Ch01. AI Introduction

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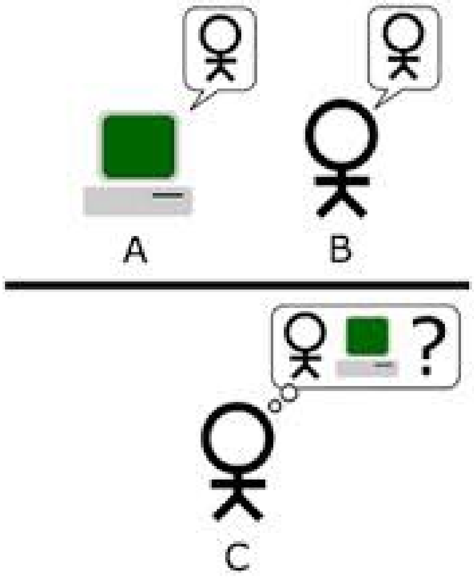
POSTECH

http://hwanjoyu.org

The Turing Test, 1950

"Can machines think?"



Q: Please write me a sonnet on the subject of the Forth Bridge.

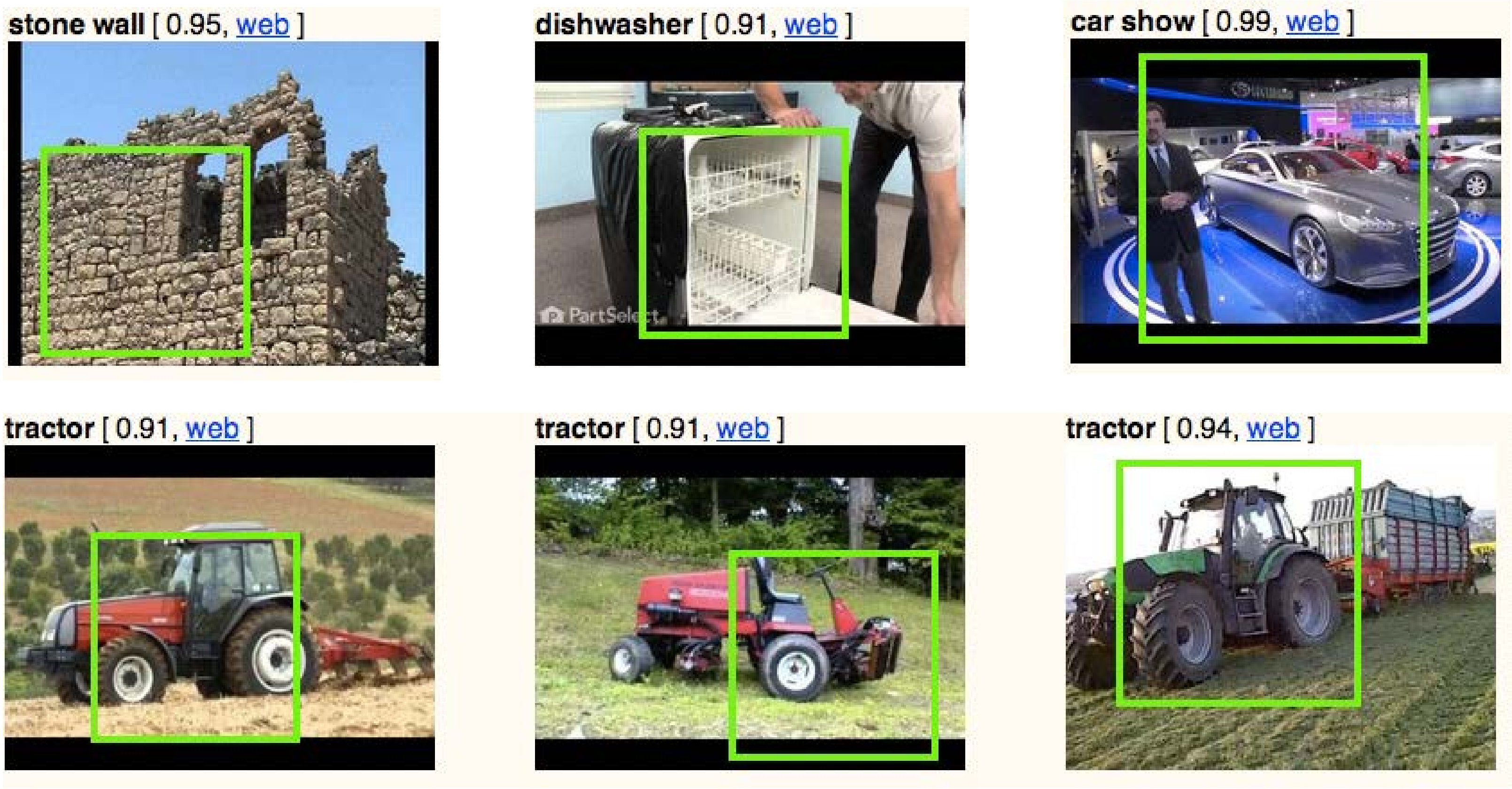
A: Count me out on this one. I never could write poetry.

Q: Add 34957 to 70764.

