Overview in Artificial Intelligence

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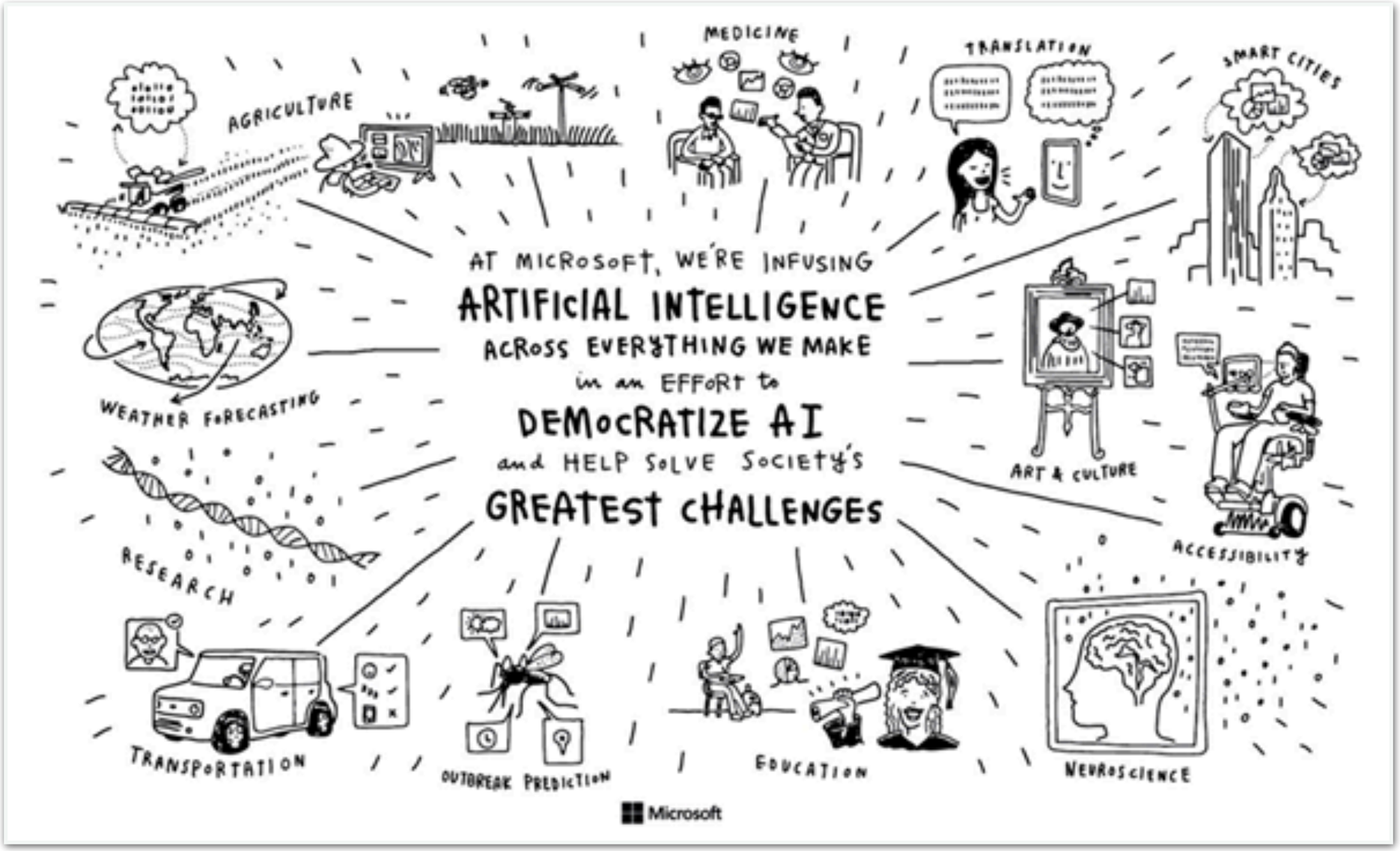
Short Biography

- **Name:** Teeradaj Racharak (X)
- **Work as:** Logician, Computer Scientist
- **Affiliation:** Japan Advanced Institute of Science and Technology (Kanazawa city, Japan)
- **Academic Position:** Assistant Professor of Artificial Intelligence (AI), School of Information Science
- **Research Interests:** Formal development of *human intelligence* for AI, in particular:
  - Machine learning
  - Computational logic
  - Explainable AI (XAI)
- **Contact:** r.teeradaj@gmai.com

(Me in Nara, 2018)

Artificial Intelligence (AI)



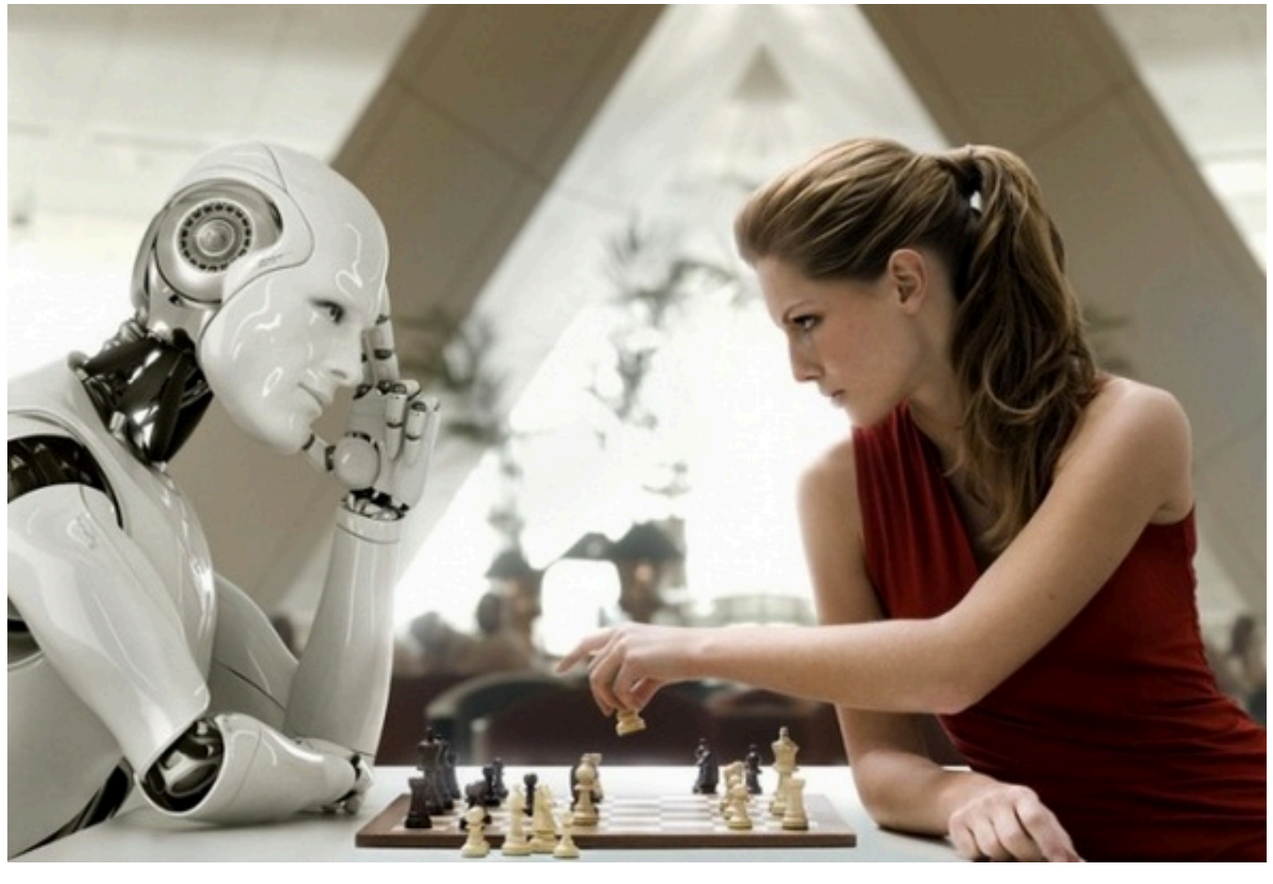
How to create computers/machines with some human intelligence
e.g. reasoning, natural language understanding, learning, *etc. ?*

https://www.thewindowsclub.com/
microsoft-explains-artificial-intelligence

Artificial Intelligence (AI)

Designing and building machines that behaves intelligently

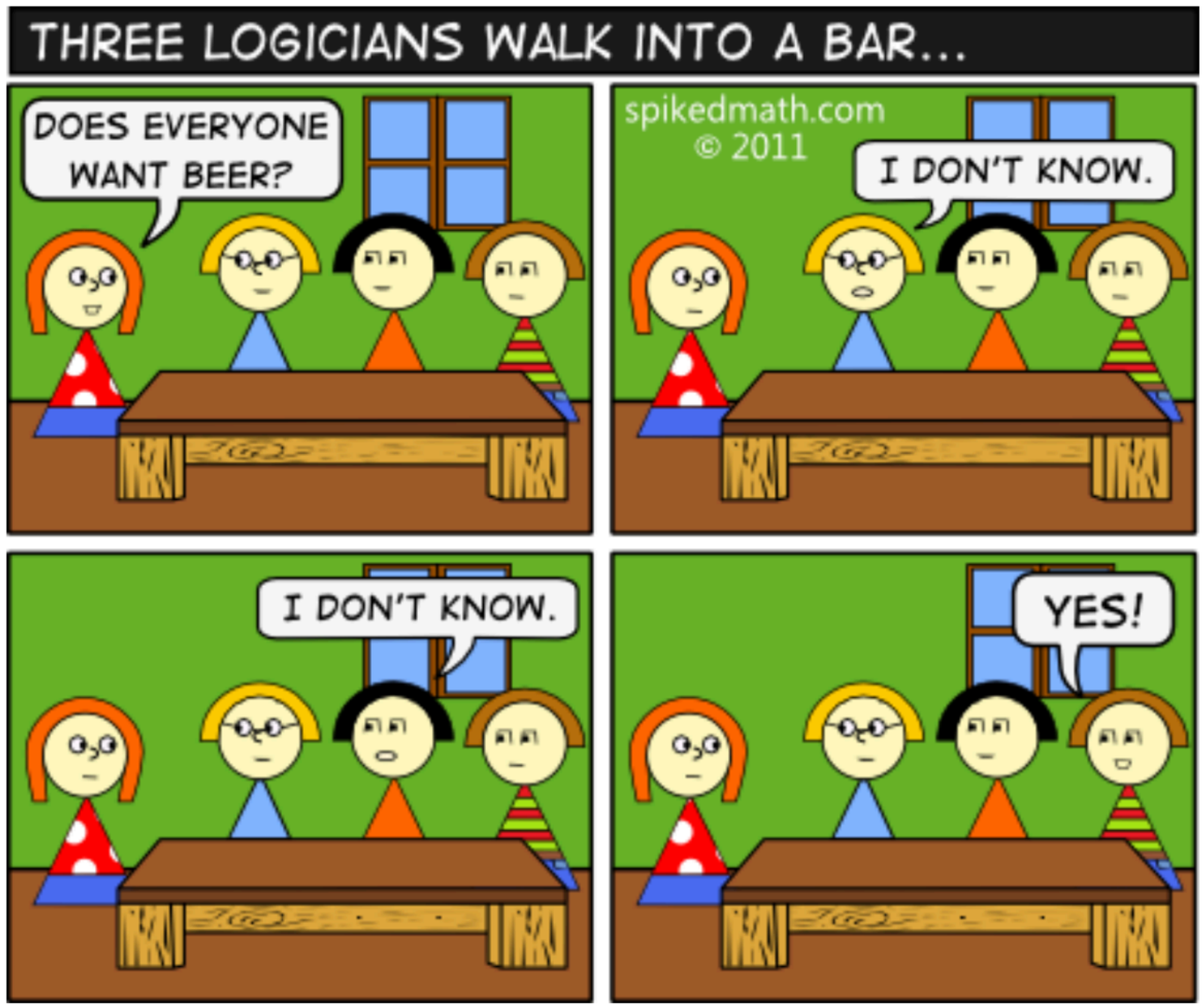
behaves intelligently $\approx$ human-like



learn and reason

Can a machine ~~behave~~ like a human?

Example of Agent Reasoning



Example of Reasoning

Argument mining is an emerging field of KR + NLP !

Cathy V. Hathorn

★★★★★ **Best Book**

September 12, 2018

Format: Kindle Edition | Verified Purchase

Loved this novel. Think this book is Deanna best work, loved it. Great writer will be looking for more of her books

noonie

★★★☆☆ **Entertaining**

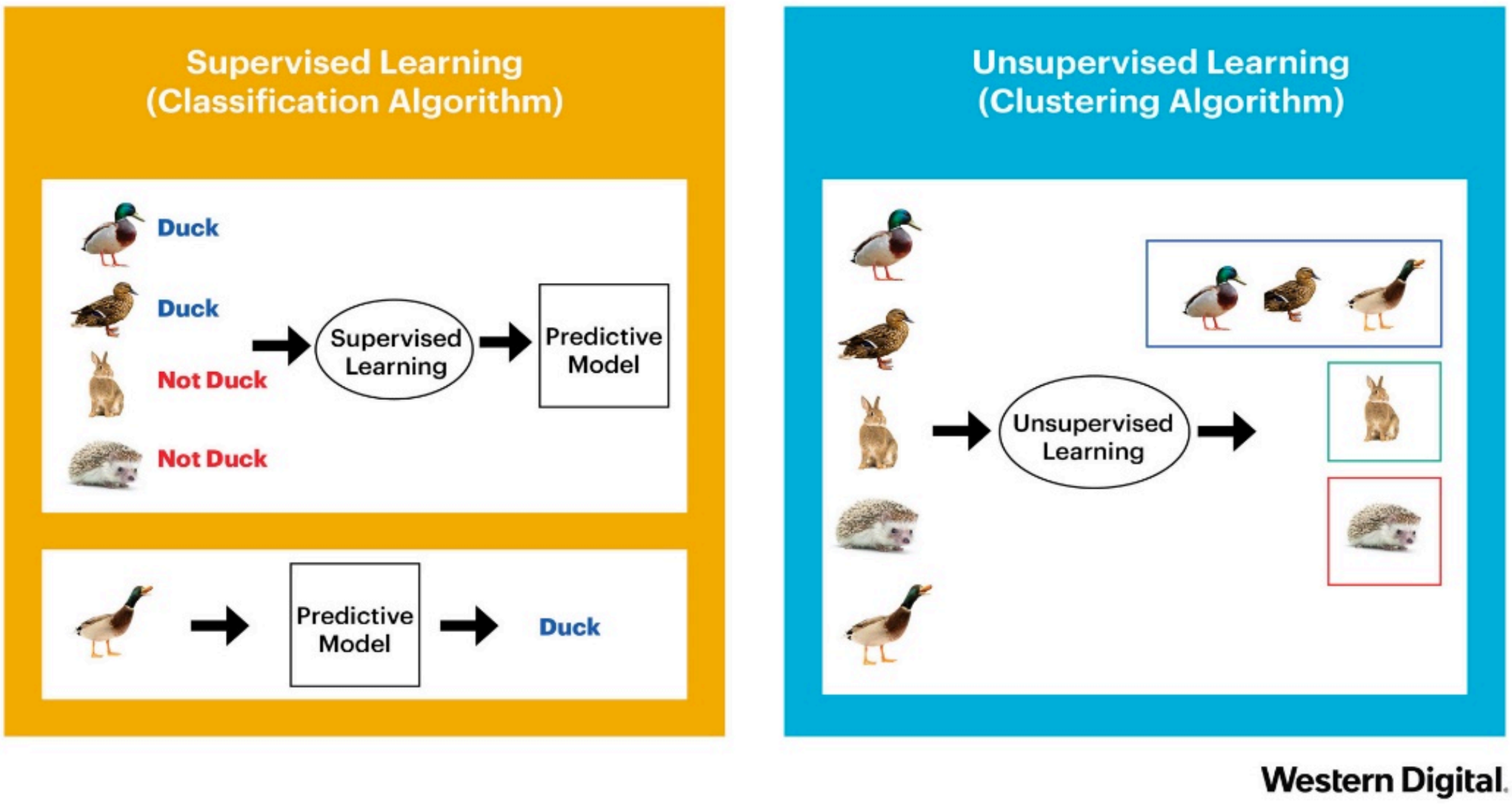
November 27, 2018

Format: Kindle Edition

I felt the book at times went on and on about detail that wasn't interesting..bottom line it was ok just wordy..

