CS 181 - Artificial Intelligence

Kewei Tu, Xuming He
Fall 2020

Administrative Stuff

▸ Instructors:

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  ▸ Office hours: TBA

Administrative Stuff

▸ Classes

  ▸ Mon/Wed 8:15-9:55am @教学中心301
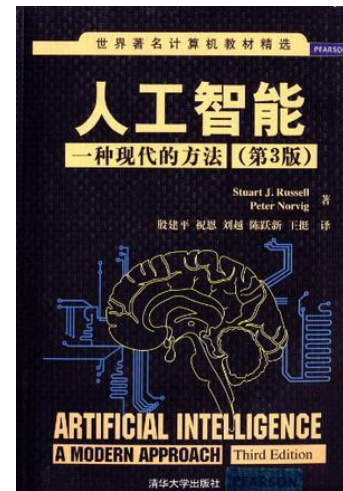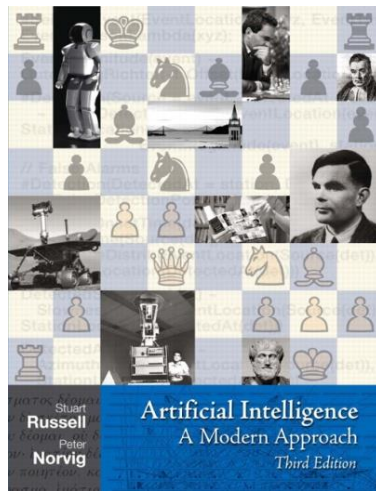
  ▸ 16 weeks

  ▸ Language: English

▸ Prerequisite

  ▸ Programming Languages, Data Structures and Algorithms

  ▸ Discrete Mathematics

  ▸ Probability and Statistics

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▸ Main textbook

    ▸ [AIMA] Artificial Intelligence: A Modern Approach, Stuart Russell and Peter Norvig, 3rd edition, 2009.

    ▸ [中译版] 人工智能：一种现代的方法（第3版），2013

▸ Additional reference books may also be used

Administrative Stuff

▸ Blackboard

  ▸ Announcements, homework assignments, slides, etc.

▸ Piazza

  ▸ Discussion and QA

  ▸ http://piazza.com/shanghaitech.edu.cn/fall2020/cs181

▸ AutoLab

  ▸ Programming assignments

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▸ Grading (tentative)

  ▸ 6 homework assignments (10%)

  ▸ 6 programming assignments (25%)

  ▸ Project (15%): 2nd half of the semester

  ▸ Midterm exam (25%): in late Oct

  ▸ Final exam (25%): in late Dec or early Jan

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‣ Plagiarism

  ‣ All assignments must be done individually

    ‣ You may not look at solutions from any other source

    ‣ You may not share solutions with any other students

    ‣ Plagiarism detection software will be used on all the programming assignments

  ‣ Way of collaboration

    ‣ You may discuss together or help another student debug code; however, you cannot dictate or give the exact solution

Administrative Stuff

- Plagiarism punishment
  - When one student copies from another student, both students are responsible
  - Zero point on the assignment or exam in question
  - Repeated violation will result in an F grade for this course as well as further discipline at the school/university level

A brief overview of AI

What is artificial intelligence?

‣ AI = Robots?

Definition
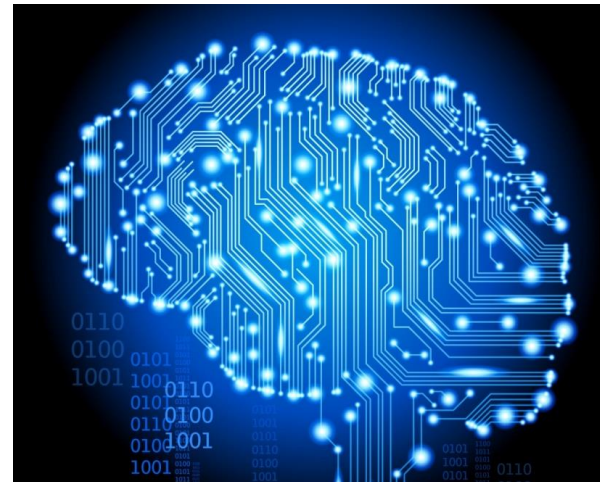
Artificial Intelligence

Machines (Computers)

Rationality:
Ability to maximize goal achievement given available information

Artificial Intelligence

▸ AI vs. Human Intelligence

  ▸ Brains (human minds) are good at rational thinking, but not perfect

  ▸ "Brains are to intelligence as wings are to flight"

A brief history

▸ Lots of early speculation & research
  ▸ Turing: "Computing Machinery and Intelligence" (1950)

I.—COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. *The Imitation Game.*

I propose to consider the question, 'Can machines think?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed

Alan Turing

A brief history

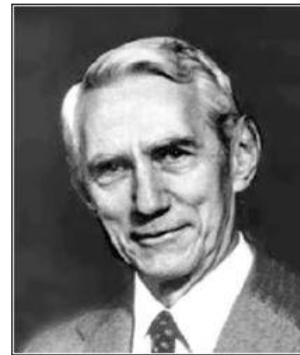- Birth (1956)
  - Dartmouth workshop
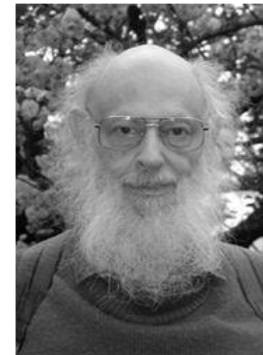
Dartmouth Conference: The Founding Fathers of AI
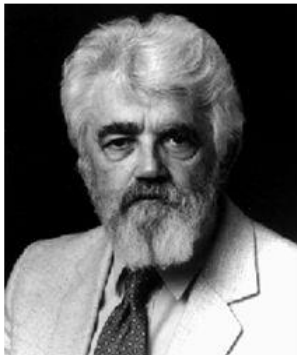
John McCarthy   Marvin Minsky   Claude Shannon   Ray Solomonoff

Alan Newell   Herbert Simon   Arthur Samuel

And several other people…

A brief history

- Great expectations (1950s-1960s)
  - A variety of methodology
    - e.g., symbolism, connectionism
- AI winter (1970s)
  - Downfall of perceptron
  - Lighthill report
- Boom (1980s)
  - Revival of neural networks
- More scientific methods (1990s-2000s)
  - Statistical approaches

Very rough timeline

A brief history

‣ The past ten years

  ▸ Rise of big data and deep learning

  ▸ AI becomes one of the hottest areas in CS

  ▸ Great interest from industry and public

  ▸ Many real-world applications

Growth of annually published papers, by topic (1996-2017)

