouTube]



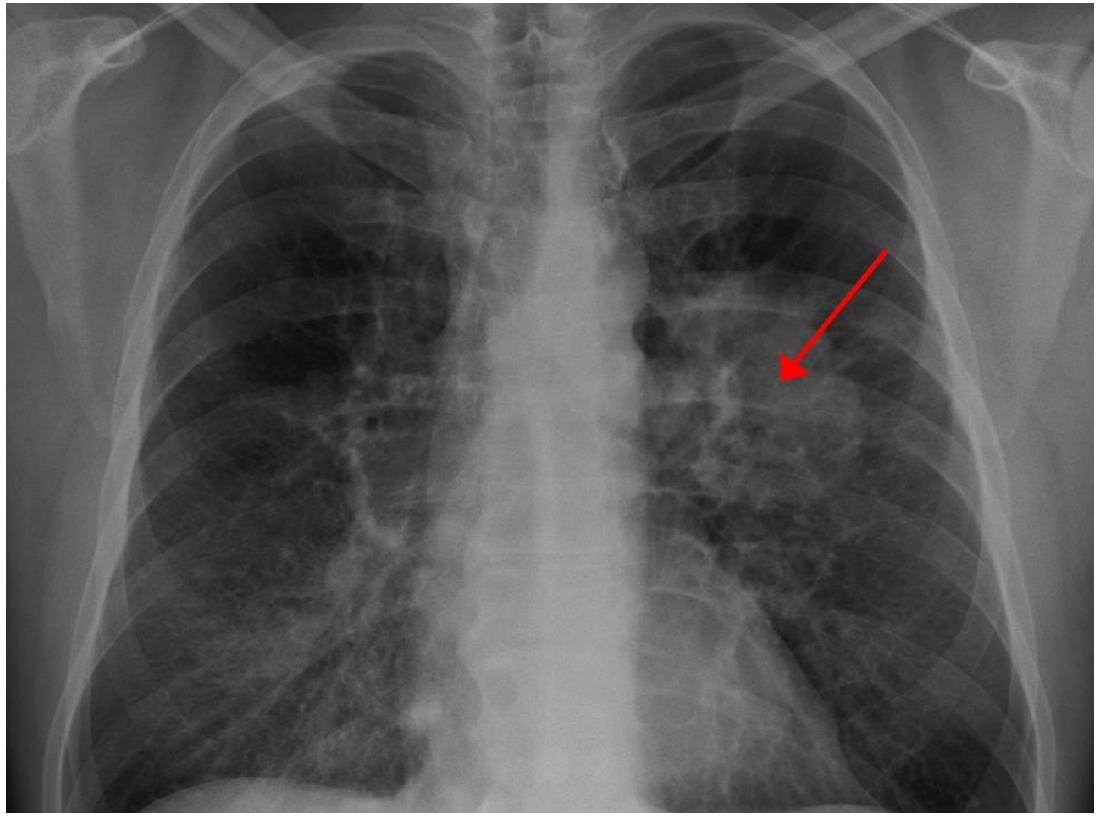
Vision

Seeing can also be challenging

Vision

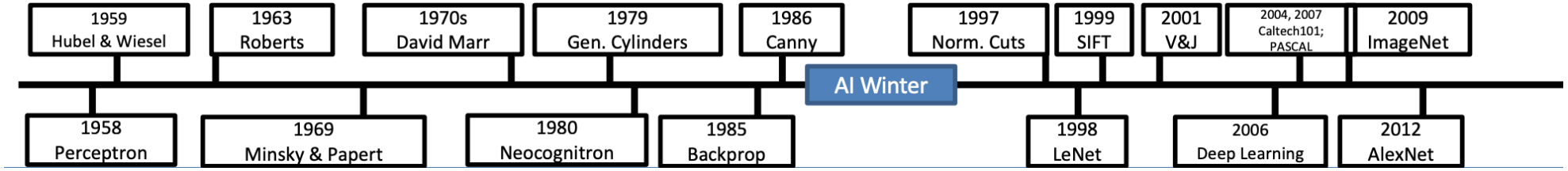
"Not seeing" in real-life can have dire consequences.

- Medical errors are the third leading cause of death



Computer Vision

- Building AI to see what humans see (e.g., autonomous driving)
- Building AI to see what humans don't see (e.g., medical imaging diagnosis, quality control in manufacturing, astronomy)
- Building AI to see what humans want to see (e.g., weather, security surveillance)



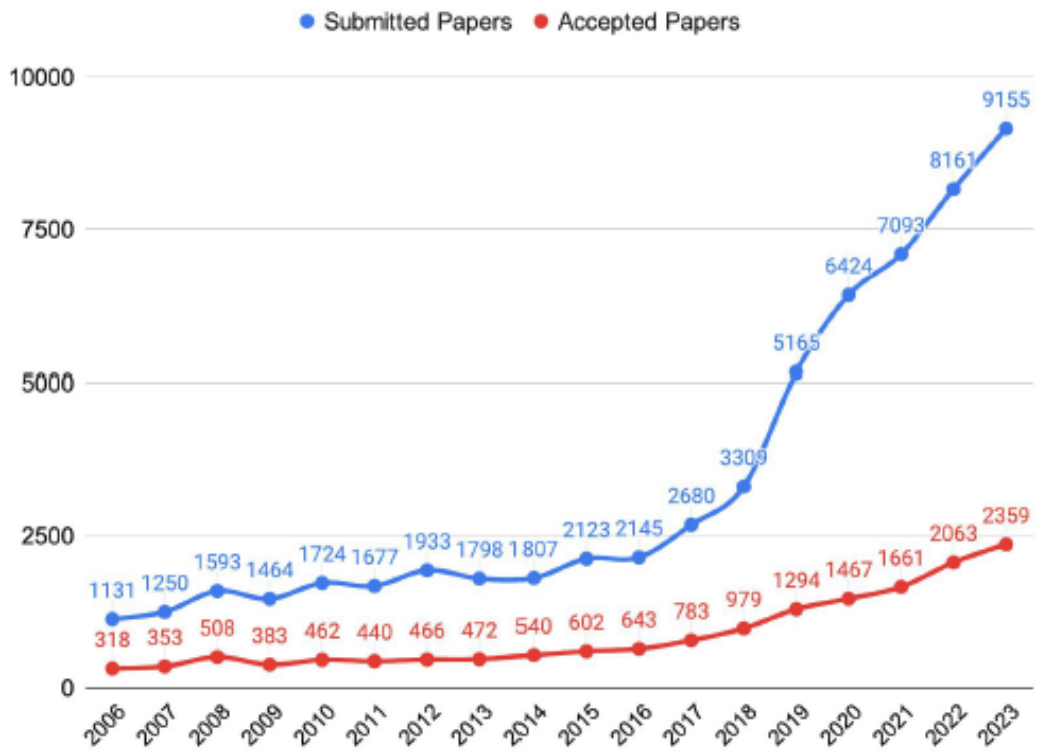
ImageNet (2009)

ImageNet has been instrumental in advancing computer vision and deep learning research.

- ImageNet is a large scale visual recognition challenge: 1,000 object classes, 1,431,167 images
  - **Prof. Li Fei-Fei, PI, Stanford University**
  - Prof. Jia Deng, Princeton University
  - Prof. Olga Russakovsky, Princeton University
  - Prof. Alex Berg, UNC Chapel Hill, Facebook, Shopagon
  - Prof. Kai Li, Princeton University
- Why is ImageNet important?
  - A high-quality benchmark: Object categorization was recognized to be one of the most fundamental capabilities of both human and machine vision
  - Data: More data to enable more generalizable machine learning algorithms

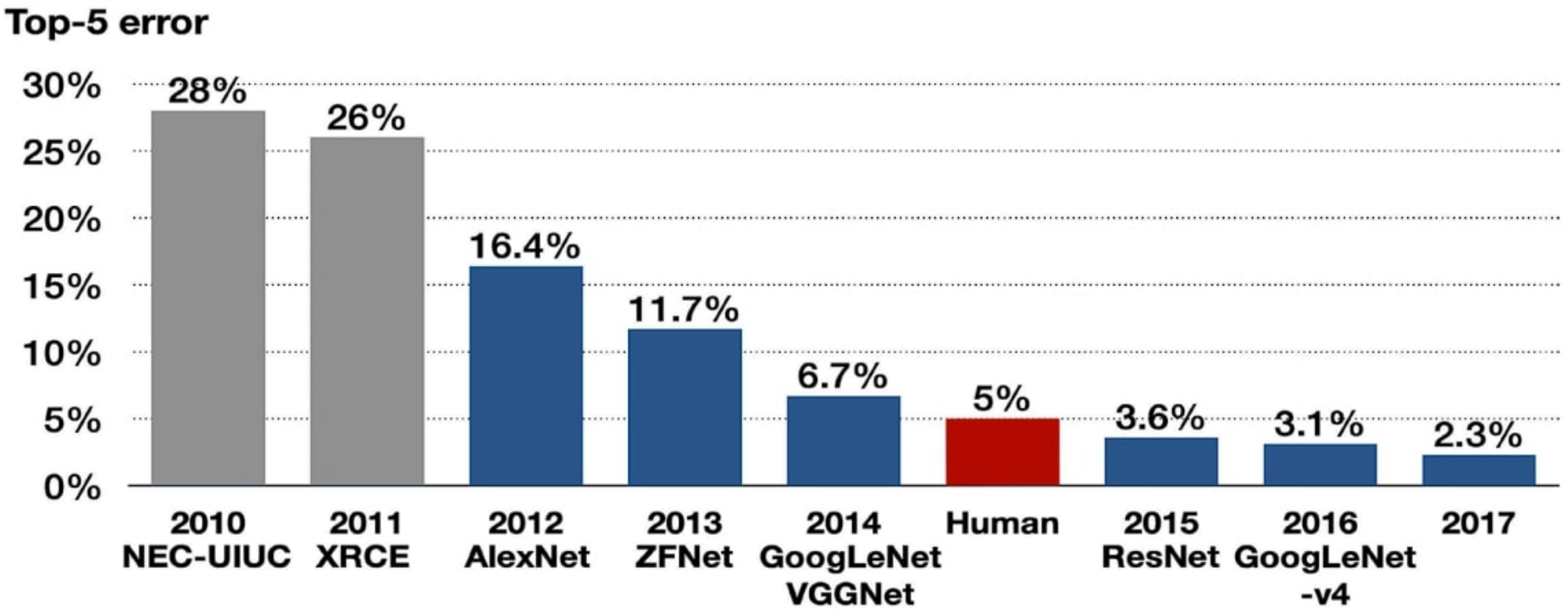
After ImageNet (2009)

A boom in the number of papers submitted to and accepted in Conference on Computer Vision and Pattern Recognition (CVPR), the top conference in Computer Vision.