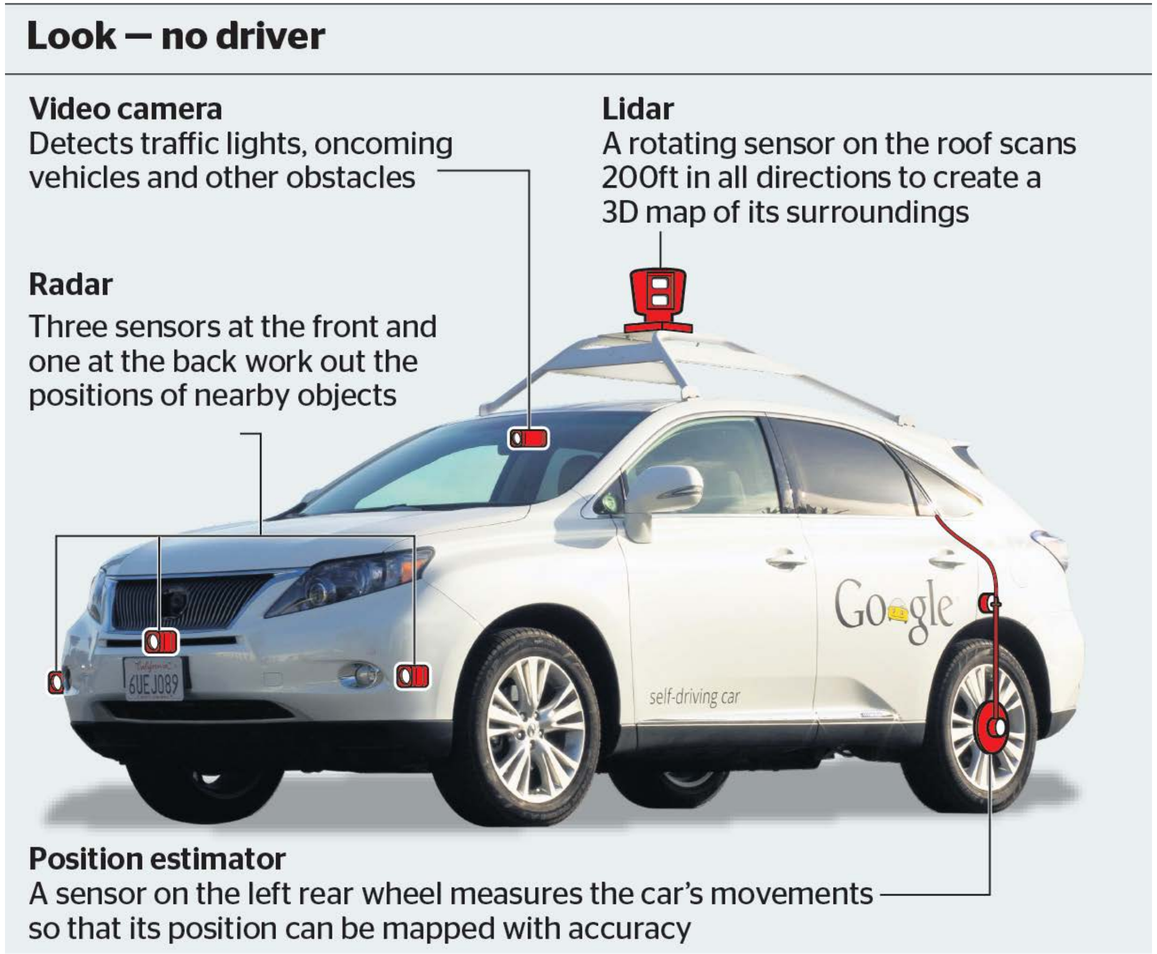
A: (Pause about 30 seconds and then give as answer) 105621.

What can computer do better than Human?