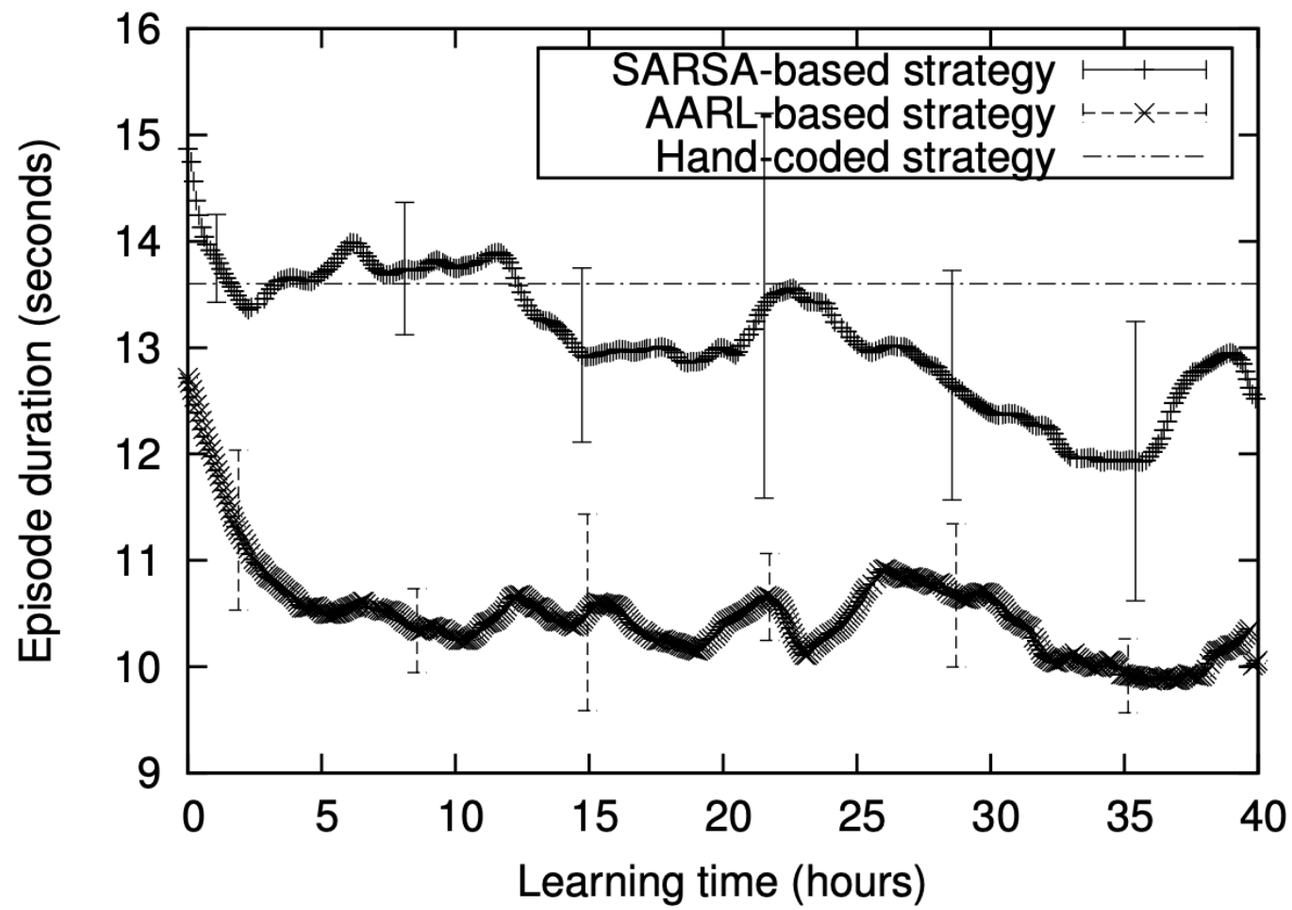
(reviews made on amazon.com)

Example of Learning



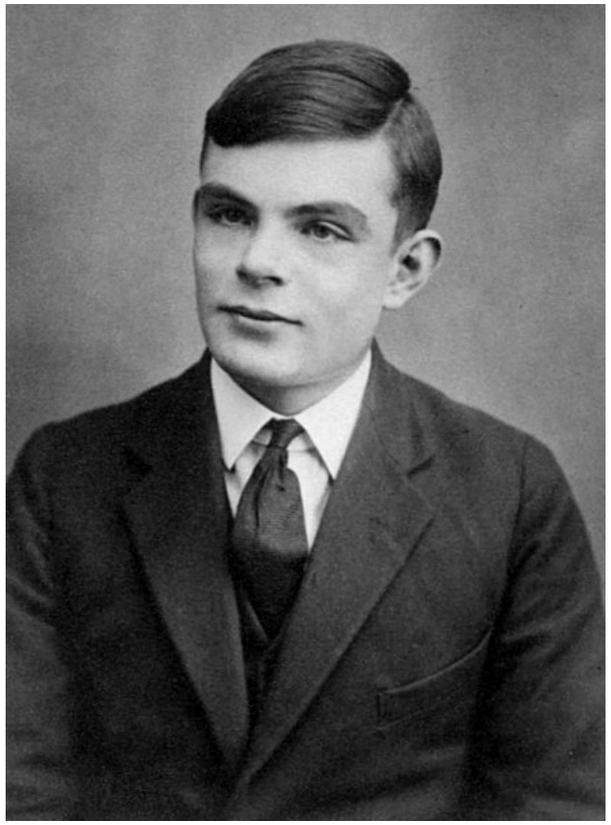
Integration between Learning and Reasoning

Gao, Yang, and Francesca Toni, Argumentation Accelerated Reinforcement Learning for Cooperative Multi-Agent Systems, *ECAI,* 2014



The Father of Theoretical CS and AI

Alan Mathison Turing OBE FRS (/ˈtjʊərɪŋ/; 23 June 1912 – 7 June 1954) was an English mathematician, computer scientist, logician, cryptanalyst, philosopher, and theoretical biologist.[2] Turing was highly influential in the development of theoretical computer science, providing a formalisation of the concepts of algorithm and computation with the Turing machine, which can be considered a model of a general-purpose computer.[7][8][9] Turing is widely considered to be the father of theoretical computer science and artificial intelligence.[10] Despite these accomplishments, he was never fully recognized in his home country during his lifetime due to his homosexuality, which was then a crime in the UK.



(Turing aged 16)

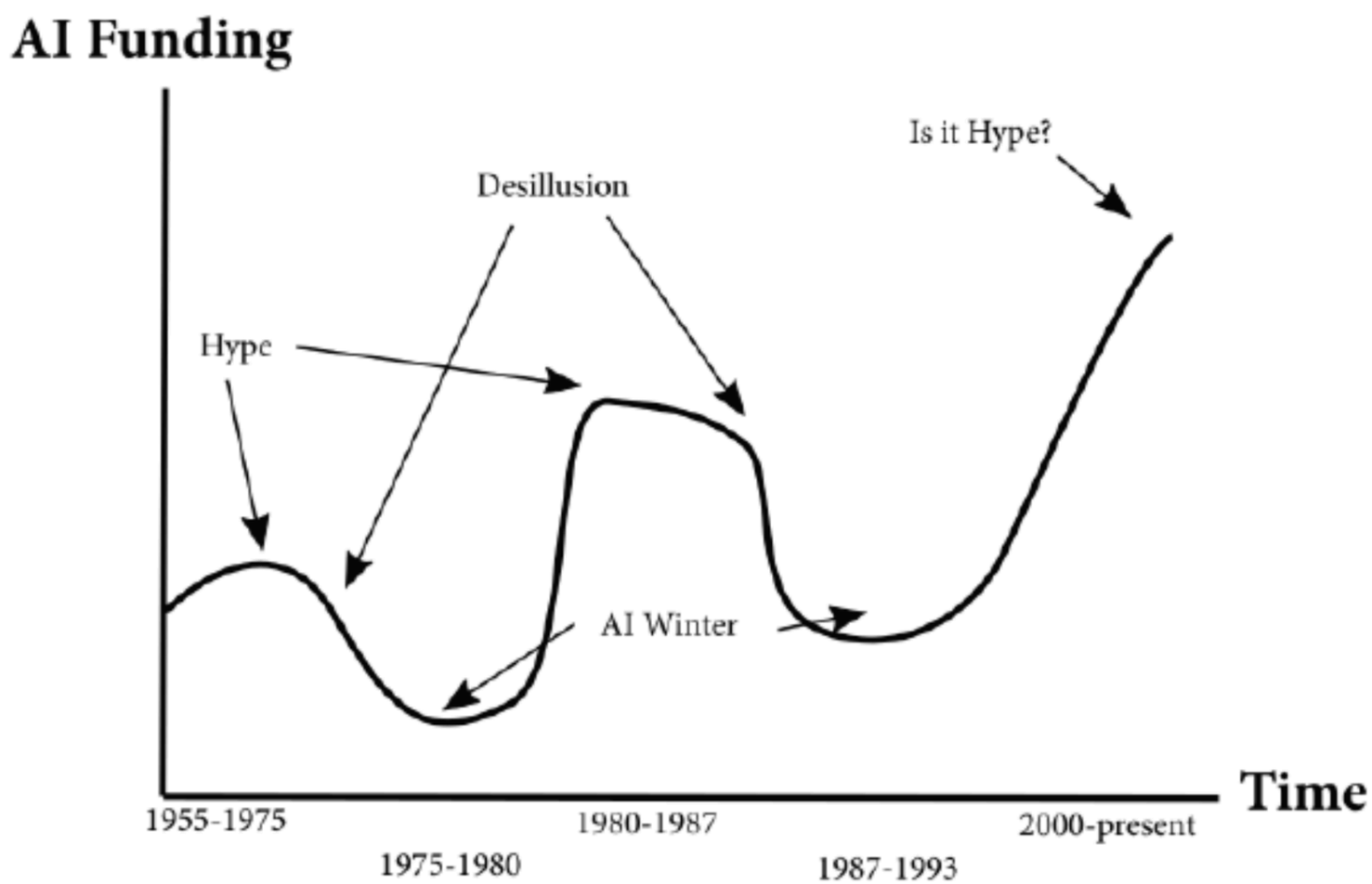
https://en.wikipedia.org/wiki/Alan_Turing

AI Research History

- 1931: Kurt Gödel demonstrated the inherent limitations of every formal axiomatic system capable of modelling basic arithmetic.
- 1936: Alan Turing published a paper 'On Computable Numbers, with an Application to the Entscheidungsproblem'. This work was later known as 'Turing' machine.
- 1943: First computational model based on human brain was introduced by McCulloch and Pitts.
- 1949: Donal Hebb published a book "Organization of Behavior" talking about relationship between neurals.
- 1950: Alan Turing published another paper 'Computing Machinery and Intelligence', where we asked "Can machines think?".
- 1959: Machine learning field was introduced from IBM.
- 1969 - 1980: first AI winter(Paper by Minsky and Papert about XOR problem).

AI Research History

- Second boom: 1980 - 1987 on expert systems.
- Second winter: 1987-1993.
- Third boom: starting from 2007

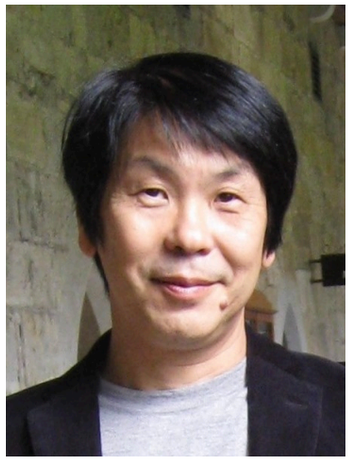


Next Hype of AI?

Some researchers are committed to studies and development work that will go beyond the current boom. For example,

- Katsumi Inoue (National Institute of Informatics, Japan) said "Research is still weak on 'inference' of human's thinking".

Analysis of mankind's scientific discovery process has revealed that hypothetical reasoning, called abduction,
plays an important role, according to Inoue.



He has built an abduction-based computer program and has used it to analyze chemical reactions.
As a result, he has found a till-now-undiscovered reaction.

(https://asia.nikkei.com/Business/Biotechnology/Deep-learning-sparks-third-artificial-intelligence-boom)

Next Hype of AI?

FRANCESCA ROSSI
IBM, University of Padova *(on leave)*

Common sense reasoning and natural language understanding,
AI-powered question/answering systems are very useful, but they lack the capability to sustain a dialog. Deep natural language understanding is still a challenge, as well as common sense reasoning capabilities. Metrics that could measure both these capabilities could help advance in dialog-based AI systems, and also in many other aspects of AI. The AI index could add metrics to follow the advancements in tests and challenges related to these capabilities, such as: the Winograd Schema Challenge, The Aristo project at AI2 and the associated Kaggle competitions on science exams, and Dialog-based challenges such as the IBM Debater.

Cooperation with humans
It is also important to move from human vs machine to human+machine environments, if we want AI to augment human intelligence rather than replacing it. Metrics to show the advancements in this could be number of non-autonomous systems where humans are the final decision makers but are supported by machines.

AI Reasoning + Learning
Machine learning is very successful in many applications, since it can discover hidden correlation within huge amounts of data. This allows to make very accurate predictions. However, in many domains we need to go beyond correlation and derive causality information, in order to move from prediction to intervention and be able to shape the future. A possible metric about this could be the number of causality papers at AI conference (not just ML, also AI conferences like AAAI or IJCAI)

(https://aiindex.org/)

Next Hype of AI?

Construct

- C1: Programming Abstractions for Cyber-Physical Systems
- C2: Composition and Abstraction with Explications
- C3: Supervision of Dynamic Dependable Systems
- C4: Distributed Knowledge and Information Flow
- C5: Combining Program Analysis and Run-Time Monitoring
- C6: Fast, Safe, and Perspicuous Run-Time Planning

Analyze & Explicate

- A1: Analysing and Explicating Dynamical and Hybrid Systems
- A2: Probabilistic Causality and Explications
- A3: Description Logic Explications
- A4: Logic-Based Perspicuous Run-Time Supervision
- A5: Operational Explications of Classifier Predictions

Expliain & Interact

- E1: Interactive Exploration of Visual Models
- E2: Safe Handover in Mixed-Initiative Control
- E3: Knowledge-Driven Inspection
- E4: Immersive Analysis of Cyber-Physical Systems

Foundations of Perspicuous Software Systems
Collaborative Research Center 248

(https://www.perspicuous-computing.science/)

perspicuous /pəˈspɪkjʊəs/
adjective *formal*
clearly expressed and easily understood; lucid.
able to give an account or express an idea clearly.

Next Hype of AI?