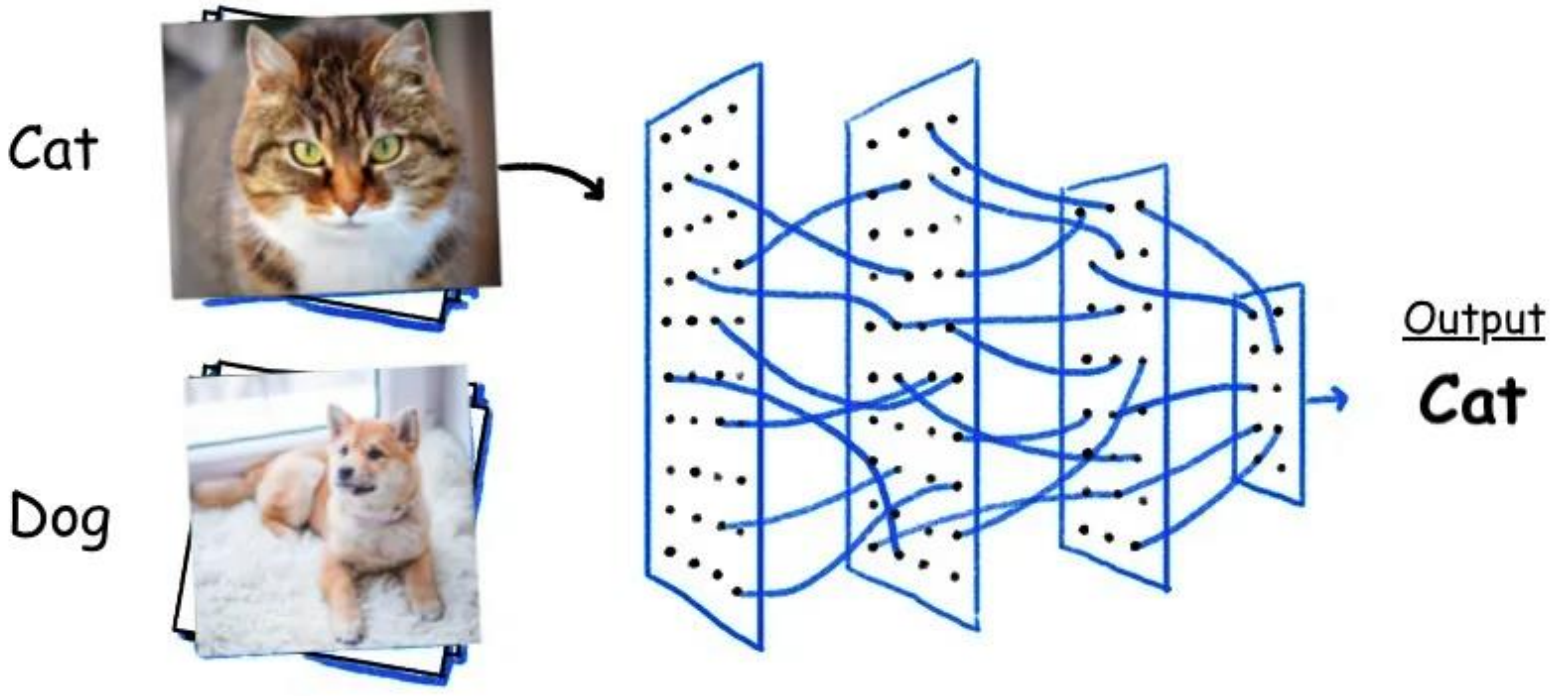
After ImageNet (2009)

The emergence of a series of deep learning architectures that become the backbone of the modern CV applications, including AlexNet (2012) and ResNet (2015).

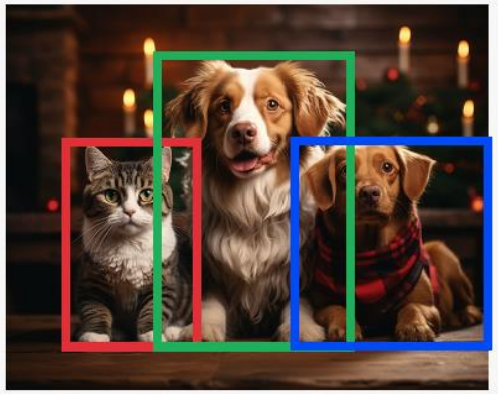
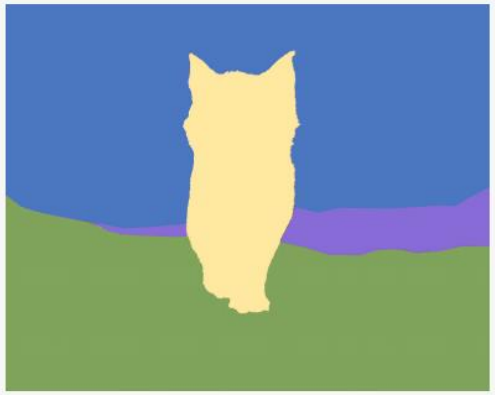


Building AI to See What Humans See

Object categorization



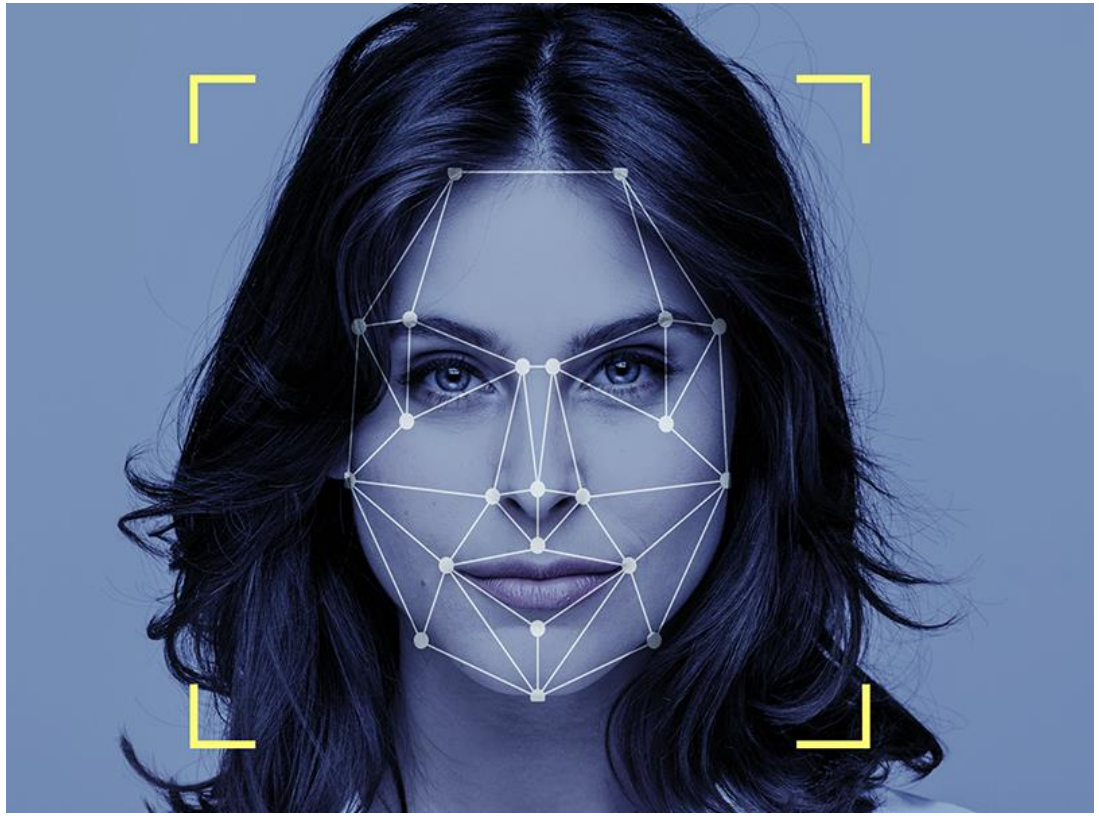
Tasks Beyond Image Classification

Localization + Classification	Object Detection	Semantic Segmentation	Instance Segmentation
			
CAT	CAT, DOG, DOG	GRASS, CAT, HILL, SKY	CAT, DOG, DOG
Single object	Multiple objects	No objects, just pixels	Multiple objects