Source: Scopus
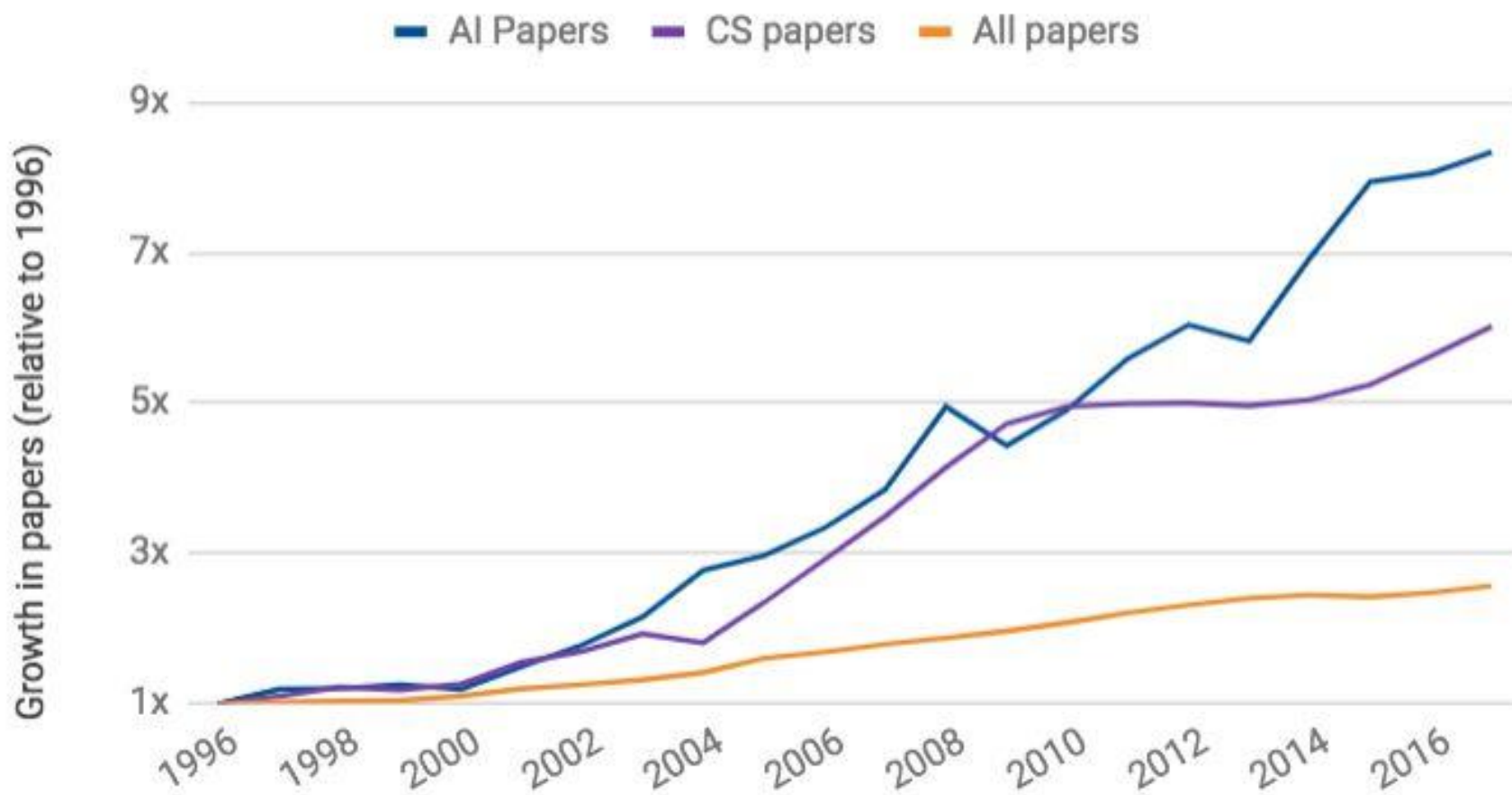
Attendance at large conferences (1984-2019)
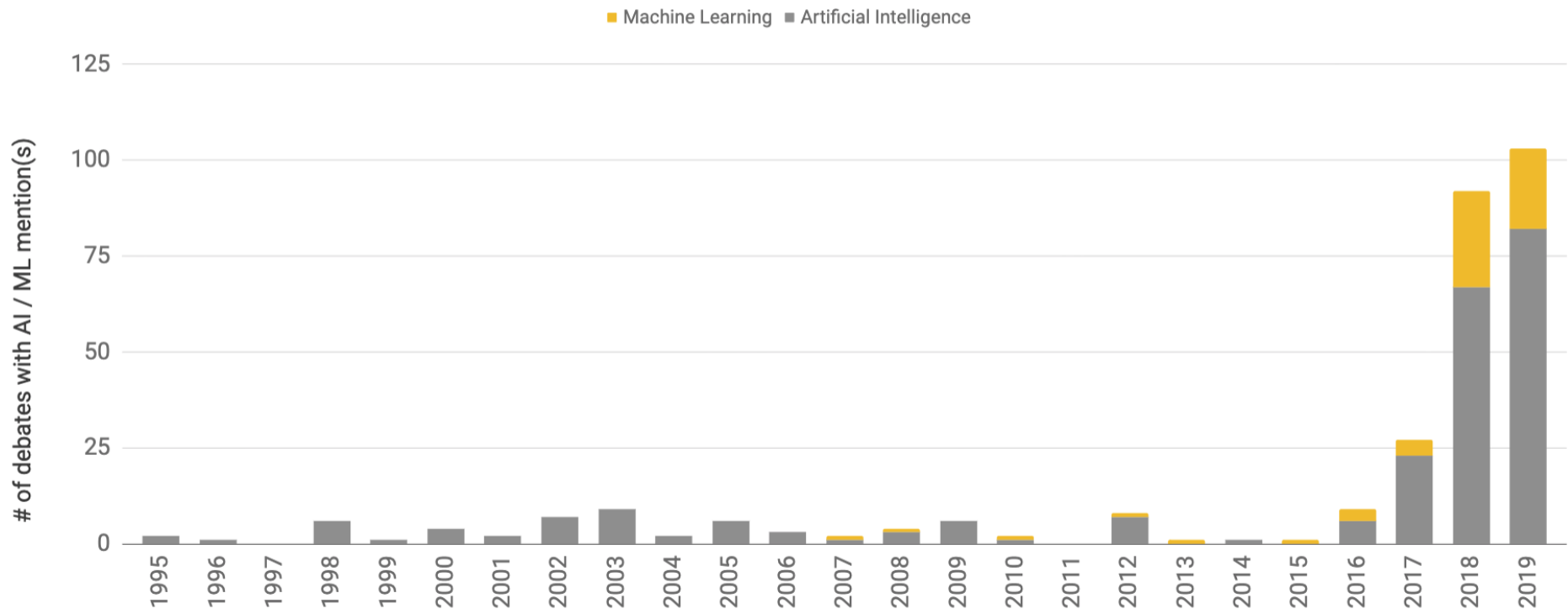
Source: Conference provided data.
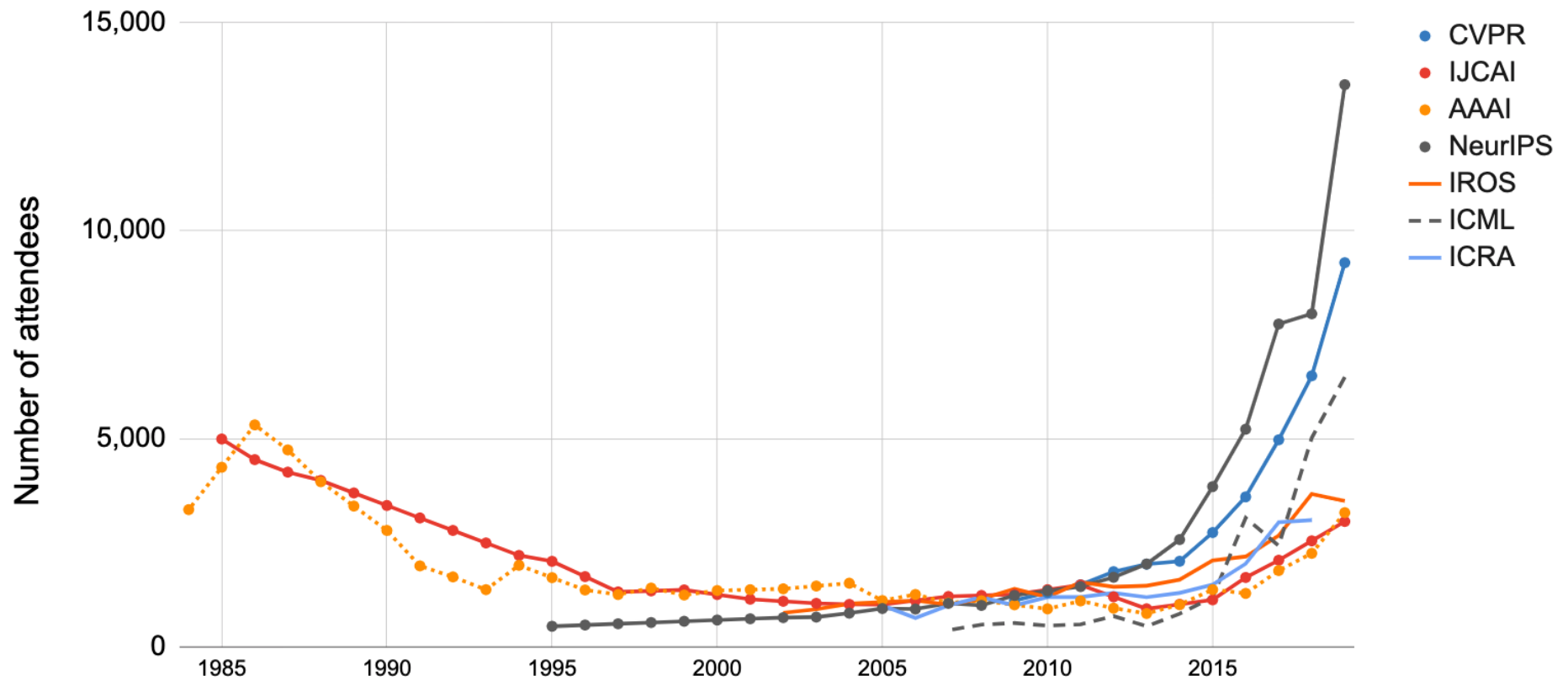
AI startups (U.S., Jan '95 - Jan '18)
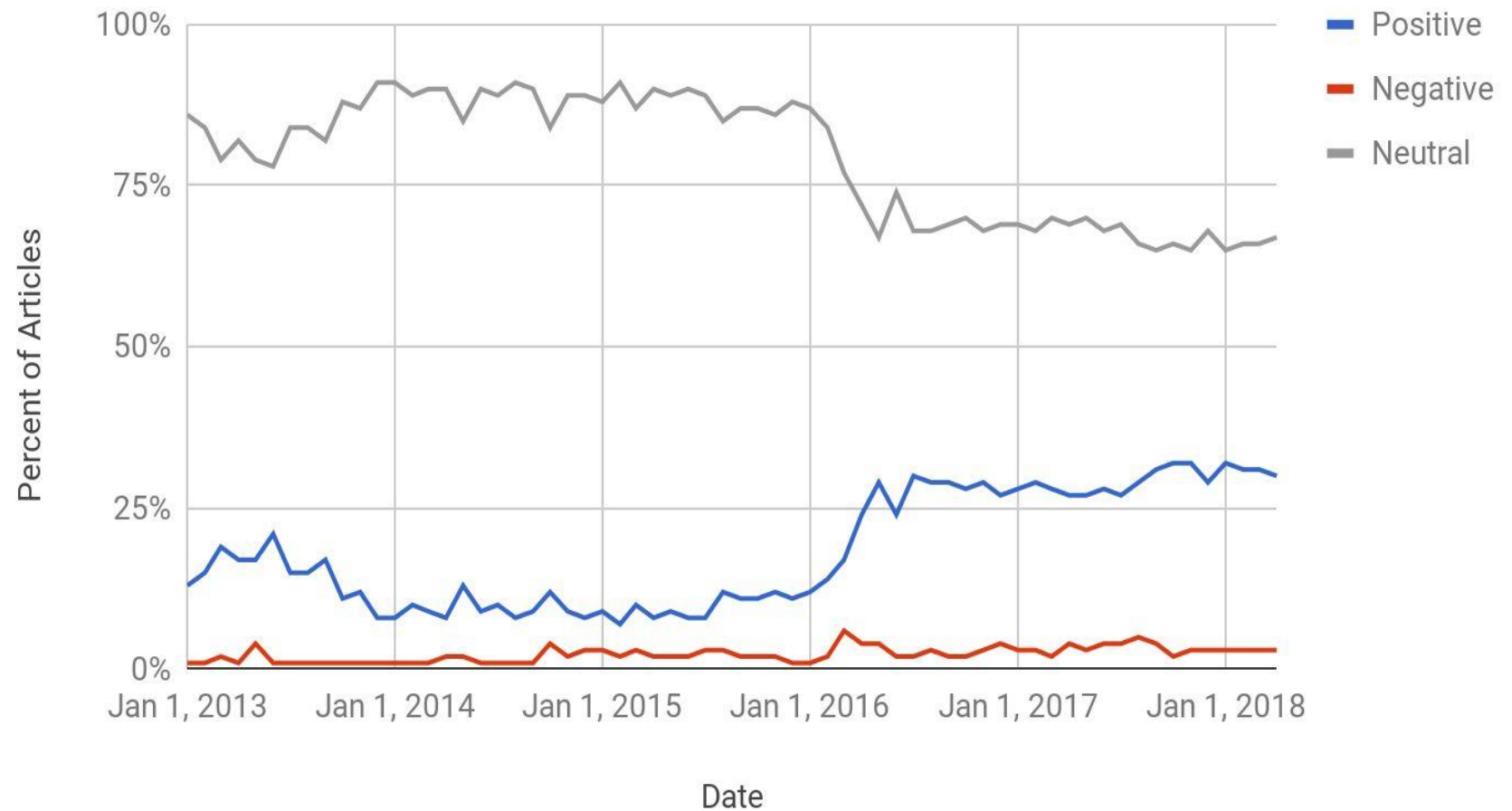Source: Sand Hill Econometrcs
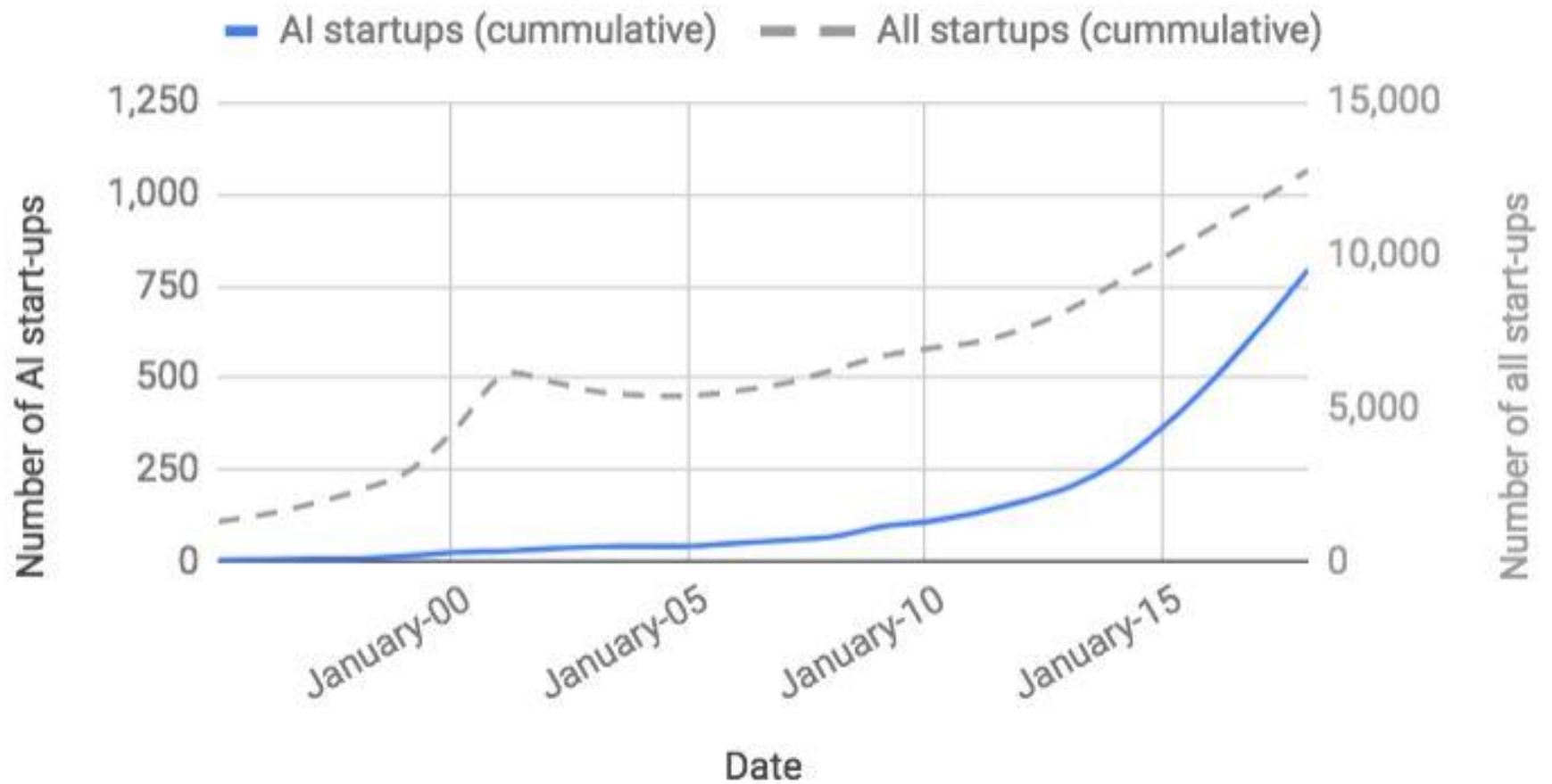
AI and ML mentions in U.S. Congress (1995-2019)