January 20, 2019

Facebook and the Technical University of Munich Announce New Independent TUM Institute for Ethics in Artificial Intelligence

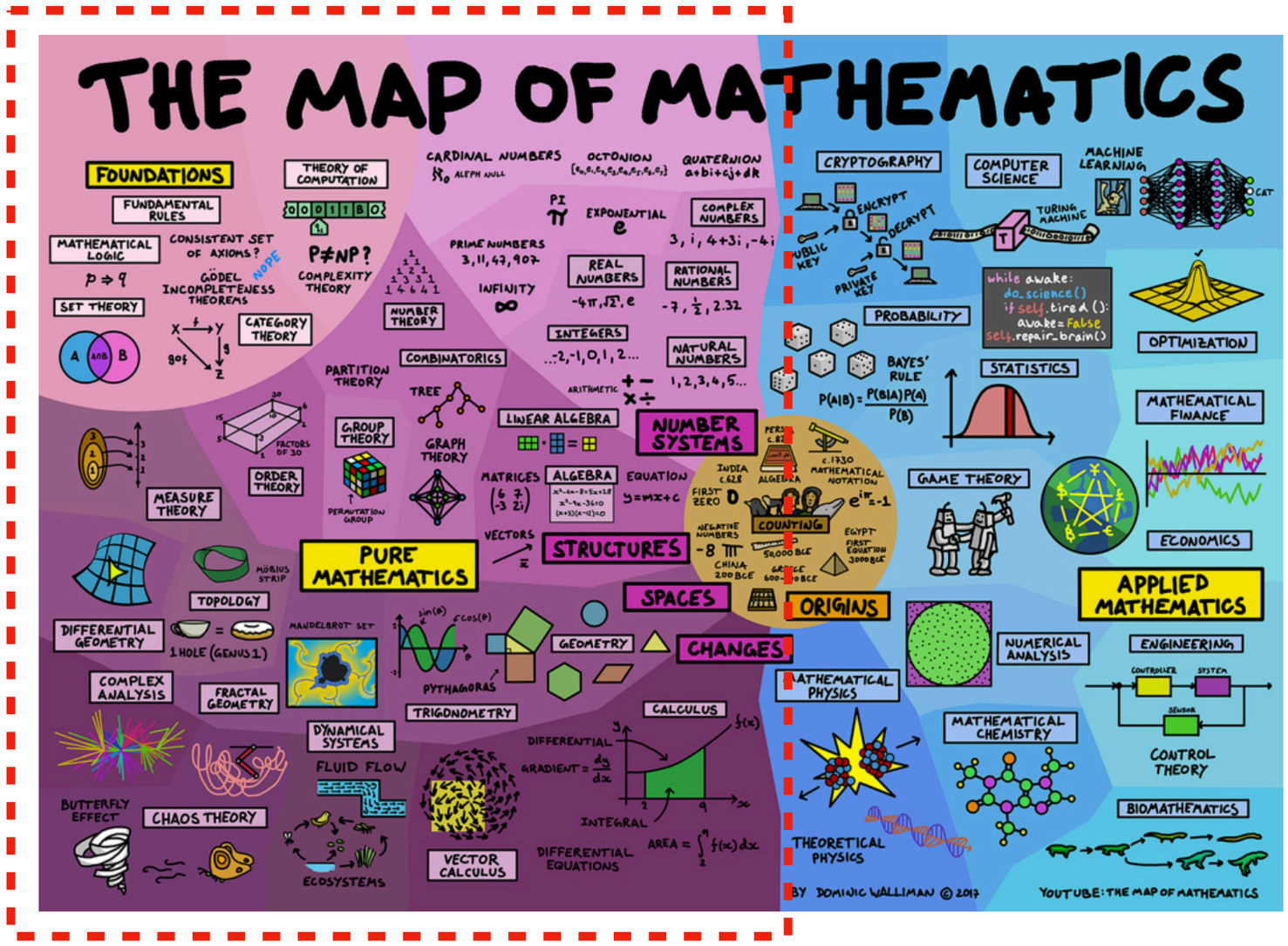
"Core questions arise around trust, privacy, fairness or inclusion, for example, when people leave data traces on the internet or receive certain information by way of algorithms.

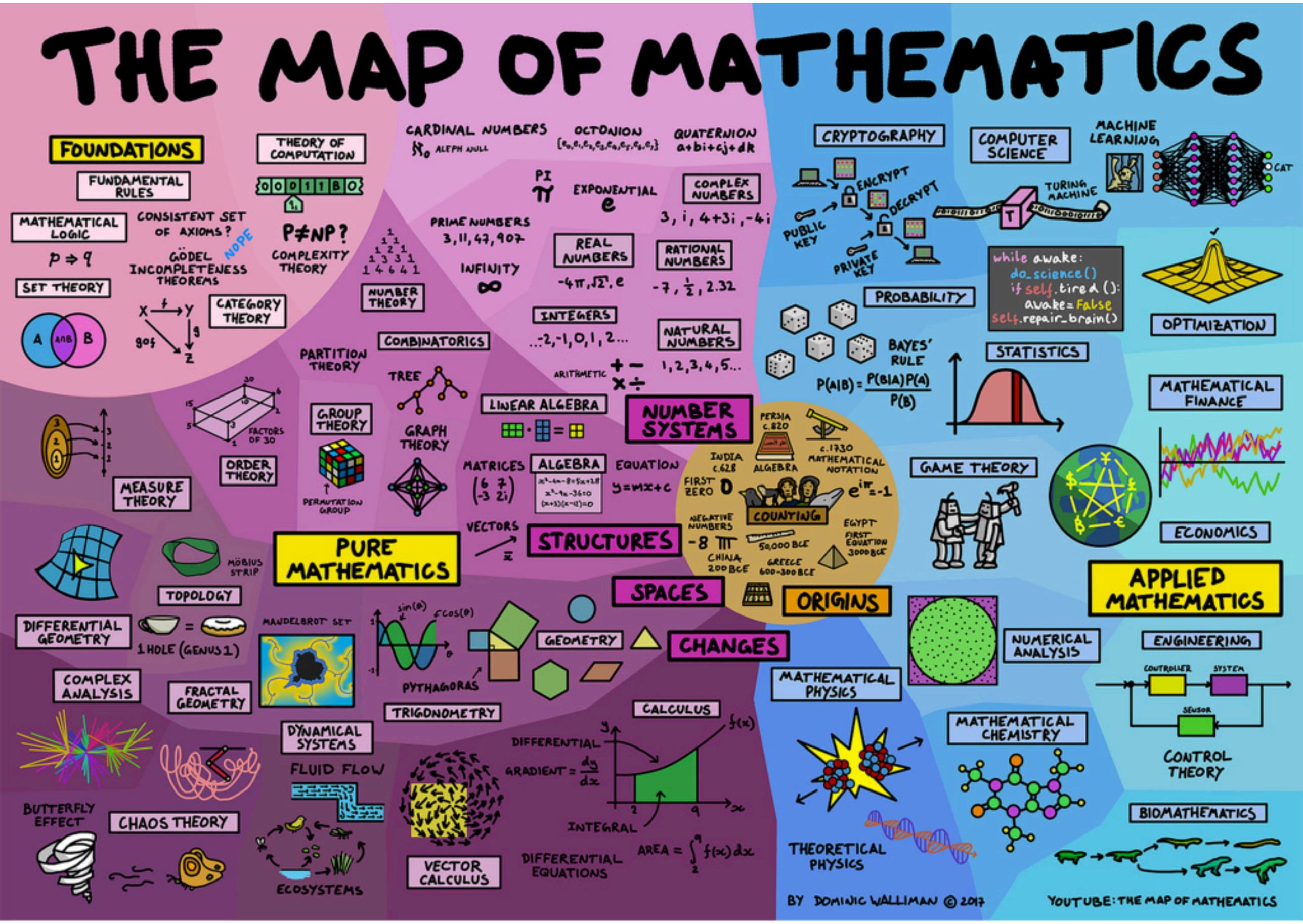
We will also deal with transparency and accountability, for example in medical treatment scenarios, or with rights and autonomy in human decision-making in situations of human-AI interaction."
— TUM Professor Dr. Christoph Lütge

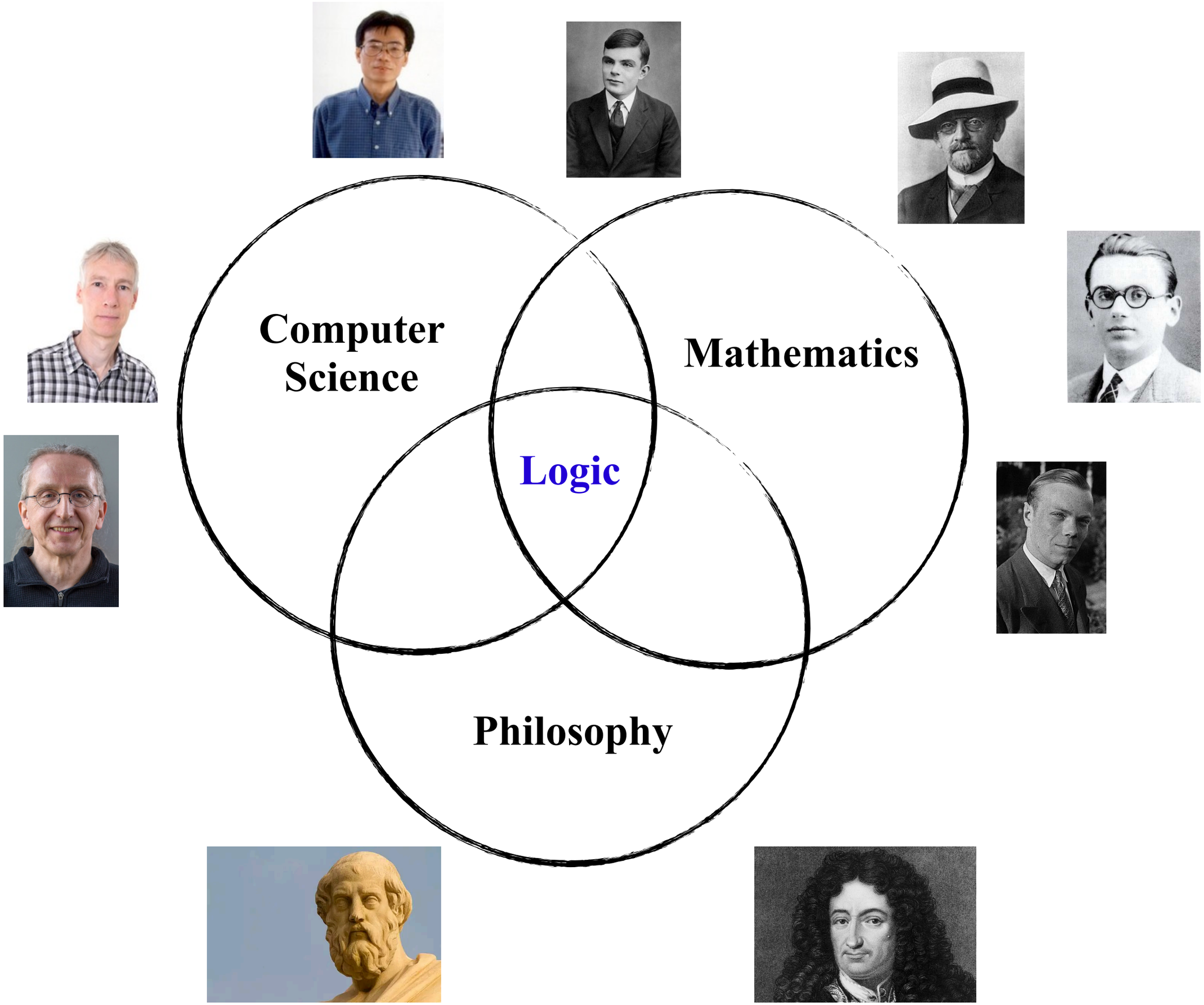
(https://newsroom.fb.com/news/2019/01/tum-institute-for-ethics-in-ai/)

This Morning's Talk

Goal: Walk through 'logic', which plays the basics of 'reasoning'




THE MAP OF MATHEMATICS
FOUNDATIONS
FUNDAMENTAL RULES
MATHEMATICAL LOGIC
p ⇒ q
CONSISTENT SET OF AXIOMS?
NOPE
GÖDEL INCOMPLETENESS THEOREMS
SET THEORY
A ∩ B
CATEGORY THEORY
THEORY OF COMPUTATION
P≠NP?
COMPLEXITY THEORY
CARDINAL NUMBERS
ℵ0 ALEPH NULL
OCTONION
QUATERNION
a+bi+cj+dk
PI
π
EXPONENTIAL
e
COMPLEX NUMBERS
3, i, 4+3i, -4i
PRIME NUMBERS
3, 11, 47, 907
INFINITY
∞
REAL NUMBERS
-4π, √2, e
RATIONAL NUMBERS
-7, 1/2, 2.32
NUMBER THEORY
INTEGERS
...-2, -1, 0, 1, 2...
NATURAL NUMBERS
1, 2, 3, 4, 5...
ARITHMETIC
+ − × ÷
COMBINATORICS
PARTITION THEORY
TREE
GRAPH THEORY
FACTORS OF 30
ORDER THEORY
MEASURE THEORY
GROUP THEORY
PERMUTATION GROUP
LINEAR ALGEBRA
MATRICES
ALGEBRA
EQUATION
y=mx+c
VECTORS
NUMBER SYSTEMS
STRUCTURES
PURE MATHEMATICS
MÖBIUS STRIP
TOPOLOGY
DIFFERENTIAL GEOMETRY
1 HOLE (GENUS 1)
MANDELBROT SET
COMPLEX ANALYSIS
FRACTAL GEOMETRY
sin(θ)
cos(θ)
PYTHAGORAS
TRIGONOMETRY
GEOMETRY
SPACES
CHANGES
DYNAMICAL SYSTEMS
FLUID FLOW
BUTTERFLY EFFECT
CHAOS THEORY
ECOSYSTEMS
VECTOR CALCULUS
CALCULUS
DIFFERENTIAL
GRADIENT = dy/dx
INTEGRAL
DIFFERENTIAL EQUATIONS
AREA = ∫ f(x) dx
PERSIA c.820
ALGEBRA
INDIA c.628
c.1730 MATHEMATICAL NOTATION
FIRST ZERO 0
e^iπ = -1
COUNTING
NEGATIVE NUMBERS
-8
CHINA 200 BCE
50,000 BCE
EGYPT FIRST EQUATION 3000 BCE
GREECE 600-300 BCE
ORIGINS
CRYPTOGRAPHY
ENCRYPT
DECRYPT
PUBLIC KEY
PRIVATE KEY
COMPUTER SCIENCE
TURING MACHINE
MACHINE LEARNING
CAT
while awake:
do_science()
if self.tired():
awake=False
self.repair_brain()
OPTIMIZATION
PROBABILITY
BAYES' RULE
P(A|B) = P(B|A)P(A) / P(B)
STATISTICS
MATHEMATICAL FINANCE
GAME THEORY
ECONOMICS
APPLIED MATHEMATICS
NUMERICAL ANALYSIS
ENGINEERING
CONTROLLER
SYSTEM
SENSOR
CONTROL THEORY
MATHEMATICAL PHYSICS
THEORETICAL PHYSICS
MATHEMATICAL CHEMISTRY
BIOMATHEMATICS
BY DOMINIC WALLIMAN © 2017
YOUTUBE: THE MAP OF MATHEMATICS


Computer Science
Mathematics
Logic
Philosophy

Logic

Philosophical Logic

- subject concerned with the most general laws of truth
- systematic study of the form of valid inference
- *aka.* logic in philosophy

Mathematical Logic

- subfield of mathematics
- meta-mathematics
- foundation of mathematics
- theoretical computer science
- *aka.* login in mathematics

Computational Logic

- the use of logic (in philosophy) to perform or reason about computation
- *aka.* logic in computer science

Basic AI Approaches

AI

Data-based AI

- *aka.* machine learning
- want a computer to learn from data *e.g.*
  - find insights from large datasets
  - make predictions w.r.t. high dimensionality