Building AI to See What Humans See

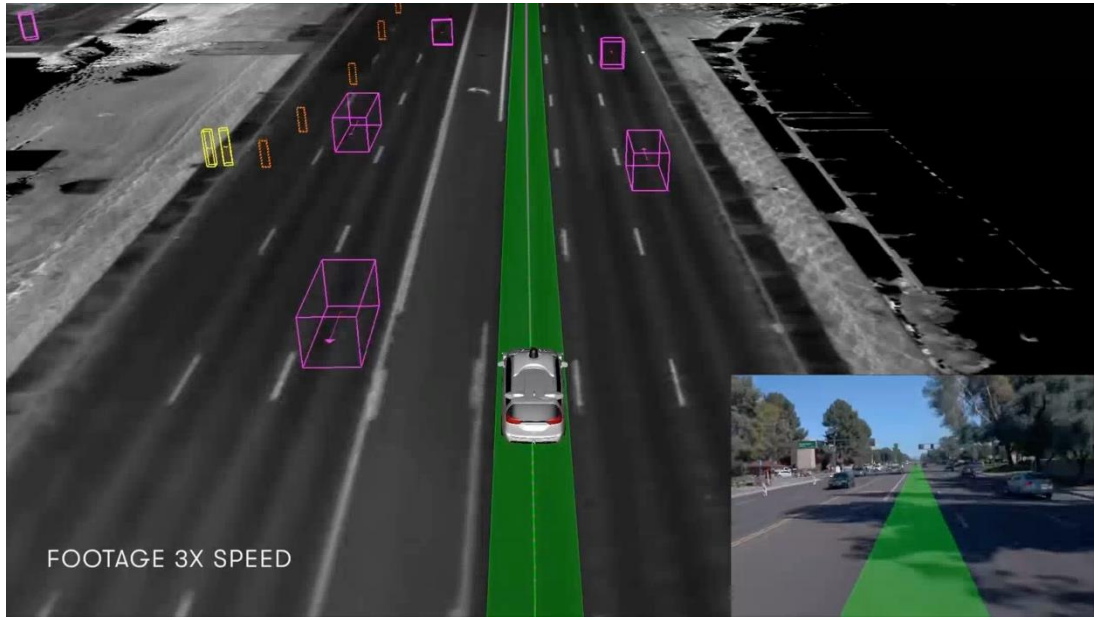
Facial detection and recognition

- Facial detection
  - Feature extraction (e.g., eyes, nose, mouth)
  - Face location
- Feature recognition
  - Feature mapping (e.g., the distance between eyes, jawline shape)
  - Matching in database



Building AI to See What Humans See

Autonomous driving



Waymo’s autonomous driving technology navigates a police-controlled intersection [YouTube]

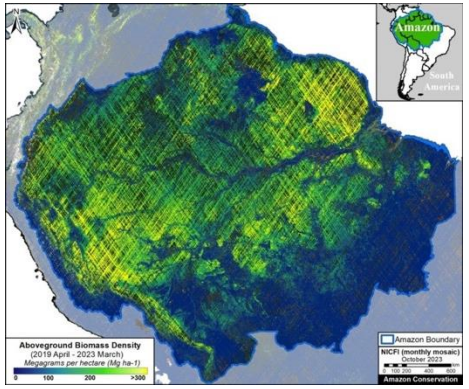
Tesla's FSD 12.6.1 Hardware 3 [YouTube]

Building AI to See What Humans Don’t See

Fine-grained object categorization

Building AI to See What Humans Don’t See

Computer Vision in Environmental Conservation Applications [Source]

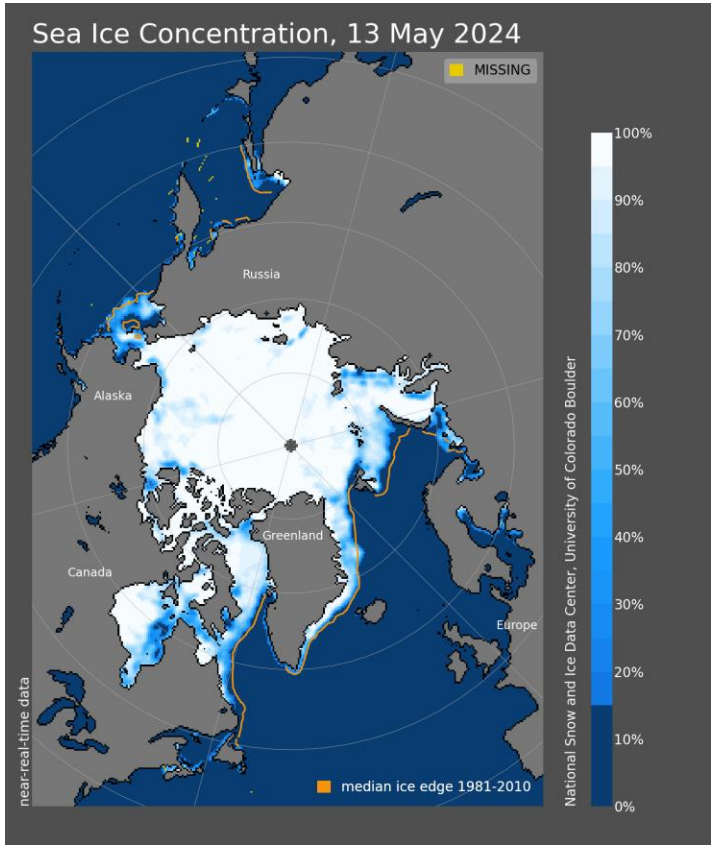


Forest Conservation

Pollution Detection and Control

Ocean and Marine Life Conservation

Wildlife Monitoring and Protection



Climate Change Impact Assessment

Building AI to See What Humans Want to See

Smart Sensors + AI can recognize useful daily life activities to provide insights for clinicians and caretakers

Infection

- Fever
- Urinary frequency
- Respiratory rate

Mobility

- Falls
- Slowed movements
- Immobility

Diet

- Fluid intake
- Pill consumption
- Alcohol consumption

Other concerns of the design of AI systems

- Data privacy
- Diagnostic accuracy
- ...

Building AI to See What Humans Want to See

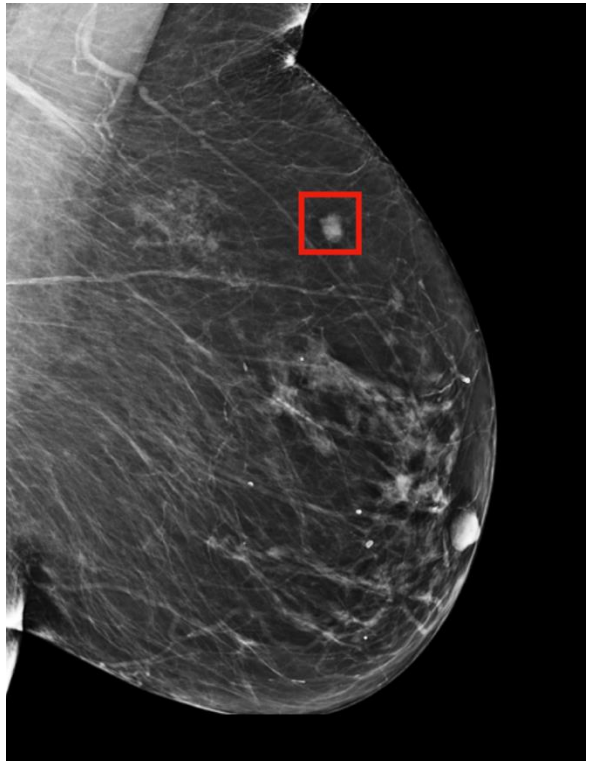
Deep learning to improve breast cancer detection on screening mammography

- Breast Cancer is the second leading cause of cancer deaths among U.S. women
- Role of Computer Vision
  - Deep Learning Algorithms: Enhance accuracy in detecting breast cancer on mammograms
  - End-to-End Training: Efficiently uses datasets with varying levels of annotation
- Benefits
  - Transferability: Models can be fine-tuned for different mammography platforms with minimal additional data.
  - Promise for Clinical Tools: Potential to significantly reduce false positives and negatives, improving early detection and treatment outcomes.

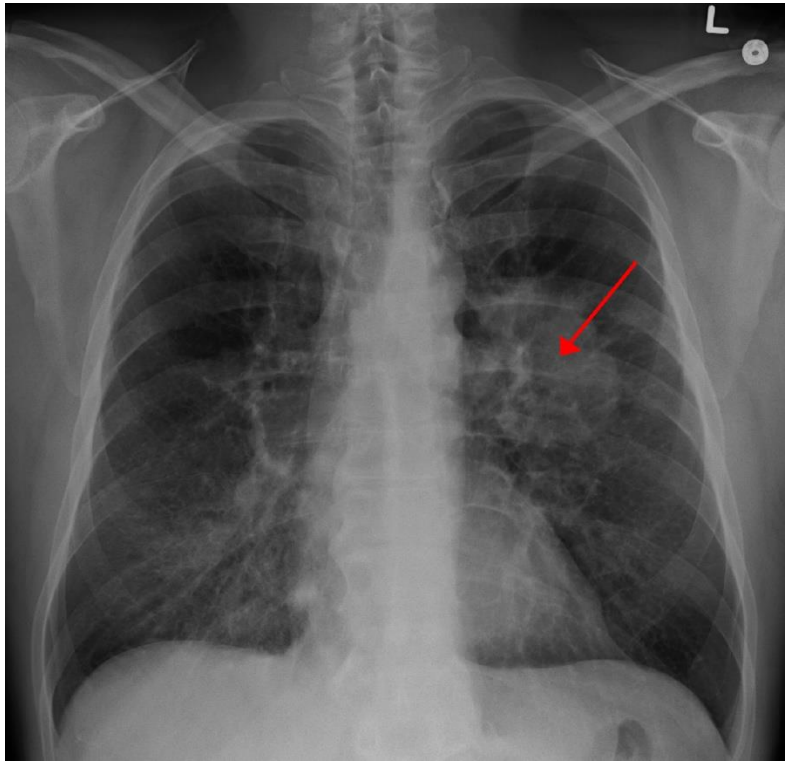
Shen, L., Margolies, L. R., Rothstein, J. H., Fluder, E., McBride, R., & Sieh, W. (2019). Deep learning to improve breast cancer detection on screening mammography. *Scientific reports*, 9(1), 12495.