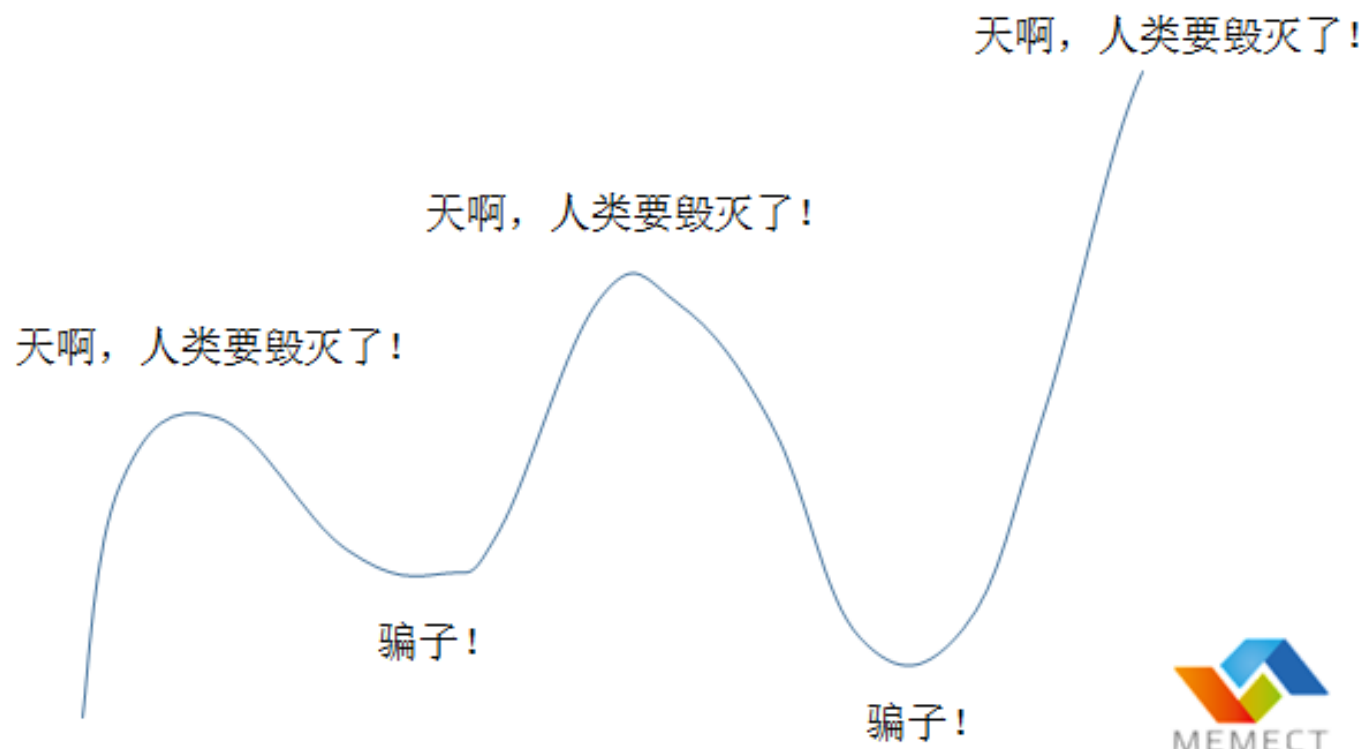Source: U.S. Congressional Record website, the McKinsey Global Institute.