Knowledge-based AI

- *aka.* mathematical logic / computational logic
- want a computer to reason from data *e.g.*
  - hypotheses made on the basis of evidence and reasoning
- want to store knowledge in a machine-readable way

General Topics in AI

- Problem Solving and Search
- Knowledge Representation and Reasoning
- Uncertain Knowledge
- Learning and Acquisition
- Planning

มโนกรรม

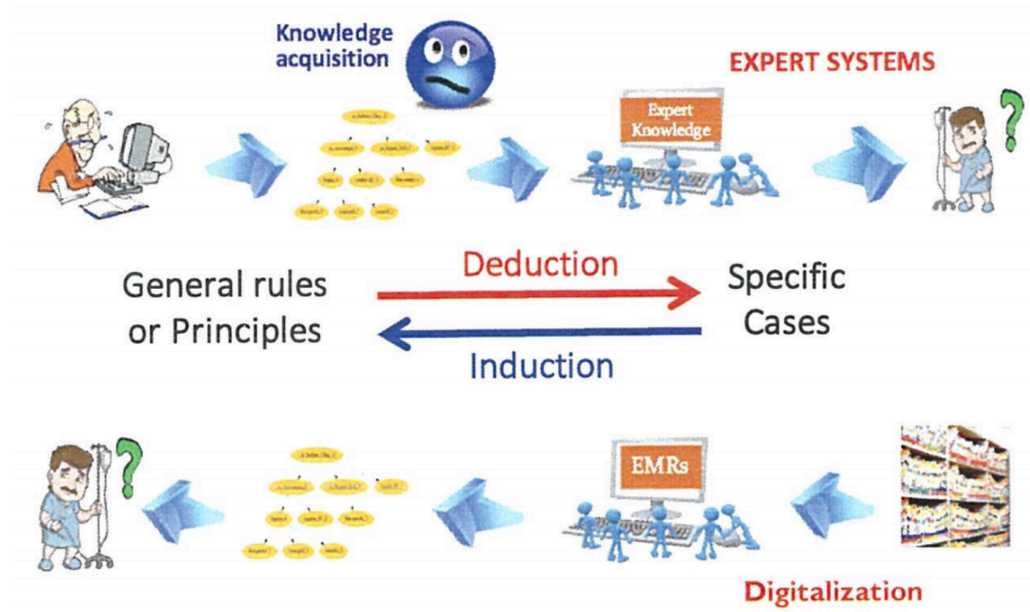
- Communicating

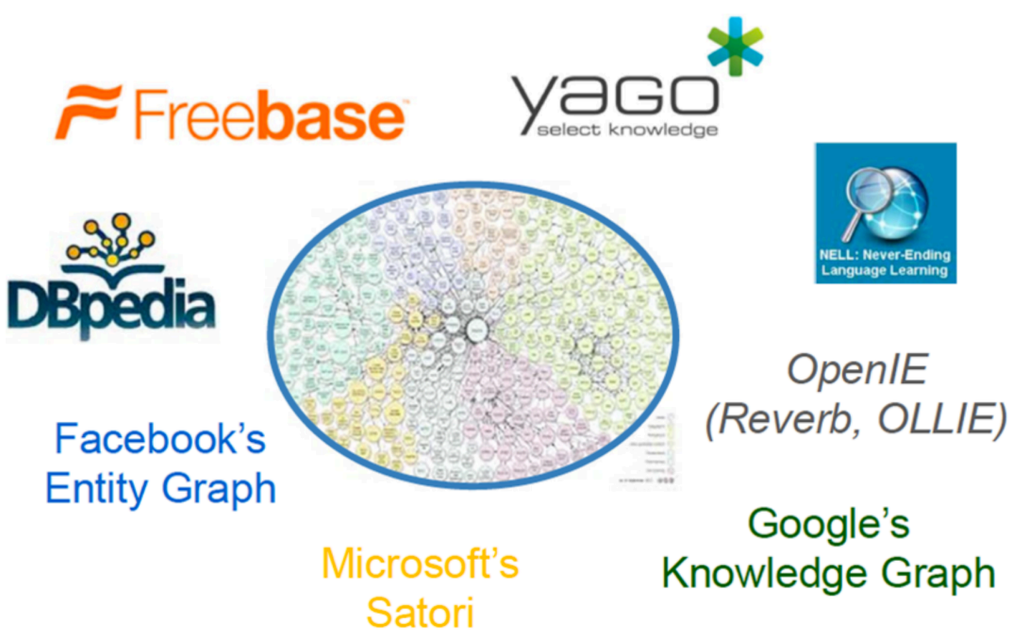
วจีกรรม

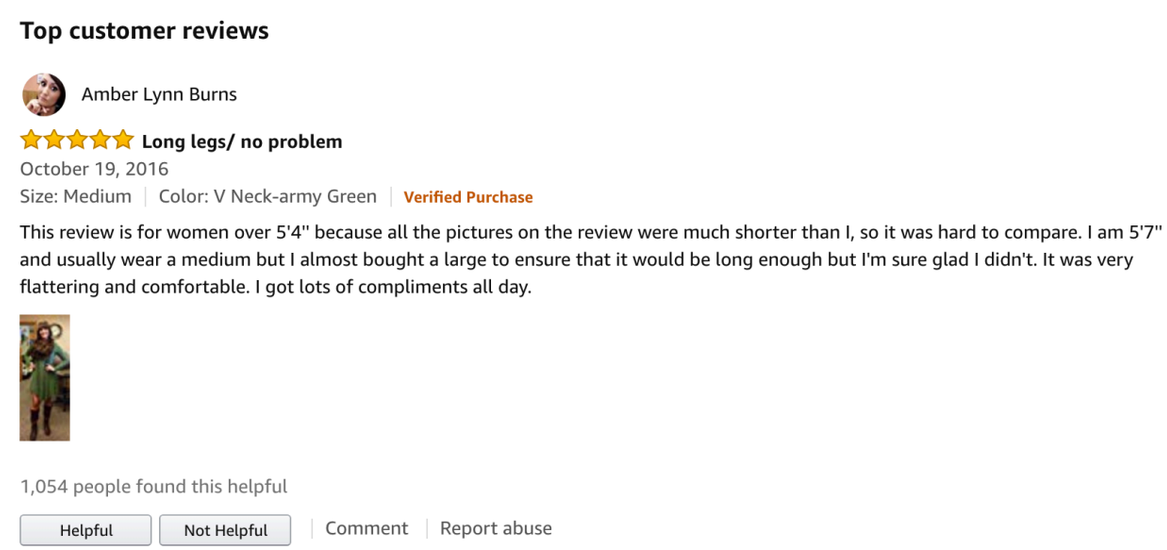
- Perceiving
- Acting
- Applications

กายกรรม

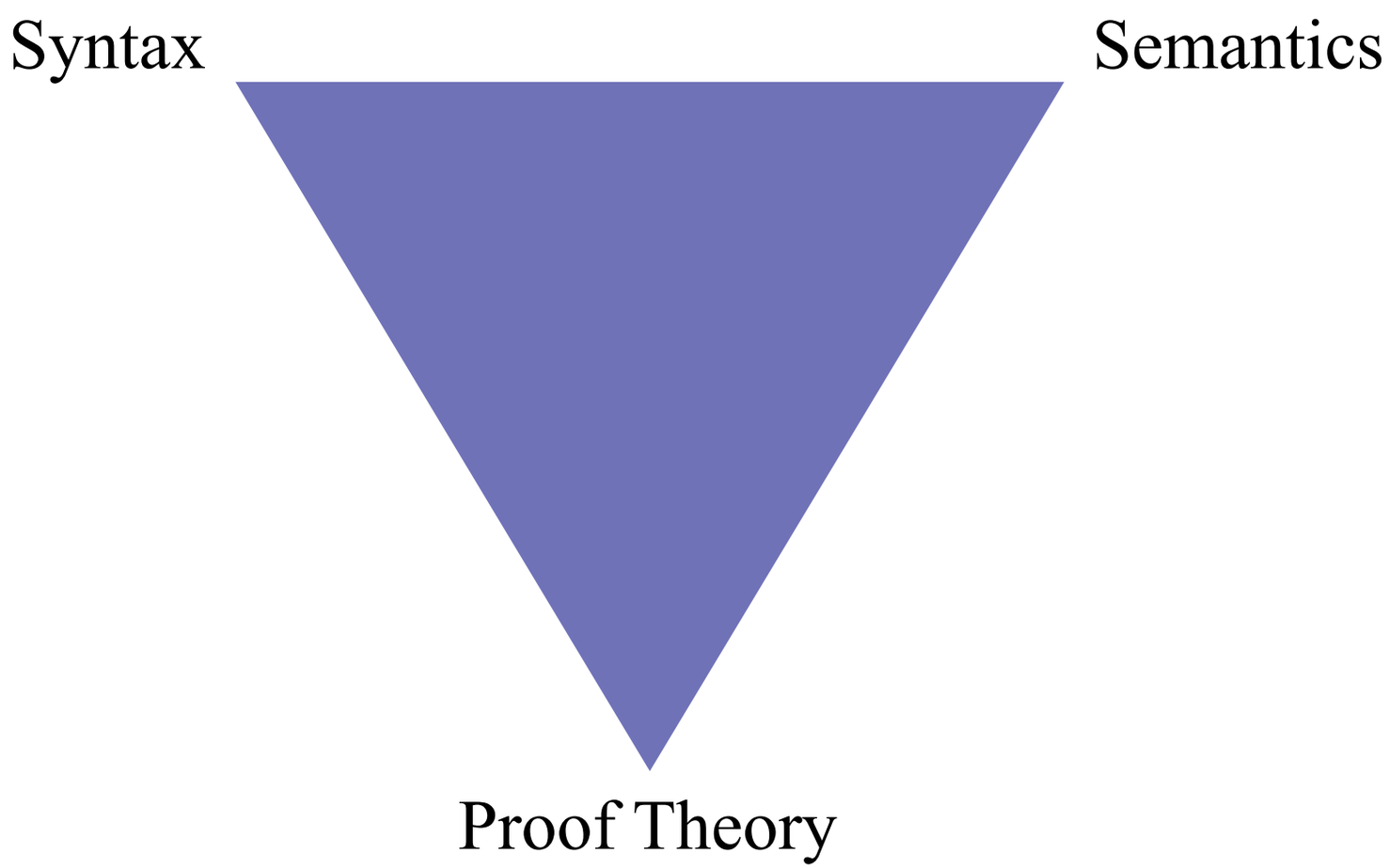
Logic in Artificial Intelligence







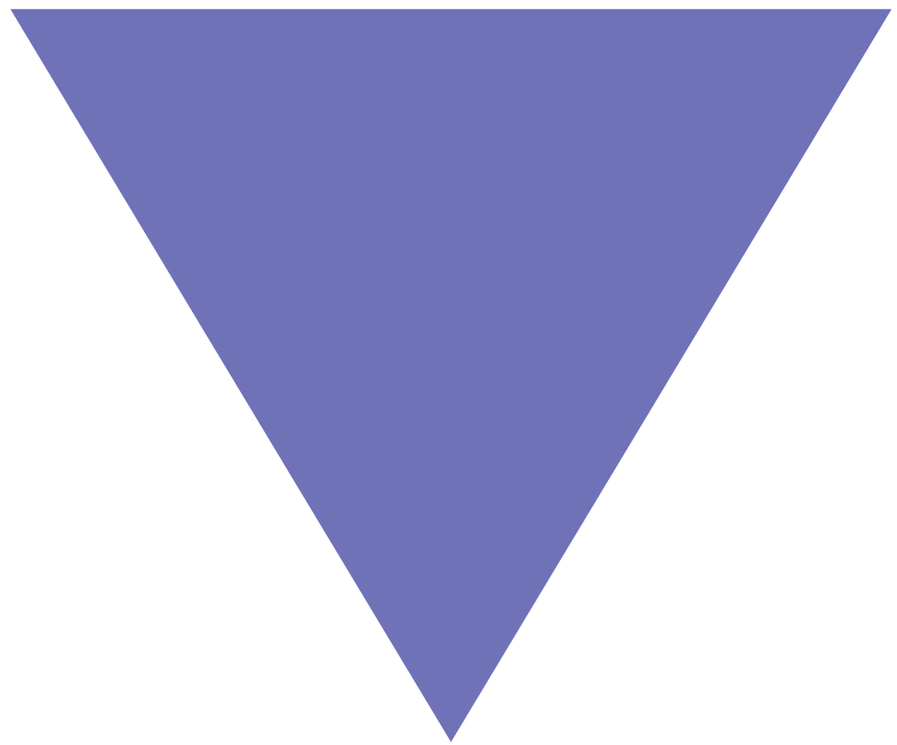
Basic Framework of Logic



Basic Framework of Logic

Syntax
- symbols
- language
- *etc.*

Semantics
- interpretation
- valuation function
- *etc.*



Proof Theory
- computation
- calculus
- *etc.*

Propositional Logic (PL)

- Propositions are basic elements *e.g.* $P, Q, R, \ldots$

$$P \mid P \wedge Q \mid P \vee Q \mid P \rightarrow Q \mid P \leftrightarrow Q \mid \neg P$$

Ex. Let

- **P : ฉันดื่มเบียร์**
- **Q: ฉันดื่มไวน์**

- Semantics of propositional sentences

P	Q	$P \vee Q$	$P \wedge Q$	$\neg P$
T	T	T	T	F
T	F	T	F	F
F	T	T	F	T
F	F	F	F	T

$\wedge$: … and …

$\vee$: … or …

$\rightarrow$: if … then …

$\leftrightarrow$: … if and only if …

$\neg$: not …

Propositional Logic (PL)

- Syntax:

$$P, Q, P \wedge Q, P \vee Q, P \rightarrow Q, \neg P, \ldots$$

- Semantics:

$$v(P) = 1,\ v(Q) = 0,\ v(P \wedge Q) = \min\{1,0\}$$

- Proof Theory:
  - ex. given P and Q, show that $P \wedge Q$ is also true.

$$\frac{[P] \qquad [Q]}{P \wedge Q} \wedge I$$

'Natural Deduction' - a kind of proof calculus introduced by Gentzen in 1994

ถ้า 'ฉันดื่มเบียร์' 'ฉันดื่มไวน์' เป็นเหตุการณ์ที่เกิดขึ้นจริง
แล้ว การสรุปว่า 'ฉันดื่มเบียร์และฉันดื่มไวน์' เป็นการสรุปที่ถูกต้องหรือไม่

(Gerhard Gentzen)

Natural Deduction

$$\frac{\phi \quad \psi}{\phi \wedge \psi}\ \wedge i \qquad \frac{\phi \wedge \psi}{\phi}\ \wedge e_1 \qquad \frac{\phi \wedge \psi}{\psi}\ \wedge e_2$$

$$\frac{\phi}{\neg\neg\phi}\ \neg\neg i \qquad \frac{\neg\neg\phi}{\phi}\ \neg\neg e$$

$$\frac{\boxed{\begin{array}{c}\phi\\ \vdots\\ \psi\end{array}}}{\phi \rightarrow \psi}\ \rightarrow i \qquad \frac{\phi \vee \psi \quad \boxed{\begin{array}{c}\phi\\ \vdots\\ \chi\end{array}} \quad \boxed{\begin{array}{c}\psi\\ \vdots\\ \chi\end{array}}}{\chi}\ \vee e$$

Natural Deduction

P : ฉันดื่มเบียร์ก่อนโค้ด
Q : ฉันดื่มไวน์ก่อนโค้ด
R : ฉันเขียนโค้ดได้ดี

- Show that $(P \wedge Q) \rightarrow R \vdash P \rightarrow (Q \rightarrow R)$

'... สามารถสรุปว่า ...'

