The Third AI Summer

2021 Taipei Summer School

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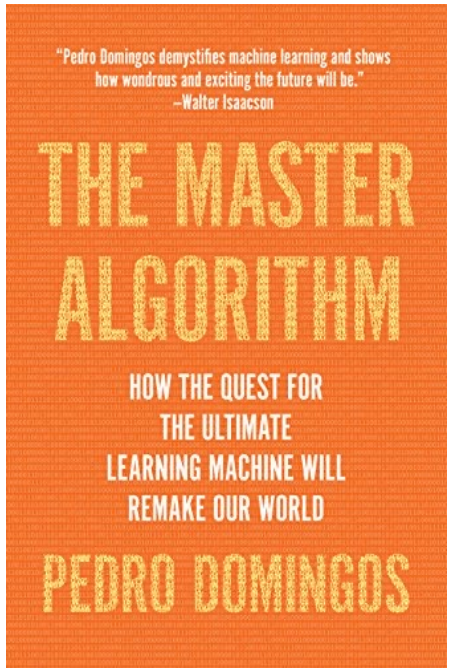
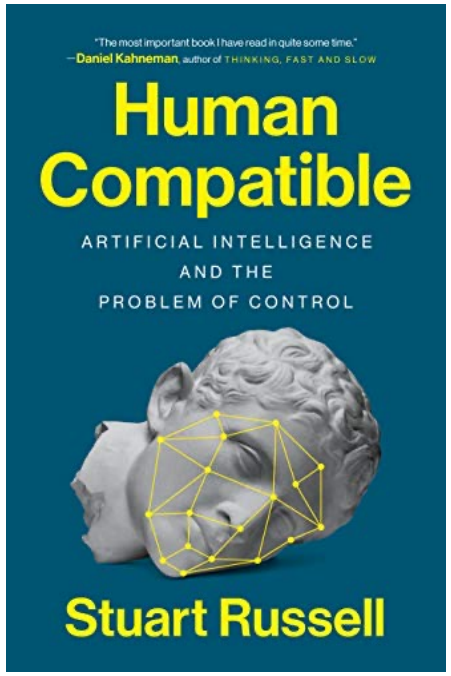
Big Picture?

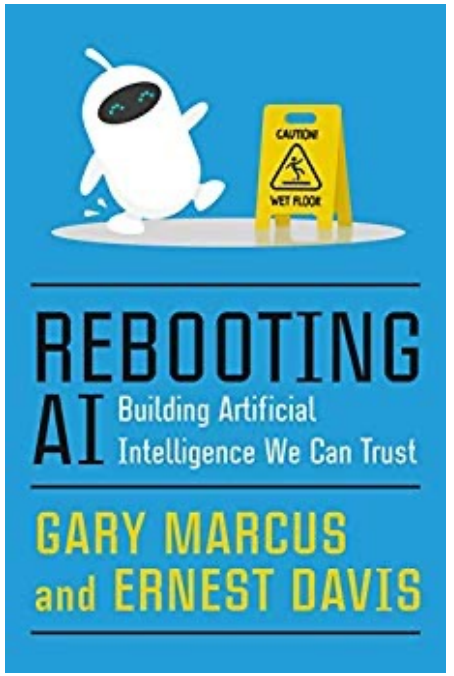
History?



Dangers?



Future?

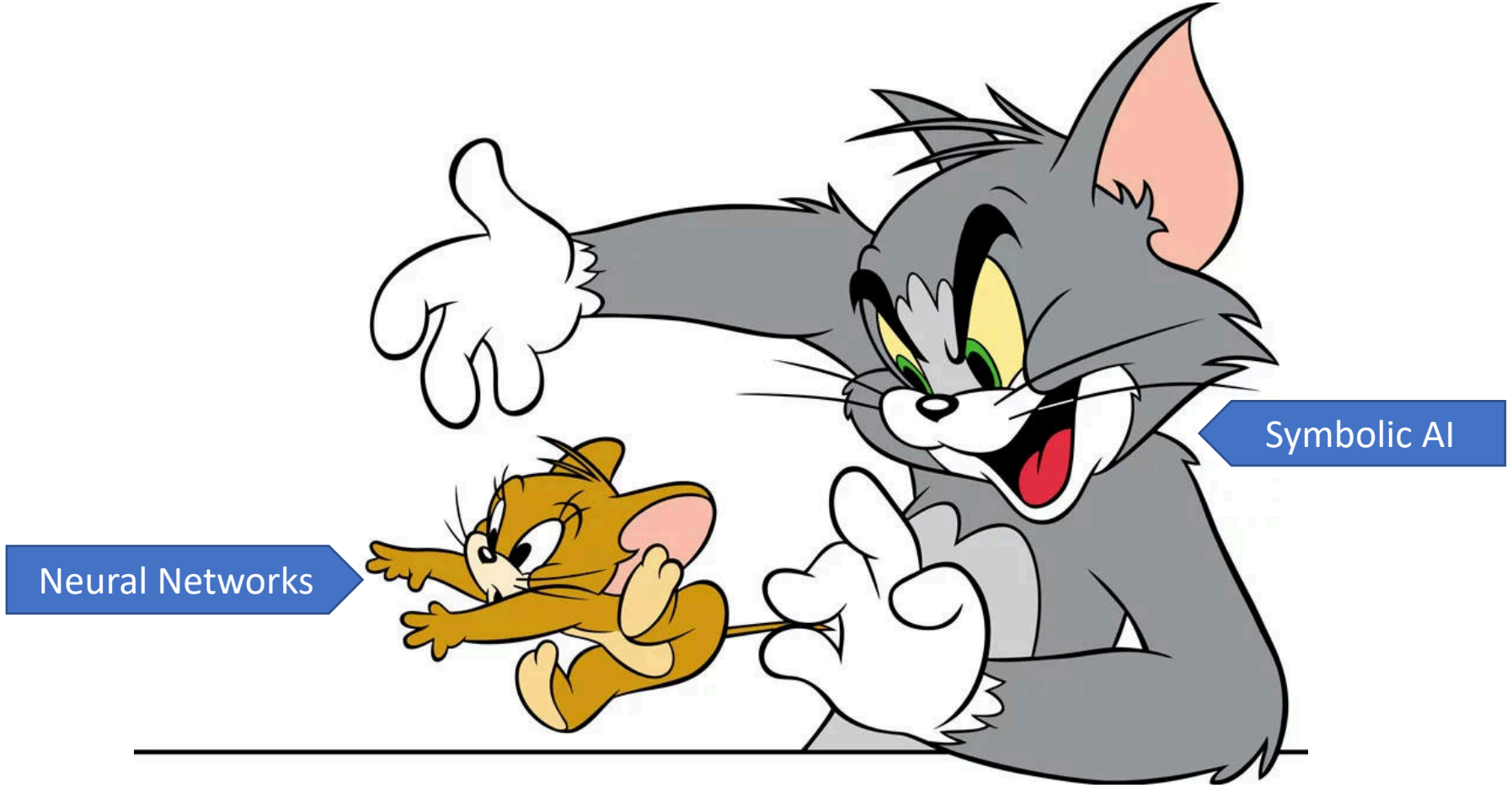


Three in One

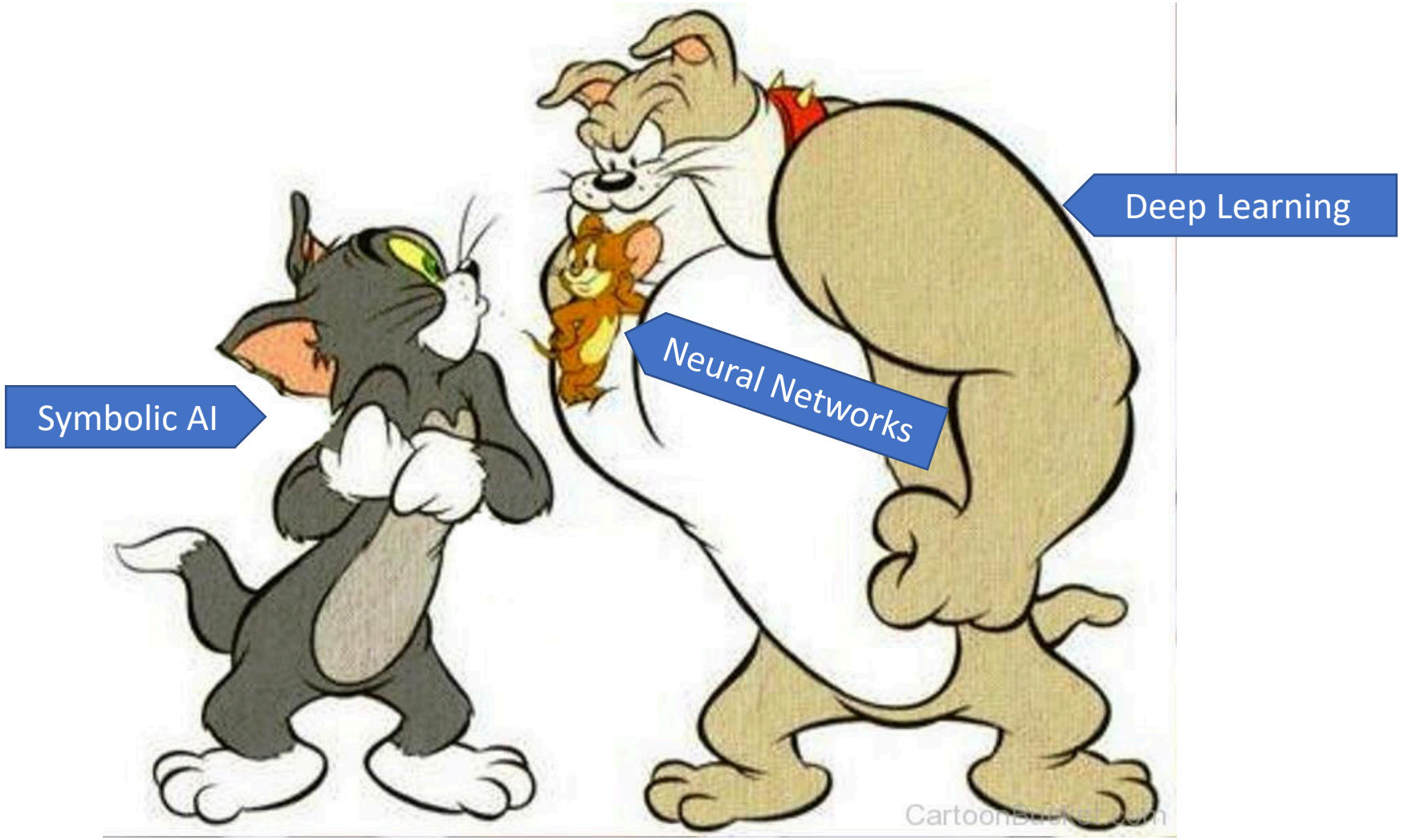
Part I: History of AI
Part II: AI for Bad
Part III: Future of AI