Real-World Impact of Computer Vision

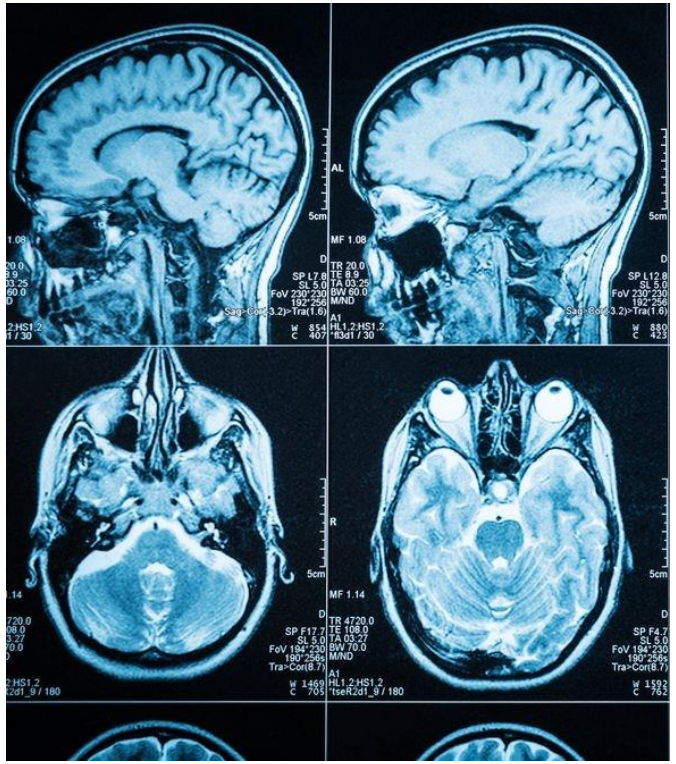
Biology, medicine, healthcare



Breast Cancer



Lung Disease



Brain Scan

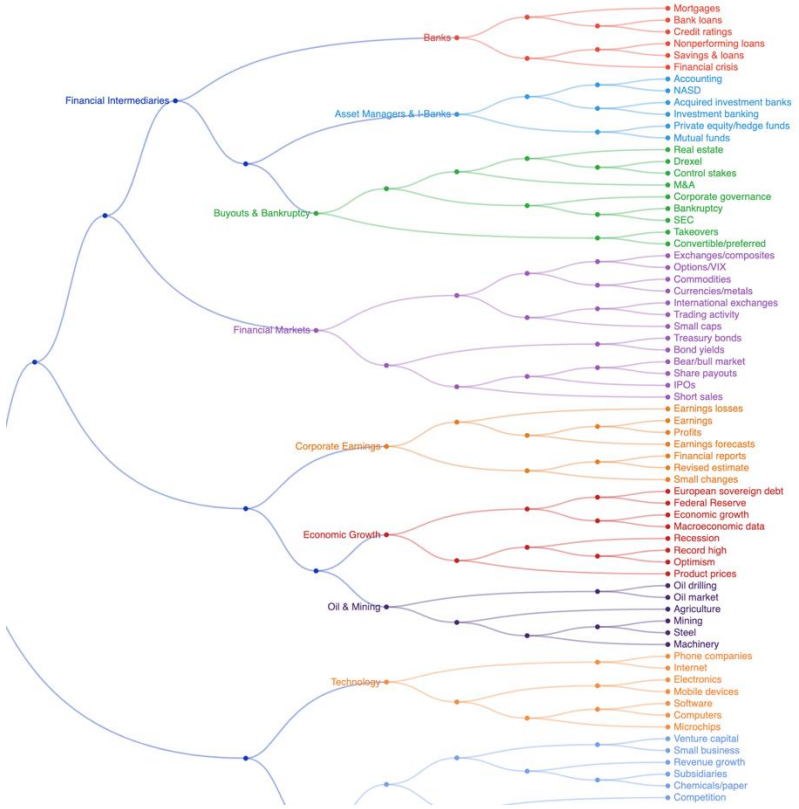
Natural Language Processing

Applications of NLP are everywhere because people communicate almost everything in language: web search, advertising, emails, customer service, language translation, virtual agents, medical reports, politics, etc.

Text Classification

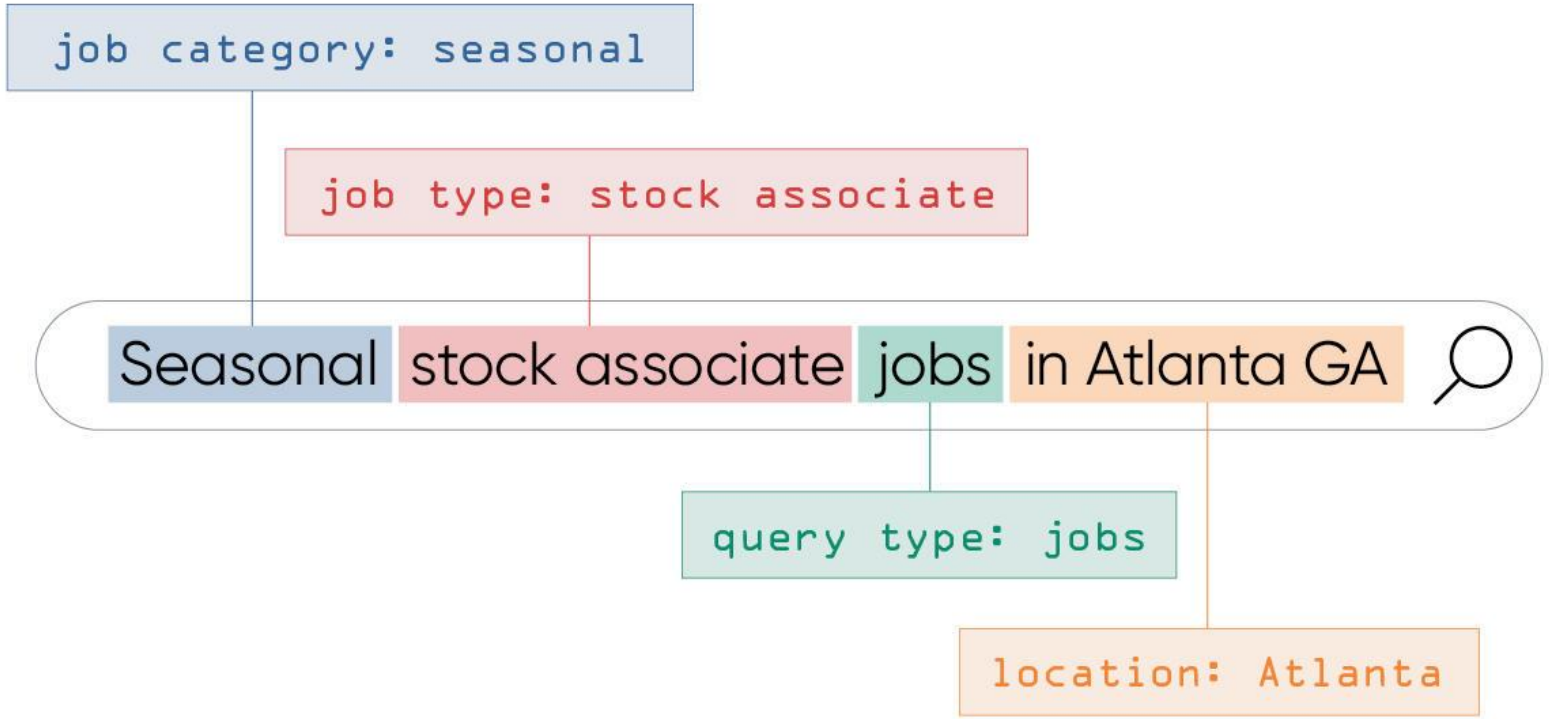
Categorizing text into predefined labels or groups

- Sentiment analysis
  - Reviews on online platforms, such as Amazon and Google Maps
  - Investor's sentiment on the stock market based on news and social media
- News topic labeling
  - The Structure of Economic News
- Spam detection



Named Entity Recognition (NER)

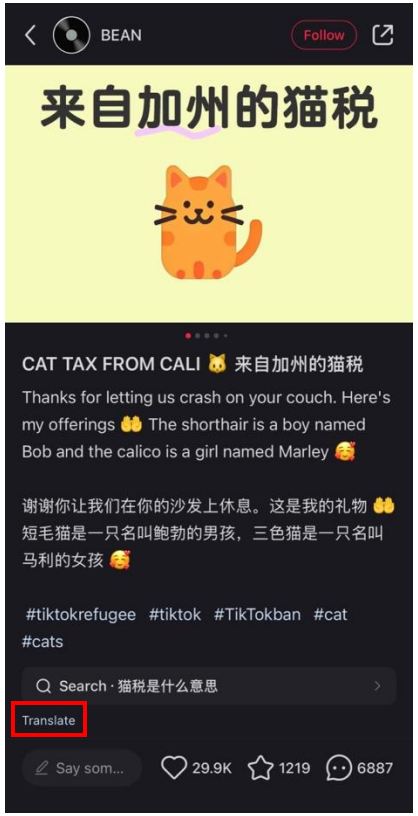
Identifying and classifying entities like names, dates, locations, and organizations in text