$$
\dfrac{\dfrac{\dfrac{\dfrac{[P] \quad [Q]}{P \wedge Q} \qquad [(P \wedge Q) \rightarrow R]}{R}}{Q \rightarrow R}}{P \rightarrow (Q \rightarrow R)}
$$

Natural Deduction

P : ฉันดื่มเบียร์ก่อนโค้ด
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'Syntactical Consequence operator'

$$
\dfrac{\dfrac{\dfrac{\dfrac{[P] \quad [Q]}{P \wedge Q} \qquad [(P \wedge Q) \rightarrow R]}{R}}{Q \rightarrow R}}{P \rightarrow (Q \rightarrow R)}
$$

Natural Deduction

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'Syntactical Consequence operator'

$$\dfrac{\dfrac{\dfrac{\dfrac{[P] \quad [Q]}{P \wedge Q} \qquad [(P \wedge Q) \rightarrow R]}{R}}{Q \rightarrow R}}{P \rightarrow (Q \rightarrow R)}$$

P	Q	R	$P \wedge Q$	$(P \wedge Q) \rightarrow R$	$Q \rightarrow R$	$P \rightarrow (Q \rightarrow R)$
1	1	1	1	1	1	1
1	0	0	0	1	1	1
0	1	0	0	1	0	1
0	0	1	0	1	1	1
1	1	0	1	0	0	0
1	0	1	0	1	1	1
0	1	1	0	1	1	1
0	0	0	0	1	1	1

'Semantical Consequence operator' $\models$

Applications of PL

- Boolean Satisfiability problem (*aka.* SAT)
  - It asks whether the variables of a given boolean formula can be ‘consistently’ replaced by the values *True* or *False* in such a way that the formula evaluates to *True*.
  - *E.g.* $(P \vee Q \vee \neg R) \wedge (\neg P \vee \neg Q \vee S) \wedge (R \vee S)$

Applications of PL

- Boolean Satisfiability problem (*aka.* SAT)
  - It asks whether the variables of a given boolean formula can be ‘consistently’ replaced by the values *True* or *False* in such a way that the formula evaluates to *True*.
  - *E.g.* $(P \vee Q \vee \neg R) \wedge (\neg P \vee \neg Q \vee S) \wedge (R \vee S)$
  - Used in ‘automotive configuration’ *e.g.* BMW manufacturing [1]

[1] Walter, Rouven, Christoph Zengler, and Wolfgang Küchlin. "Applications of MaxSAT in Automotive Configuration." *Configuration Workshop*. Vol. 1. No. 2. 2013.

Automotive Configuration

SAT gives answer ‘unsatisfiable’ if constraints are inconsistent.

The after-sales asks for extensions, replacements, or removal of components of a valid configuration with minimal effort.

1. Validation of a partial configuration
2. Forced components
3. Redundant components

Table 1: Component families with limitations

family	alternatives	limit
engine	E_1, E_2, E_3	$= 1$
gearbox	G_1, G_2, G_3	$= 1$
control unit	C_1, C_2, C_3, C_4, C_5	$= 1$
dashboard	D_1, D_2, D_3, D_4	$= 1$
navigation system	N_1, N_2, N_3	≤ 1
air conditioner	AC_1, AC_2, AC_3	≤ 1
alarm system	AS_1, AS_2	≤ 1
radio	R_1, R_2, R_3, R_4, R_5	≤ 1

[1] Walter, Rouven, Christoph Zengler, and Wolfgang Küchlin. "Applications of MaxSAT in Automotive Configuration." *Configuration Workshop*. Vol. 1. No. 2. 2013.

First-order Logic (FOL)

- Constant term: *a, b, c, ...*
- Variable term: *x, y, z, ...*
- Predicate: **P**, **Q**, **R**, ...
- Function: f, g, h, ...
- Literal: **P***(a),* ...
- Quantifier: ∀, ∃

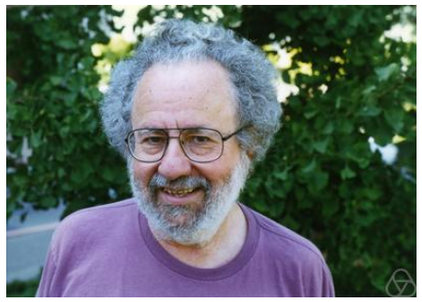
"all human beings are mortal"

$\forall x[\textbf{Human}(x) \rightarrow \textbf{Mortal}(x)]$

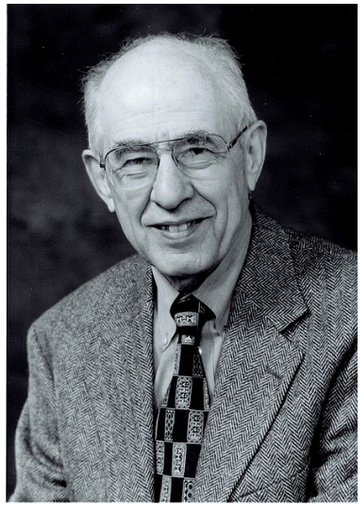
"some birds do not fly"

$\exists x[\textbf{Bird}(x) \wedge \neg\textbf{Fly}(x)]$

Other Proof Calculus



(Martin Davis)



(Hilary Putnam)

“used to show syntactical consequence”

- Natural Deduction (Gentzen, 1994)
- Analytic Tableau (Beth, 1995)
- Resolution (Davis and Putnam, 1960)
- Hilbert’s style Axiomatization (Hilbert, 1927)

(David Hilbert)

Applications of FOL

Example. Cats like fish. Cats eat everything they like. Josef is a cat. Prove that Josef eats fish.

$$\neg\textbf{Cat}(x) \lor \textbf{Likes}(x, \textbf{fish})$$

$$\neg\textbf{Cat}(y) \lor \neg\textbf{Likes}(y, z) \lor \textbf{Eats}(y, z)$$

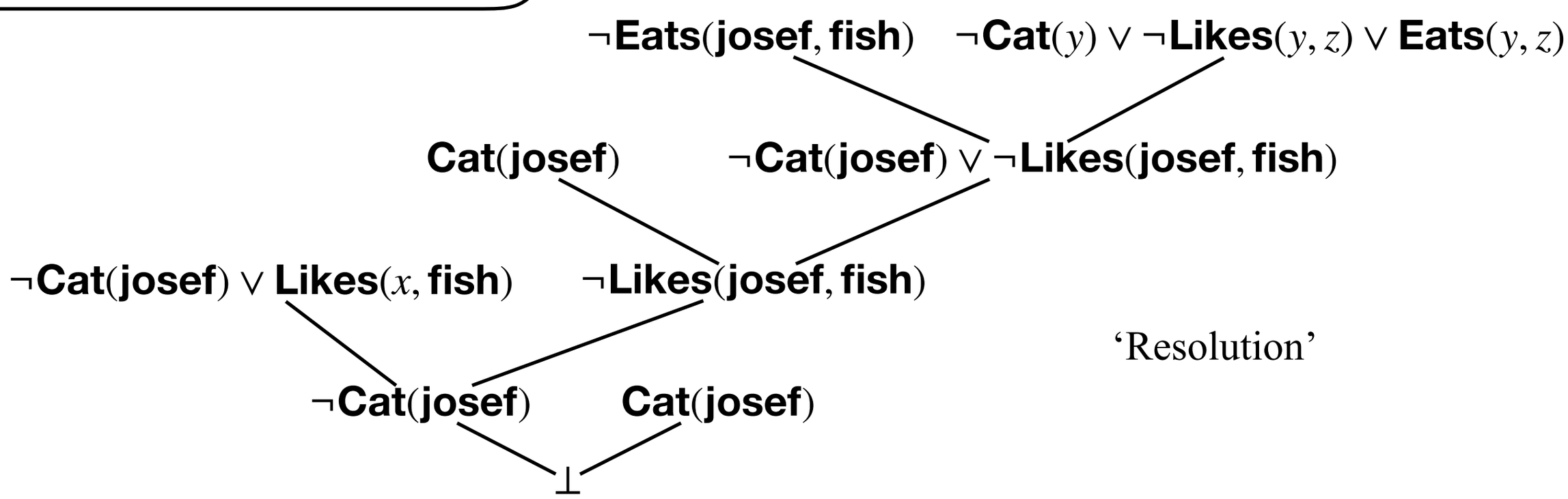
$$\textbf{Cat}(\textbf{josef})$$

$$\vdash \textbf{Eats}(\textbf{josef}, \textbf{fish})$$

Applications of FOL

Example. Cats like fish. Cats eat everything they like. Josef is a cat. Prove that Josef eats fish.

$$\left.\begin{array}{l} \neg\textbf{Cat}(x) \vee \textbf{Likes}(x, \textbf{fish}) \\ \neg\textbf{Cat}(y) \vee \neg\textbf{Likes}(y, z) \vee \textbf{Eats}(y, z) \\ \textbf{Cat}(\textbf{josef}) \end{array}\right\} \vdash \textbf{Eats}(\textbf{josef}, \textbf{fish})$$



'Resolution'

Applications of FOL

- *Example.* Tony, Mark, and Ellen are members of Hoofers club. Every member of Hoofers club is either a skier or a mountain climber or both. No mountain climber likes rain and all skiers like snow. Ellen dislikes whatever Tony likes and likes whatever Tony dislikes. Tony likes rain and snow.

Query: Is there a member of Hoofers club who is a mountain climber but not a skier?

Applications of FOL

- *Example.* Tony, Mark, and Ellen are members of Hoofers club. Every member of Hoofers club is either a skier or a mountain climber or both. No mountain climber likes rain and all skiers like snow. Ellen dislikes whatever Tony likes and likes whatever Tony dislikes. Tony likes rain and snow.

  Query: Is there a member of Hoofers club who is a mountain climber but not a skier?

KB:

$$\forall x(\textbf{Skier}(x) \vee \textbf{Climber}(x))$$

$$\neg\exists x(\textbf{Climber}(x) \wedge \textbf{Likes}(x, \textbf{rain}))$$

$$\forall x(\textbf{Skier}(x) \rightarrow \textbf{Likes}(x, \textbf{snow}))$$

$$\forall x(\textbf{Likes}(\textbf{ellen}, x) \leftrightarrow \neg\textbf{Likes}(\textbf{tony}, x))$$

$$\textbf{Likes}(\textbf{tony}, \textbf{rain}) \quad \textbf{Likes}(\textbf{tony}, \textbf{snow})$$

Query:

$$\vDash \exists x(\textbf{Climber}(x) \wedge \neg\textbf{Skier}(x))$$

RDB as a logic

Climber

ID	Name
1	Smith
2	Bob

Likes

ClimberID	ObjectID
1	1

Object

ID	Name
1	Rain
2	Snow

RDB as a logic

Climber

ID	Name
1	Smith
2	Bob

Likes

ClimberID	ObjectID
1	1

Object

ID	Name
1	Rain
2	Snow

Climber(1,**smith**)

Climber(2,**Bob**)

Likes(1,1)

Object(1,**rain**)

Object(2,**snow**)

RDB as a logic

Climber

ID	Name
1	Smith
2	Bob

Likes

ClimberID	ObjectID
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Object

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Climber(1,**smith**)

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Query: Find an object that Climber Smith likes ?

RDB as a logic

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ID	Name
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Likes

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Object

ID	Name
1	Rain
2	Snow

Climber(1,**smith**)

Climber(2,**Bob**)

Likes(1,1)

Object(1,**rain**)

Object(2,**snow**)

Query: Find an object that Climber Smith likes ?

SQL: select Object.name
from Climber, Likes, Object
where Climber.Name = ‘Smith’ and Climber.ID = Likes.ClimberID
and Likes.ObjectID = Object.ID

RDB as a logic

Climber

ID	Name
1	Smith
2	Bob

Likes

ClimberID	ObjectID
1	1

Object

ID	Name
1	Rain
2	Snow

Climber(1,**smith**)

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and Likes.ObjectID = Object.ID

FOL: **RDB** $\models$ **Climber**(1,**smith**) $\wedge$ **Likes**(1,x) $\wedge$ **Object**(x, y)

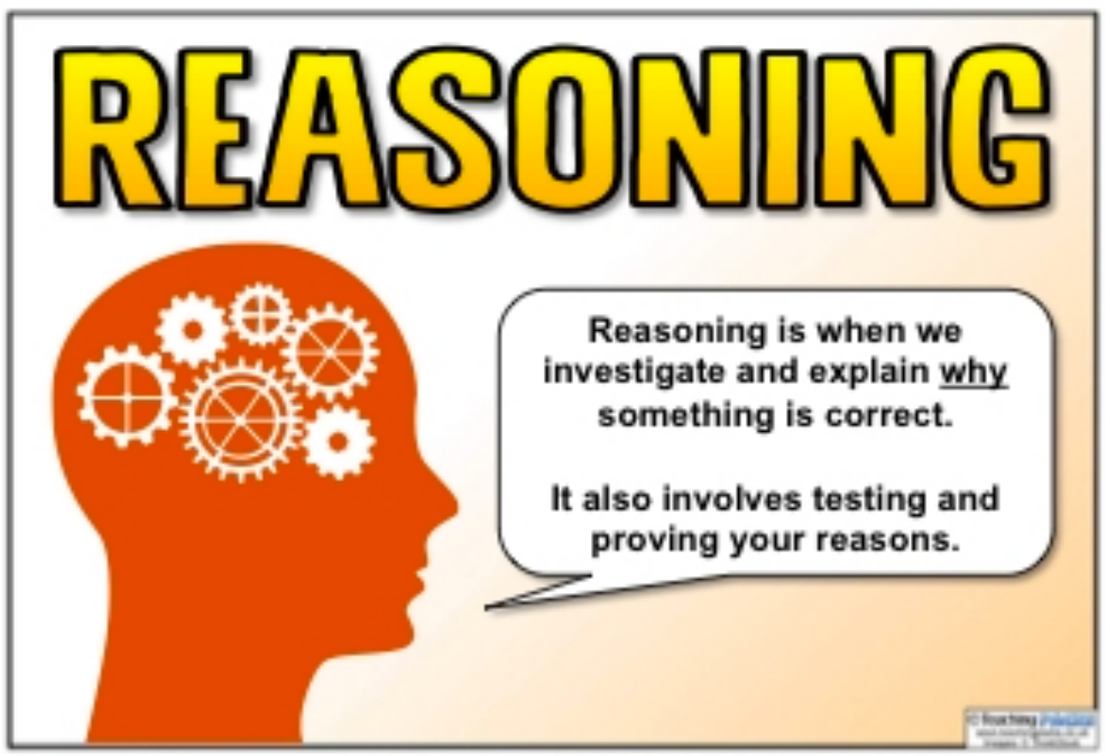
Recap - 1st Part

- Basic framework of logic
- Knowledge Representation
- Usage of SAT solver for automotive configuration

Next, let’s talk more about ‘automated reasoning’ …

What is (automated) reasoning?

- The action of thinking about something in a logical way
- Finding implicit information from a represented knowledge using proof techniques



Example

- Cats like fish. Cats eat everything they like. Josef is a cat.
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$$\neg\textbf{Cat}(x) \vee \textbf{Likes}(x, \textbf{fish})$$
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$$\textbf{Cat}(\textbf{josef})$$

$$\vdash \textbf{Eats}(\textbf{josef}, \textbf{fish})$$

Road to Automated Reasoning

(Gottfried Wilhelm Leibniz)

First tried by Leibniz (1646 - 1716)
to find an algorithm for verifying
the validity of a formula

Road to Automated Reasoning

(Gottfried Wilhelm Leibniz)

(David Hilbert)

Revived by Hilbert in 1920s

Road to Automated Reasoning

(Gottfried Wilhelm Leibniz)

(Kurt Gödel)

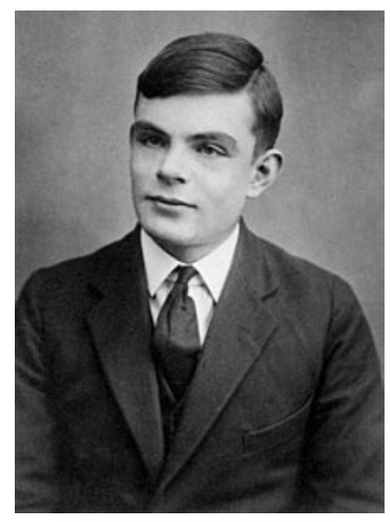
(David Hilbert)

In any axiomatic system, there will be ‘propositions’ which can neither be proved nor disproved in that system (1931).

