

The Role of AI and Creativity in Scientific Inquiry

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Mots/Machines #6
Science, AI, Creativity and Creation
Brest, France, March 8, 2024

Slogan # 1

November 30, 2022

Prehistory

3 million years to
3000 BC

Paleolithic	Neolithic	Acient Age	Medieval Age	Modern Age	Contemporary Age
3 million years to 10000 BC	10000 BC	3000BC to 476AC	476 AC to 1492 AC	1492 to 1789 AC	1789 AC to 2011 AC
First human species 2.5 million years BC	Agriculture begins 10000 BC 	Invention of writing 3000BC 	Fall of Western Roman Empire 476 AC 	Colombus discovered America 1492 AC 	French Revolution 1789 AC 
 Use of fire 1 million years BC 					

when was chatgpt released

[All](#) [News](#) [Images](#) [Shopping](#) [Videos](#) [More](#)

Tools

About 167.000.000 results (1,05 seconds)

ChatGPT / Initial release date

November 30, 2022

Who made ChatGPT? ChatGPT was created by OpenAI, an AI and research company. The company launched ChatGPT on November 30, 2022. OpenAI is also responsible for creating DALL-E 2, a popular AI art generator, and Whisper, an automatic speech recognition system.

4 days ago



ZDNet

<https://www.zdnet.com> > ... > Artificial Intelligence[What is ChatGPT and why does it matter? Here's ... - ZDNET](#)

People also search for

GPT-4
March 14,
2023GPT-3
June 11, 2020DALL-E
January 5,
2021

Feedback

People also ask

ChatGPT

Software

ChatGPT is an artificial intelligence chatbot developed by OpenAI and released in November 2022. The name "ChatGPT" combines "Chat", referring to its chatbot functionality, and "GPT", which stands for Generative Pre-trained Transformer, a type of large language model. [Wikipedia](#)

Initial release date: November 30, 2022**Platform:** Cloud computing**Engine:** GPT-3.5; GPT-4**License:** Proprietary**Stable release:** May 24, 2023; 10 days ago**Programming language:** Python**Developer:** OpenAI, Microsoft Corporation

Feedback

New Historical Era?

Pre-history	History	Post-history
Before 3,000 BC	3,000 BC until Nov 30, 2022	After Nov 30, 2022
No written sources	Written sources	Generated sources ¹²

¹ “While we have safeguards in place, the system may occasionally generate incorrect or misleading information and produce offensive or biased content. It is not intended to give advice.”

² “ChatGPT can make mistakes. Consider checking important information.”

Motivation: Science, AI, Creativity and Creation

- Revolutionary progress in IR and NLP
 - ★ Main driver are ever larger language models
 - ★ Trained on endless next token prediction (or images patches)
- By nature a text (image) generation or completion model
 - ★ Free generation obviously “creative”?
 - ★ Prompted generation controls just “bounded creativity” ?
- Four Slogans
 - ★ #1: *November 30, 2022*
 - ★ #2: *AI Strengths and Limitations*
 - ★ #3: *Foundations of Creativity*
 - ★ #4: *Empowering Users?*

Slogan # 2

AI Strengths and Limitations

Representation and Retrieval

- Search is about matching query and document representations
 - ★ Library approaches with **controlled vocabulary** for 150 years
 - ★ **Natural language** (free and full text) approaches since 1950s
 - ★ **Vector space** since 1970s
 - ★ **Learned representations** (SVD, MDS, LSI, ...) since 1990s
- Representation learning revisited
 - ★ Analytic approaches worked but too (exponentially) complex
 - ★ word2vec revisited LSI with neural approximations
 - ★ Transformers on long input sequences made a key difference

Enables Different Ways of Information Access!

- In a way addresses many of the **information science** complaints!
 - ★ No more 10 blue links!
 - ★ Asked for **information** (and not **document**) retrieval
 - ★ Asked for supporting of complex tasks
 - ★ Asked for more human like interactions
- With all (or many) limitations and remaining issues
 - ★ Grammatical, coherent, ... and sensitive and relevant to prompt
 - ★ Passes **Turing test** and Simon's “**bounded rationality**”?
 - ★ Still far better than what I ever expected to see in my life time!