Part I: History of AI

The Cartoon History of AI

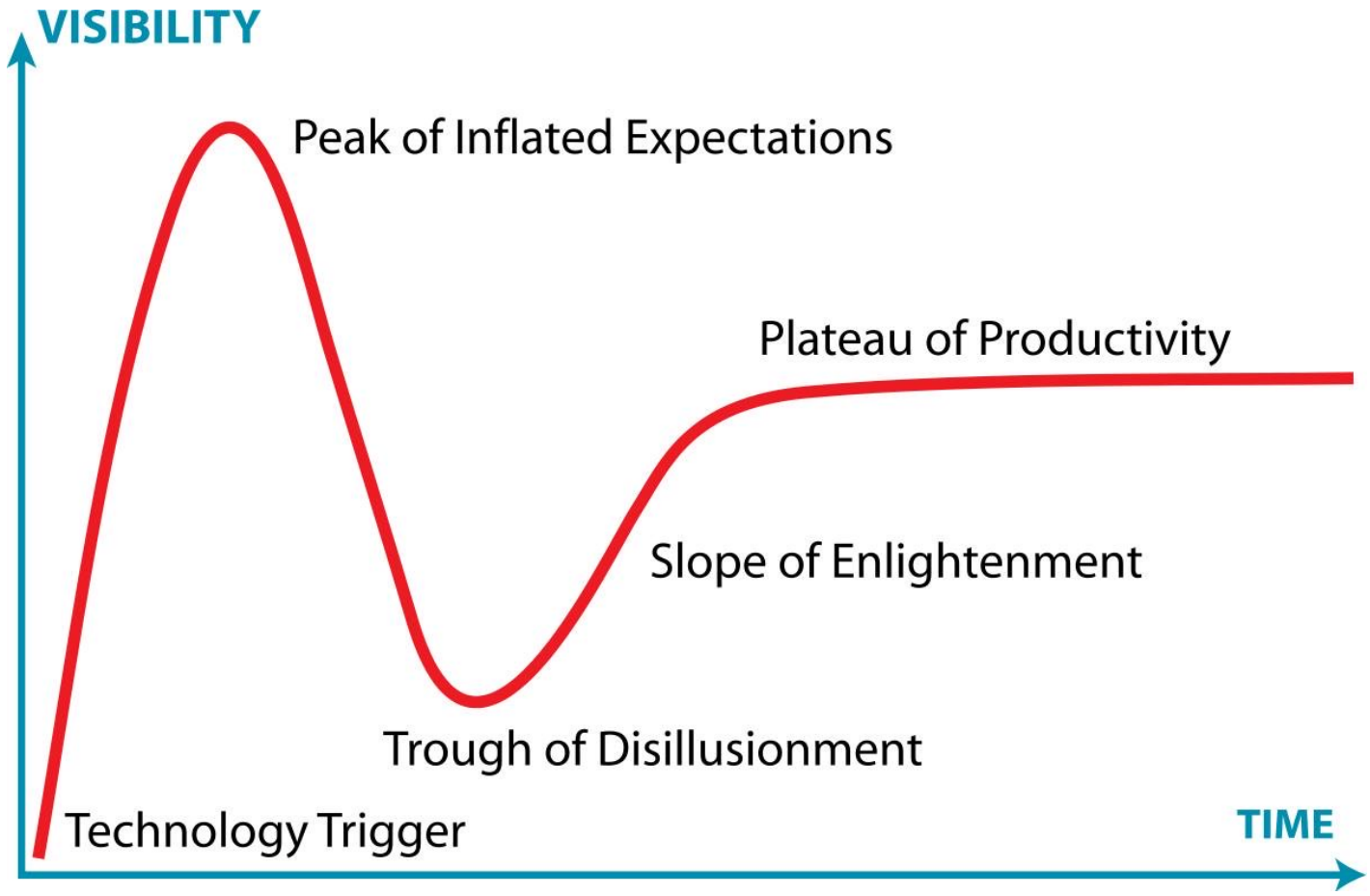


The Cartoon History of AI



AI Summers and Winters

- Enthusiasm, funding, and approaches to AI have been cyclical
- Enduring insights have blossomed in each summer



Gartner Hype Cycle

Overview

- Overview of a few of the enduring insights from each AI summer
- First Summer: Irrational Exuberance (1948 – 1966)
- First Winter (1967 – 1977)
- Second Summer: Knowledge is Power (1978 – 1987)
- Second Winter (1988 – 2011)
- Third Summer (2012 – ?)
- Why there might not be a third winter!

First Summer: Irrational Exuberance (1948 – 1966)

William Walter Grey's Tortoises

Insight 1: The Tortoise's Legacy

1A: Artificial Neural Networks

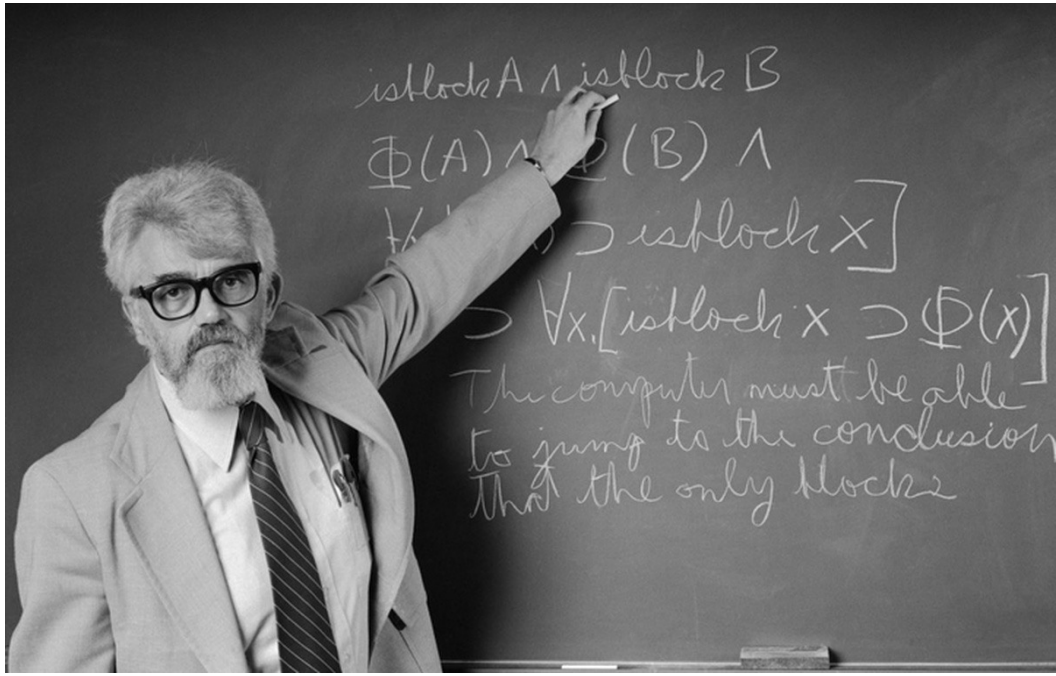
- McCulloch & Pitts neuron (1943)
- Perceptron: Single-layer learning (Rosenblatt 1958)
- Backpropagation: Multi-layer learning (Werbos 1974; Rummelhart, Hinton, Williams 1986)
- Parameter sharing: Convolutional networks (Fukushima 1980; LeCun 1989)

1B: Behavior = Agent + Environment

- Self-organizing machines (Turing 1948)
- Dynamic programming (Bellman 1957)
- Temporal difference learning (Witten 1977; Sutton & Barto 1981)
- Self-play (Samuels 1959; Tesauro 1992)

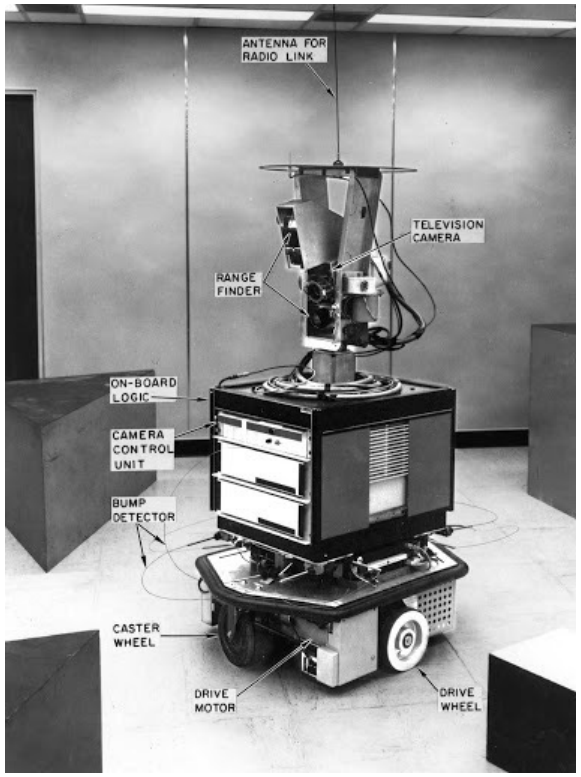
Insight 2: Declarative Knowledge Representation