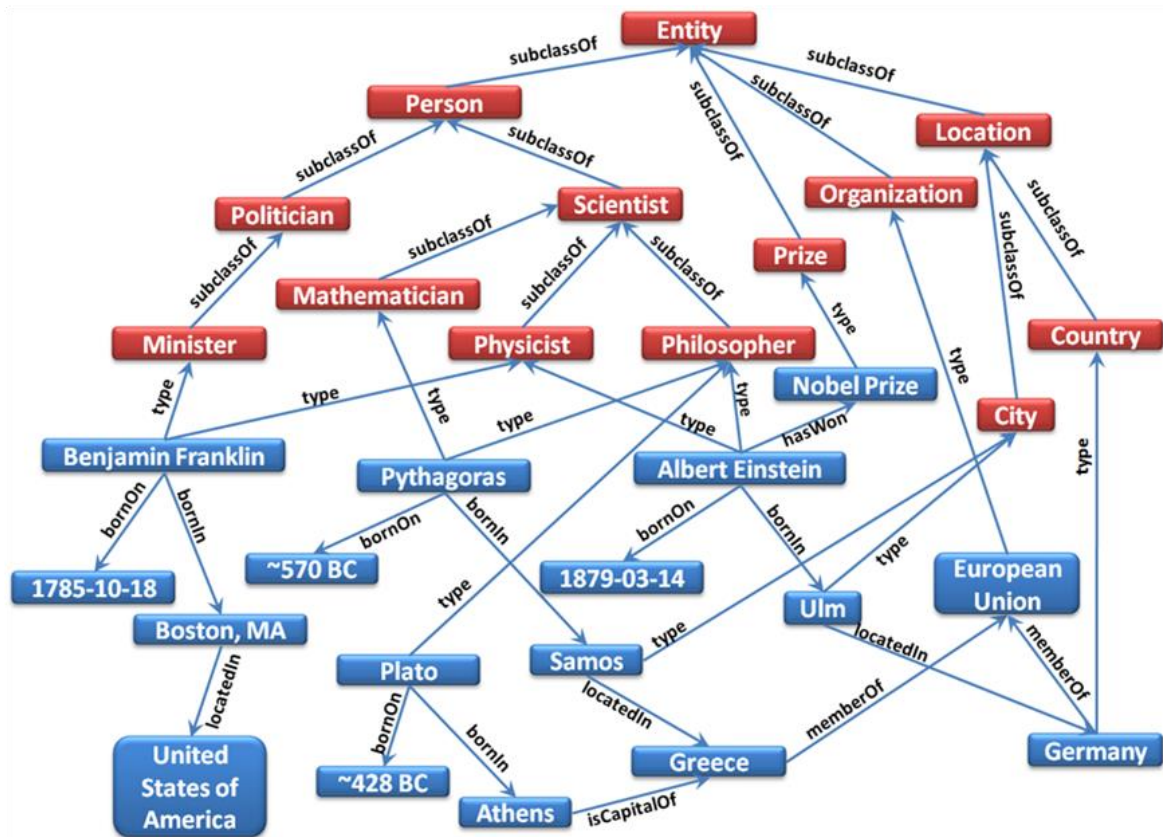# Sentiment of articles referencing AI

Source: TrendKite

Legend:
- Positive
- Negative
- Neutral

Y-axis: Percent of Articles (100%, 75%, 50%, 25%, 0%)

X-axis: Date (Jan 1, 2013; Jan 1, 2014; Jan 1, 2015; Jan 1, 2016; Jan 1, 2017; Jan 1, 2018)

A brief history

Subfields of AI

▸ Knowledge Representation and Reasoning

Subfields of AI

‣ Machine Learning
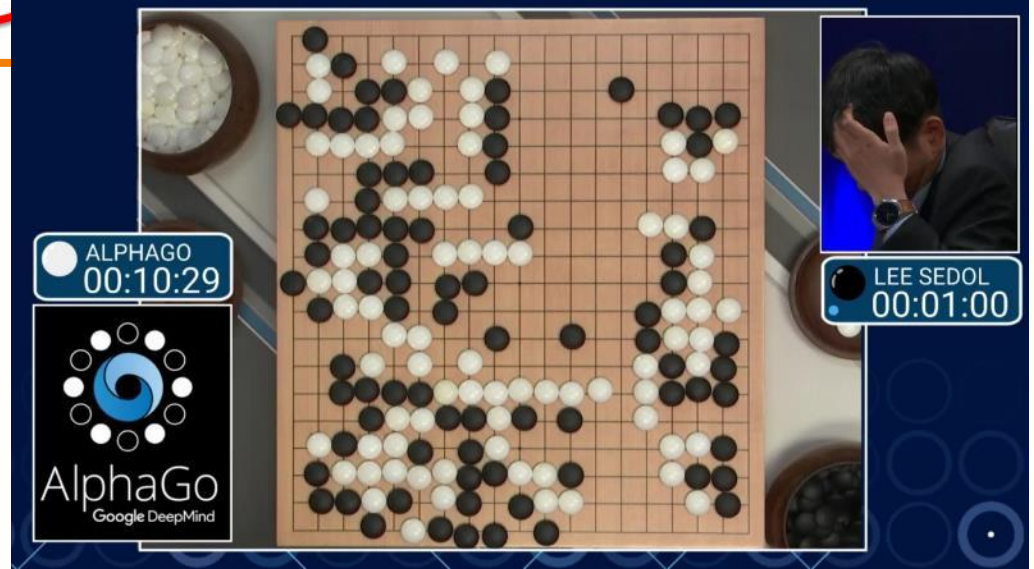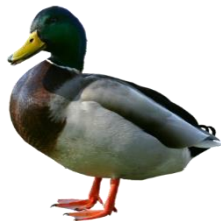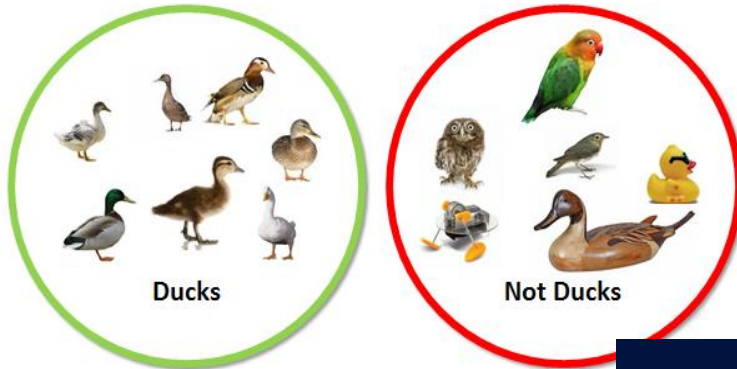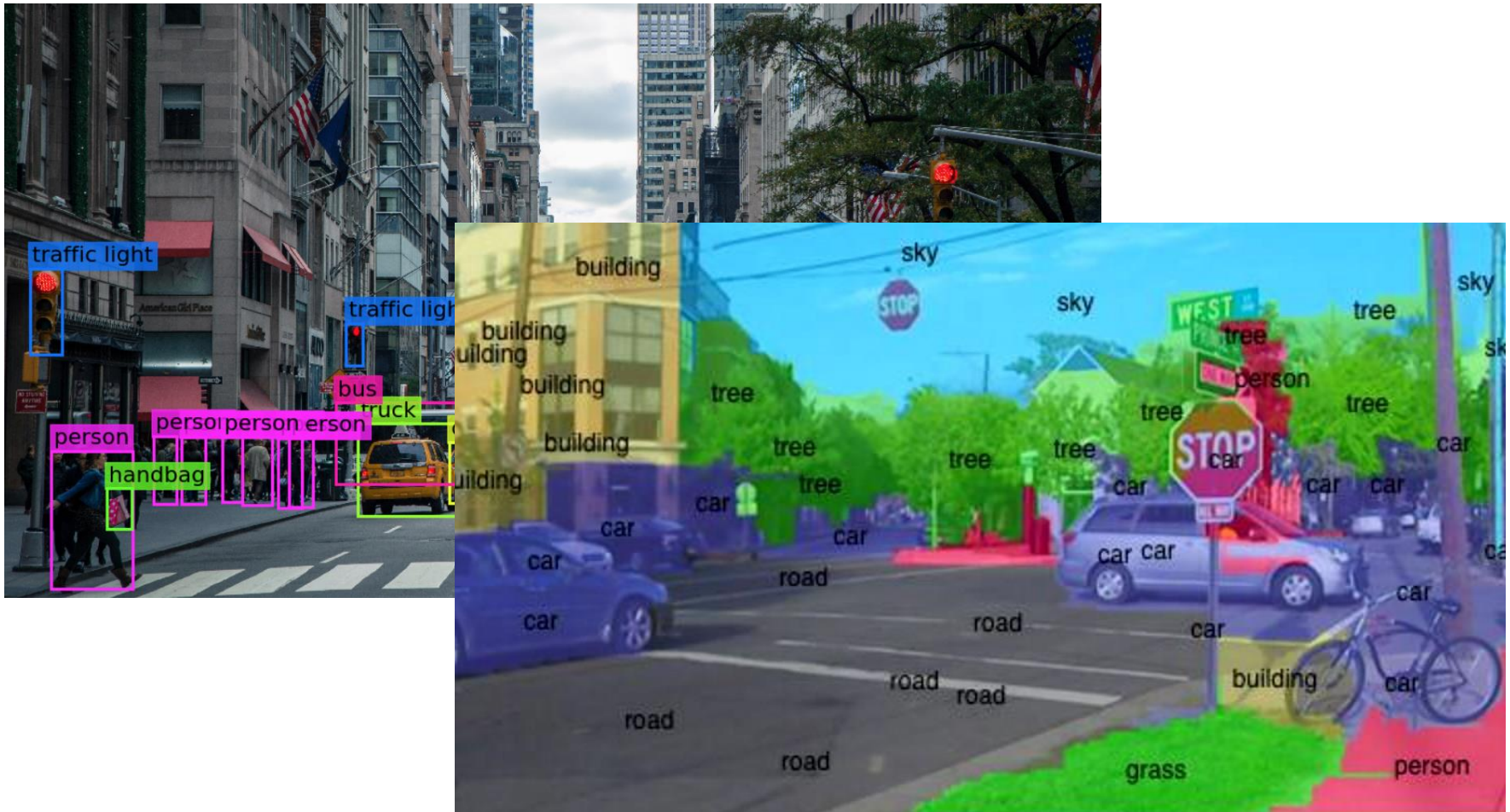
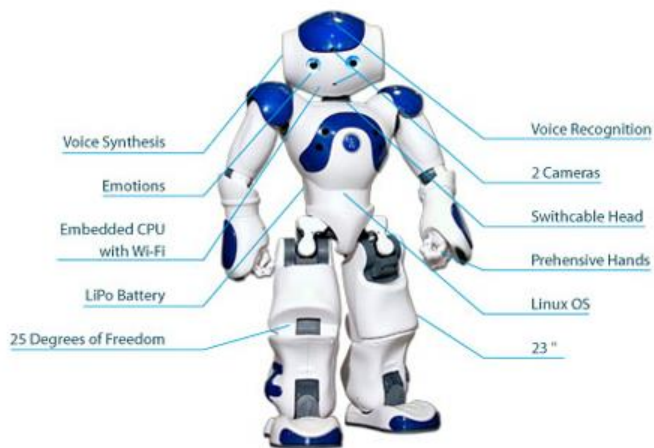# Subfields of AI