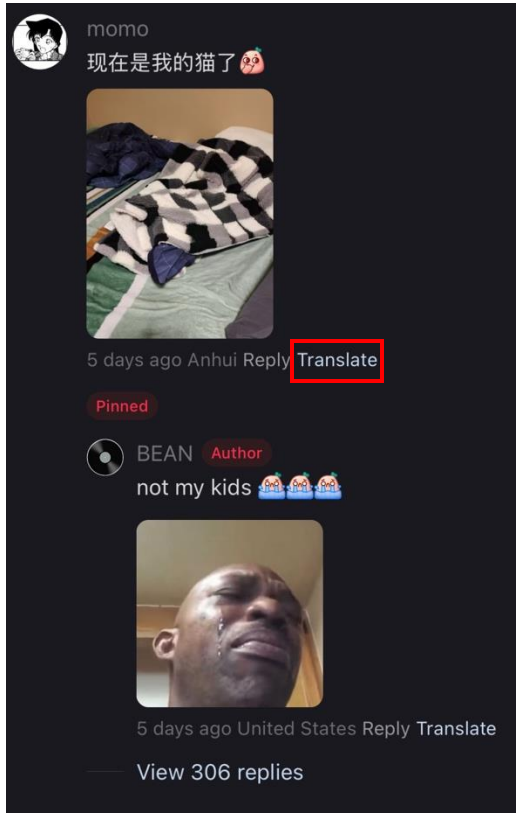


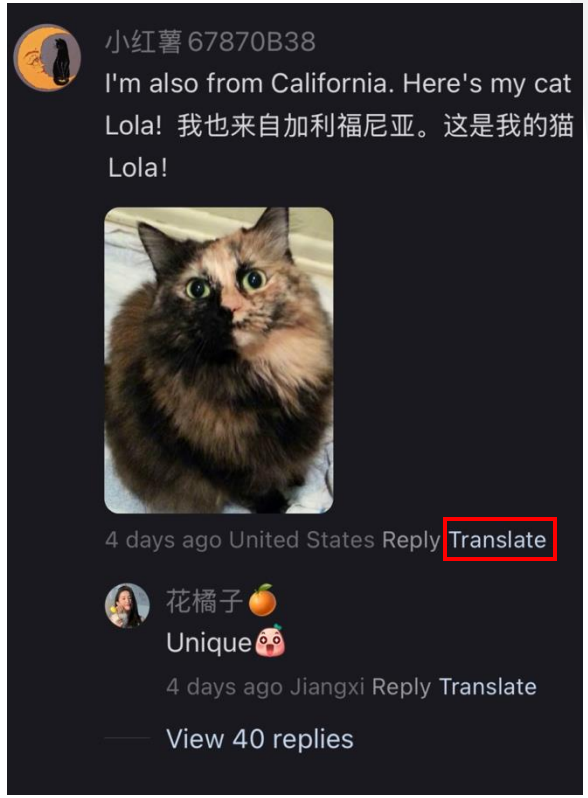
Machine Translation

Automatically translating text from one language to another

- RedNote enables its translation function in response to an influx of 'TikTok Refugees'







Other NLP Tasks

- Text summarization
  - Generating a concise summary of a longer text while retaining key information
  - Example: Summarizing a news article into a few sentences
- Question answering
  - Automatically answering questions posed in natural language based on a given context or knowledge base
  - Example: Answering "What is the capital of France?" with "Paris"
- Text generation
  - Creating coherent and contextually relevant text based on a prompt or input
  - Example: Generating a product description or writing a short story

Natural Language Processing

The evolution of NLP algorithms has consistently expanded their capabilities, enabling breakthroughs across a wide range of natural language processing tasks.

Statistical Learning
(1990s – Early 2010s)

- Dictionary-based approach
- Topic modelling
- Hidden Markov models
- Support vector machines

Deep Learning
(2010s – Late 2020s)

- Recurrent Neural networks (RNNs)
- Word embeddings
- Attention mechanisms (Transformers)

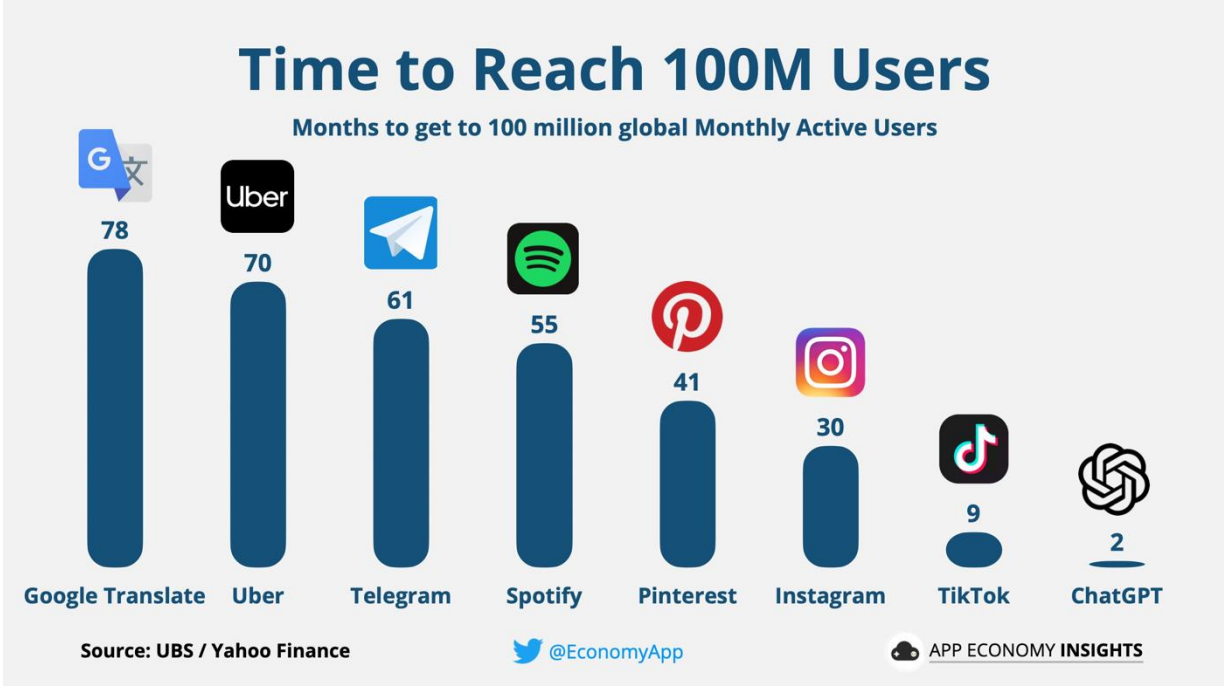
Large Language Models
(2020s – Present)

- BERT
- Generative Pretrained Transformers (GPT)

Generative AI and Large Language Models

ChatGPT represents a significant milestone in natural language processing and AI

- OpenAI launched GPT3.5 and ChatGPT in 2022
- ChatGPT sprints to 100 million users within 3 months