- Logic Theorist: Mathematical theorem proving (Newell, Shaw, & Simon 1956)
- Advice Taker: Commonsense knowledge (McCarthy 1958)
- Semantic networks: Graph representations (Richens 1958)
- KL-ONE: Object-oriented logic (Brachman 1977)
- Bayesian networks: Probabilistic graph representations (Pearl 1985)
- Probabilistic relational models (Friedman et al. 1999)
- Knowledge graphs (Google 2012)



John McCarthy

Insight 3: Efficient Combinatorial Search



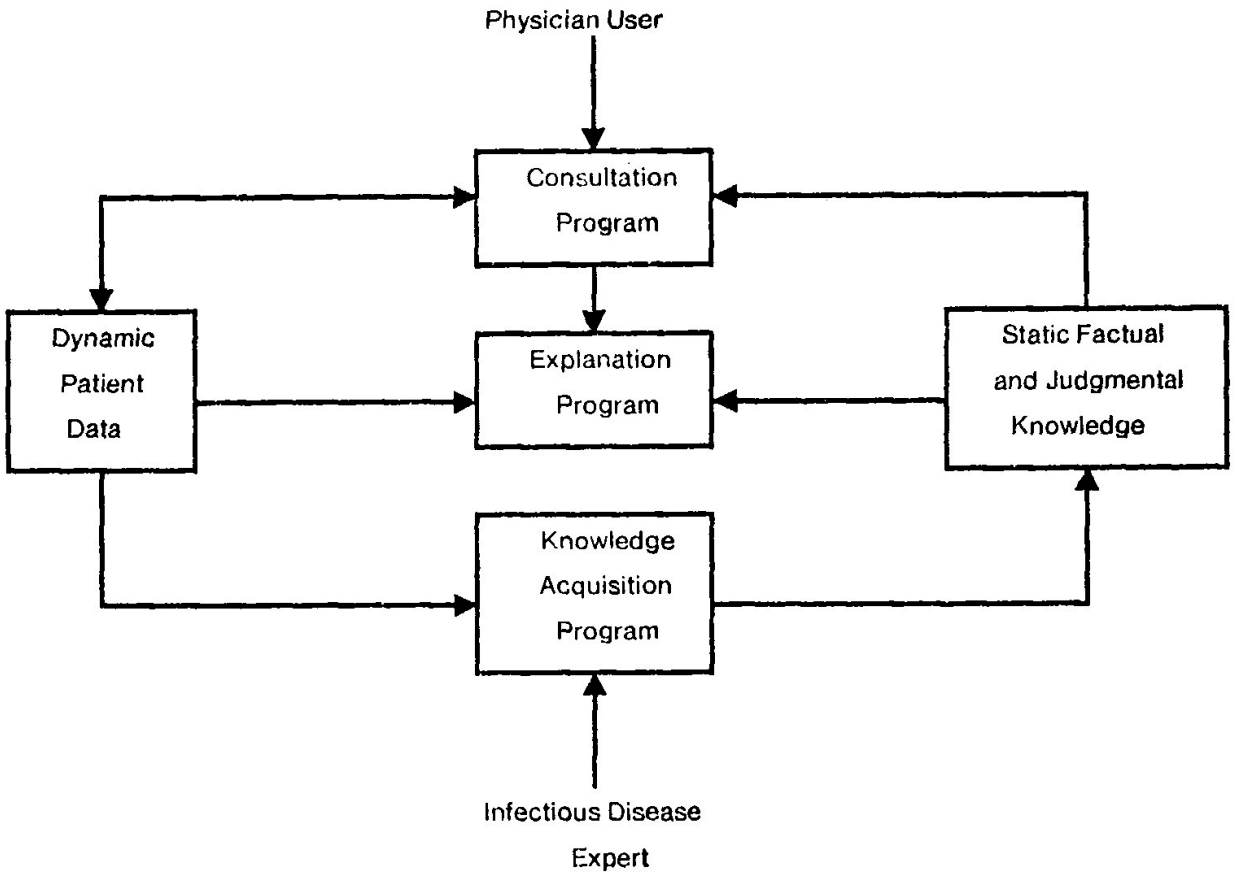
Shakey the Robot

- Game-tree search (Samuels 1952)
- Model finding (Davis, Putnam, Logemann, & Loveland 1962)
- A* (Hart, Nilsson, & Raphael 1968)
- Means-ends analysis (Newell, Shaw, & Simon 1960; Nilsson et al. 1969)
- Hierarchical planning (Tate 1975)
- Conflict-driven learning (Marquis-Silva & Sakallah 1996)
- Planning as satisfiability (Kautz & Selman 1992)
- Local search for SAT (Selman & Kautz 1993)
- Optimization with parity constraints (Ermon et al. 2013)

First Winter (1967 – 1977)

- DARPA funding cuts
  - Early failure of practical speech recognition and autonomous tank project
  - Mansfield Amendment (1969) mandated that DARPA stop funding basic undirected research
- United Kingdom: Lighthill Report (1973)
  - Criticized failure of AI outside of toy micro-worlds
  - Claimed AI could never tame combinatorial explosion of real-world domains
  - Complete dismantling of AI research in UK

Second Summer: Knowledge is Power (19[67]8 – 1987)



MYCIN (Shortliffe & Buchannan 1976)

Second Summer: Knowledge is Power (19[67]8 – 1987)

RULE035

PREMISE: ($AND (SAME CNTXT GRAM GRAMNEG)
(SAME CNTXT MORPH ROD)
(SAME CNTXT AIR ANAEROBIC))
ACTION: (CONCLUDE CNTXT IDENTITY BACTEROIDES TALLY .6)

IF: 1) The gram stain of the organism is gramneg, and
2) The morphology of the organism is rod, and
3) The aerobicity of the organism is anaerobic
THEN: There is suggestive evidence (.6) that the identity of the organism is bacteroides

MYCIN (Shortliffe & Buchannan 1976)

Insight: Modeling Expert Knowledge

Knowledge Engineering

- Dendral (Feigenbaum et al. 1968)
- MYCIN (Shortliffe & Buchannan 1975)
- XCON (Dermott 1978)

Knowledge Induction

- Decision tree learning (Quinlan 1986)
- Inductive logic programming (Muggleton 1991)
- Decision-theoretic expert systems (Heckerman, Horvitz, Nathwani 1992)

Edward Feigenbaum

Second Winter (1988 – 2011)

- Knowledge-engineered expert systems proved costly to maintain
- Collapse of market for specialized AI workstations
- Failure of Japan's Fifth-Generation AI effort based on Prolog hardware and software

Third Summer: Deep Learning (2012 – ?)

China’s Sputnik Moment

Third Summer: Deep Learning (2012 – ?)

Insight 1: Hierarchical Representation Learning

- While knowledge representation was all about capturing hierarchies…
- Traditional machine learning considered only two levels of representation: *feature* and *class*
- Deep learning's innovation was to learn hierarchical representations

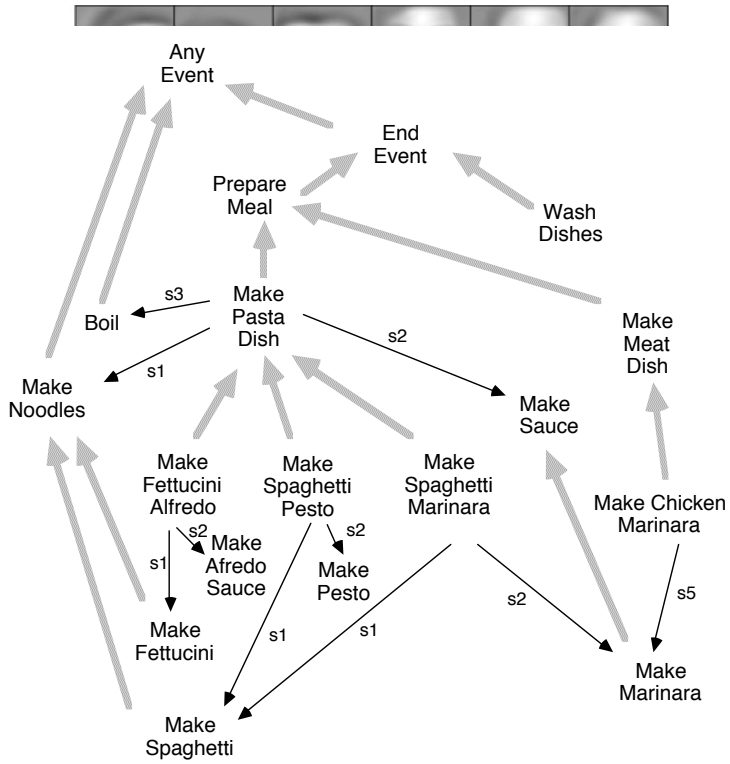


Image by Hofmann and Kautz (1998)

Insight 2: Similarity

- Deep learning representations directly support concept similarity
- Reasoning about similarity is vital for most real-world domains
- Not captured by probability!