Issues in Generative LLMs

- Spurious text completion after each source sentence is simplified

Example of SimpleText Task 3 output versus input: deletions, insertions, and whole sentence insertions

As various kinds of output devices emerged , such as highresolution printers or a display of PDA (Personal Digital Assistant) ,the . The importance of high-quality resolution conversion has been increasing . |This paper proposes a new method for enlarging an image with high quality . It will involve using a combination of high-speed imaging and high-resolution video . |One of the largest biggest problems on image enlargement is the exaggeration of the jaggy edges . This is especially true when the image is enlarged , as in this case . |To remedy this problem , we propose a new interpolation method ,which . This method uses artificial neural network to determine the optimal values of interpolated pixels . |The experimental results are shown and evaluated . The results are compared to other studies and found to be inconclusive . |The effectiveness of our methods is discussed by comparing with the conventional methods . Our methods are designed to help people with mental health problems , not just as a way to cure them . |

Issues in Generative LLMs (2)

- Fraction of sentences with hallucination varies from 0 to 55%
- Existing evaluation measures **insensitive to hallucination!**

Run	# Input Sentences	Spurious Content	
		Number	Fraction
AiirLab_run1	245	58	0.24
CYUT_run1	757	12	0.02
MiCroGerk_GPT-3	245	1	0.00
NLPalma_BLOOMZ	245	135	0.55
Pandas_alpaca-lora-both-alpaca-simplifier-tripple_10	245	3	0.01
QH_run3	245	1	0.00
Smroltra_SimpleT5	245	0	0.00
TeamCAU_task_2.2_ST5	245	0	0.00
TheLangVerse_openai-curie-finetuned	245	1	0.00
ThePunDetectives_GPT-3	245	0	0.00
UAms_Large_KIS150	757	213	0.28
UBO_SimpleT5	245	0	0.00
irgc_pegasusTuner007plus_plus	245	57	0.23

Great Strengths + Great Limitations

Complex document

Silvano "Nano" Campeggi (January 23, 1923 – August 29, 2018) was an Italian artist who designed and produced the artwork for the posters of many classic Hollywood films. His iconic images are associated with the golden era of Hollywood and Campeggi is now generally regarded as the most important graphic artist and poster designer in the history of American cinema.

In the following decades, Campeggi designed and produced the poster and advertising graphics for over 3000 films, working not only under contract with the MGM studios, but also with Warner Brothers, Paramount, Universal, Columbia Pictures, United Artists, RKO, Twentieth-Century Fox and several other movie studios. Sixty-four of the films he illustrated won Oscars, including "Casablanca", "Ben-Hur", "Singin' in the Rain", "An American in Paris", "West Side Story", "Exodus", "Breakfast at Tiffany's", and "Gigi".

Campeggi died on 29 August 2018, at the age of 95.

Simple document

Silvano "Nano" Campeggi (January 23, 1923 – August 29, 2018) was an Italian artist. He designed and produced the artwork for the posters of many classic Hollywood movies.

Campeggi was known for his poster designs for "Casablanca", "Singin' in the Rain", and "Breakfast at Tiffany's".

Campeggi died on August 29, 2018 in Florence from respiratory failure at the age of 95.

Simplification by pretrained $\hat{O} \rightarrow \text{LED}$ para

Silvano "Nano" Campeggi (born January 23, 1923 – August 29, 2018) was an Italian artist. He designed and produced the artwork for the posters of many Hollywood movies. Campeggi is now known as the most important picture artist and poster designer in the history of American movies.

Over the following many years, Campeggi designed and produced the poster and advertising pictures for many movies. Sixty-four of the films he illustrated won awards. They included "Casablanca", "Ben-Hur", "Singin' in the Rain", "An American in Paris" and "Gigi."

Campeggi died on 29 August 2018, when he was 95.

Simplification by BARTpara

Silvano "Nano" Campeggi (January 23, 1923 – August 29, 2018) was an Italian artist. He designed and produced the artwork for the posters of many classic Hollywood movies.

Campeggi designed and produced the poster and advertising graphics for over 3000 movies, working not only under contract with the MGM studios, but also with Warner Brothers, Paramount, Universal, Columbia Pictures, United Artists, RKO, Twentieth Century Fox and several other movie studios. Sixty-four of the movies he illustrated won Oscars, including "Casablanca", "Ben-Hur", "Singin' in the Rain", "An American in Paris", "West Side Story", "Exodus", "Breakfast at Tiffany's", and "Gigi".

Campeggi died on 29 August 2018, at the age of 95

Simplification by PGDyn

Silvano "Nano" Campeggi (January 23, 1923 – August 29, 2018) was an Italian artist. He designed and produced the artwork for the posters of many classic Hollywood movies. His iconic images are associated with the golden era of Hollywood and Campeggi is generally regarded as the most important graphic artist and poster designer in the history of American cinema.

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Campeggi died on 29 August 2018 in Milan at the age of 95.

Simplification by $\hat{O} \rightarrow \text{BART}$ para

Silvano "Nano" Campeggi (January 23, 1923 – August 29, 2018) was an Italian artist. He designed and produced the artwork for the posters of many classic Hollywood movies. His iconic images are associated with the golden era of Hollywood.