▸ Natural Language Processing

Subfields of AI

▸ Computer Vision

Subfields of AI

- Robotics

Subfields of AI

▸ Multi-Agent System

Subfields of AI

Integration

Multi-Agent System

Robotics

Modality-Specific

Natural Language Processing

Computer Vision

Speech Recognition

Foundation

Machine Learning

Knowledge Representation & Reasoning

Uncertainty in AI

Applications of AI

▸ Spam email filter

▸ Speech recognition

▸ Search engine

▸ Modern Chinese IME

▸ Machine translation

Applications of AI

▸ Financial trading

▸ Game AI

▸ Customer service chatbot

▸ Self-driving
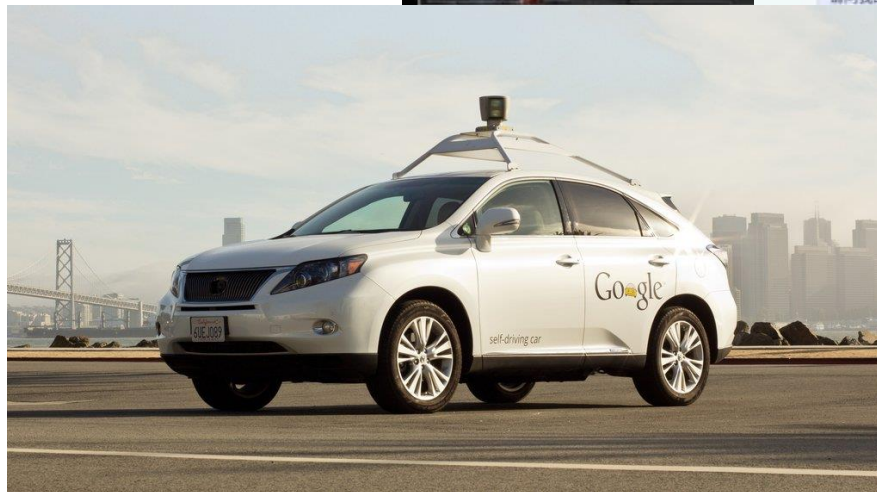
Strong AI vs. Weak AI

‣ Weak AI (Applied AI)
  ‣ AI that accomplishes specific tasks

Strong AI vs. Weak AI
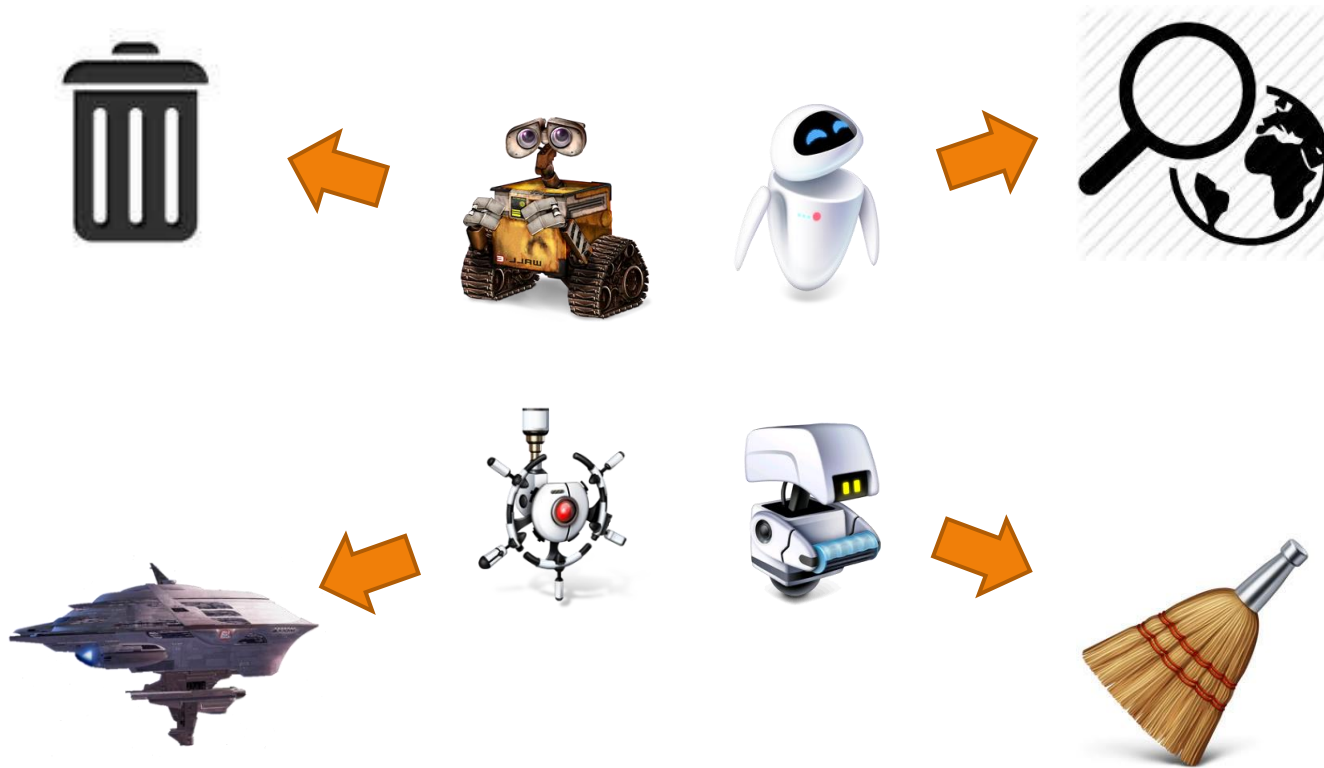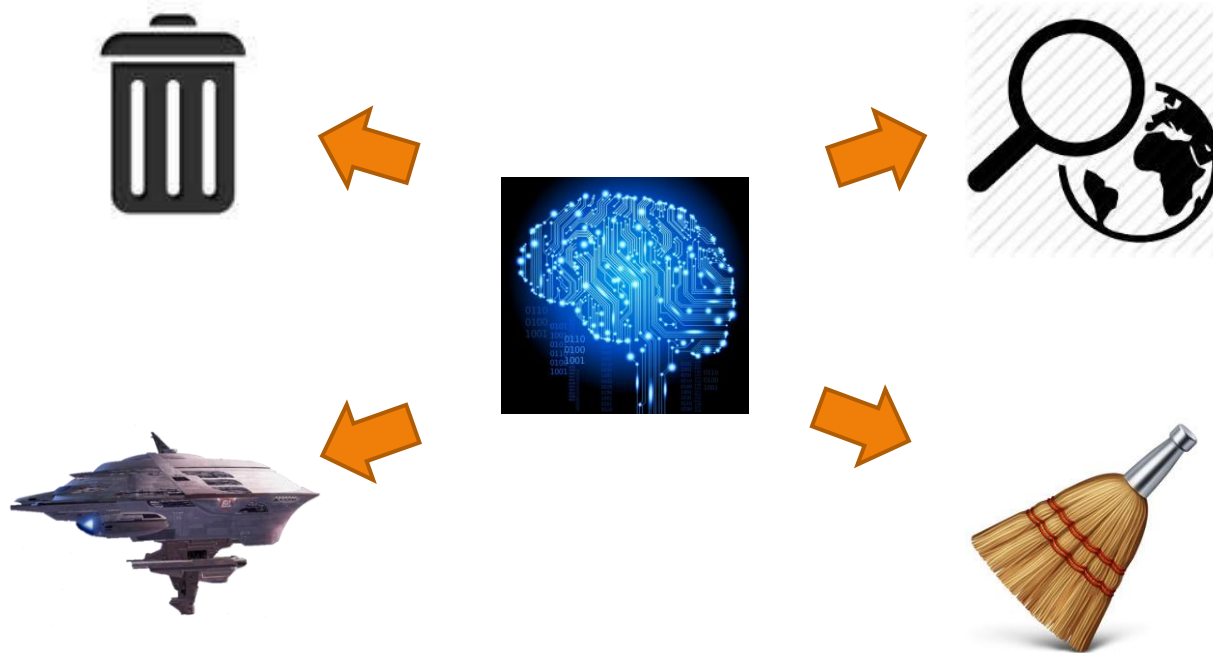
- Strong AI (General AI)
  - human-like intelligence – AI that could successfully perform any intellectual task that a human can