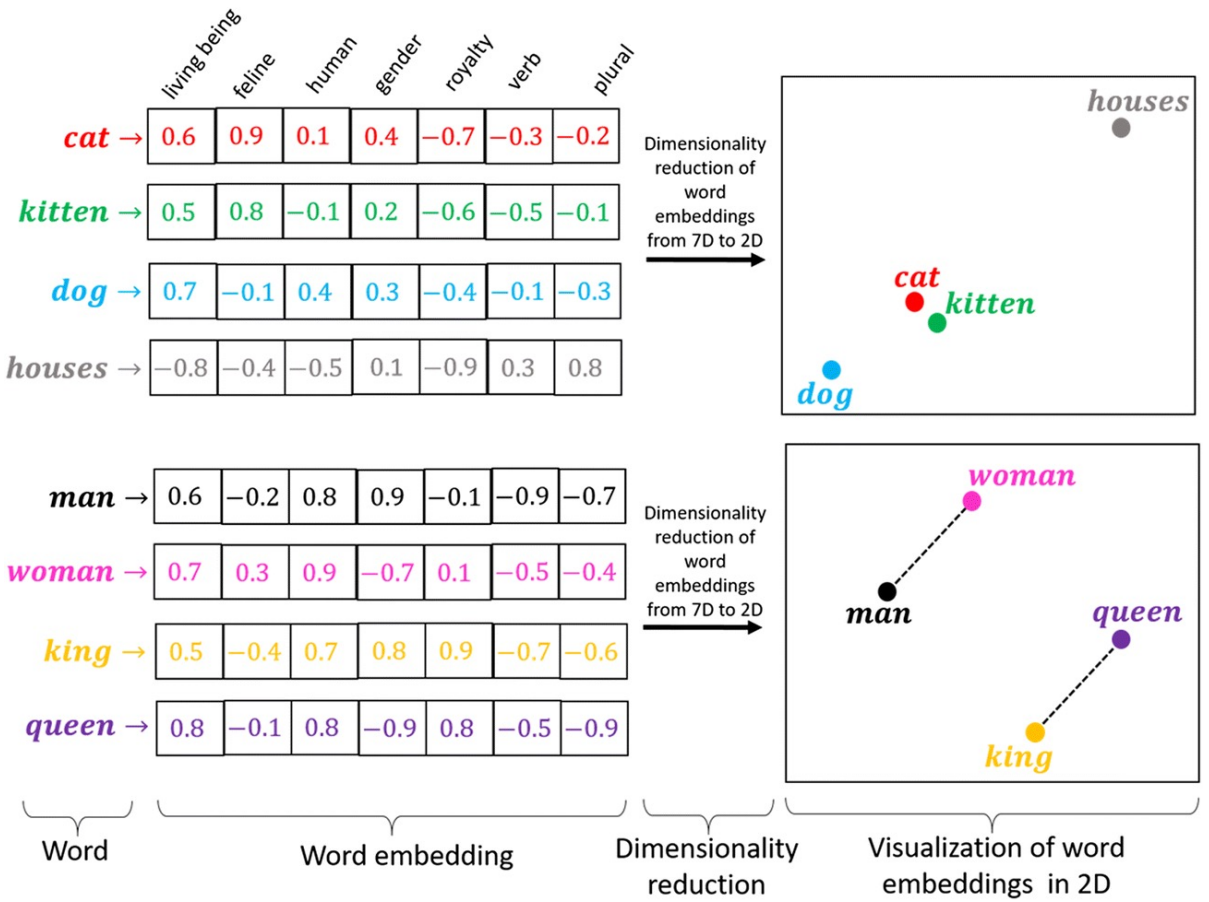


Image by David Rozado (2019)

Why Winter Might Not Return

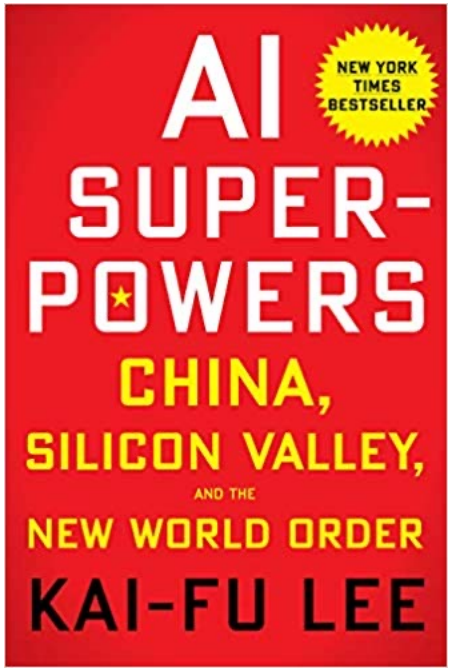
- The World's Unreasonable Predictability
- *Truly unreasonable* – who would think that "statistical monkeys at typewriters" could produce paragraphs of coherent prose?
  - Prompt: In a shocking finding, scientist discovered a herd of unicorns living in a remote, previously unexplored valley, in the Andes Mountains. Even more surprising to the researchers was the fact that the unicorns spoke perfect English.
  - GPT-2: … While examining these bizarre creatures the scientists discovered that the creatures also spoke some fairly regular English. Pérez stated, "We can see, for example, that they have a common 'language,' something like a dialect or dialectic." Dr. Pérez believes that the unicorns may have originated in Argentina, where the animals were believed to be descendants of a lost race of people who lived there before the arrival of humans in those parts of South America.

Non-Human Intelligence

- Deep learning can create a simulacra of human intelligence, *without being anything like* human intelligence
- Compare with octopus intelligence
  - Could a creature with a lifespan of 3 years, which cannibalizes the male after mating, and spawns 70,000 offspring ever really understand you?
- But an octopus' brain is more like a human brain than is any deep learning systems!

It Just Works

- Despite being utterly unlike human intelligence, today's AI can drive powerful applications for good or for evil
- AI supremacy == world supremacy?
- Growing number of workshops and conference tracks on AI for Good
- So let's turn to …



Part II: AI for Bad

Overview

- Dangerous applications are enabled by third summer AI
- Threats most prominent in the news might not be the worst!
- Three examples:
  - Face recognition
  - Fake news
  - Autonomous weapons

In the News: Keeping Your Face Private

Facebook to Pay $550M to Settle Class Action Case Over Facial Recognition

Author:
Elizabeth Montalbano

January 30, 2020
/ 7:05 am

2 minute read

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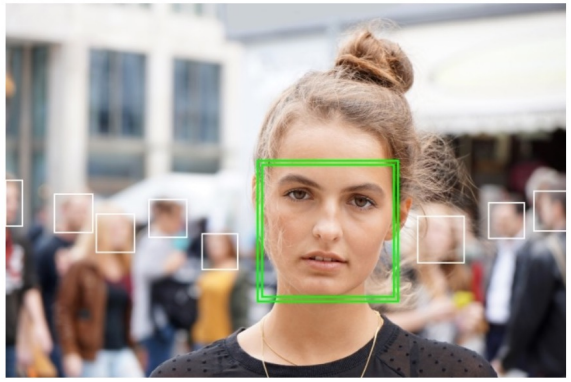

The settlement in a case over the social network's Tag Suggestions feature is the latest financial blow the company has taken over its handling of user privacy.

San Francisco Bans Facial Recognition Technology

Attendees interacting with a facial recognition demonstration at this year's CES in Las Vegas. Joe Buglewicz for The New York Times

By Kate Conger, Richard Fausset and Serge F. Kovaleski

May 14, 2019

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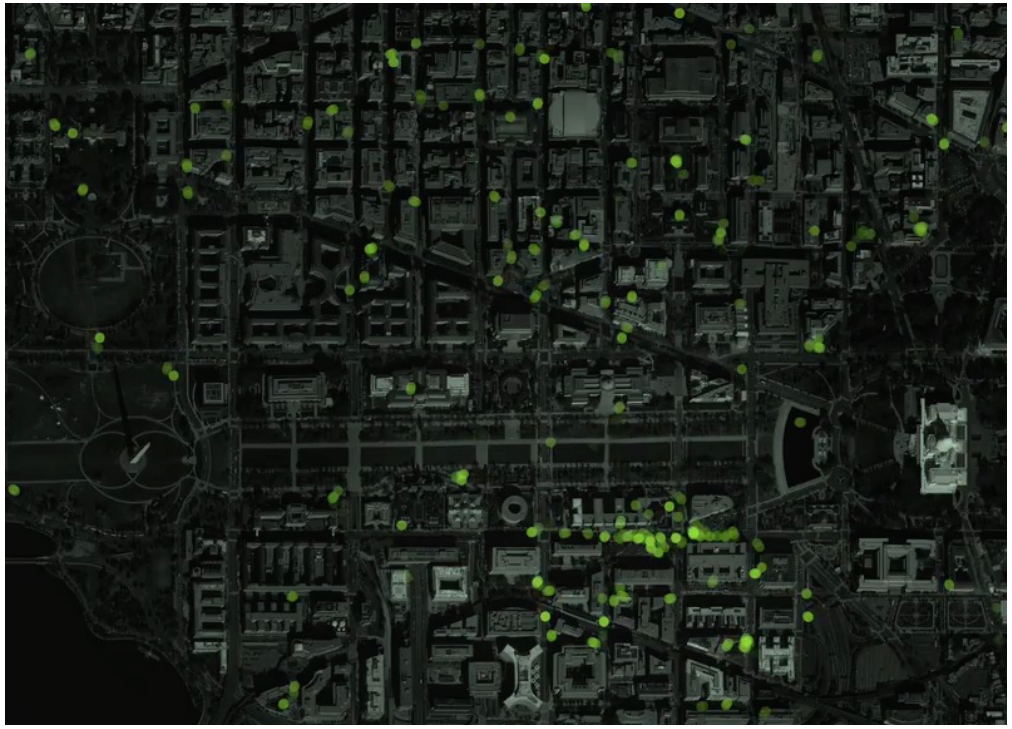
SAN FRANCISCO — San Francisco, long at the heart of the technology revolution, took a stand against potential abuse on Tuesday by banning the use of facial recognition software by the police and other agencies.