Road to Automated Reasoning

Church (1936) and Turing (1936) proved that FOL is not decidable *i.e.* there're no algorithms to check the validity of FOL formulae; however, if a formula is valid, there's an algorithm to verify it.

(Alonzo Church)



(Alan Turing)

Road to Automated Reasoning

- An important algorithm was given by Herbrand (1930)

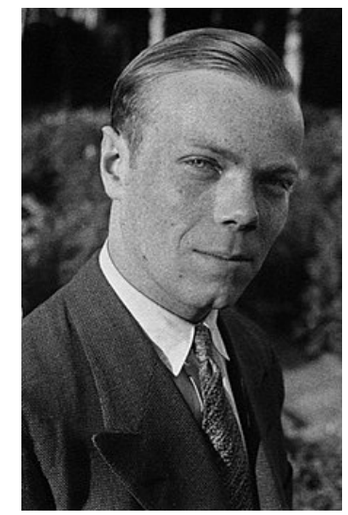
- Gilmore (1960) was one of the first to implement Herbrand's method.

(Jacques Herbrand)

Road to Automated Reasoning

(Gottfried Wilhelm Leibniz)

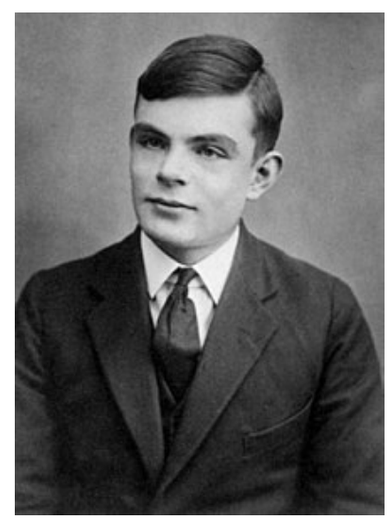
(Kurt Gödel)



(Jacques Herbrand)

(David Hilbert)

(Alonzo Church)



(Alan Turing)

Automated Reasoning

Finding implicit information from a represented knowledge using proof techniques

1. Monotonic Reasoning
2. Non-monotonic Reasoning

“Type of Reasoning”

1. Closed-world Assumption
2. Opened-world Assumption

“View of Reasoning”

Monotonic *vs.* Non-monotonic

Monotonic logic

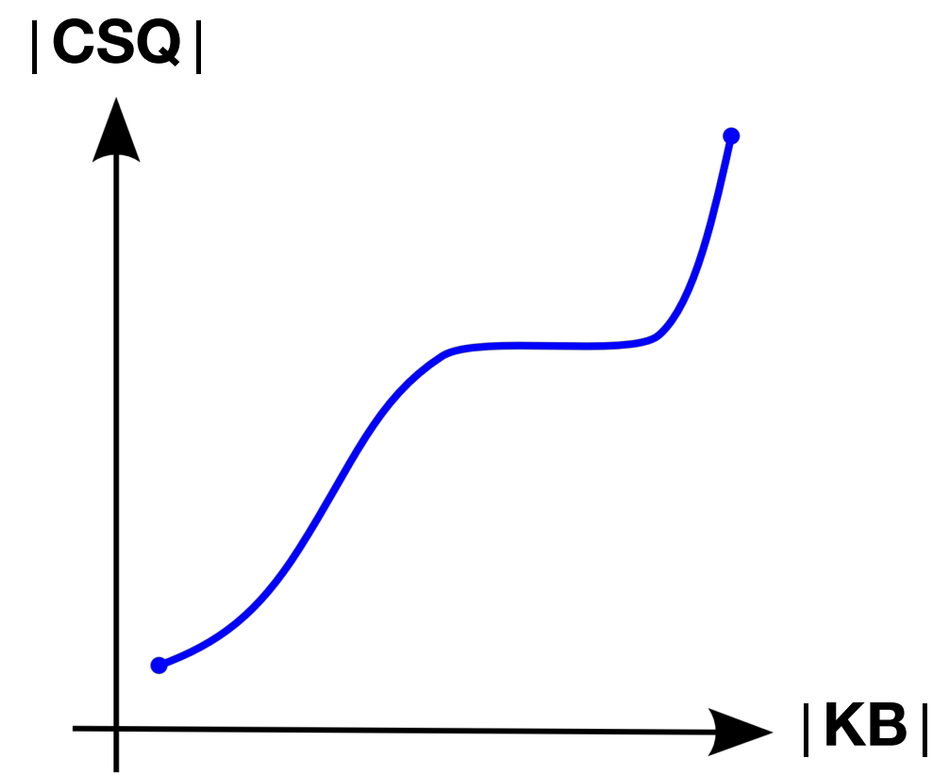
- Once you get a conclusion, the addition of new facts won't change the conclusion.

Non-monotonic logic

- New information can affect the conclusion.

|**KB**| : Size of knowledge base

|**CSQ**| : Size of derived consequences



(monotonic function)

Closed-world Assumption

- All ‘true’ propositions must be mentioned as ‘facts’.
- If a proposition cannot be proved, it is ‘false’, *e.g.*

  ➡Database systems.

Closed-world Assumption

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- If a proposition cannot be proved, it is ‘false’, *e.g.*

  ➡Database systems.

Climber

ID	Name
1	Smith
2	Bob

Likes

ClimberID	ObjectID
1	1

Object

ID	Name
1	Rain
2	Snow

Query: Does Smith like snow?
Answer: No

Opened-world Assumption

- All ‘true’ propositions must be mentioned as ‘facts’.
- If a proposition cannot be proved, it is ‘unknown’, *e.g.*

Climber

ID	Name
1	Smith
2	Bob

Likes

ClimberID	ObjectID
1	1

Object

ID	Name
1	Rain
2	Snow

Query: Does Smith like snow?
Answer: I don’t know

Automated Reasoning in AI

Non-monotonic Reasoning

- Abductive logic
- Belief revision
- Defeasible logic
- Argumentation theory

⋮

George de La Tour: Le Tricheur à l'as de carreau

Monotonic Reasoning

- Propositional logic
- Modal logic
- Description logic
- Existential rules

⋮

- First-order logic
- Higher-order logic

Automated Reasoning in AI

Non-monotonic Reasoning

- Abductive logic
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⋮

George de La Tour: Le Tricheur à l'as de carreau

Monotonic Reasoning

- Propositional logic
- Modal logic
- Description logic
- Existential rules

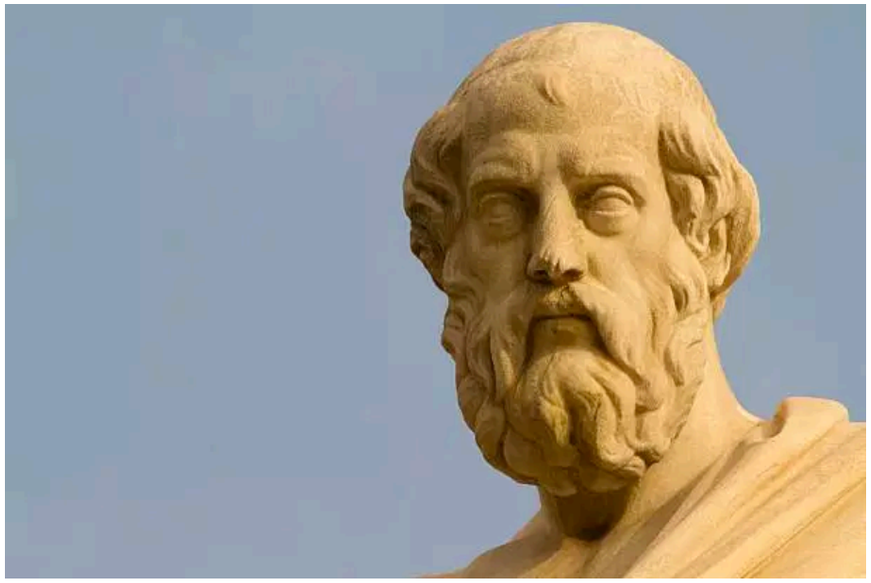
⋮

- First-order logic
- Higher-order logic

Argumentation in History

- Plato's Dialectic
  The dialectical method is discourse between two or more people holding different points of view about a subject, who wish to establish the truth of the matter guided by reasoned arguments.

- Leibniz's Dream
  "The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are *dispute among persons,* we can simply say: Let us calculate [*calculemus*], without further ado, to see who is right"



(Plato)

(Gottfried Wilhelm Leibniz)

Argumentation Nowadays

- Abstract Argumentation (Dung, 1995)

The 2018 Classic Paper Awards

ELSEVIER

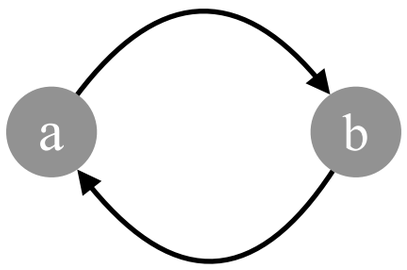
Artificial Intelligence

Volume 77, Issue 2, September 1995, Pages 321-357

On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and *n*-person games ☆

Phan Minh Dung ✉

(Phan Minh Dung, AIT)



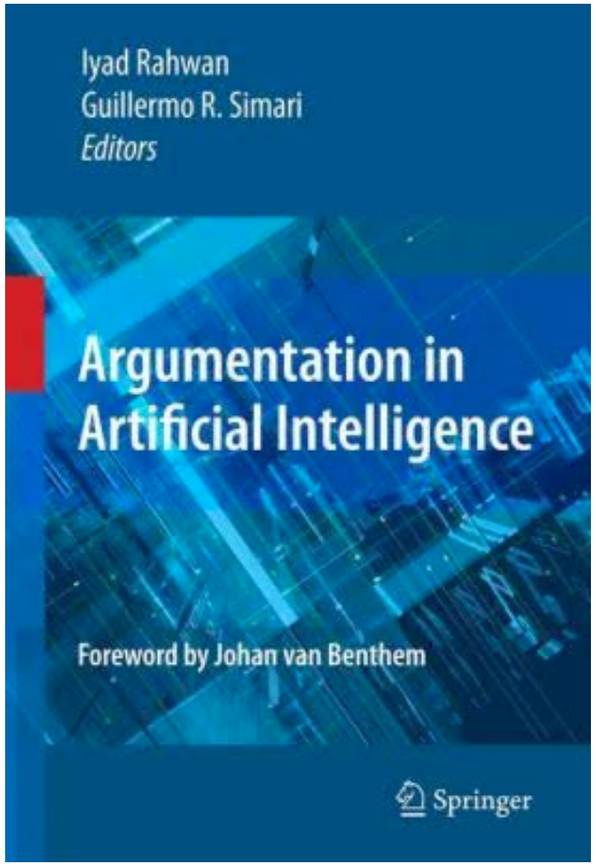
a: Nixon is a pacifist

b: Nixon is ‘not’ a pacifist

Link to AIJ 2018 award: http://aij.ijcai.org/index.php/aij-awards

Argumentation Nowadays

- "Argumentation" as *keyword* at all major AI conferences
- Dedicated Conference: COMMA, TAFA workshop, and *etc.*
- Specialized Journal: Argument & Computation
- 2 Text Books:
    1. Besnard, Hunter: Elements of Argumentation. MIT Press, 2008
    2. Rahwan, Simari (eds.): Argumentation in Artificial Intelligence. Springer, 2009.



Customer’s Behavior Analysis

Top customer reviews

Amber Lynn Burns

Long legs/ no problem

October 19, 2016

Size: Medium | Color: V Neck-army Green | **Verified Purchase**

This review is for women over 5'4'' because all the pictures on the review were much shorter than I, so it was hard to compare. I am 5'7'' and usually wear a medium but I almost bought a large to ensure that it would be long enough but I'm sure glad I didn't. It was very flattering and comfortable. I got lots of compliments all day.

1,054 people found this helpful

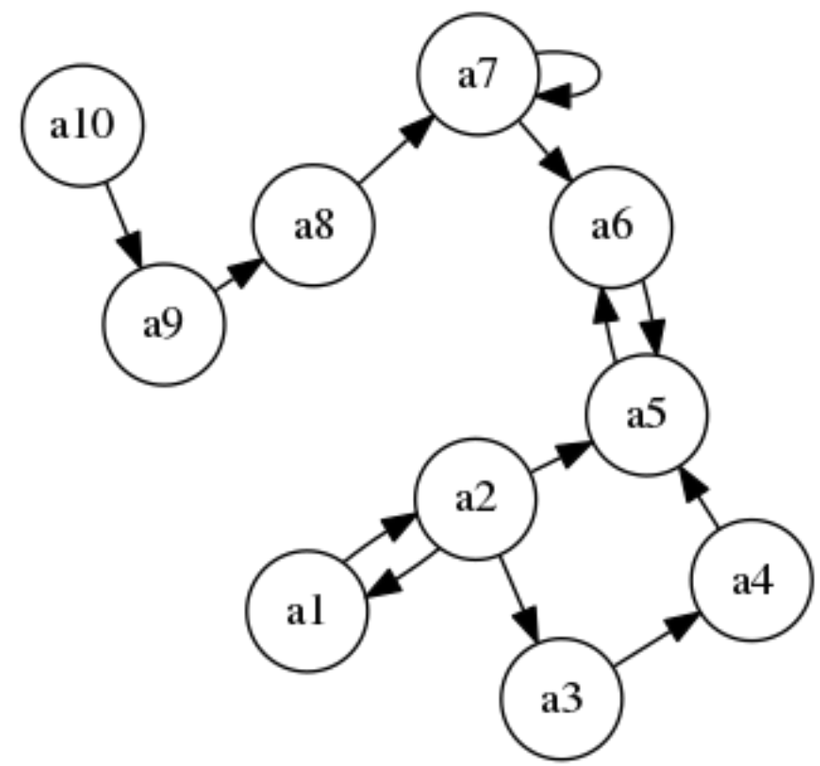
Helpful | Not Helpful | Comment | Report abuse

- Simone Gabbriellini, Francesco Santini: From Reviews to Arguments and from Arguments Back to Reviewers' Behaviour. ICAART (Revised Selected Papers) 2016: 56-72
- Simone Gabbriellini, Francesco Santini: From Arguments and Reviewers to their Simulation - Reproducing a Case-Study. ICAART (1)2016: 74-83

Customer's Behavior Analysis

ID	Positive arguments	#App.
A	the kid loved it	78
B	it fits well	65
C	it has a good quality/price ratio	52
D	it has a good quality	44
E	it is durable	31
F	it is shipped fast	25

ID	Negative arguments	#App.
a	it has a bad quality	18
b	it is not sewed properly	17
c	it does not fit	12
d	it is not full	11
e	it is not as advertised	8
f	it is not durable	7



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Description Logic (DL)

- Logic for representing ‘description’ of knowledge

Knowledge Base

$\mathbf{Cat} \equiv \mathbf{Mammal} \sqcap \exists \mathbf{hasCover}\,.\,\mathbf{Fur}$

$\mathbf{VegetarianCat} \equiv \mathbf{Mammal} \sqcap \exists \mathbf{hasCover}\,.\,\mathbf{Fur} \sqcap \exists \mathbf{eats}\,.\,\mathbf{Salad}$

$\mathbf{Salad} \sqsubseteq \mathbf{Plant}$

Query: Is a vegetarian cat a kind of cat?
(or, equivalently $\models \mathbf{VegetarianCat} \sqsubseteq \mathbf{Cat}$)

… reasoning …

(Franz Baader)

(Ian Horrocks)

Description Logic (DL)

- Logic for representing ‘description’ of knowledge

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$\mathbf{Salad} \sqsubseteq \mathbf{Plant}$

(Franz Baader)

Query: Is a vegetarian cat a kind of cat?
(or, equivalently $\models \mathbf{VegetarianCat} \sqsubseteq \mathbf{Cat}$)

Answer: Yes, it is !