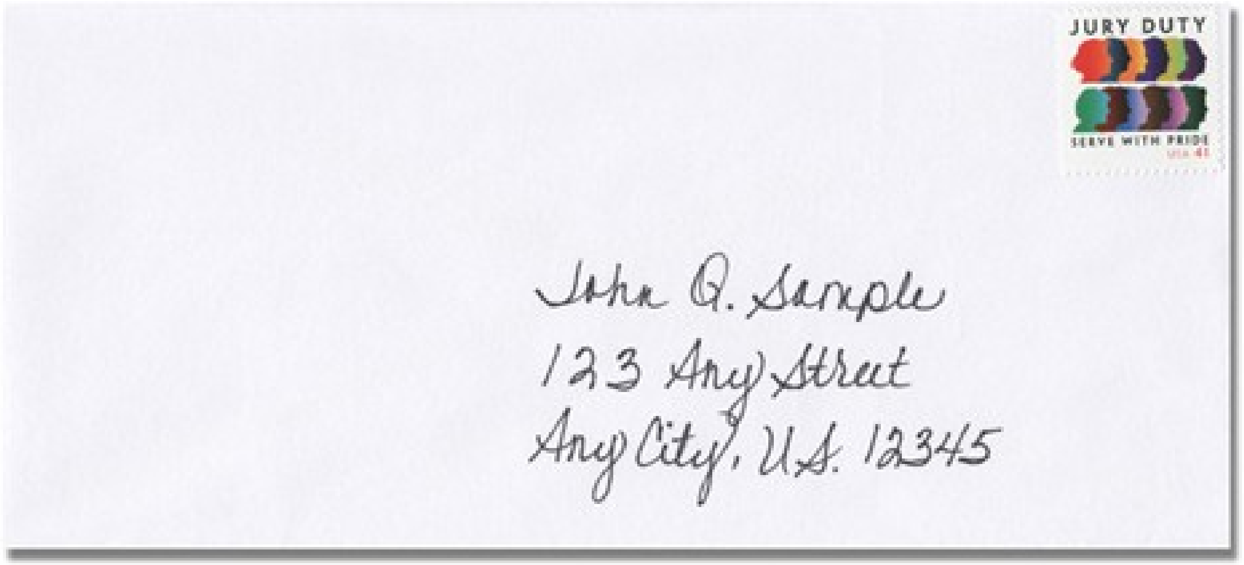
Computer Vision



Autonomous Driving



Handwriting Recognition

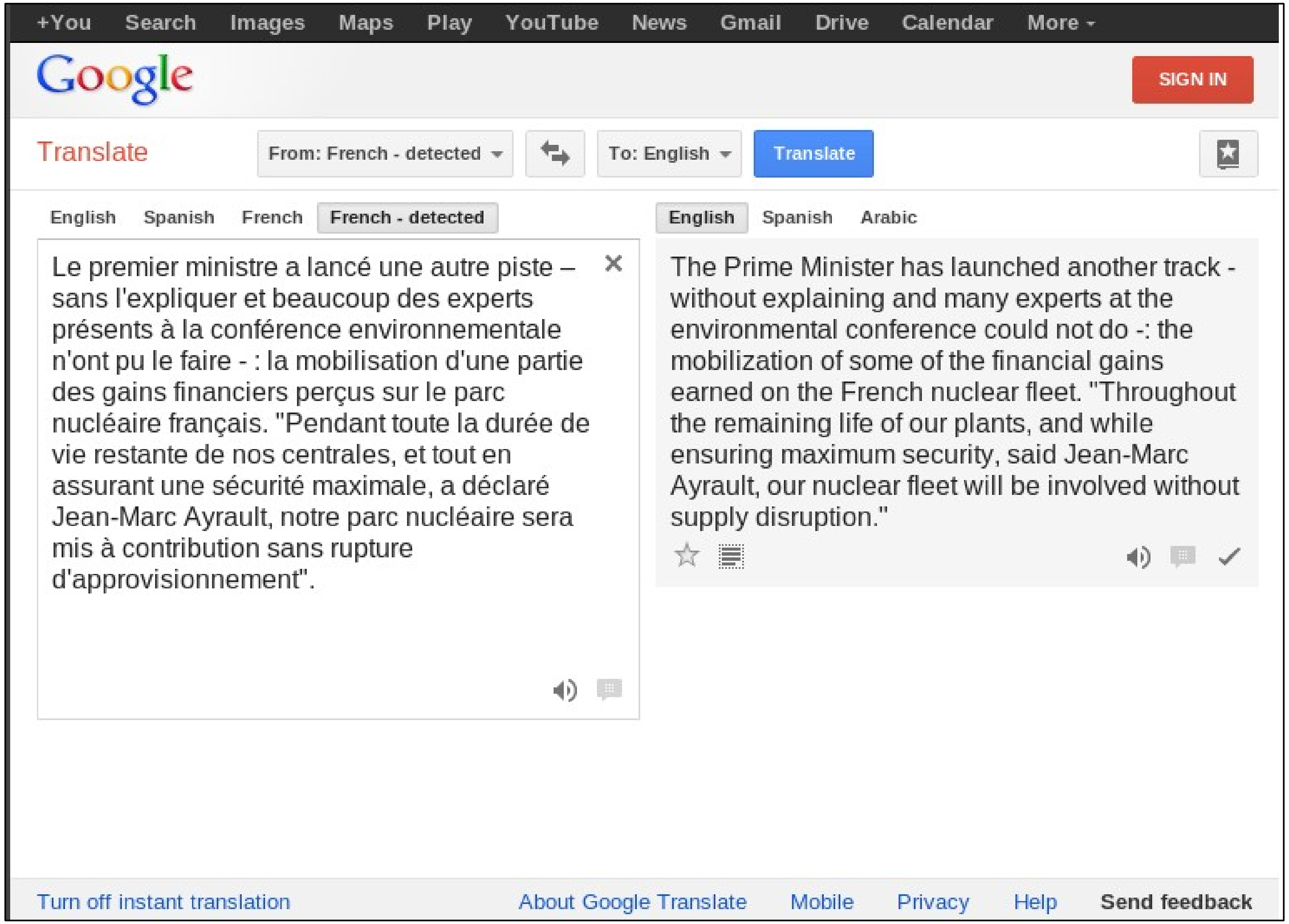


Sentiment Analysis

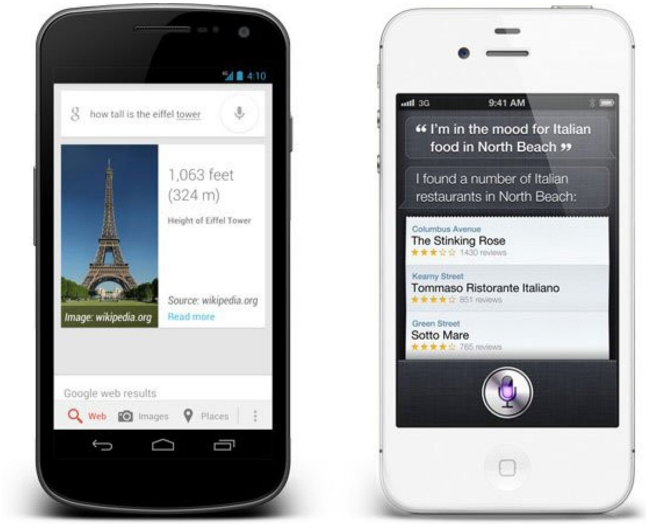
“This movie should have NEVER been made. From the poorly done animation, to the beyond bad acting. I am not sure at what point the people behind this movie said "Ok, looks good! Lets do it!" I was in awe of how truly horrid this movie was.”

Positive or Negative ?

Machine Translations



Virtual Assistants



Dialog System

2016 ten breakthrough technology from MIT technology review

Chat bot

Tutor robot

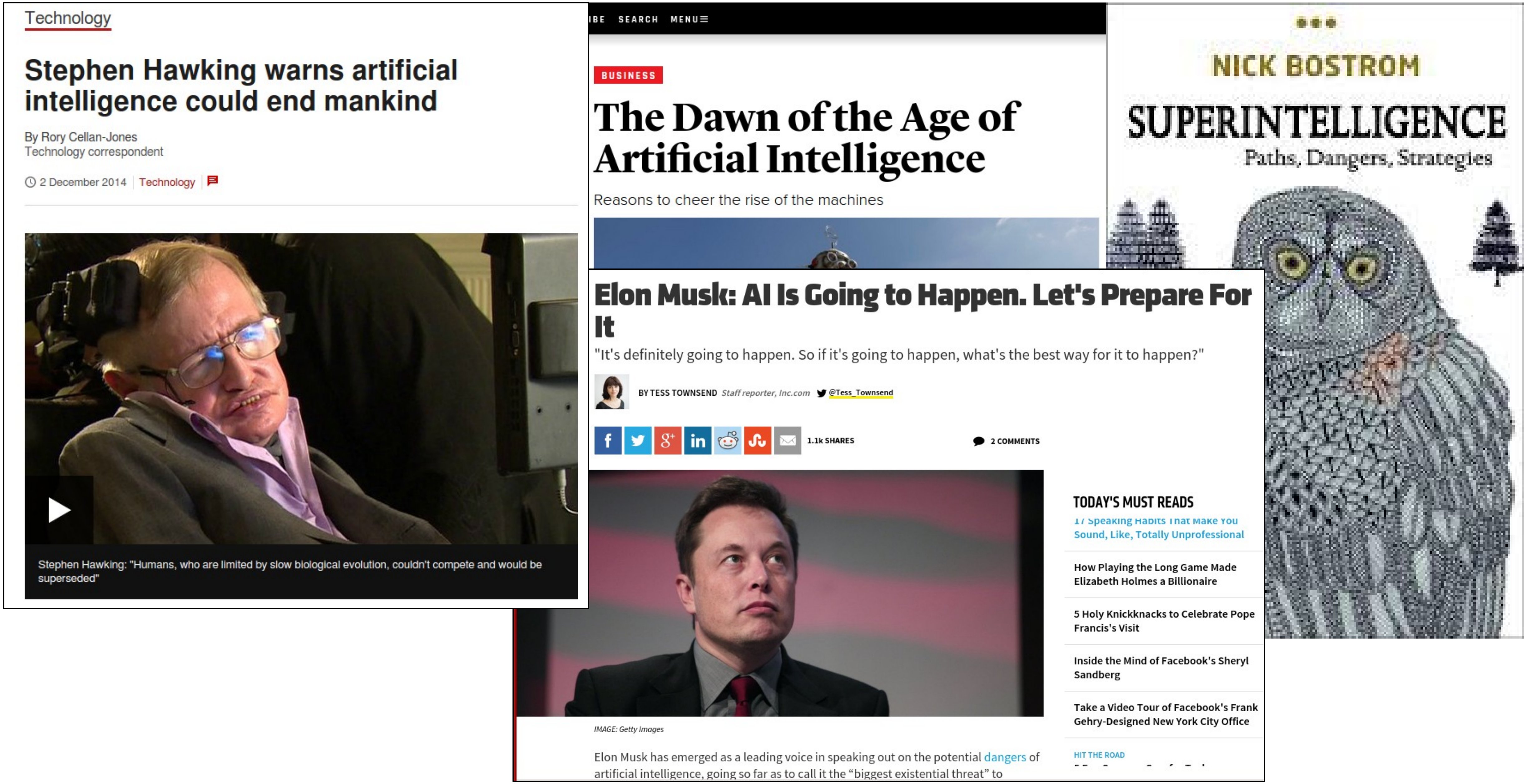
...