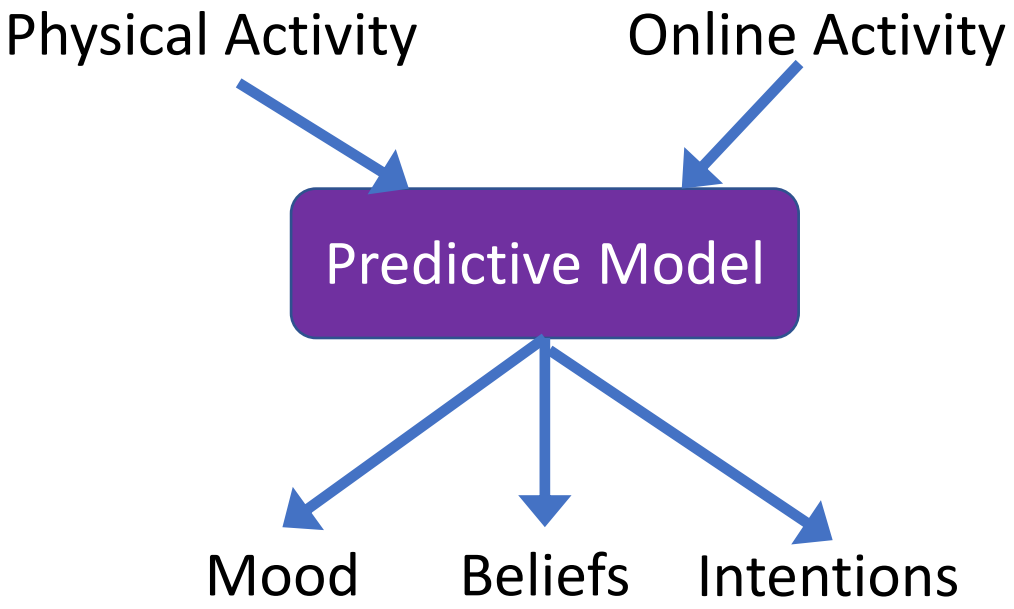
In the News: Keeping Your Face Private

- Face Recognition == Threat
- But your mobile phone apps are giving your location away – no AI needed!
- A. Sadilek, H. Kautz & J. P. Bigham (2012), Finding Your Friends and Following Them to Where You Are
- L. Liao, D. J. Patterson, D. Fox, and H. Kautz (2007), Learning and Inferring Transportation Routines



New York Times, “Twelve Million Phones, One Dataset, Zero Privacy”, Dec. 19, 2019

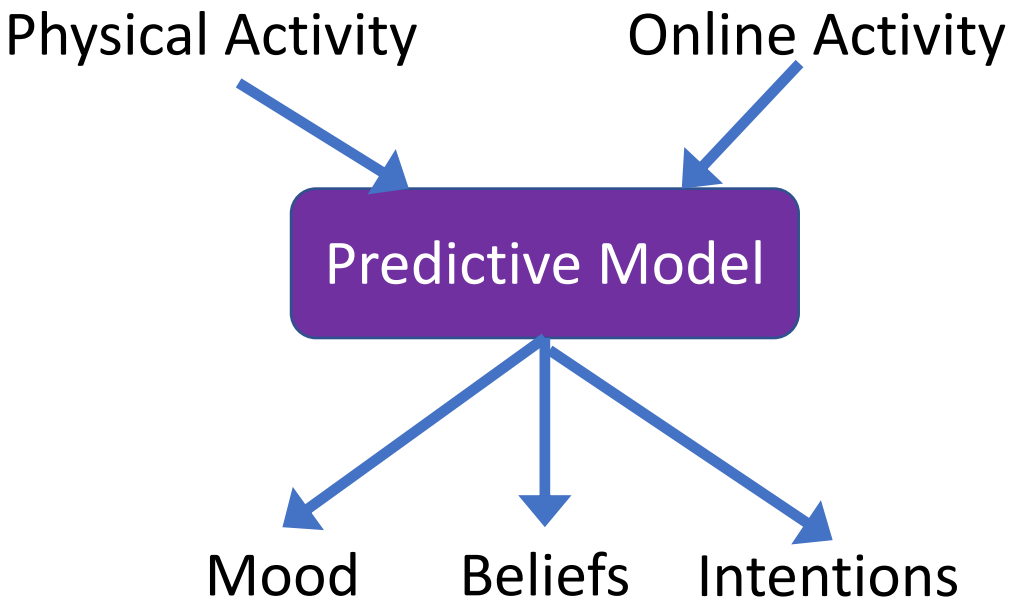
Greater Threat: Keeping Your Mind Private



Can be used for GOOD

Detecting Low Self-Esteem in Youths from Web Search Data (Zaman, Acharyya, Kautz, & Silenzio 2019)

Greater Threat: Keeping Your Mind Private



But this is about BAD…

Greater Threat: Keeping Your Mind Private

Xinjiang Re-Education Camp

- Totalitarian states are inefficient when they target entire demographic groups for repression
  - Cost
  - Radicalization
  - International pressure
- AI enables precise micro-targeting of wrong-thinkers

In the News: Fake News

Artificial intelligence (AI)

New AI fake text generator may be too dangerous to release, say creators

The Elon Musk-backed nonprofit company OpenAI declines to release research publicly for fear of misuse

▲ The AI wrote a new passage of fiction set in China after being fed the opening line of Nineteen Eighty-Four by George Orwell (pictured). Photograph: Mondadori/Getty Images

But Fake News is Old News

$50,000 REWARD.—WHO DESTROYED THE MAINE?—$50,000 REWARD.

EDITION FOR GREATER NEW YORK

NEW YORK JOURNAL

AND ADVERTISER.

NO. 3,372. —NEW YORK, THURSDAY, FEBRUARY 17, 1898.—16 PAGES. PRICE ONE CENT

DESTRUCTION OF THE WAR SHIP MAINE WAS THE WORK OF AN ENEMY

$50,000!

$50,000 REWARD!

For the Detection of the Perpetrator of the Maine Outrage!

Assistant Secretary Roosevelt Convinced the Explosion of the War Ship Was Not an Accident.

The Journal Offers $50.000 Reward for the Conviction of the Criminals Who Sent 258 American Sailors to Their Death. Naval Officers Unanimous That the Ship Was Destroyed on Purpose.

$50,000!

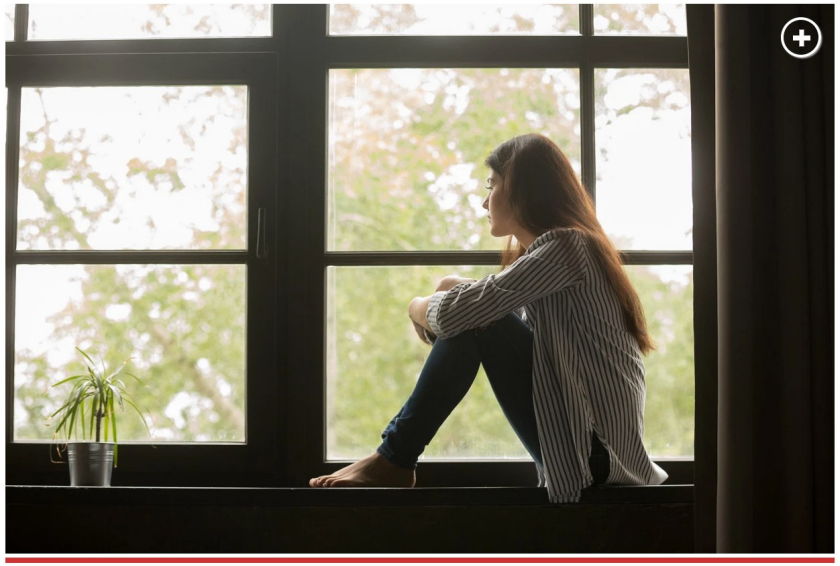
$50,000 REWARD!

For the Detection of the Perpetrator of the Maine Outrage!

Greater Threat: Fake Friends

1 in 5 millennials are lonely and have ‘no friends’: survey

By Hannah Frishberg August 2, 2019 | 5:19pm



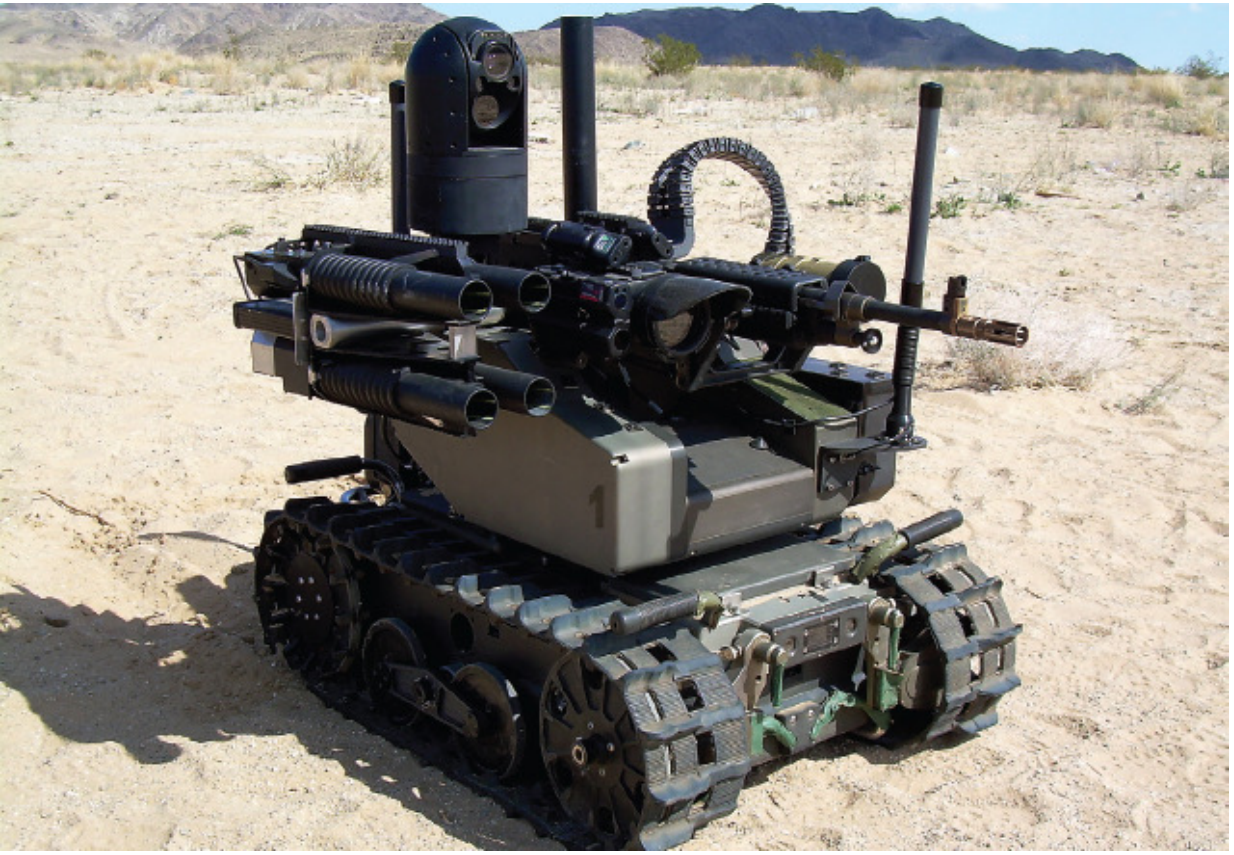
Suicide is Gen Z's second-leading cause of death, and it's a worse epidemic than anything millennials faced at that age

Andy Kiersz and Allana Akhtar Oct 17, 2019, 12:09 PM

- The suicide rate for people aged 10 to 24 increased by 56% between 2007 to 2017, according to new data from the CDC.
- For children aged 10 to 14, the suicide rate tripled between 2007 to 2017 after years of decline.
- Suicide had increased among millennials, but the data suggests Gen Z might be most at risk for mental illness.