(Ian Horrocks)

Description Logic (DL)

Instances

$\mathbf{Mammal}(\mathbf{garfield})$

$\mathbf{Fur}(\mathbf{f17})$

$\mathbf{Lasagna}(\mathbf{l23})$

$\mathbf{hasCover}(\mathbf{garfield}, \mathbf{f17})$

$\mathbf{eats}(\mathbf{garfield}, \mathbf{l23})$

$\forall \mathbf{eats} \,.\, \mathbf{Beef}(\mathbf{garfield})$

Terminologies

$\mathbf{Cat} \equiv \mathbf{Mammal} \sqcap \exists \mathbf{hasCover} \,.\, \mathbf{Fur} \sqcap \forall \mathbf{eats} \,.\, \mathbf{Meat}$

$\mathbf{Meat} \equiv \mathbf{Beef} \sqcup \mathbf{Chicken}$

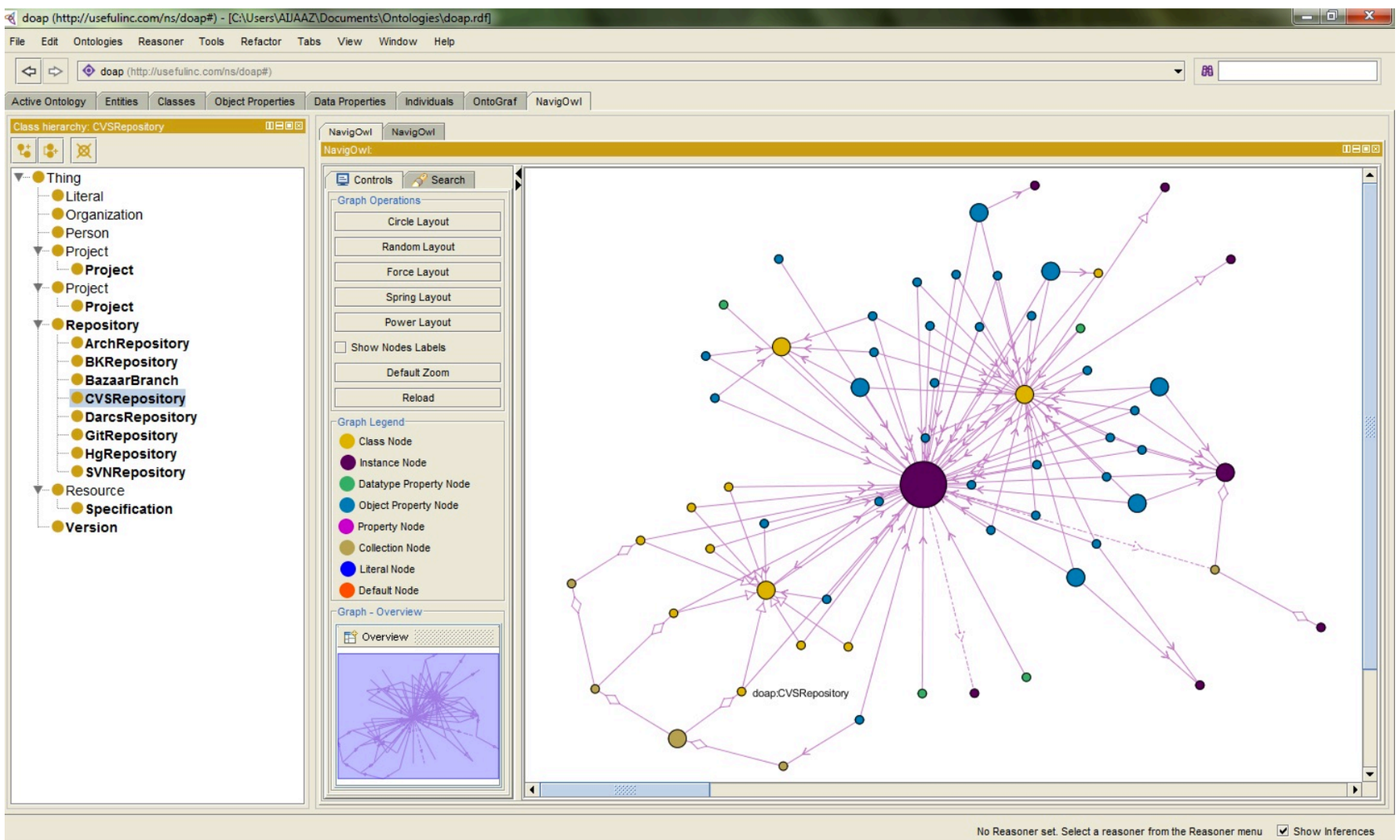
$\bot \equiv \mathbf{Lasagna} \sqcap \mathbf{Beef}$

KB

Conclusions

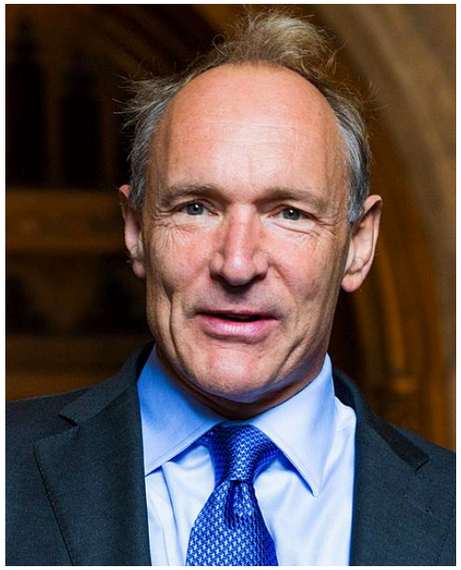
1. Instances are ‘inconsistent’ w.r.t. terminologies
2. garfield is an instance of Cat

Applications of DL



Semantic Web as Web 3.0

"I have a dream for the Web, in which computers become capable of analyzing all the data on the web — the content, links, and transactions between people and computers."



(Tim Berners-Lee)

Semantic Web is an extension of the World Wide Web through standards by W3C. The standards promote common data formats and exchange protocols on the Web, most fundamentally the *Resource Description Framework* (RDF)

Knowledge Graph

Freebase

yago
select knowledge

NELL: Never-Ending Language Learning

DBpedia

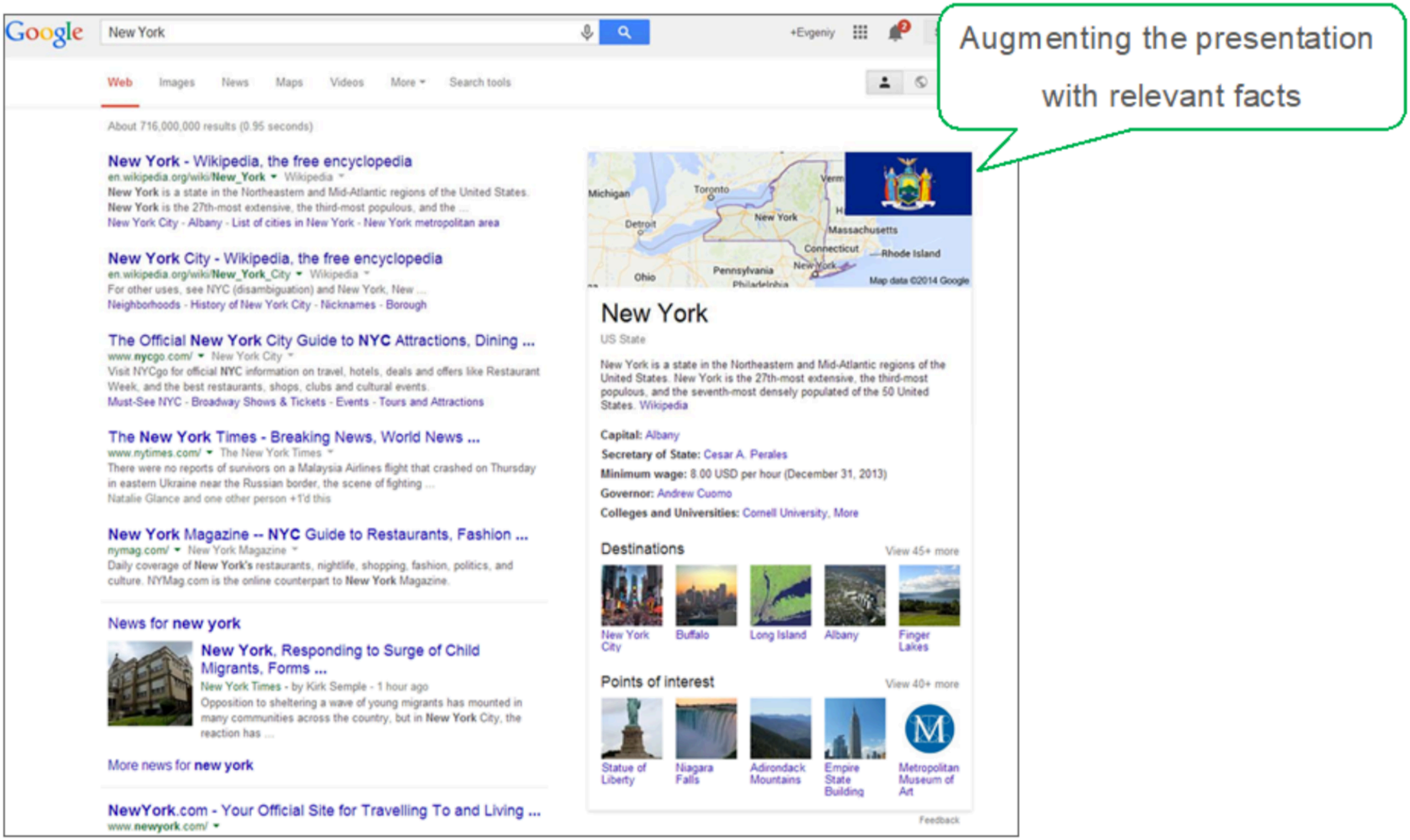
OpenIE
(Reverb, OLLIE)