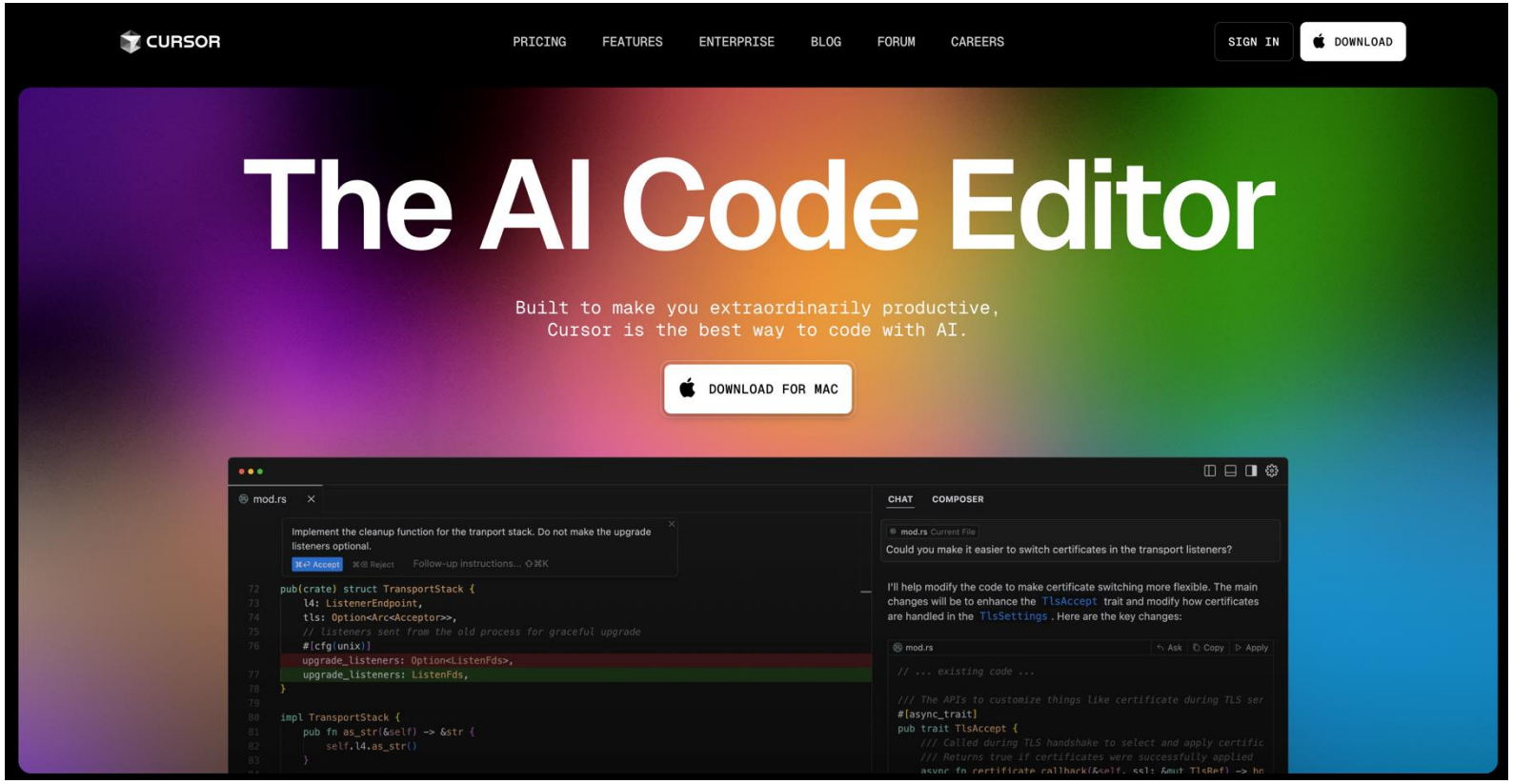


Your Experience with Generative AI

- Have you used GenAI tools like ChatGPT, DeepSeek, or others? How often do you use GenAI?
- Which specific tasks do you use GenAI for?
- How do you ensure the information or content generated by AI is accurate and reliable?
- What's the most surprising or interesting thing you've discovered while using GenAI?
- Are there tasks where you feel AI falls short or isn't helpful? What are they?
- What new applications of Generative AI are you excited to see in the future?

GenAI Copilots

Cursor is an AI-powered code editor that helps developers write and understand code faster



Song Writing Usi Suno

Suno is an AI music generation platform that allows users to create original songs by providing text prompts.

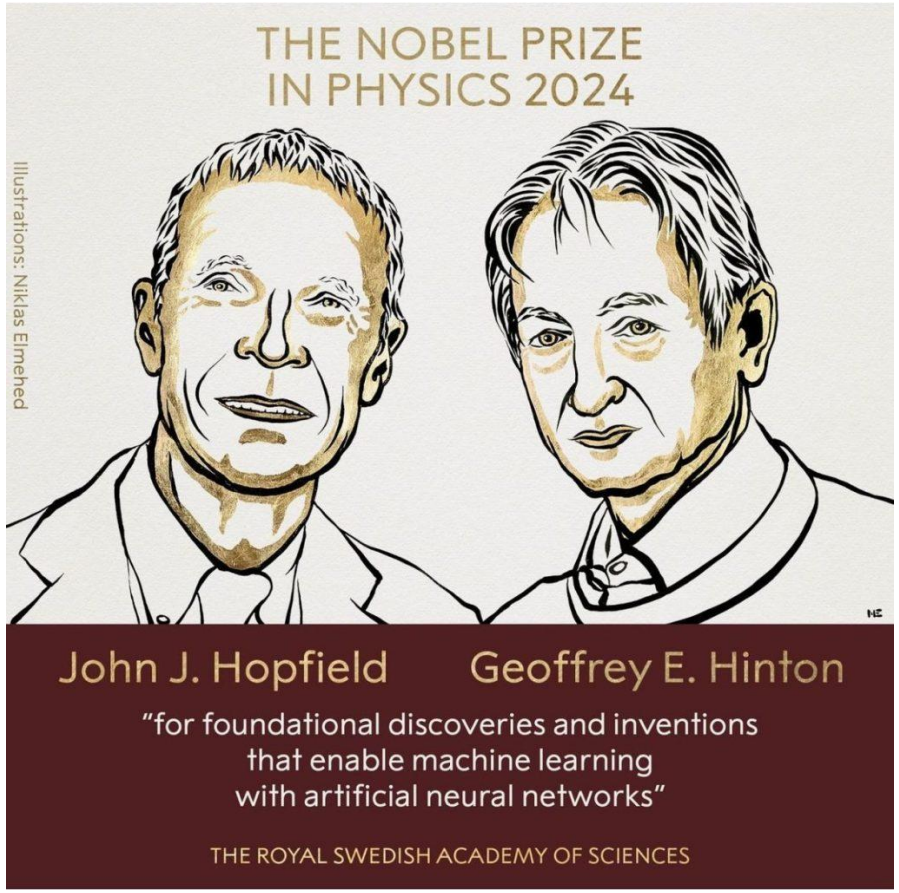
- Workflow of song writing using GenAI
  - Lyrics Creation: Use AI tools like Suno to generate or refine lyrics. You can input a few lines or a theme and the AI can expand on it
  - Melody and Harmony Development: AI can help compose melodies and harmonies. Tools can suggest chord progressions, generate melodies based on lyrical content, or even create backing tracks
  - Arrangement and Production: Once the basic elements are in place, AI can assist in arranging the song. This includes suggesting instrumentations, creating drum patterns, and structuring the song (verse, chorus, bridge, etc.)
- Link to Suno Library

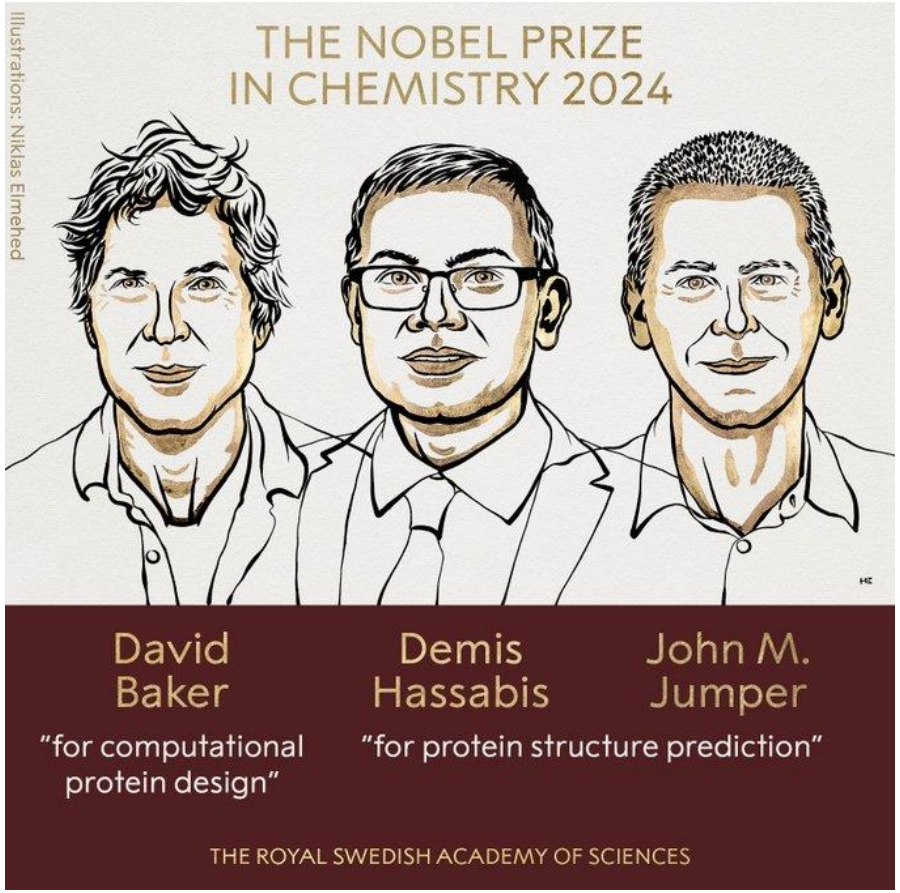
Google NotebookLM

NotebookLM is Google's AI-powered note-taking tool that helps users analyze, summarize, and interact with their documents using natural language.

- NotebookLM provides a new way of
  - consuming knowledge
  - disseminating research
- Examples
  - A Podcast generated based on my paper on online lending
  - A Podcast generated based on this set of slides

2024 Nobel Prize





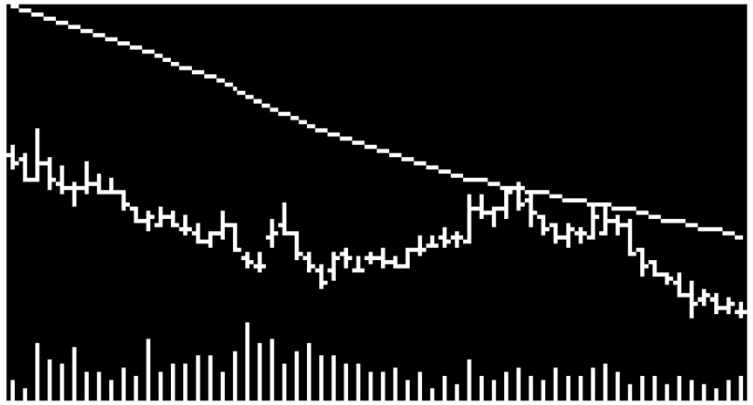
Deep Learning in Business and Finance

The application of Deep Learning in Business and Finance is still at its infancy and presents huge opportunities.