Strong AI vs. Weak AI

- ▶ Q1: What is the woman in the middle doing?
  - ▶ Action recognition, a CV problem
- ▶ Q2: What is the woman on the left going to do?
  - ▶ Reasoning about context and intention (beyond current CV)
- ▶ Q3: This photo was taken in Europe in 2015. What was going on?
  - ▶ Knowing background knowledge by reading news, …

▶

Central problems of (strong) AI

▸ Knowledge Representation (KR)

   ▸ Knowledge: facts, beliefs, concepts, skills, … that are accumulated over time
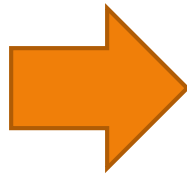
Central problems of (strong) AI

‣ Inference

　‣ How to utilize knowledge to derive new information based on existing information
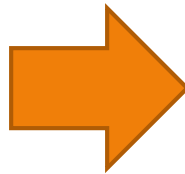
Central problems of (strong) AI

▸ Learning

▸ How to accumulate knowledge from experience and education
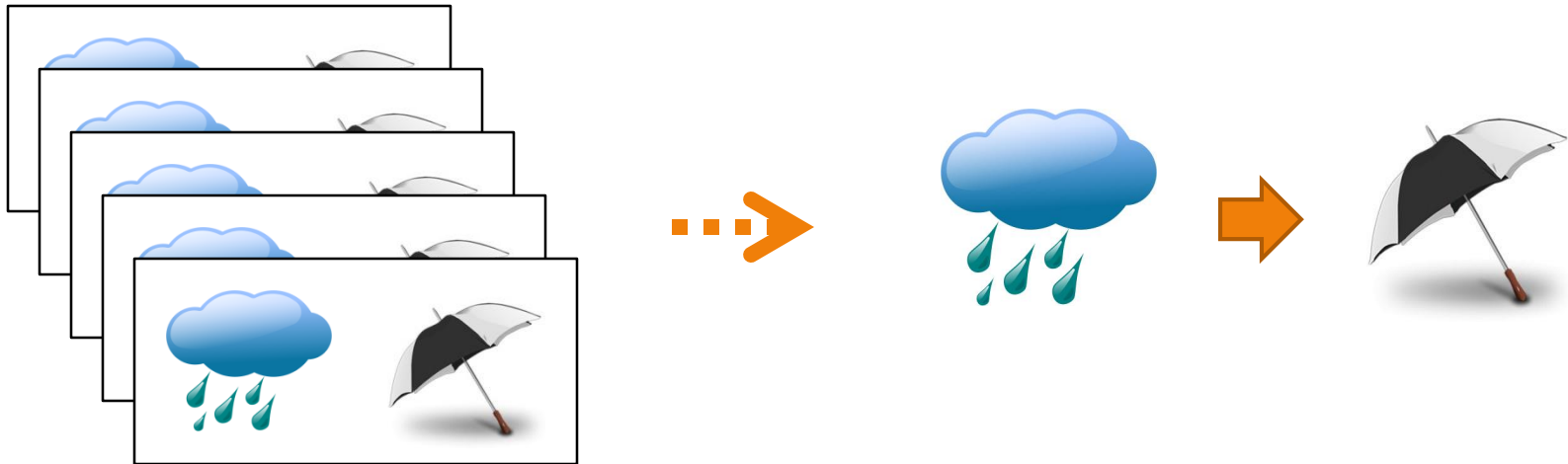
Three types of approaches

Symbolism

$$+ \quad - \quad \times \quad \div$$
$$\neg \quad \vee \quad \perp \quad \cong$$
$$\in \quad \cap \quad \subseteq \quad \Sigma$$
$$\partial \quad \nabla \quad \wedge \quad \Pi$$
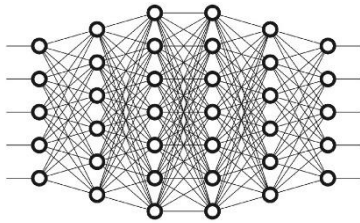
Connectionism
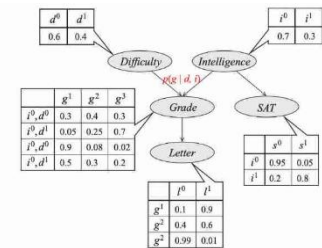
Statistical Approaches

Symbolism

▸ Representing knowledge with symbols and their compositions (expressions)

▸ Inference and learning is done by manipulating symbols (e.g., logic)

$$\forall x \forall y, Human(x) \wedge Place(y) \wedge At(x,y) \wedge Rain(y)$$
$$\rightarrow \exists z, Umbrella(z) \wedge Use(x,z)$$

Symbolism

‣ History

- ‣ Dominant during 1950s – 1980s
- ‣ Fell out of favor in 1980s – 1990s
- ‣ Integration with statistical approaches (2000s)
- ‣ Integration with neural approaches (2010s)

Connectionism

- ▸ Representing knowledge with interconnected networks of simple units
  - ▸ Neural networks
- ▸ Inference
  - ▸ Follow the computation specified by the network from input to output
- ▸ Learning
  - ▸ optimization of connection weights
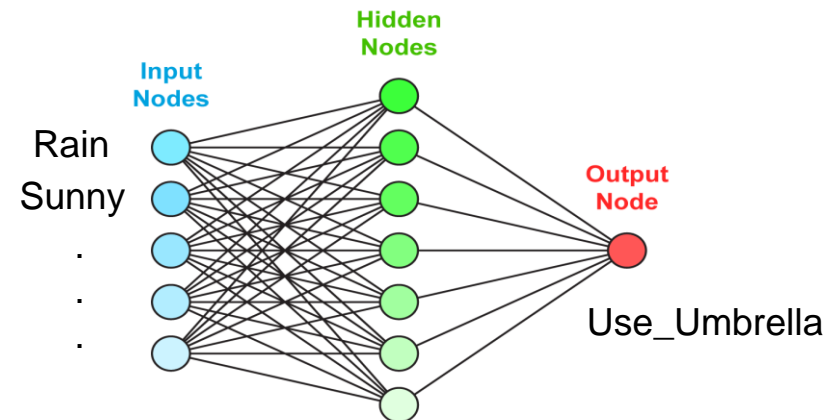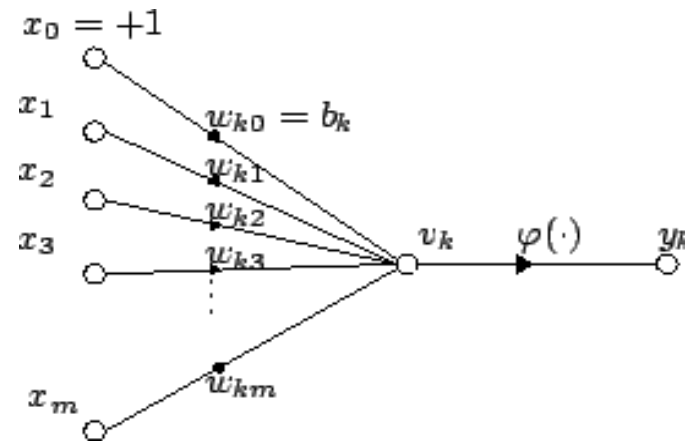
Connectionism

▸ History of connectionism: rose and fell for several times

- ▸ 1940s: pioneer work, e.g., McCulloch-Pitts model
- ▸ 1958: invention of perceptron (Rosenblatt)
- ▸ 1969: "Perceptron" published (Minsky & Papert)
  - ▸ Publicized key issues of perceptron (e.g., XOR)
- ▸ 1970s: AI winter
- ▸ 1980s: revival of connectionism
  - ▸ Hopfield net, BP algorithm
  - ▸ Rumelhart & McClelland (1986): Parallel Distributed Processing
- ▸ 1990s-2000s: overtaken in popularity by other methods
- ▸ 2010s: rise of deep learning
  - ▸ Since ~2012: dominates CV
  - ▸ Since ~2015: dominates NLP