Greater Threat: Fake Friends

In the News: Autonomous Weapons



Modular Advanced Armed Robotic System
Quentic North America

Defense Innovation Board AI Ethical Guidelines

- Human beings should exercise appropriate levels of judgment and remain responsible for the development, deployment, use and outcomes of DOD AI systems.
- Does this mean human-in the loop?

Ethical Military Use of AI != Human in the Loop

Larry Lewis

- Senior Advisor for the State Department on Civilian Protection, Obama administration
- Member US Delegation for UN Deliberations on Lethal Autonomous Weapons Systems
- Artificial intelligence may make weapons systems and the future of war relatively less risky for civilians than it is today

Killer robots reconsidered: Could AI weapons actually cut collateral damage?

By Larry Lewis, January 10, 2020

The Bulletin of the Atomic Scientists, 10 Jan 2020

Greater Threat: Autonomous Weapons of Environmental War: Deep Sea Mining

The Atlantic Sign In Subscribe

History's Largest Mining
About to Begin

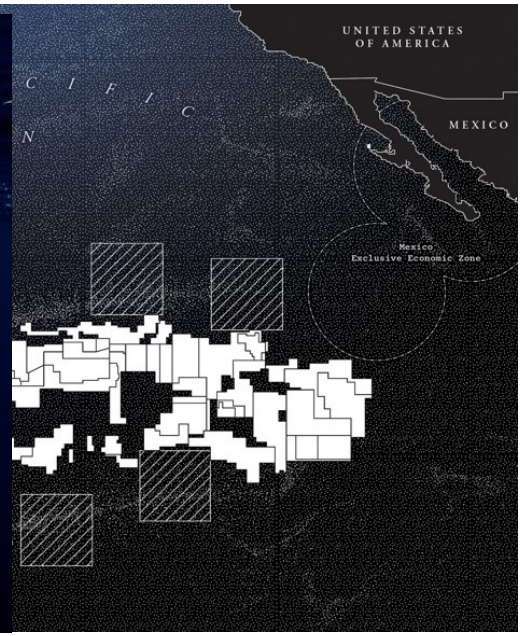
It's underwater—and the consequences are uni

Elicia Edijanto

Story by Wil S. Hylton | JANUARY/FEBRUARY 2020 ISSUE | SCIENCE

AI is also a big part of the defense of oceans!

Woods Hole "Sentry" UAV



The Mariana Trench

Part III: Future of AI

The Marcus-LeCun Twitter War

- *Editor's note: artistic license has been applied to the quotations*

- Marcus: AI systems need to perform symbolic reasoning!
- LeCun: Yes, been working on that.

Overview

- Violent agreement on the need to bring together the neural and symbolic traditions
- How do neuro and symbol systems interact?
  - symbolic Neuro symbolic
  - Symbolic[Neuro]
  - Neuro ; Symbolic
  - Neuro: Symbolic → Neuro
  - $\text{Neuro}_{\text{Symbolic}}$
  - My favorite: Neuro[Symbolic]

symbolic Neuro symbolic

- Deep learning SOP (Standard Operating Procedure)

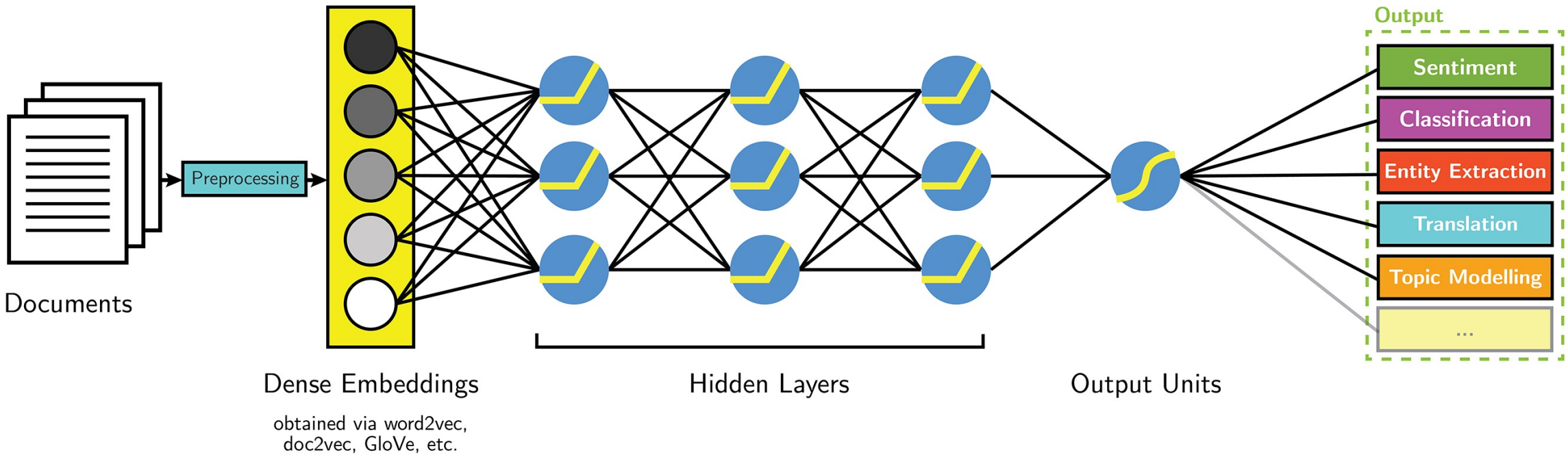
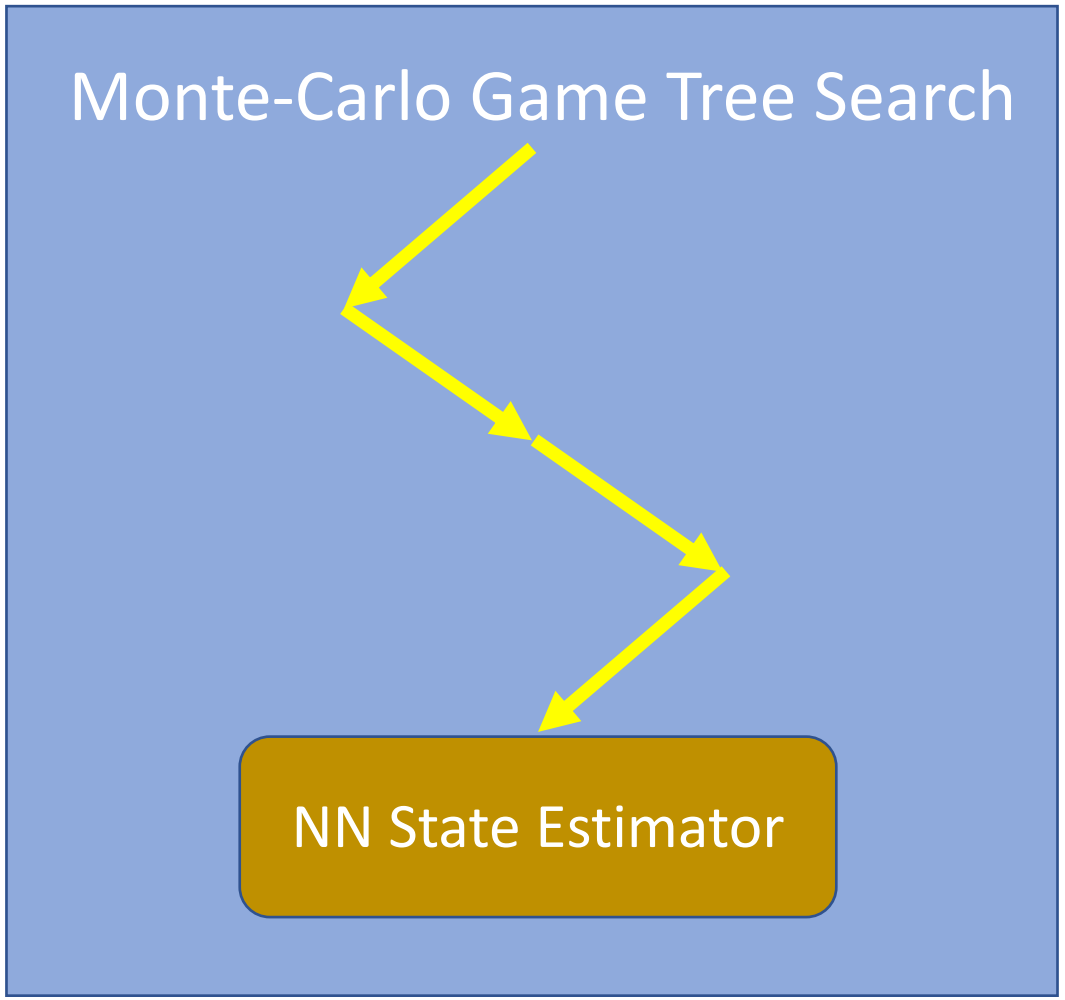