Return Predictability Based on Images

Jiang, J., Kelly, B., & Xiu, D. (2023). (Re-) Imag (in) ing price trends. *Journal of Finance*, 78(6), 3193-3249.

- Predicting price trends is a fundamental question
- Build a convolutional neural network to predict the price trends based on OHLC (Open-High-Low-Close) images
- Advantages over traditional time series prediction
  - Automated signal generation
  - Relational attributes of the data are obvious in images, but less obvious in tabular time-series data
  - Technical trading hinges on the presence of geometric shapes visually defined and observed by human cognition
- The predictive patterns based on the CNN approach
  - are distinct from trend signals analyzed in the literature
  - give more accurate return predictions
  - translate into more profitable investment strategies



Market Data Image

Sales Prediction with Satellite Images

With Satellite Images, Wall Street Analysts Spy On Wal-Mart [Source]

- Crowded parking lots suggest higher sales
- UBS analysts use pictures like this of Wal-Marts around the country to help them estimate the company's sales
- Similar ideas
  - Combining satellite imagery and machine learning to predict poverty, *Science* (2016)
  - Satellite pictures of big ports as a proxy for broad economic activity
  - Satellite pictures of the planet to analyze the supply and health of commodities, such as corn, soybeans, wheat, in order to predict the commodity prices

Satellite Image of a Wal-Mart Parking Lot in Wichita, Kansas

Sales Prediction with Satellite Images

How to do it using GenAI?

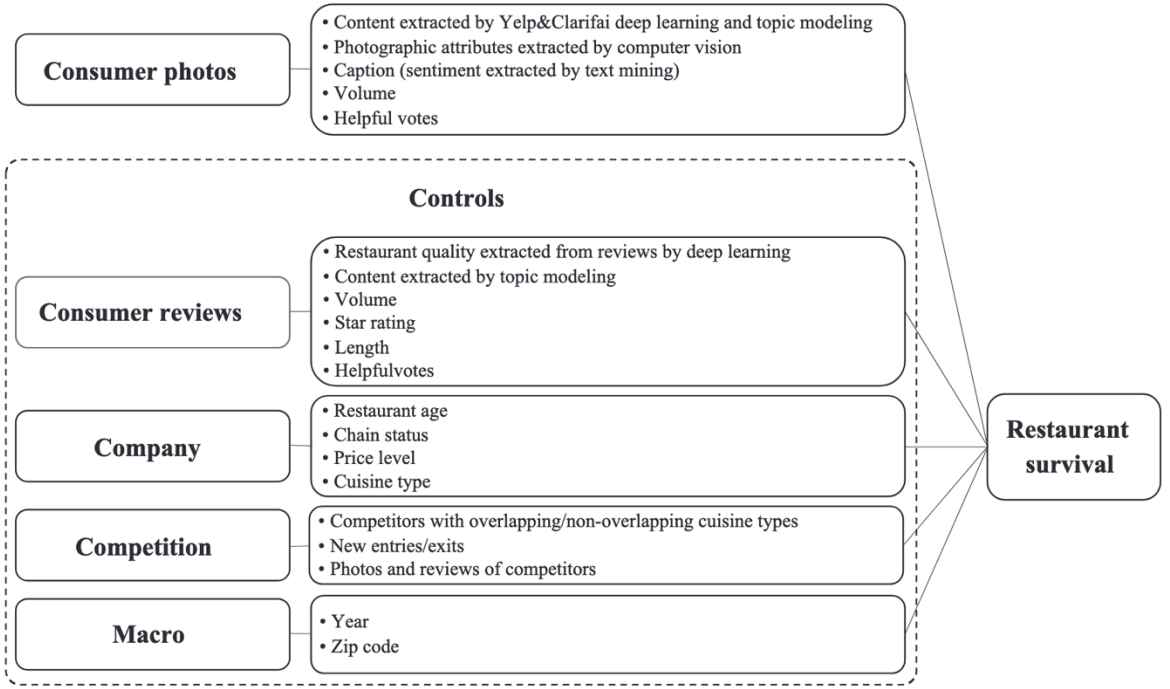
- Instructions in natural language
- Agents
  - Image collection
  - Image analysis
  - Statistical analysis
  - Report writing

Satellite Image of a Wal-Mart Parking Lot in Wichita, Kansas

Restaurant Survival and Consumer-Posted Photos

Zhang, M., & Luo, L. (2023). Can consumer-posted photos serve as a leading indicator of restaurant survival? Evidence from Yelp. *Management Science*, 69(1), 25-50.

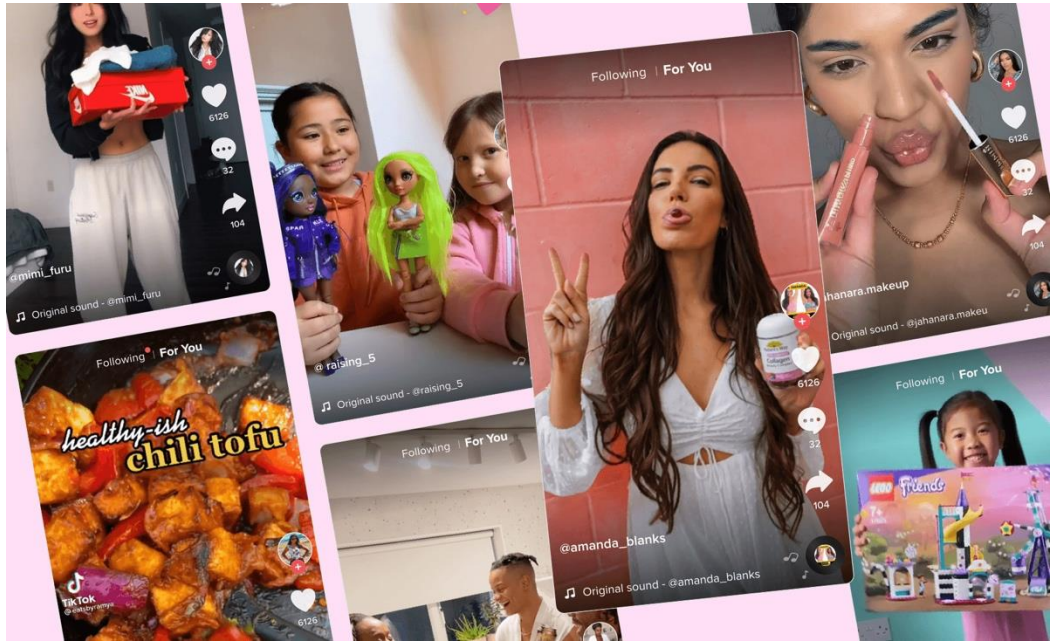
- Are consumer-posted photos a leading indicator of restaurant survival?
- Photo attributes
  - Content of photos (e.g., food, interior, outside, drink, menu)
  - Photographic attributes (e.g., color, composition, figure-group relationships)
  - Photo caption (Sentiment)



TikTok Influencer Advertising

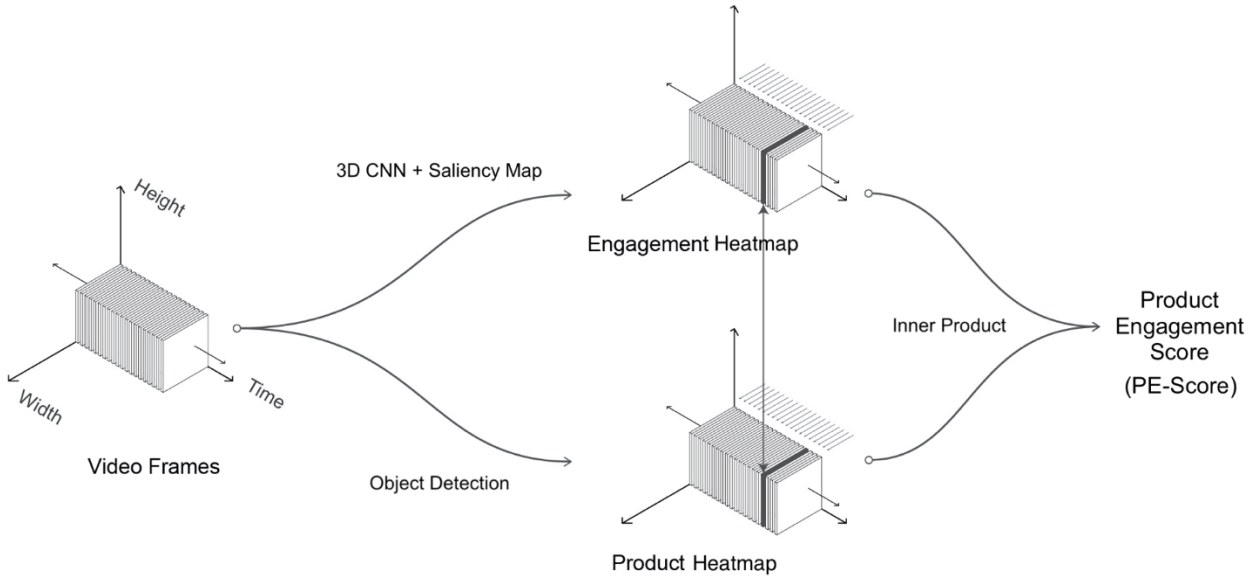
Yang, J., Zhang, J., & Zhang, Y. (2024). Engagement that sells: Influencer video advertising on TikTok. *Marketing Science*.

- Background
  - Influencer video ads on platforms like TikTok often engage users but fail to convert that engagement into sales
  - Current metrics (likes, shares, comments) inadequately predict sales conversion
- How can we measure and predict the effectiveness of influencer video advertisements on TikTok in driving product sales?