▸

Connectionism
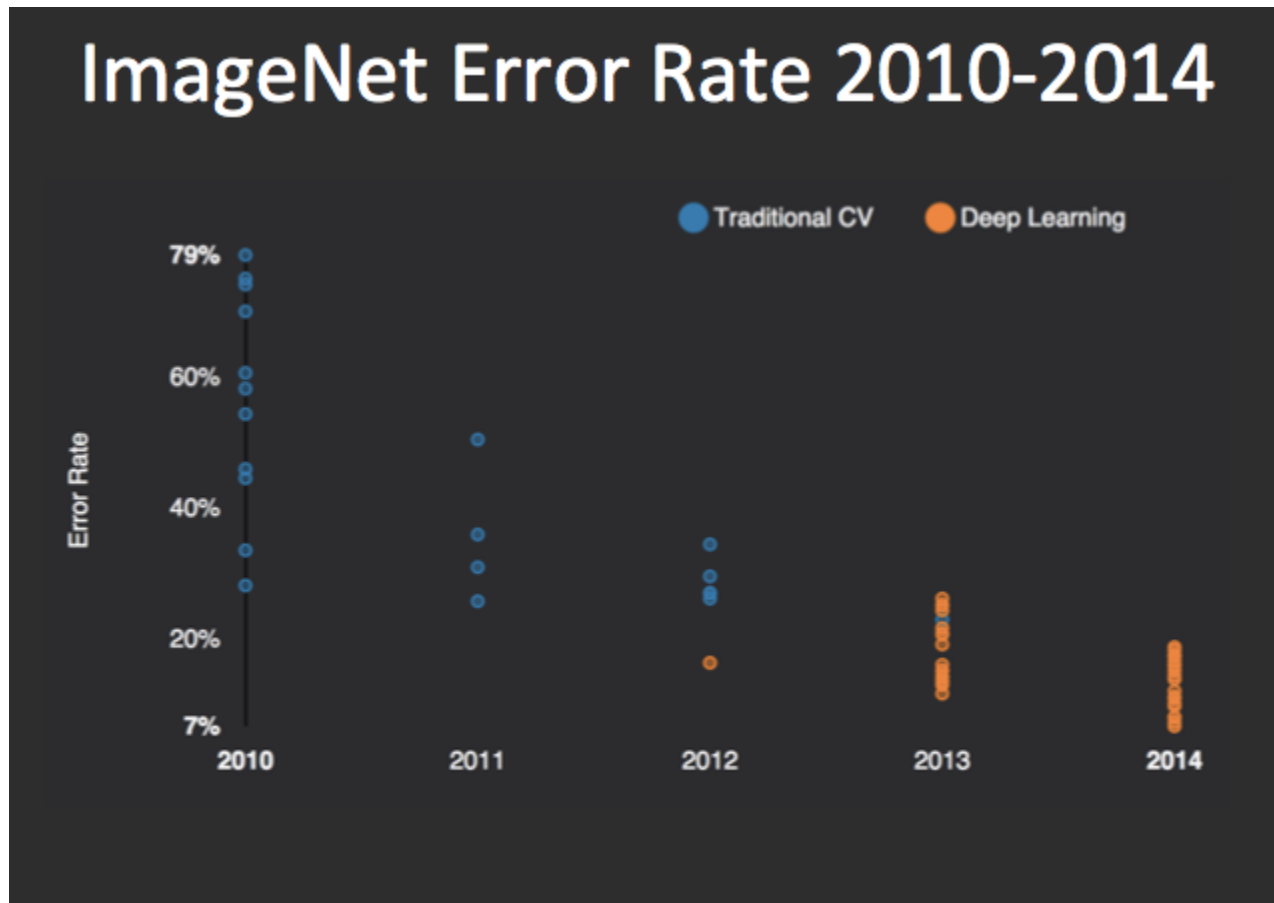
Statistical Approaches
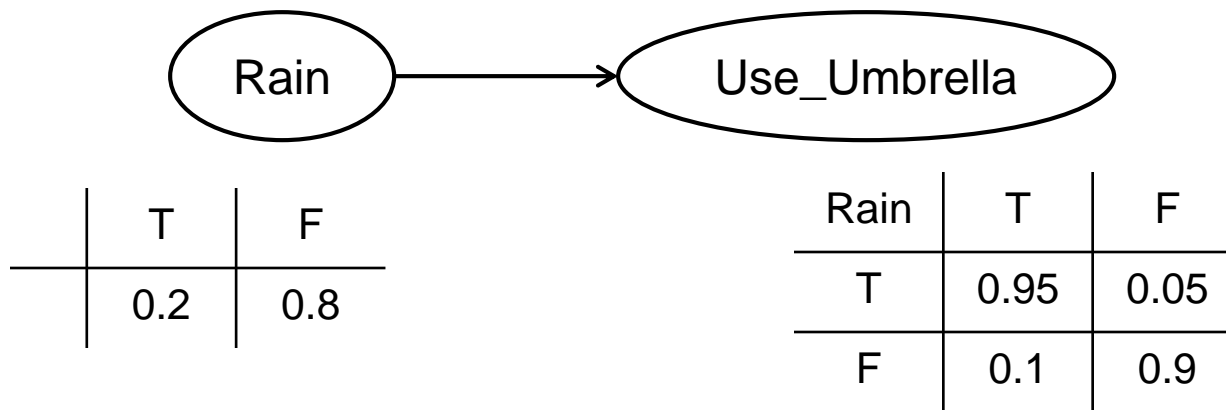
‣ Representing knowledge with probabilistic models