Image from https://blog.aylien.com/

Symbolic[Neuro]

- Neural pattern recognition subroutine within a symbolic problem solver
- AlphaGo (2016)
- AlphaZero (2017)



Symbolic[Neuro]

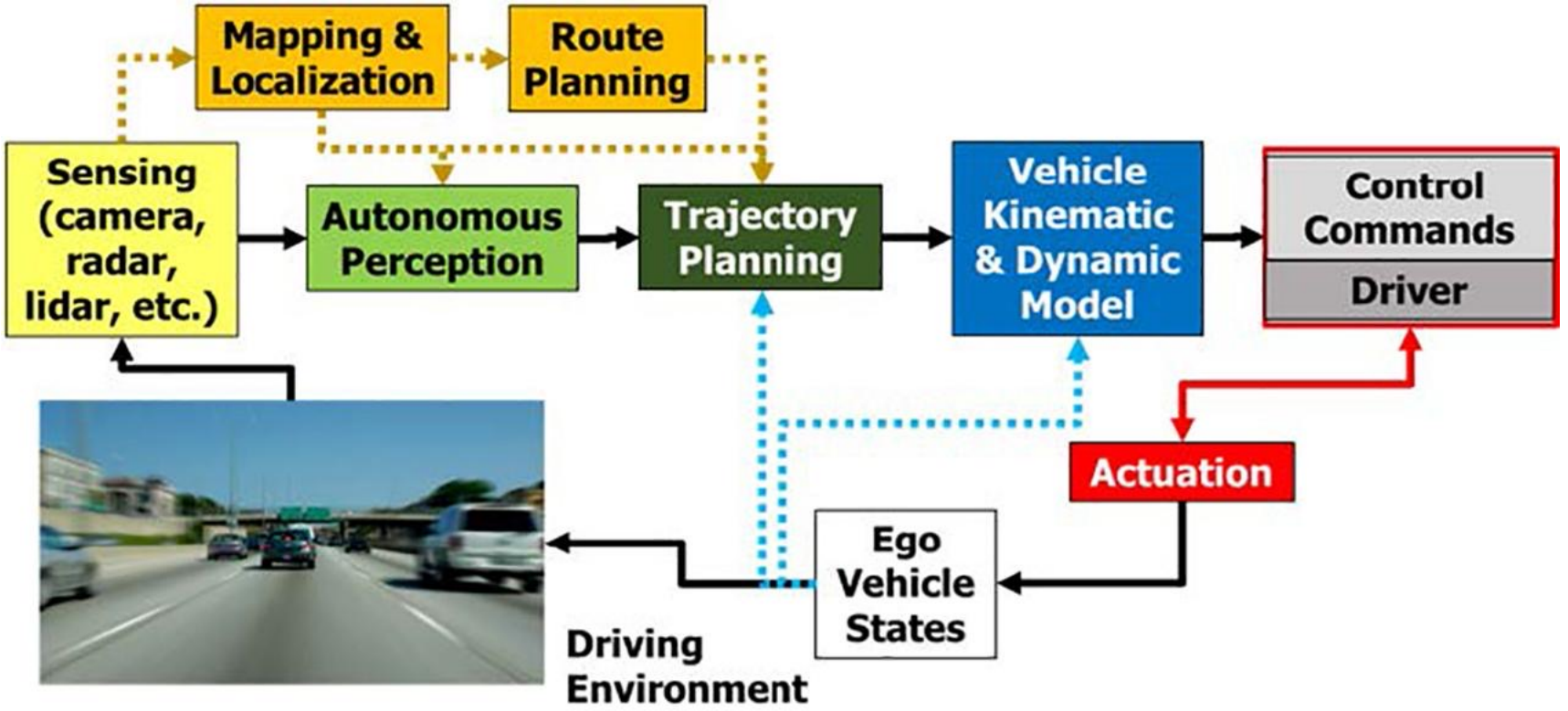
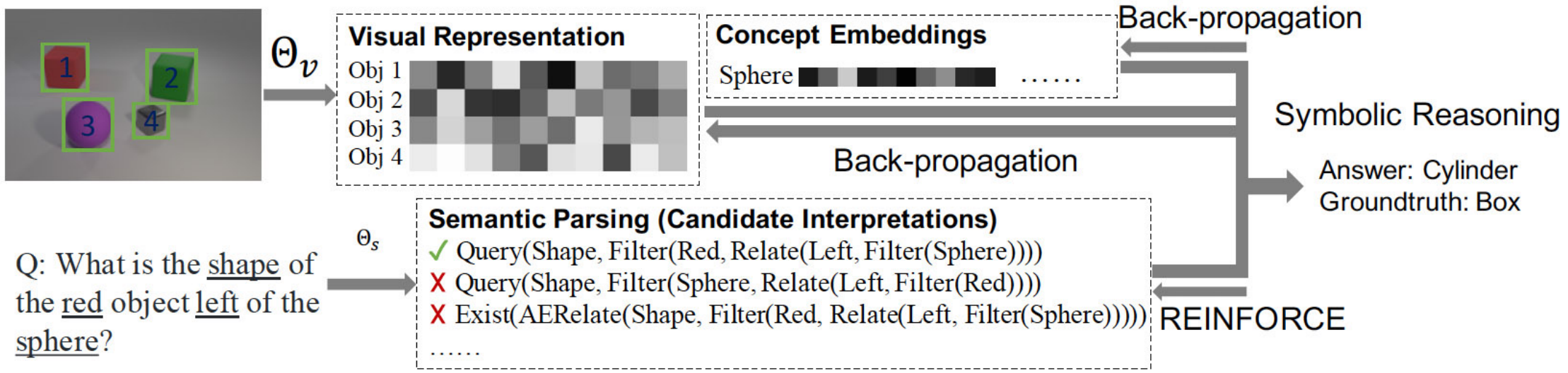


Image from https://deepdrive.berkeley.edu/

Neuro ; Symbolic

- Cascade from neural network into symbolic reasoner
- Neuro-Symbolic Concept-Learner (Mao, Gan, Kohli, Tenenbaum, Wu 2019)



Neuro: Symbolic → Neuro

- *Training* compiles away symbolic rules
  - Rule A → B becomes an input-output training pair (A, B)
  - Deep Learning for Symbolic Mathematics (Lample & Charton 2020)
- But no guarantee of correctness

input: $\int x^n \, dx$ output: $(1/n+1)\, x^{n+1}$

Neuro$_{\text{Symbolic}}$

- Symbolic rules are used as *templates* for structures within the neural network
  - Tensor Product Representations (Smolensky et al. 2016)
  - Logic Tensor Networks (Serafina & Garcez 2016)
- Demonstrated for encoding abstraction and part-of hierarchies
- Open: What about true combinatorial reasoning by cases?

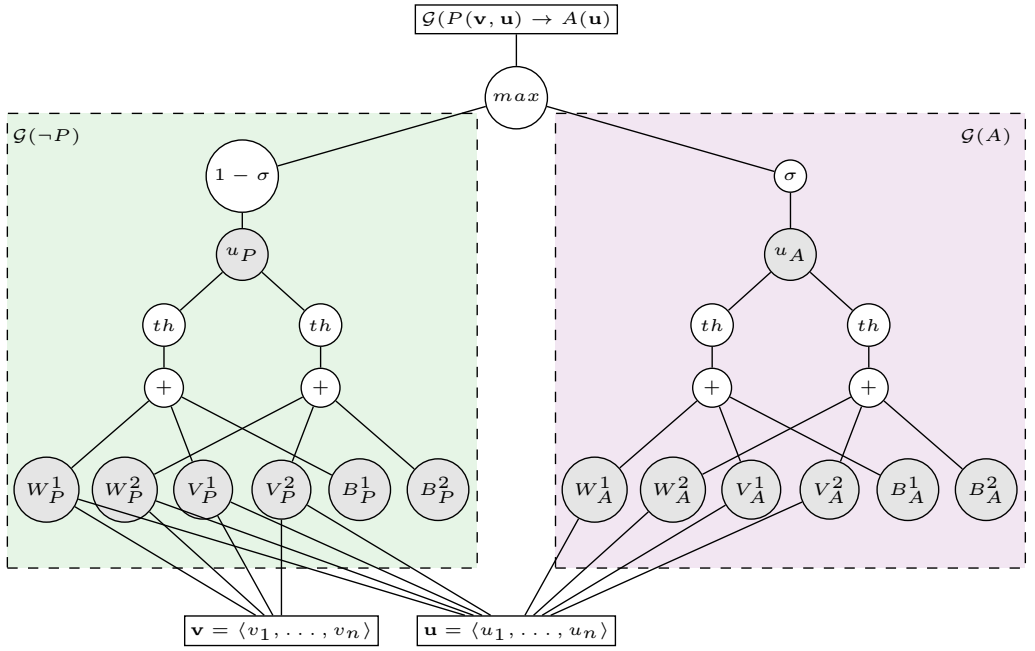
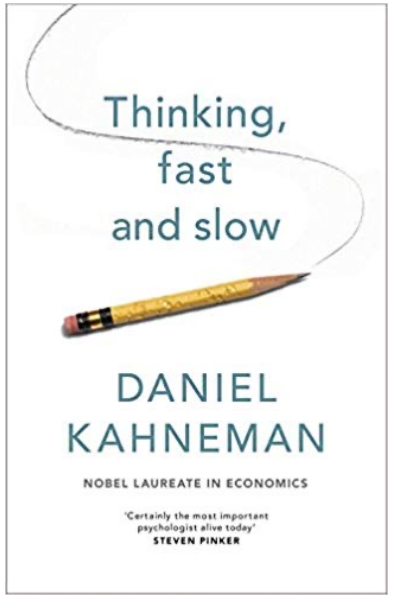
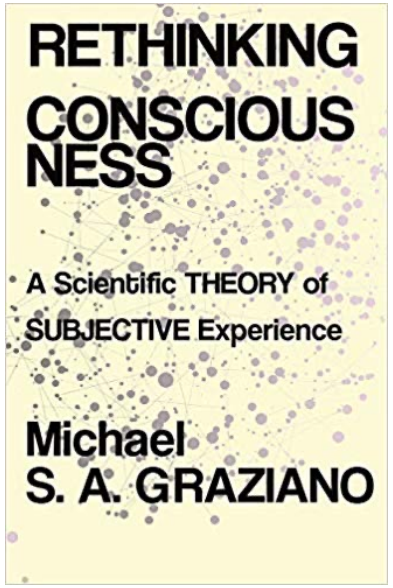


Fig. 1. Tensor net for $P(x, y) \rightarrow A(y)$, with $\mathcal{G}(x) = \mathbf{v}$ and $\mathcal{G}(y) = \mathbf{u}$ and $k = 2$.