Measure Engagement

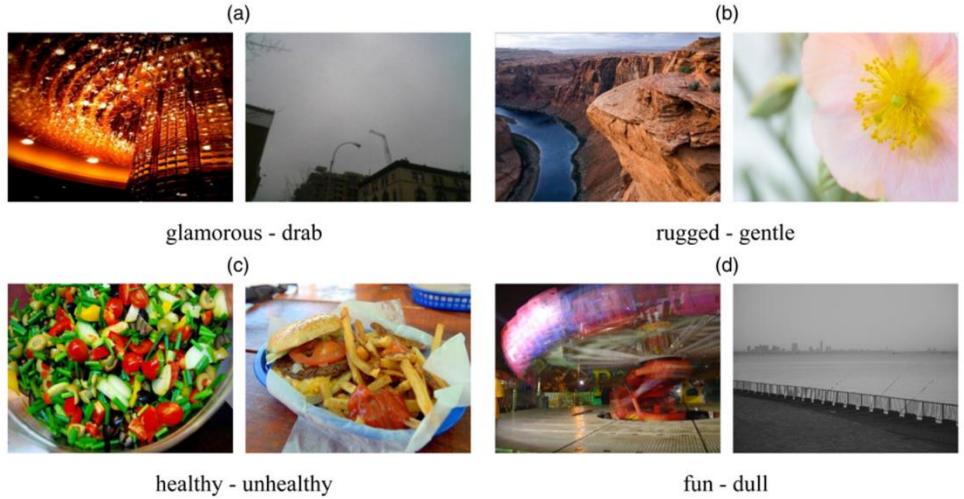
- Train a convolutional neural network on video-level engagement data
- The PE (Product Engagement)-score: An automatic and consistent measure of product engagement that predicts sales



Extract Brand Image Portrayed on Social Media

Liu, L., Dzyabura, D., & Mizik, N. (2020). Visual listening in: Extracting brand image portrayed on social media. *Marketing Science*, 39(4), 669-686.

- BrandImageNet, a multi-label convolutional neural network, that analyzes images posted by consumers and extract perceptual brand attributes, such as "glamorous," "rugged," "healthy," and "fun"
- Firms can use the BrandImageNet model to
  - track brand perceptions
  - evaluate the effectiveness of brand positioning strategies
  - identify gaps between intended and actual brand portrayals



Sample Images

Measuring Corporate Culture Using NLP

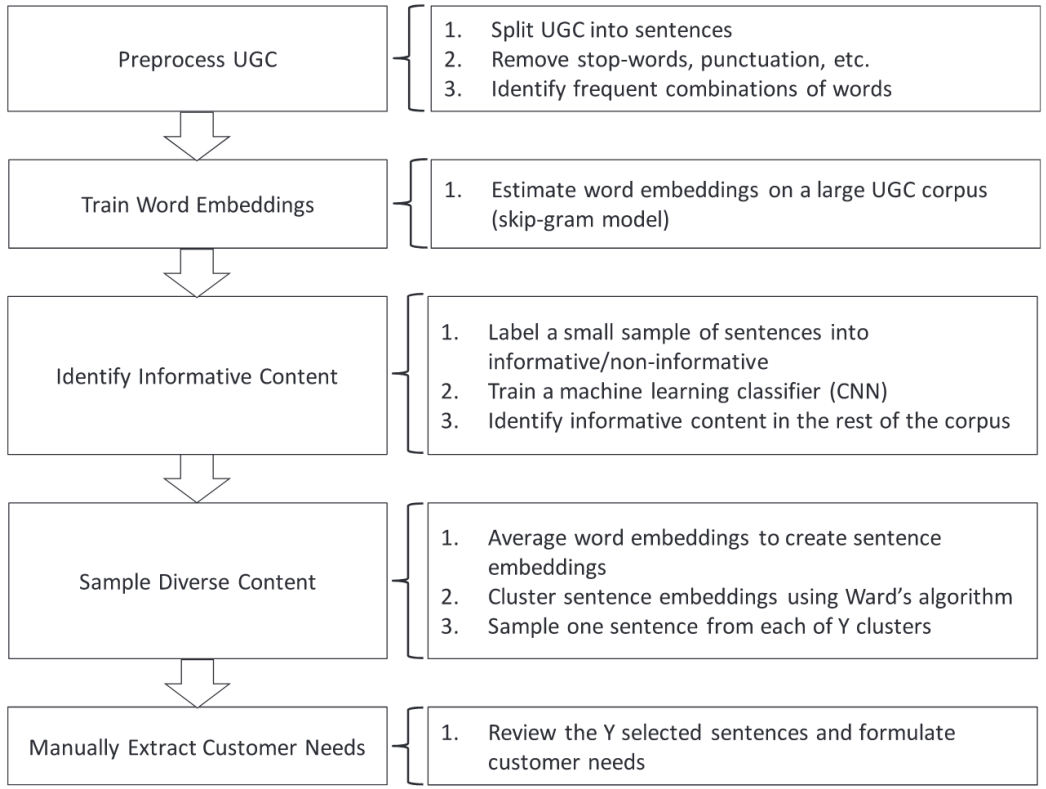
Li, K., Mai, F., Shen, R., & Yan, X. (2021). Measuring corporate culture using machine learning. *Review of Financial Studies*, 34(7), 3265-3315.

- Feng Mai is a former Stevens Faculty
- Leverage word embedding models (specifically, the word2vec model) to analyze 209,480 earnings call transcripts, scoring five key cultural values: *innovation*, *integrity*, *quality*, *respect*, and *teamwork*
- Enable us to study how corporate culture correlates with various business outcomes and how it is shaped by major corporate events like mergers and acquisitions (M&As)
  - Corporate culture correlates with business outcomes, including operational efficiency, risk-taking, earnings management, executive compensation design, firm value, and deal making, and that the culture-performance link is more pronounced in bad times
  - Corporate culture is shaped by major corporate events, such as mergers and acquisitions

Identifying Customer Needs from User-Generated Content

Timoshenko, A., & Hauser, J. R. (2019). Identifying customer needs from user-generated content. *Marketing Science*, 38(1), 1-20.

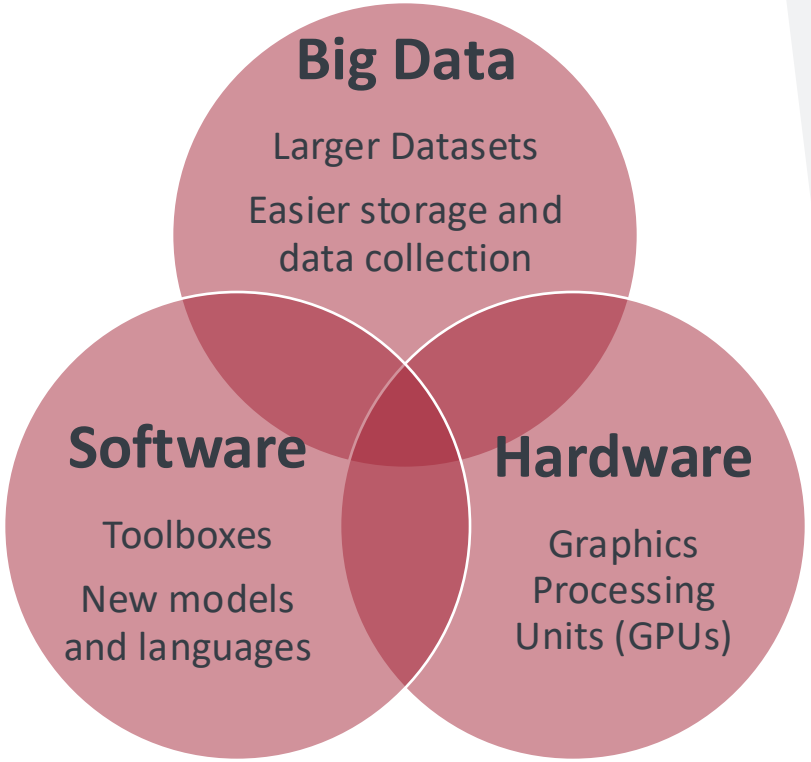
- Background
  - Traditional methods like interviews and focus groups for identifying customer needs are costly and time-consuming.
  - UGC offers a rich alternative data source but is challenging to analyze due to scale, redundancy, and unstructured nature.
- A machine-learning hybrid approach is introduced, combining automation with human judgment, to identify customer needs from reviews



Reflections

The unstructured nature of images and text presents both challenges and opportunities

- Challenges of analyzing unstructured data
  - How to represent the data?
  - How to model the data?
  - What do you want to extract from the data?
- If we abstract the ML applications at the level of data, model, and prediction, i.e., $Y = f(X) + \epsilon$, the execution is the easiest step
- Equipped with data, software, and hardware today, creativity and ideas are what matters



Learning Objectives for This Course

- A basic understanding of the fundamental concepts/methods in machine learning (deep learning)
- Implementation and application of machine learning models for solving financial problems
- Hands-on experience with advanced techniques for leveraging LLMs, including prompt engineering, RAG, and fine-tuning
- (Develop an intuition of what to model that matters to investment and business)

Acknowledgement

The lecture note has benefited from various resources, including those listed below. Please contact Zonghao Yang (zyang99@stevens.edu) with any questions or concerns about the use of these materials.

- Lecture Notes on Deep Learning Fundamentals by Léonard Boussioux at University of Washington
- Seminar on “What we see and what we value: AI with a human perspective” Fei-Fei Li, January 2024 [YouTube]

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THANK **YOU**

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