Humans versus Machines

1997: Deep Blue (chess)

2011: IBM Watson (Jeopardy!)

2016: AlphaGo


Technology
Stephen Hawking warns artificial intelligence could end mankind
By Rory Cellan-Jones
Technology correspondent
2 December 2014 | Technology
Stephen Hawking: "Humans, who are limited by slow biological evolution, couldn't compete and would be superseded"
SEARCH MENU
BUSINESS
The Dawn of the Age of Artificial Intelligence
Reasons to cheer the rise of the machines
NICK BOSTROM
SUPERINTELLIGENCE
Paths, Dangers, Strategies
Elon Musk: AI Is Going to Happen. Let's Prepare For It
"It's definitely going to happen. So if it's going to happen, what's the best way for it to happen?"
BY TESS TOWNSEND Staff reporter, Inc.com @Tess_Townsend
1.1k SHARES
2 COMMENTS
IMAGE: Getty Images
Elon Musk has emerged as a leading voice in speaking out on the potential dangers of artificial intelligence, going so far as to call it the "biggest existential threat" to
TODAY'S MUST READS
Sound, Like, Totally Unprofessional
How Playing the Long Game Made Elizabeth Holmes a Billionaire
5 Holy Knickknacks to Celebrate Pope Francis's Visit
Inside the Mind of Facebook's Sheryl Sandberg
Take a Video Tour of Facebook's Frank Gehry-Designed New York City Office
HIT THE ROAD

AI Winter
(AI 암흑기)

- 1956: Dartmouth workshop, John McCarthy coined ”AI”
- 1960: checkers playing program, Logical Theorist
- 1966: ALPAC report cuts off funding for translation
- 1974: Lighthill report cuts off funding in UK
- 1970-80s: expert systems (XCON, MYCIN) in industry
- 1980s: Fifth-Generation Computer System (Japan); Strategic Computing Initative (DARPA)
- 1987: collapse of Lisp market, government funding cut
- 1990-: rise of machine learning
- 2010s: heavy industry investment in deep learning
- ???

Many AI Applications

...
Web search
Speech recognition
Handwriting recognition
Machine translation
Information extraction
Document summarization
Question answering
Spelling correction
Image recognition
3D scene reconstruction
Human activity recognition
Autonomous driving
Music information retrieval
Automatic composition
Social network analysis
...

...
Product recommendation
Advertisement placement
Smart-grid energy optimization
Household robotics
Robotic surgery
Robot exploration
Spam filtering
Fraud detection
Fault diagnostics
AI for video games
Financial trading
Dynamic pricing
Protein folding
Medical diagnosis
Medical imaging
...

Characteristics of AI Tasks

High societal impact (affect billions of people)

Diverse (language, games, robotics)

Complex (really hard)

Two sources of complexity

Computational Complexity

- Most AI problems are NP-hard
- Go – 361^{200} trajectories that a player would have to consider to play optimally.

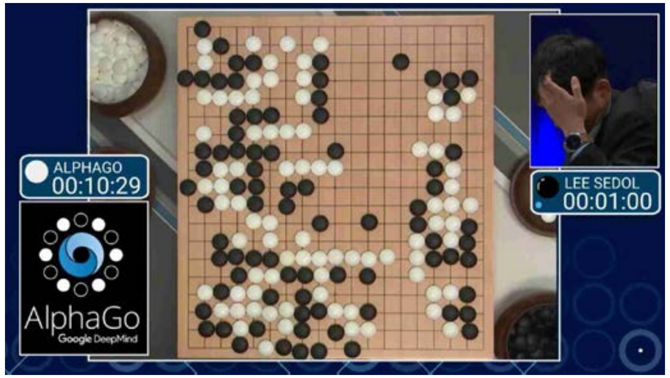
Information Complexity

- Translate a sentence
- Classify a bird from image

Resources

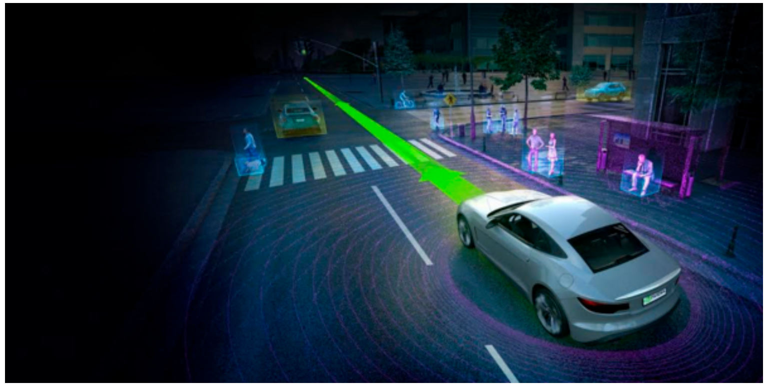
Computation (time/memory)

Information (data)