Facebook's
Entity Graph

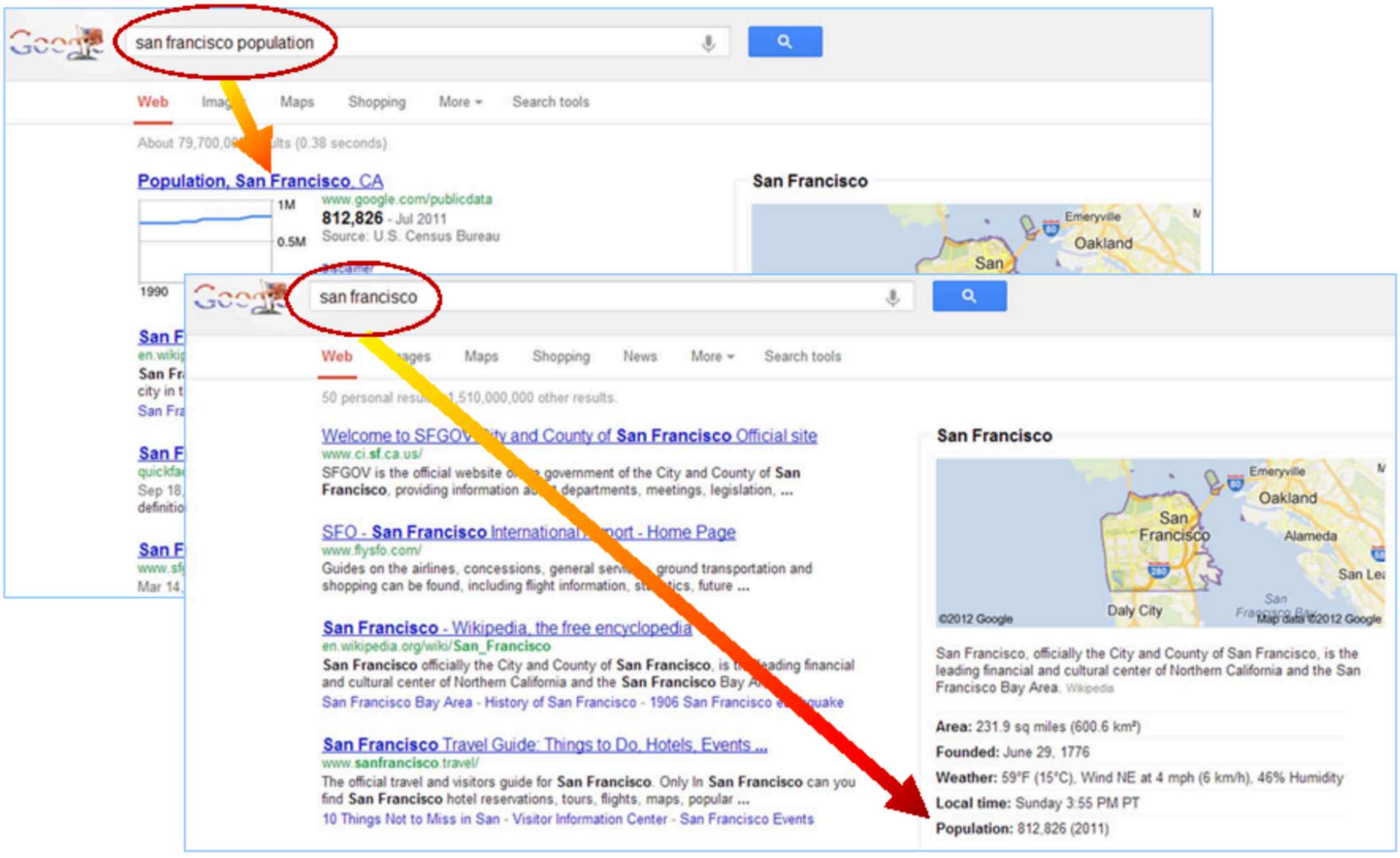
Microsoft's
Satori

Google's
Knowledge Graph

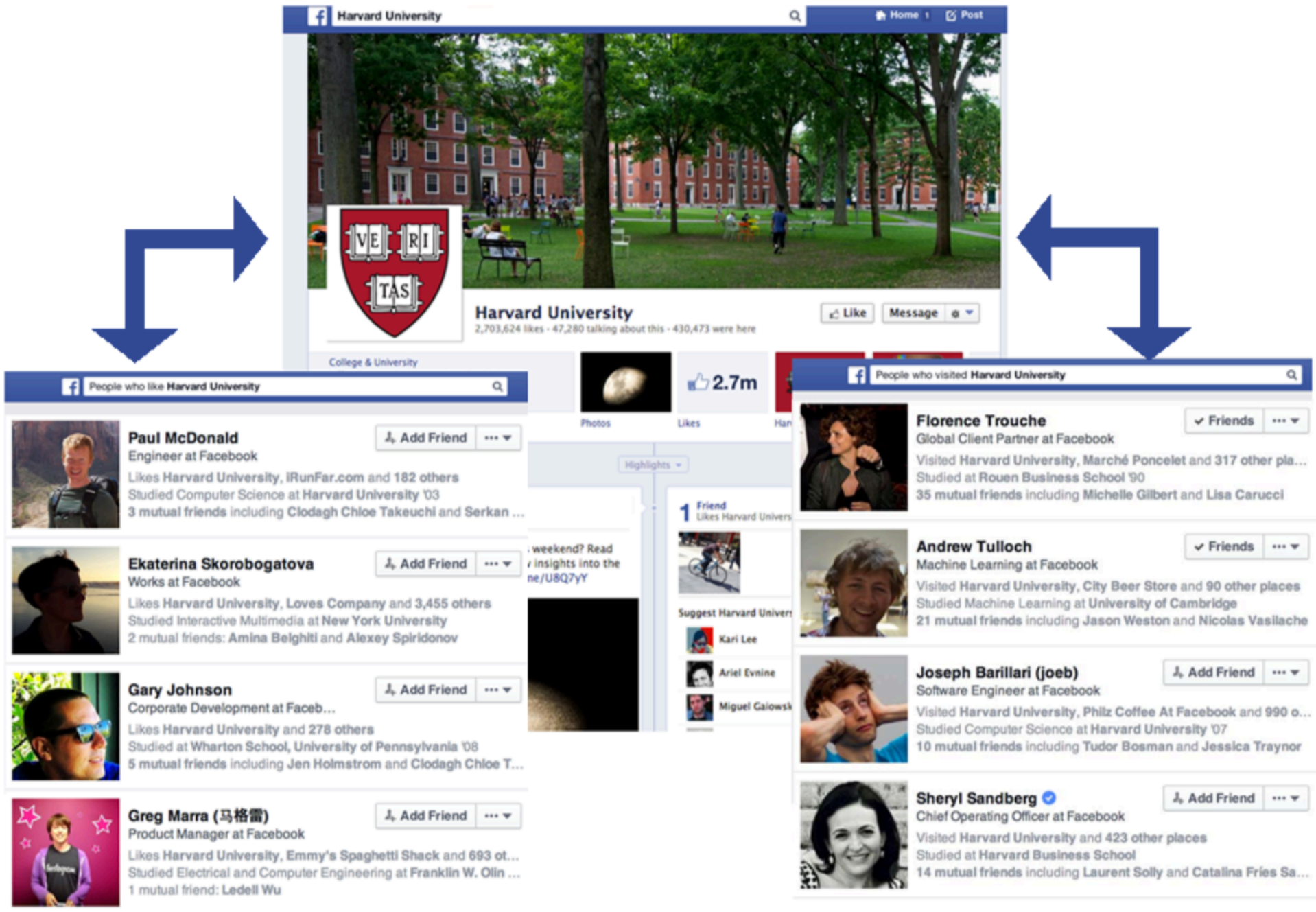
Surfacing Structured Results in Web Search



Surfacing Facts Proactively



Connecting People, Places, and Things



Supplemental Reasoning

- Classical logical reasoners justify the validity of a formula *i.e.* either ‘true’ or ‘false’ *e.g.*
  Q: Is a vegetarian cat a kind of Cat?
  A: Yes, it is.

- In some situations, we prefer ‘graded’ answers *e.g.*
  Q: In which degree, a vegetarian cat is like a cat?
  A: It is 100% cat.

  - This leads to study ‘similarity measure’ in knowledge base.

- Teeradaj Racharak, Boontawee Suntisrivaraporn, and Satoshi Tojo, Personalizing a concept similarity measure in the description logic $\mathcal{ELH}$ with preference profile, In Computing and Informatics vol. 37, no. 3, pp. 581-613, 2018

Similarity in Knowledge Base

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$\mathbf{Salad} \sqsubseteq \mathbf{Plant}$

Knowledge Base

Query: In which degree, Vegetarian Cat is similar to Cat ?

… Computing …

Similarity in Knowledge Base

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$\mathbf{Salad} \sqsubseteq \mathbf{Plant}$

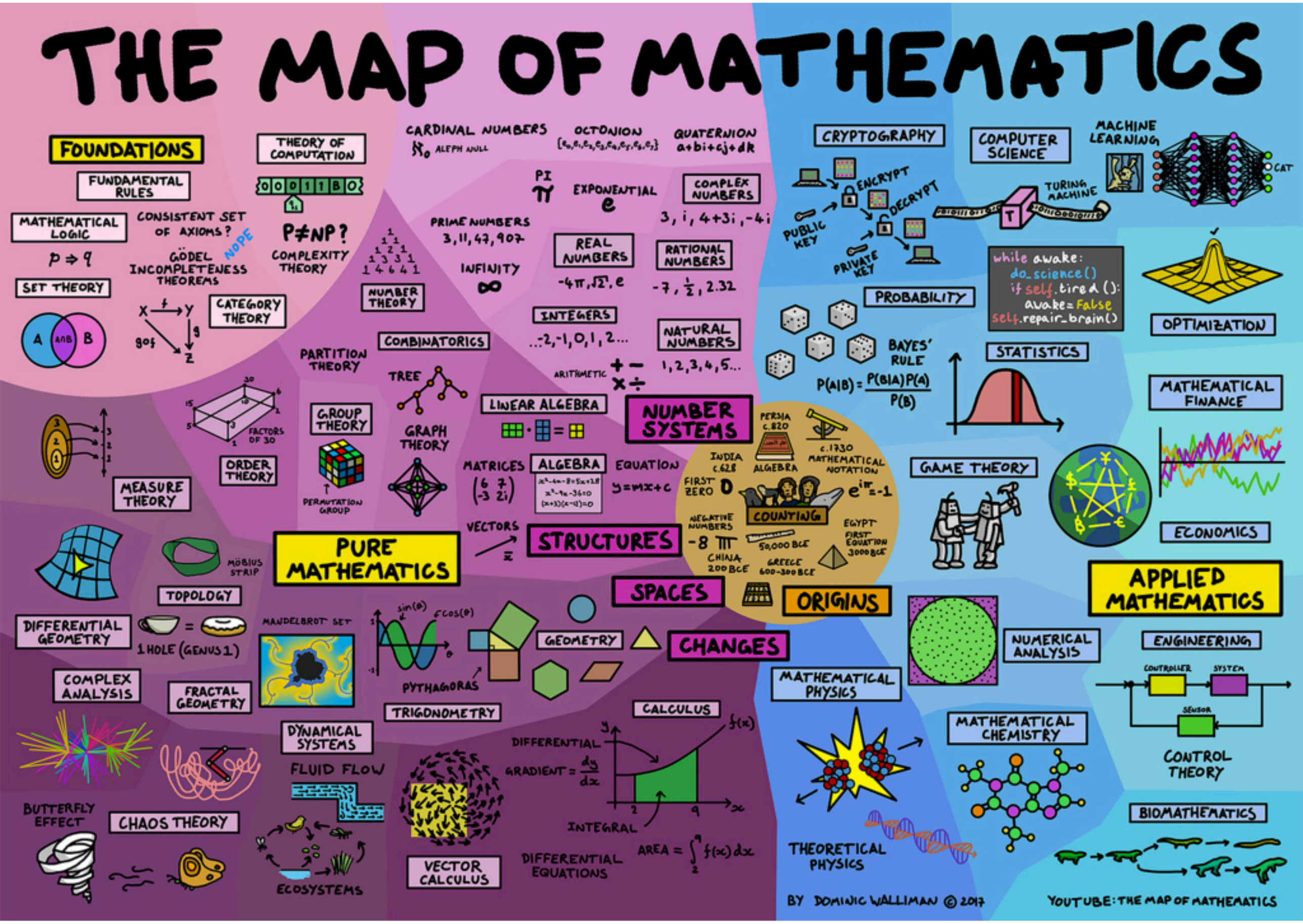
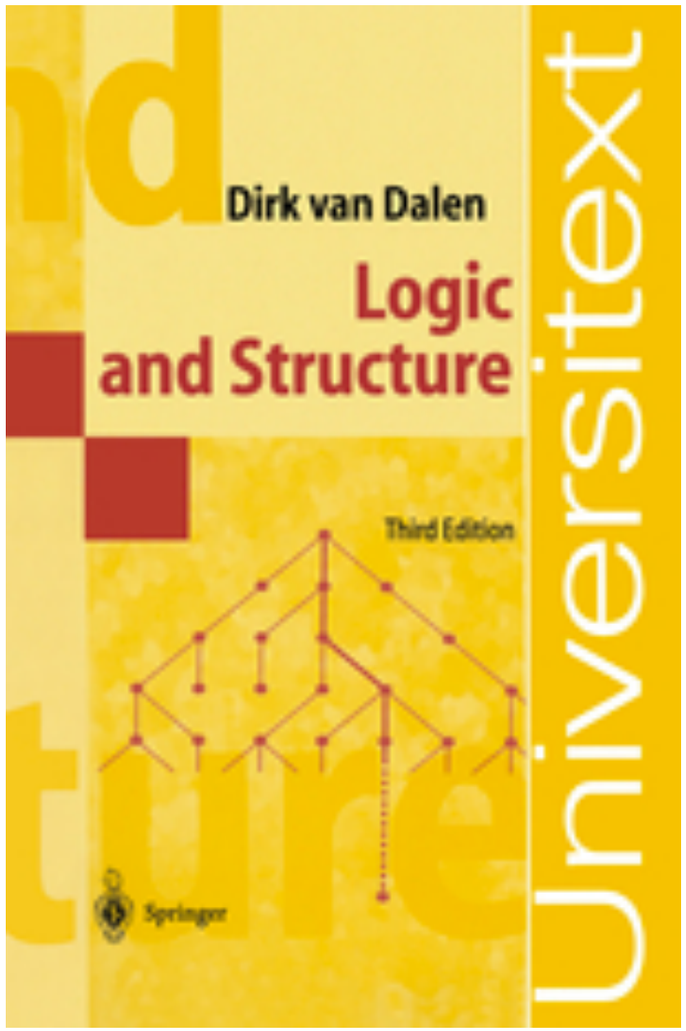
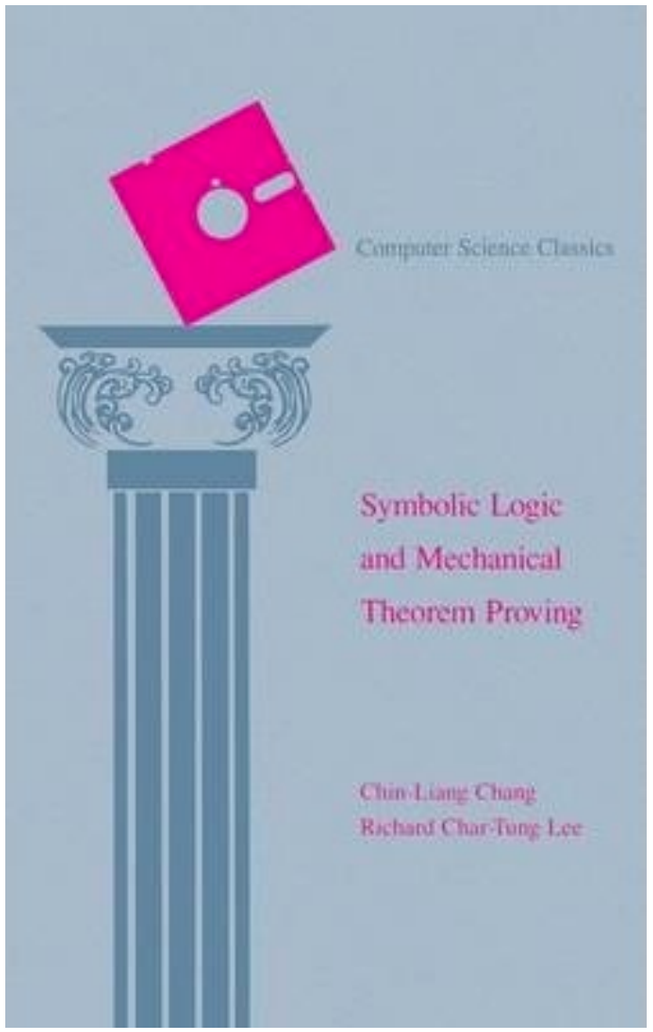
Knowledge Base

Query: In which degree, Vegetarian Cat is similar to Cat ?

Answer: 0.83 degree (or 83%) !

Recap - 2nd Part

- Basics of knowledge representation and reasoning
- Monotonic reasoning *vs.* non-monotonic reasoning
  - Argumentation theory
  - Description logic
- Closed-world assumption *vs.* opened-world assumption


THE MAP OF MATHEMATICS
FOUNDATIONS
FUNDAMENTAL RULES
MATHEMATICAL LOGIC
p ⇒ q
CONSISTENT SET OF AXIOMS?
NOPE
GÖDEL INCOMPLETENESS THEOREMS
SET THEORY
A ∩ B
CATEGORY THEORY
THEORY OF COMPUTATION
P≠NP?
COMPLEXITY THEORY
CARDINAL NUMBERS
ℵ0 ALEPH NULL
OCTONION
QUATERNION
a+bi+cj+dk
PI
π
EXPONENTIAL
e
COMPLEX NUMBERS
3, i, 4+3i, -4i
PRIME NUMBERS
3, 11, 47, 907
INFINITY
∞
REAL NUMBERS
-4π, √2, e
RATIONAL NUMBERS
-7, 1/2, 2.32
NUMBER THEORY
INTEGERS
...-2, -1, 0, 1, 2...
NATURAL NUMBERS
1, 2, 3, 4, 5...
ARITHMETIC
+ − × ÷
COMBINATORICS
PARTITION THEORY
TREE
GRAPH THEORY
FACTORS OF 30
ORDER THEORY
MEASURE THEORY
GROUP THEORY
PERMUTATION GROUP
LINEAR ALGEBRA
MATRICES
ALGEBRA
EQUATION
y=mx+c
VECTORS
PURE MATHEMATICS
STRUCTURES
NUMBER SYSTEMS
PERSIA c.820
ALGEBRA
INDIA c.628
c.1730 MATHEMATICAL NOTATION
FIRST ZERO 0
e^iπ=-1
COUNTING
NEGATIVE NUMBERS
-8
CHINA 200 BCE
50,000 BCE
EGYPT FIRST EQUATION 3000 BCE
GREECE 600-300 BCE
ORIGINS
SPACES
GEOMETRY
CHANGES
TOPOLOGY
MÖBIUS STRIP
DIFFERENTIAL GEOMETRY
1 HOLE (GENUS 1)
MANDELBROT SET
FRACTAL GEOMETRY
COMPLEX ANALYSIS
sin(θ)
cos(θ)
PYTHAGORAS
TRIGONOMETRY
DYNAMICAL SYSTEMS
FLUID FLOW
BUTTERFLY EFFECT
CHAOS THEORY
ECOSYSTEMS
VECTOR CALCULUS
CALCULUS
DIFFERENTIAL
GRADIENT = dy/dx
INTEGRAL
DIFFERENTIAL EQUATIONS
AREA = ∫ f(x) dx
CRYPTOGRAPHY
ENCRYPT
DECRYPT
PUBLIC KEY
PRIVATE KEY
COMPUTER SCIENCE
TURING MACHINE
MACHINE LEARNING
CAT
while awake:
do_science()
if self.tired():
awake=False
self.repair_brain()
OPTIMIZATION
PROBABILITY
BAYES' RULE
P(A|B) = P(B|A)P(A) / P(B)
STATISTICS
MATHEMATICAL FINANCE
GAME THEORY
ECONOMICS
APPLIED MATHEMATICS
NUMERICAL ANALYSIS
ENGINEERING
CONTROLLER
SYSTEM
SENSOR
CONTROL THEORY
MATHEMATICAL PHYSICS
THEORETICAL PHYSICS
MATHEMATICAL CHEMISTRY
BIOMATHEMATICS
BY DOMINIC WALLIMAN © 2017
YOUTUBE: THE MAP OF MATHEMATICS

Further Reading