My Favorite: Neuro[Symbolic]

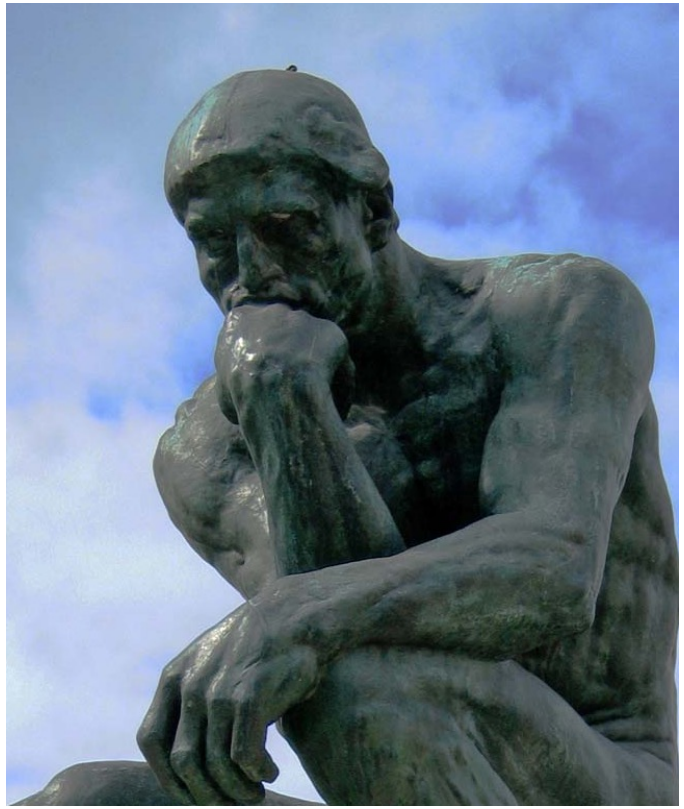
- Imbed true symbolic reasoning *inside* a neural engine
- Enable super-human and super-neuro combinatorial reasoning
  - For deliberative, Type 2 reasoning
  - Rare in ordinary animal life
  - Common in “business AI”
- Interface at the Attention Schema
  - Internal model of the system’s state of attention
  - Not the same as attention itself!

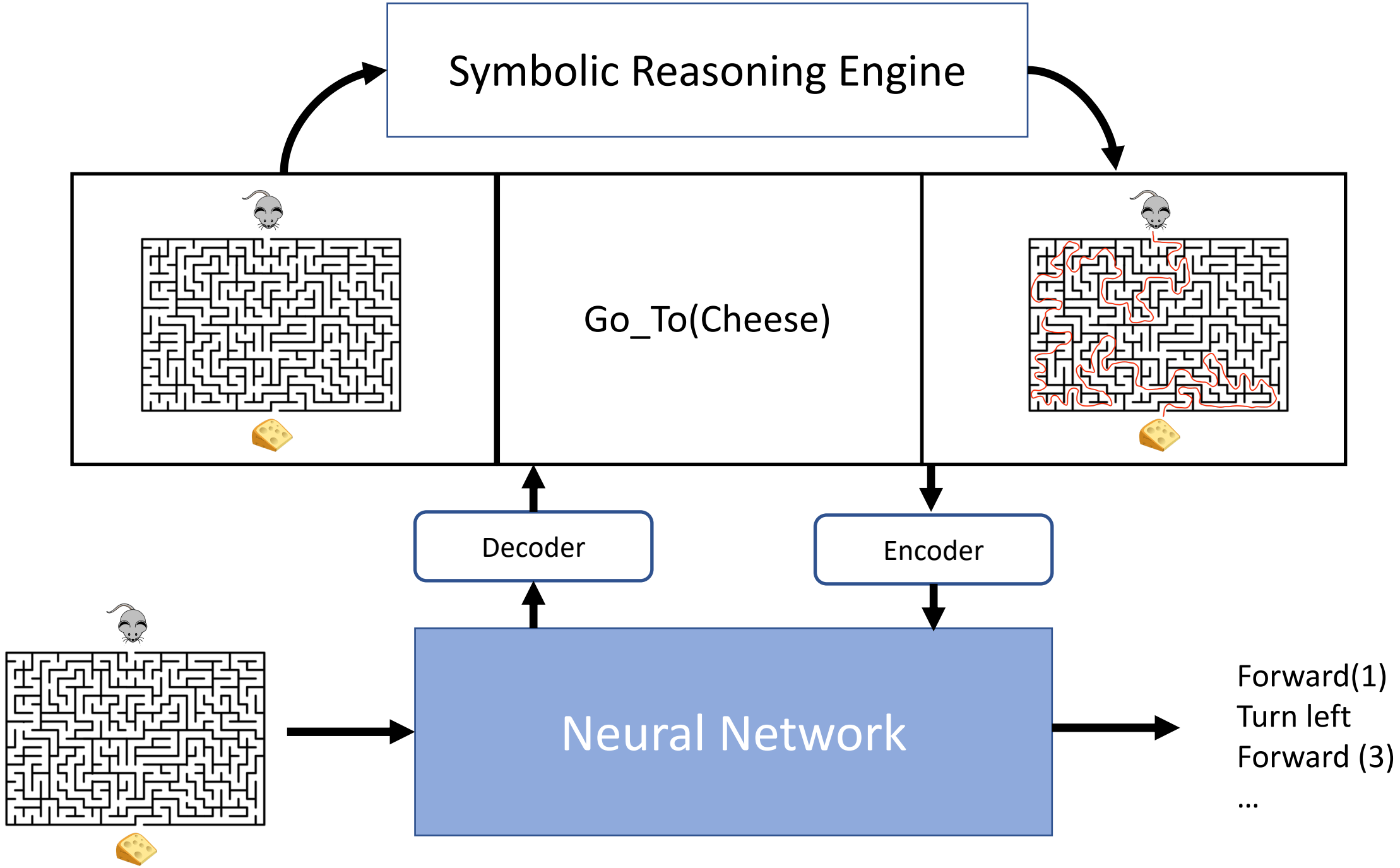




Neuro-Symbolic Interface

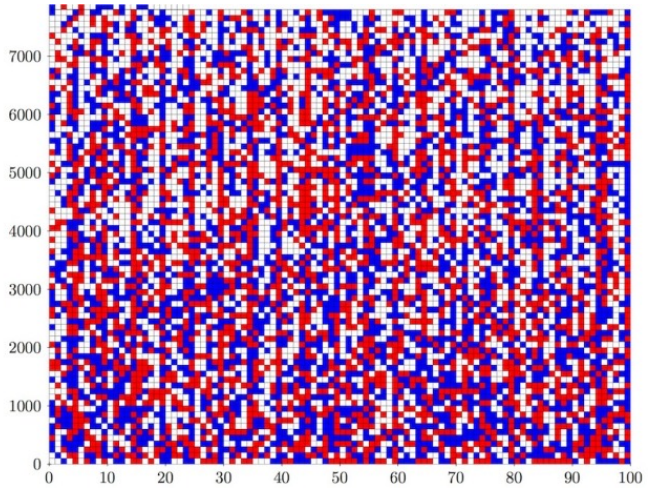
- Proposal: When attention to concepts is very high, they are decoded to symbolic entities in an attention schema
- Appearance of a goal in the attention schema signals that deliberative symbolic reasoning should be initiated
  - *I'm not just perceiving or remembering, I'm consciously thinking!*
- Efficient combinational search can then be performed over the entities in the attention schema




Symbolic Reasoning Engine
Go_To(Cheese)
Decoder
Encoder
Neural Network
Forward(1)
Turn left
Forward (3)
…

Discussion

- Why not maintain a (possibly reduced) vector representation in the attention schema?
  - Recurrent Independent Mechanisms: Bengio, Schölkopf *et al*.
- In order to leverage efficient constraint-satisfaction algorithms
  - 200 terabyte proof of the Boolean Pythagorean Triples Problem (Huele et al. 2016)



The numbers 1 to 7,824 can be coloured either red or blue so that no trio a, b and c that satisfies $a^2 + b^2 = c^2$ is all the same colour. The grid of 7,824 squares here shows one such solution, with numbers coloured red or blue (a white square can be either). But for the numbers 1 to 7,825, there is no solution.

Marijn Heule (2016)

Discussion

- The proposed symbolic solver is not differentiable, so it won't support gradient descent-based learning
- You wouldn't want to back propagate through a trillion inference steps anyway.
- The neural network can learn from inputs/outputs of SRS using non-gradient based optimization
- This scheme does not handle non-logical reasoning
- Could be extended to probabilistic reasoning, but probably not similarity-based reasoning
- Goal is expert reasoning, not commonsense reasoning: a step toward superintelligence, not human intelligence

Summary

- Each AI summer has led to enduring scientific insights
- Today's third summer is different
  - It might not be followed by a winter
  - It enables powerful applications for good and bad
- The next steps in AI are tighter symbolic-neuro integration