AlphaGo (2016)

- 30 million training data
- Tensor Processing Unit
- Deep & Reinforcement Learning



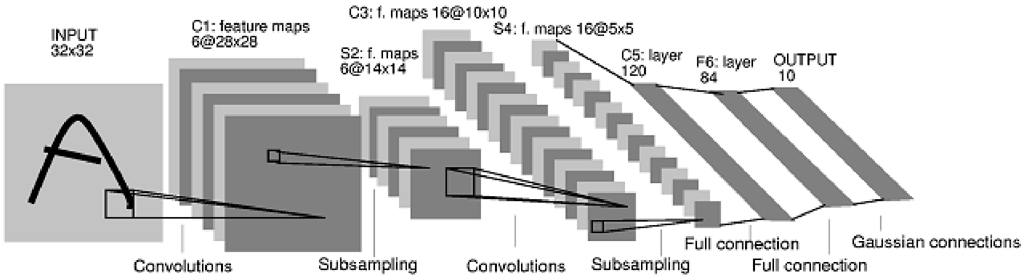
NVIDIA Self-Driving (2016)

- Vision data by driving tens of thousands miles
- NVIDIA GPU, Deep Learning

Google Translation

- Billions of translation data
- IBM's linguistic approach fails

Big Data + Hardware + Machine Learning Algorithm



How do we ~~solve~~ tackle these challenging AI tasks?

Real-world task

Real-world task

Modeling

Formal task (model)

Algorithms

Program

Algorithms (example)

- Formal task:
  - Input: list $L = \{x_1, \ldots, x_n\}$ and a function $f : X -> \mathbb{R}$
  - Output: k highest-scoring elements
- Example ($k = 2$):
  - $L :\quad A \quad B \quad C \quad D$
  - $f :\quad \mathbf{3} \quad 2 \quad \mathbf{7} \quad 1$
- Two algorithms:
  1. Scan through to find the largest, scan through again to find the second largest, etc.
  2. Sort L based on f, return first k elements

Modeling (example)

- Real-world task:
  - Input: 20 billion web pages, a keyword query
  - Output: 10 most relevant web pages
- Modeling:
  - L = list of web pages
  - $f(x) = 10 * \text{QueryMatch}(x) + 3 * \text{PageRank}(x)$
- Formal task:
  - Input: list $L = \{x_1, \ldots, x_n\}$ and a function $f : X -> \mathbb{R}$
  - Output: k highest-scoring elements

Modeling and algorithms

- Separate **what** to compute (**modeling**) from **how** to compute it (**algorithms**) => Advantage: division of labor

- What do we learn?
  - Type of models…
  - Art of modeling…
  - Developing Algorithms…

Summary so far

- Applications of AI: high-impact, diverse
- Challenges: computational/information complexity
- Paradigm: modeling + algorithms

Reflex

"Low-level intelligence" "High-level intelligence"

Sentiment Analysis

- Input: movie review

“Shows moments of promise but ultimately succumbs to cliches and pat storytelling.”

- Output: sentiment

POSITIVE or NEGATIVE

Reflex-based Models

- Input: x, a document or sentences
- Output: $f(x)$, a simple function of x

- Example: model f is a set of simple rules
  - If x contains "clichés", return NEGATIVE.
  - If x contains "promise", return POSITIVE.

Reflex-based Models: Linear model

- Use scores to capture nuances…
- Output f is determined based on scores
  - Set score = 0
  - If x contains “clichés”, score = score - 10.
  - If x contains “promise”, score = score + 5.
  - …
  - If score > 0, return POSITIVE.
- More generally…
  - Key idea: linear classifier
  - $f(x) = \text{sign}(w_1 \phi_1(x) + w_2 \phi_2(x) + \cdots)$
  - $f(x) = \sigma(\mathbf{w} \cdot \phi(x))$
- How about “not bad”?

Machine learning approach

Training examples

"… excellent script …" => positive
"… succumbs to cliches …" => negative
"… pat storytelling …" => negative

Learning algorithm

input → **Simple Program with Parameters = [3.2, 1.2, …]** → output

Machine Learning

- **Key idea: generalization**
  - Learning algorithm maximizes accuracy on **training** examples.
  - But we only care about accuracy on future **test** examples.
  - How to **generalize** from training to test?

Search problems

Markov decision processes

Adversarial games

Reflex **States**

"Low-level intelligence" "High-level intelligence"

Text Reconstruction

- Chinese is written without spaces:

是 什 4 意思

- Arabic omits (some) vowels:

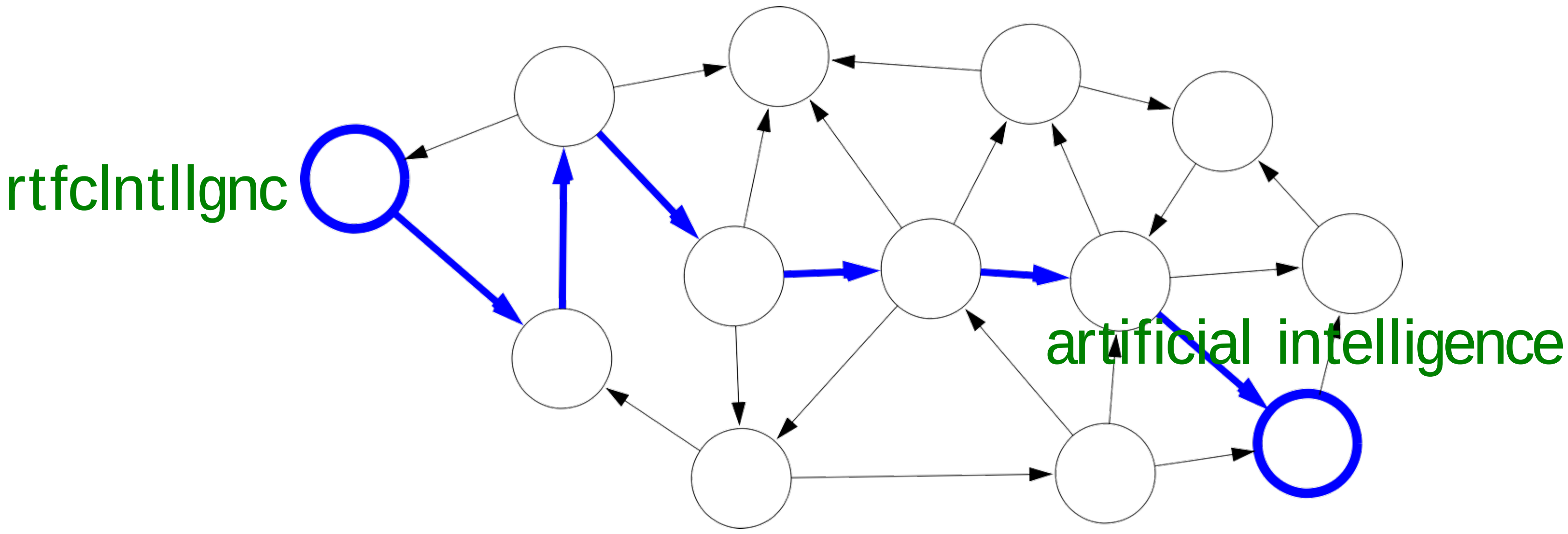
مَكْتَبَة

- Remove vowels and spaces from an English phrase:

rtfclntllgnc

State-based Models

- Solutions are represented as paths through a graph



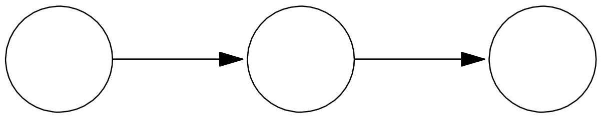
State-based Models

Key idea: state

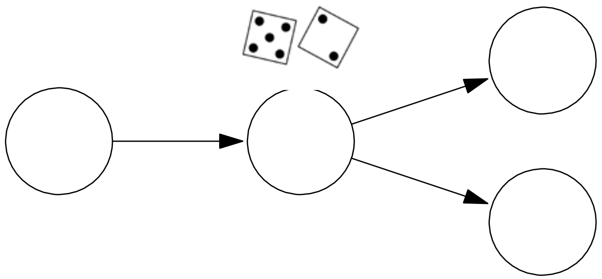
- A **state** captures all the relevant information about the past in order to act optimally in the future

State-based Models

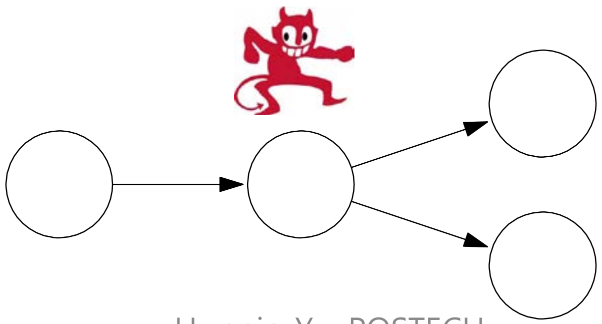
- Search problems: you control everything



- Markov decision processes: against nature (e.g., Blackjack)



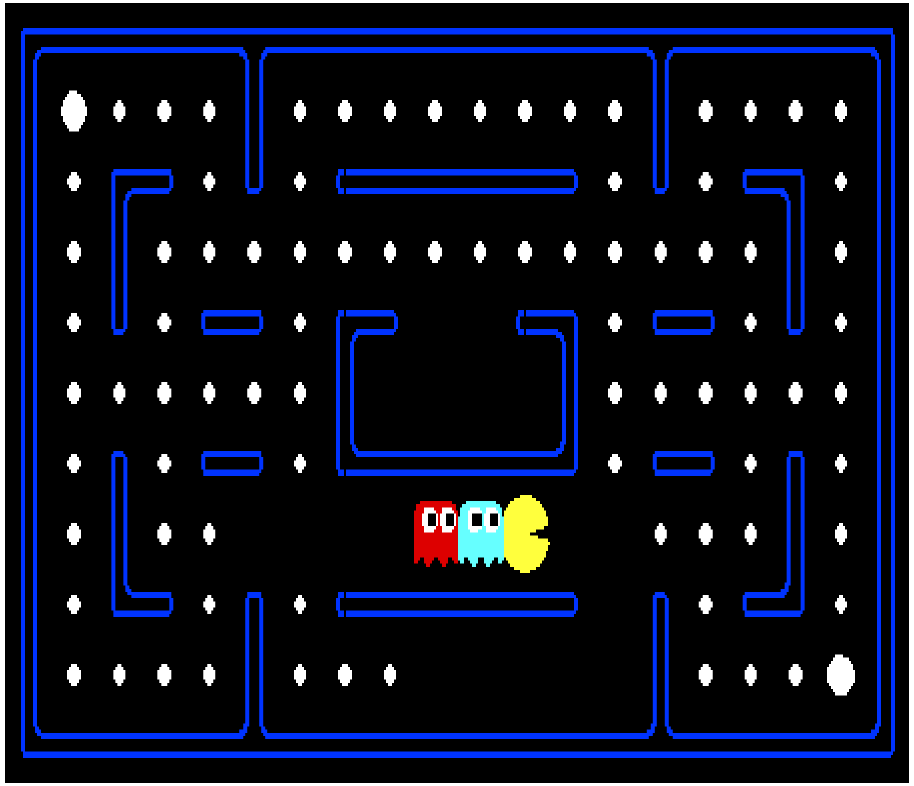
- Adversarial games: against opponent (e.g., chess)



Pac-Man

What kind of model is appropriate for playing Pac-Man against ghosts that move into each valid adjacent square with equal probability?