‣ Inference and learning is done by probabilistic inference

	T	F
	0.2	0.8

Rain	T	F
T	0.95	0.05
F	0.1	0.9

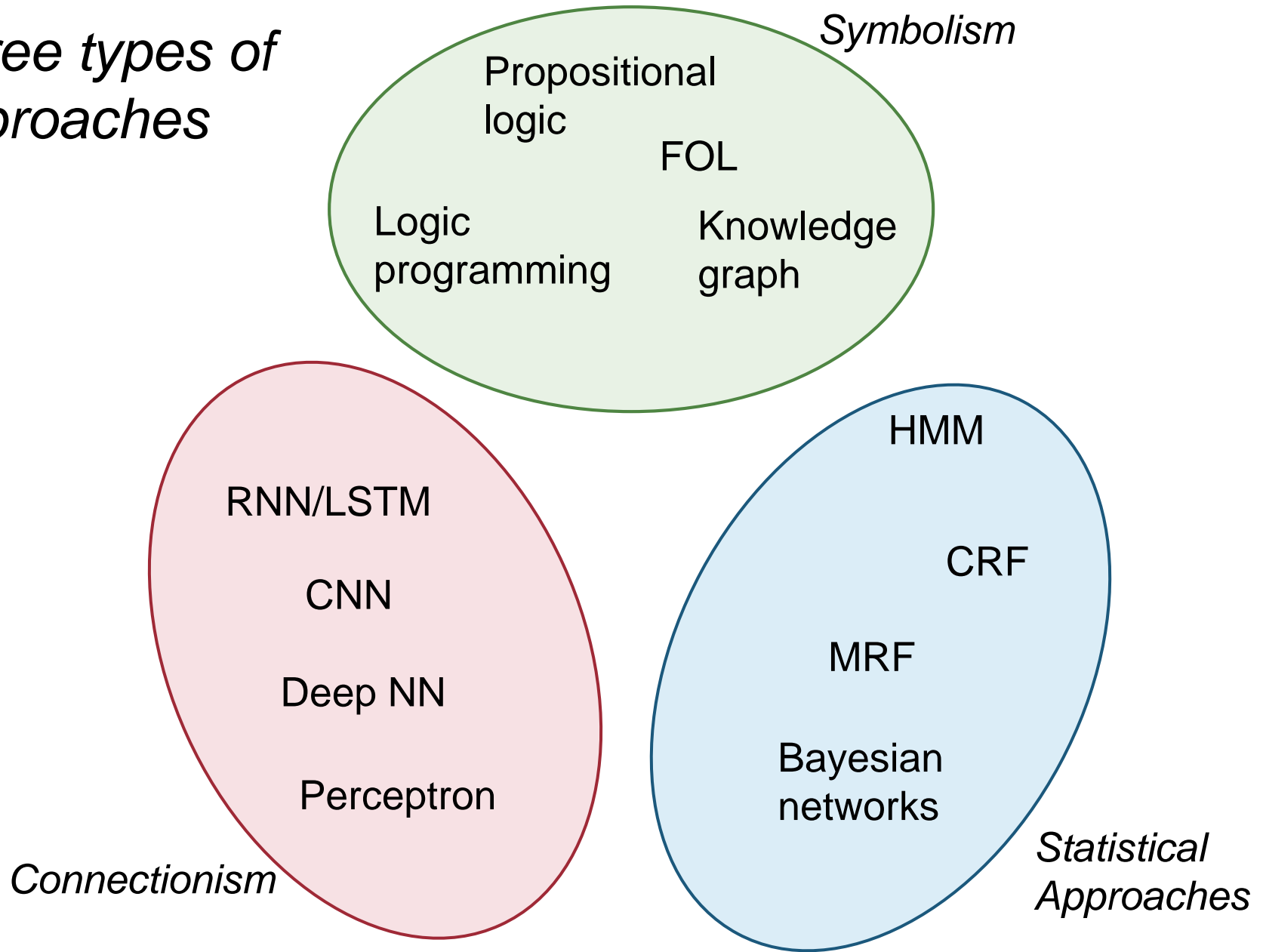# Statistical Approaches
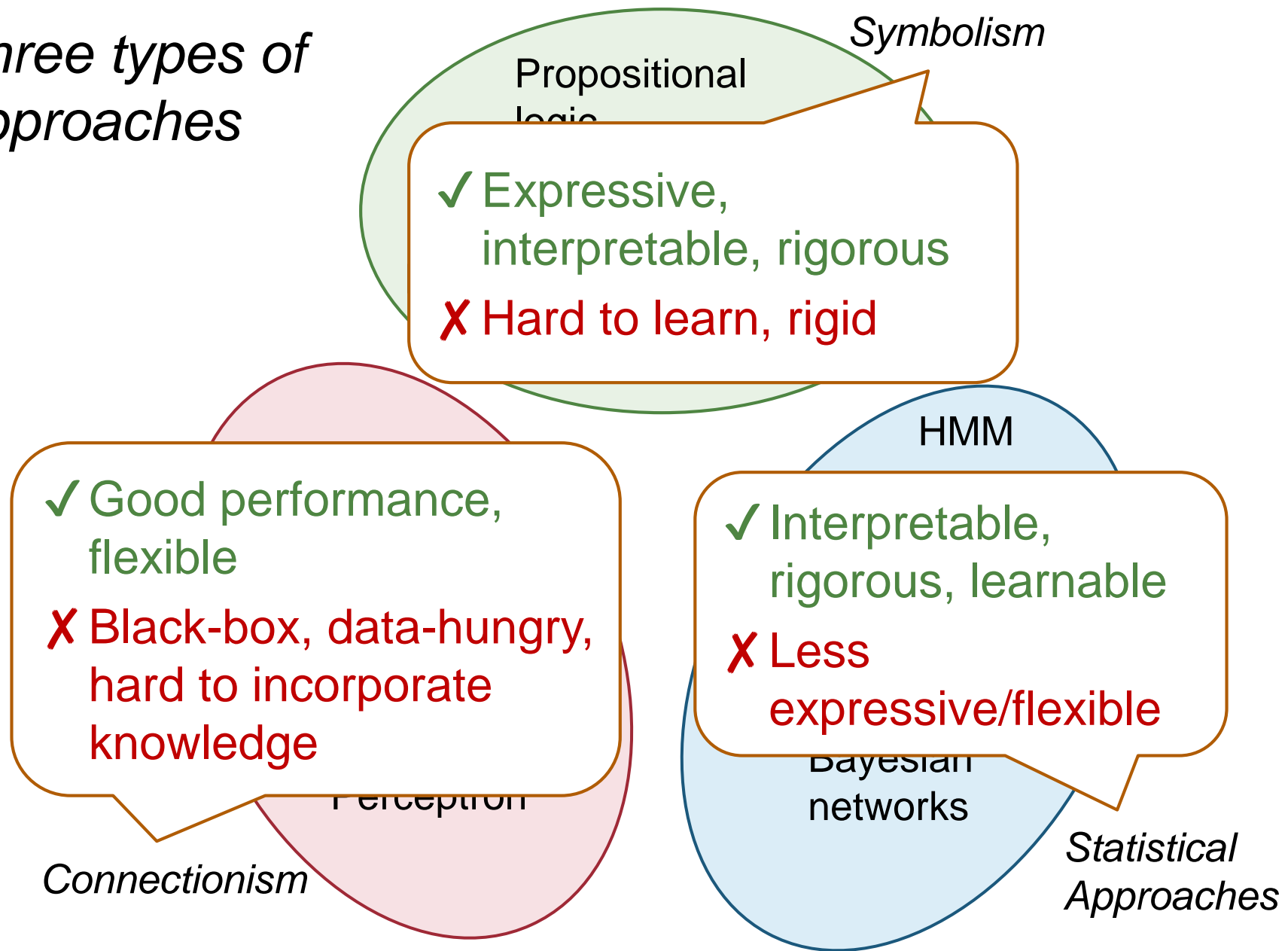
‣ History

  ‣ Become popular since 1990s

  ‣ Dominant during 2000s

  ‣ Overshadowed by deep learning in 2010s

Three types of approaches

Symbolism

- Propositional logic
- FOL
- Logic programming
- Knowledge graph

Connectionism

- RNN/LSTM
- CNN
- Deep NN
- Perceptron

Statistical Approaches

- HMM
- CRF
- MRF
- Bayesian networks

Three types of approaches

Symbolism

Propositional logic

✓ Expressive, interpretable, rigorous

✗ Hard to learn, rigid

HMM

✓ Interpretable, rigorous, learnable

✗ Less expressive/flexible

Bayesian networks

✓ Good performance, flexible

✗ Black-box, data-hungry, hard to incorporate knowledge

Perception

Connectionism

Statistical Approaches

Trends

Trends

Three types of approaches will be integrated.

Legend: Symbolism — Connectionism — Statistical

X-axis: 1950s, 1960s, 1970s, 1980s, 1990s, 2000s, 2010s, 2020s
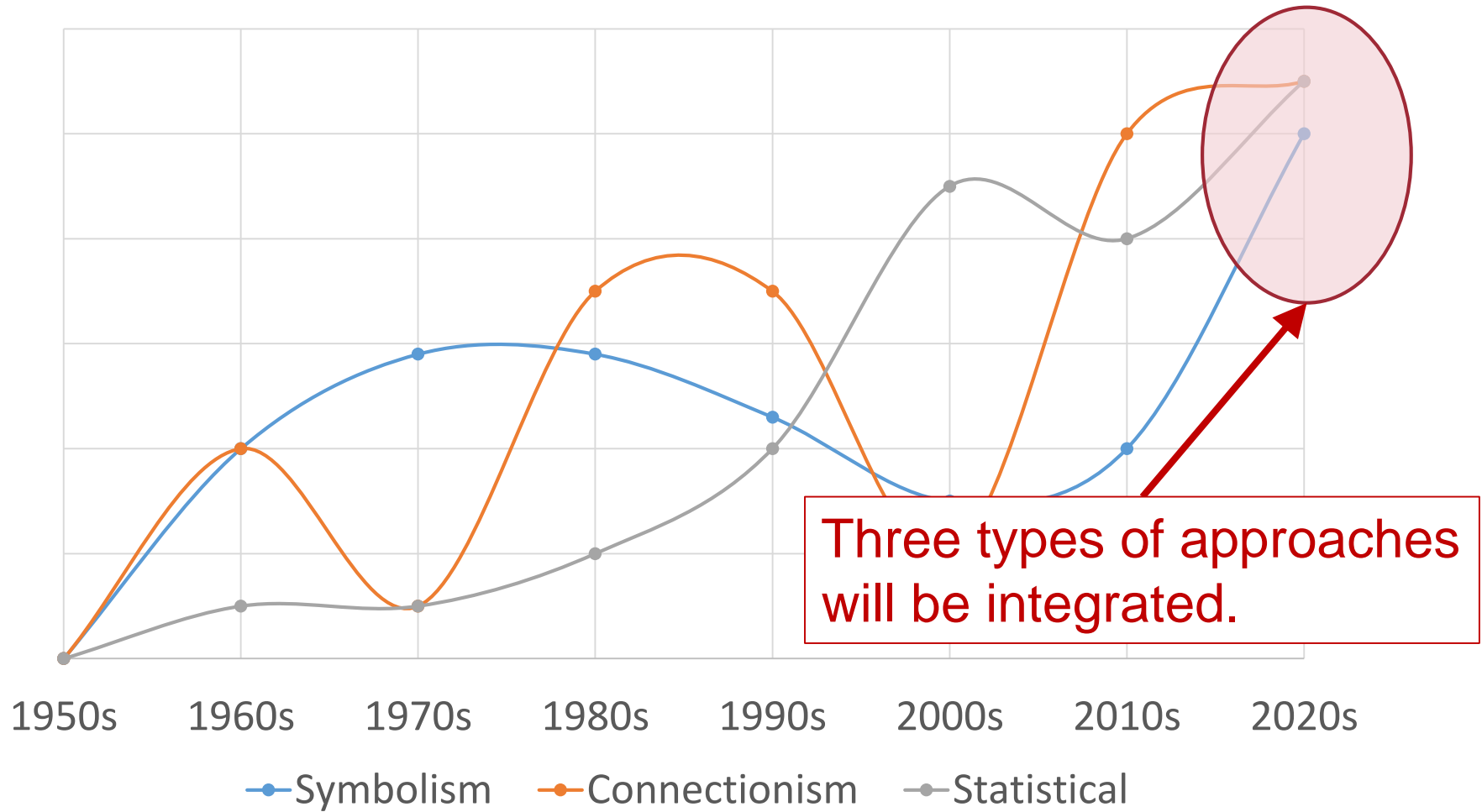
Course Overview

▸ Search

▸ Constraint satisfaction problems

▸ Game

▸ Propositional logic

▸ First-order predicate logic

▸ Probabilistic graphical models

▸ Probabilistic temporal models

▸ Probabilistic logics

▸ Introduction to natural language processing

▸ Introduction to machine learning

▸ Markov decision processes

▸ Reinforcement learning

▸