1. Search problem
2. Markov decision process
3. Adversarial game

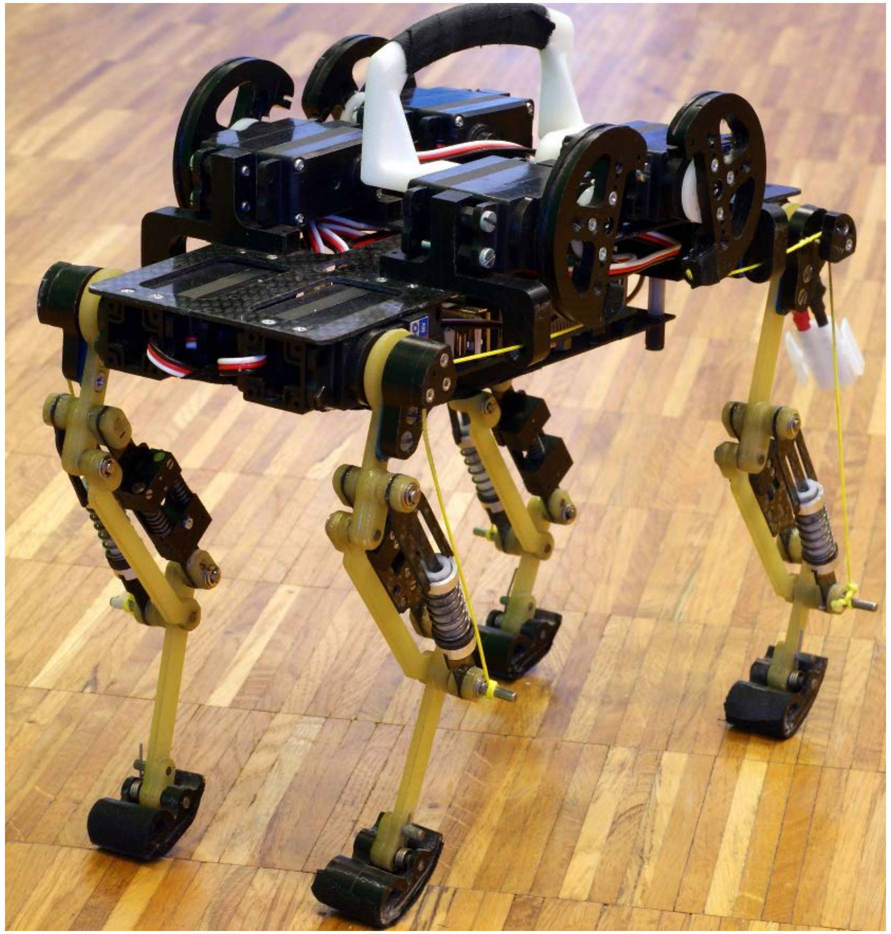


Crawling robot

Goal: maximize distance travelled by robot

Markov decision process (MDP):

- States: positions (4 possibilities) for each of 2 servos
- Actions: choose a servo, move it up/down
- Transitions: move into new position (unknown)
- Rewards: distance travelled (unknown)



Deep reinforcement learning

Playing Atari [Google DeepMind, 2013]:

- Just use a neural network for $\hat{Q}_{\text{opt}}(s, a)$
- Last 4 frames (images) => 3-layer NN => keystroke
- ϵ-greedy, train over 10M frames with 1M replay memory
- https://www.youtube.com/watch?v=V1eYniJ0Rnk

AlphaGo

- Supervised learning: on human games
- Reinforcement learning: on self-play games
- Evaluation function: convolutional neural network (value network)
- Policy: convolutional neural network (policy network)
- Monte Carlo Tree Search: search / lookahead

Search problems

Markov decision processes

Adversarial games

Constraint satisfaction problems

Bayesian networks

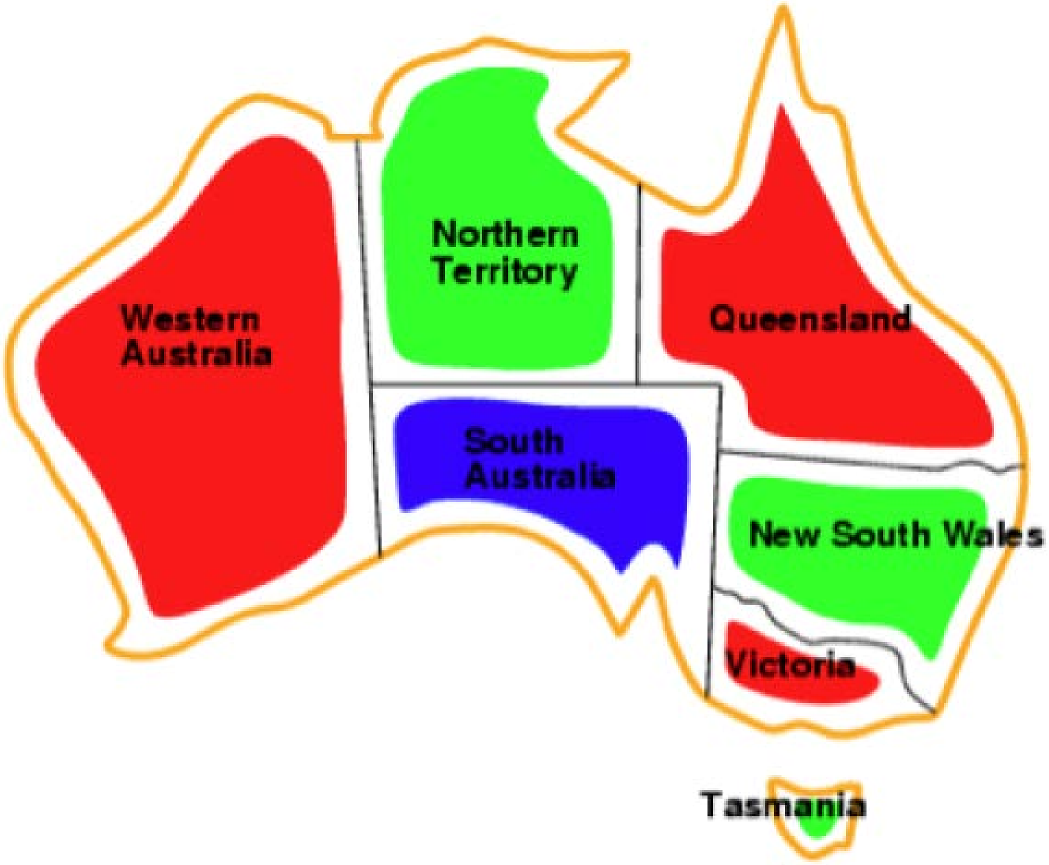
Reflex **States** **Variables**

”Low-level intelligence” ”High-level intelligence”

Constraint Satisfaction Problem (CSP)

Question: how can we color each of the 7 provinces {red, green, blue} so that no two neighboring provinces have the same color?

Map coloring



(one possible solution)

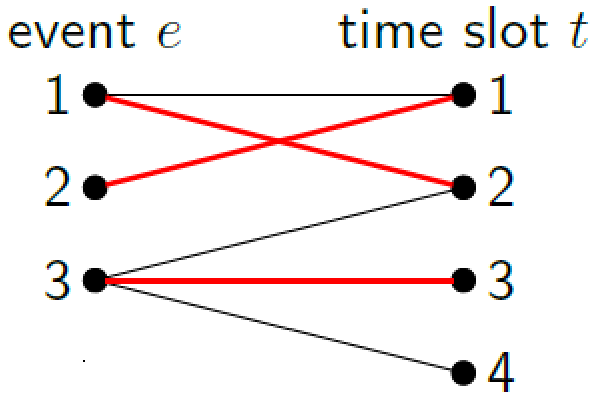
Constraint Satisfaction Problem (CSP)

Three sculptures (A, B, C) are to be exhibited in rooms 1, 2 of an art gallery.

The exhibition must satisfy the following conditions:

- Sculptures A and B cannot be in the same room.
- Sculptures B and C must be in the same room.
- Room 2 can only hold one sculpture.

Event scheduling

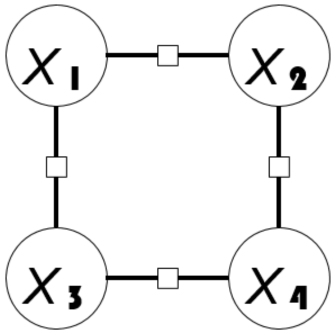


Setup:

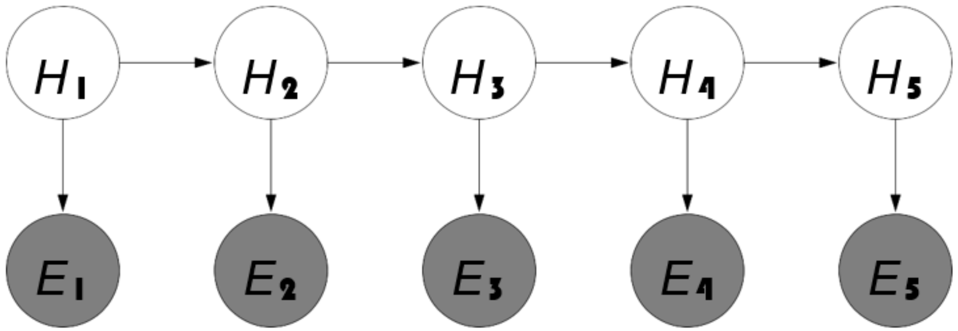
- Have E events and T time slots
- Each event e must be put in **exactly one** time slot
- Each time slot t can have **at most one** event
- Event e allowed in time slot t only if $(e, t) \in A$

Variable-based Models

- Constraint satisfaction problem: hard constraints (e.g., map coloring, scheduling)



- Bayesian networks: soft dependencies (e.g., tracking cars from sensors)



Topic modeling

Question: given a text document, what topics is it about?

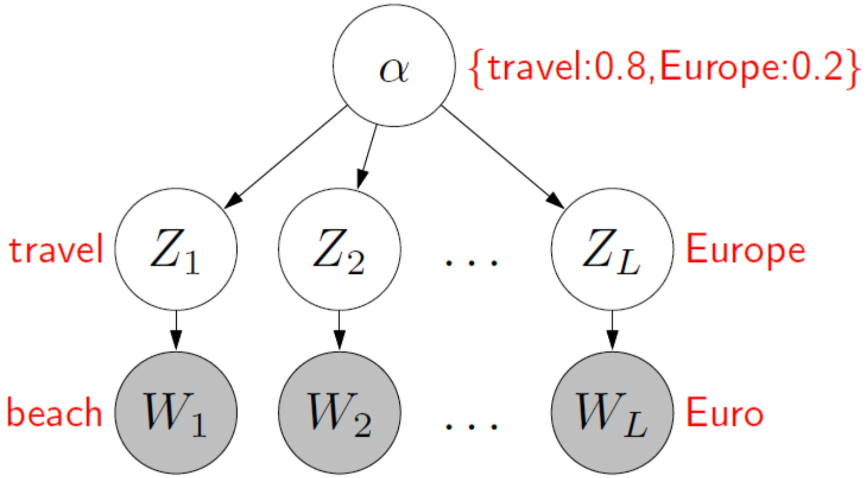
Probabilistic program: latent Dirichlet allocation

Generate a distribution over topics $\alpha \in \mathbb{R}^K$

For each position $i = 1, \ldots, L$:

Generate a topic $Z_i \sim p(Z_i | \alpha)$

Generate word $W_i \sim p(W_i | Z_i)$



Search problems

Markov decision processes

Adversarial games

Constraint satisfaction problems

Bayesian networks

Reflex **States** **Variables** **Logic**

"Low-level intelligence" "High-level intelligence"

Question

You get extra credit if you write a paper and you solve the problems.

You didn’t get extra credit, but you did solve the problems.

Did you write a paper?

Yes or No

Knowledge representation and reasoning

All students work hard.

John is a student.

Therefore, John works hard.

Variable-based models would explicitly represent all the students – this is inefficient

Need expressive power of logic to represent this …

Search problems

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Reflex **States** **Variables** **Logic**

"Low-level intelligence" "High-level intelligence"

Machine learning

Real-world task

Modeling

Formal task (model)

Algorithms

Program

Modeling is often expressed as optimization problems, which provides a mathematical specification of what we want to compute

Problem: predicting exam score y

- x: # of hours studying
- y: exam score
- Assume $y = \boldsymbol{w}x$
- $\boldsymbol{w}$ is a **learning parameter** we need to estimate (learn) from training data

- $\boldsymbol{D}_{\textbf{train}}$: set of pairs $\{(x_1, y_1), \ldots, (x_n, y_n)\}$
- $\boldsymbol{f}$: $\boldsymbol{w} \in \mathbb{R}$ that minimizes the squared error $F(w) = \sum_{i=1}^{n}(x_i w - y_i)^2$
- Example:

{(2,4)} => 2

{(2,4),(4,2)} => ?

Optimization

- Models are optimization problems:

$$\min_{x \in C} F(x)$$

- Discrete optimization: x is a discrete object

$$\min_{x \in \{abcd, xyz\}} Length(x)$$

Algorithmic tool: dynamic programming

- Continuous optimization: x is a vector of real numbers

$$\min_{x \in \mathbb{R}} (x - 5)^2$$

Algorithmic tool: gradient descent

Summary

- Applications of AI: high-impact, diverse
- Challenges: computational/information complexity
- Paradigm: modeling + algorithms
- Models: learning + [reflex, states, variables, logic]