Campeggi illustrated over 3000 movies, including "Casablanca", "Ben-Hur", "Singin' in the Rain", "An American in Paris", "West Side Story", "Exodus", "Breakfast at Tiffany's", and "Gigi".

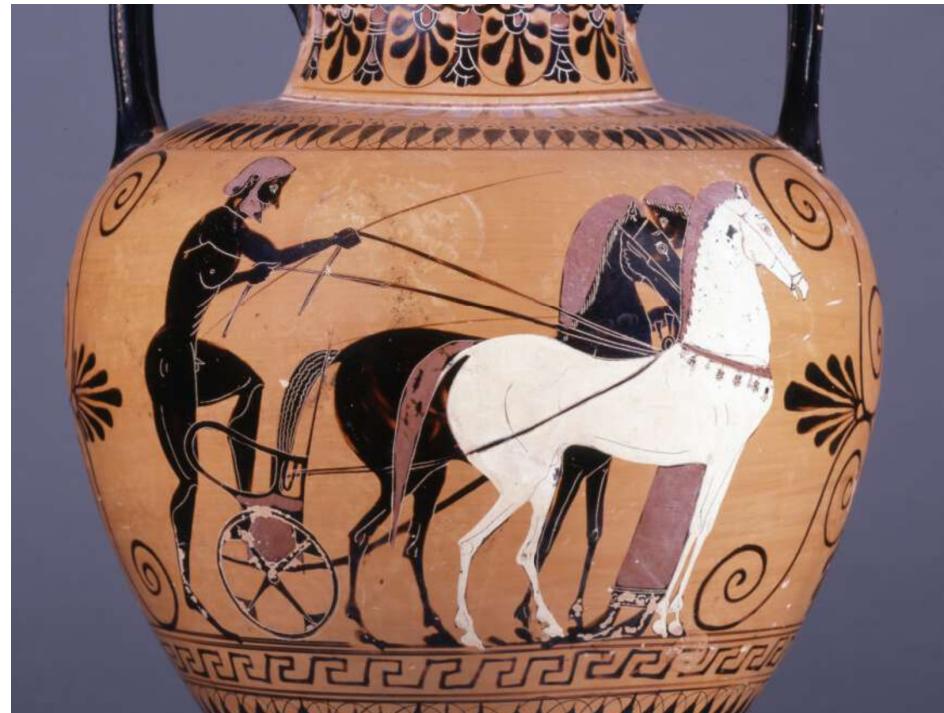
Campeggi died on 29 August 2018, at the age of 95.

Let's Start at the Beginning...



- Chariot Allegory: dialogue Socrates and Phaedrus (Plato, 370 BC)

Plato's Chariot Allegory



- See: [https://en.wikipedia.org/wiki/Phaedrus_\(dialogue\)](https://en.wikipedia.org/wiki/Phaedrus_(dialogue))
 - ★ **Charioteer** is the intellect, reason, guiding to truth
 - ★ **Horses** are the driving force: power, intuitions, passion
 - * **noble breed**: the positive/moral part of passionate nature
 - * **opposite**: irrational passions, appetites, or concupiscent nature

Something is working!

ChatGPT 3.5 ▾

How can I help you today?

Compare storytelling techniques
in novels and in films

Write a message
that goes with a kitten gif for a friend on a rou...

Come up with concepts
for a retro-style arcade game

Brainstorm names
for my fantasy football team with a frog theme

How does Plato's Chariot Allegory apply to current large language models?

ChatGPT can make mistakes. Consider checking important information.

The screenshot shows a dark-themed ChatGPT 3.5 interface. At the top left is the 'ChatGPT 3.5' logo and a dropdown menu. At the top right is an upward arrow icon. The message history starts with a user message from 'You' asking about the application of Plato's Chariot Allegory to current large language models. ChatGPT responds by explaining the allegory from 'Phaedrus' and then draws parallels to modern models. It lists five points of comparison:

- Charioteer as Model Architecture/Design:**
 - In the allegory, the charioteer represents reason and control. In the context of large language models, the architecture and design of the model can be seen as the guiding force or charioteer. The underlying structure and mechanisms influence the model's behavior and output.
- Horses as Training Data and Learning Process:**
 - The two horses symbolize the dual nature of human desires and motivations. In the case of language models, these horses can be compared to the training data and the learning process. The model learns from diverse datasets, which can contain both positive and negative examples, akin to the conflicting forces in the allegory.
- Passion and Rationality in Model Outputs:**
 - The horses' conflicting forces of passion and rationality in the allegory can be likened to the tension between different aspects of information present in the training data. The model, like the chariot, navigates through this mix, trying to balance and generate outputs that reflect both the rational and emotional aspects of language.
- Ethical Considerations and Control:**
 - Plato's allegory raises questions about the control of the charioteer over the horses. Similarly, in the context of large language models, there are ethical concerns about the control and responsibility of those designing, training, and deploying these models. Ensuring that models align with ethical guidelines and values is crucial to prevent unintended consequences.
- Model Interpretability as Charioteer's Understanding:**
 - The charioteer's understanding of the horses is essential for effective steering. Similarly, in language models, efforts towards improving interpretability and explainability can be seen as enhancing the model's "understanding" and helping users and developers navigate the outputs more effectively.

Below the list, a concluding paragraph notes that while the allegory wasn't originally intended for AI, it provides a thought-provoking lens for considering the complexities and responsibilities of AI models in the present day. It emphasizes the importance of thoughtful design, ethical considerations, and ongoing efforts to understand and guide these powerful models. At the bottom are three small icons: a reply arrow, a refresh circle, and a refresh square.

Impressive: Knows and Applies the Allegory

- ChatGPT is dodging the question, but agrees on the value!
 - ★ “*While the allegory [from 370BC!] wasn't originally intended to describe artificial intelligence, it can be a thought-provoking lens through which to consider the complexities and responsibilities associated with large language models in the present day. It underscores the importance of thoughtful design, ethical considerations, and ongoing efforts to understand and guide the behavior of these powerful language models.*”
- Yes, that's why we asked you this question!
 - ★ (Note the Socratic Method/Dialogues, an ingenious rhetoric form where you learn from questions and convey implicit knowledge!)

Where are the LLMs in the Allegory?

- **Q1** Are LLMs

- ★ (a) the **charioteer** (reason and control, guiding to the truth)
 - ★ (b) the **horses** (intuitions and generative power)
 - ★ (c) both?

- **Q2** Who is in control? Who is the **charioteer**?

- ★ (a) **You** are in control steering the model to the truth
 - ★ (b) **LLM** is in control of the generated output
 - ★ (c) there is no control: the **horses** take us somewhere

- **Q3** Which of the **horses** is the **LLM**?

- ★ (a) the **good breed horse** (high morals, rational, responsible)
 - ★ (b) the **opposite horse** (irrational passions, appetites, hallucination)
 - ★ (c) both?

Slogan # 3

Foundations of Creativity

Science and AI and Creativity and Creation

- Science + AI + Creativity + Creation
 - ★ Very challenging topic today!
 - ★ Does this even exist: maybe an empty intersection?
- Research on this started at [Symposium on AI and Scientific Creativity](#)
 - ★ 1999 edition of the AISB (oldest AI conference)
 - ★ I can discuss one of the papers [[Kamps, 1999b](#)]

John McCarthy

- Invented AI
 - ★ Well, he invented the name Artificial Intelligence
 - ★ His paper and mine were lifted to keynotes (KR'98 went viral)
 - ★ He founded the AI lab of MIT and at Stanford in the 1960's
 - ★ He founded the Stanford AI lab's reading group in the 1960's
- He didn't attend this reading group in decades
 - ★ He came after AISB and threw my paper at the table
 - ★ Told students to read it and that they should have done this...
 - ★ And this paper was about social science and humanities!
- (Pre-social media: I didn't know and heard much later...)

AISB 1999 Symposium

On the Process of Axiomatizing Theories Using Justification Criteria in the Context of Discovery

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Institute for Logic, Language and Computation

University of Amsterdam

AISB'99 Symposium on AI and Scientific Creativity
April 8–9, Edinburgh, Scotland

Product versus Process?

Especially interested in the *process* of axiomatization:
From verbal to logical formulations.

Specific strategy:

-1- Give specific operationalizations of criteria for evaluating theories

Basically the standard criteria from logic and philosophy of science.

-2- Such that the outcome is as informative as possible

No indirect proof the existence of a counterexample, but present one

-3- and such that these criteria can be determined with relative ease

Specifically, such that existing automated reasoning tools can be used

Axiomatize Theories from Sociology

Discourse in *ordinary language*

- informal, qualitative, usually partial and incomplete

Provide a *rational reconstruction* of the text

- identify concepts, claims, arguments

Provide an *initial formal theory*

- code assumptions and claims in first-order logic

Use criteria to *evaluate* the initial formalization

- think of consistency, soundness, falsifiability

Use feedback to *revise* formalization

- remedy argumentation—for example explicate theoretical presuppositions

Hans L. Zetterberg. On Theory and Verification in Sociology. Third edition, 1965

-
- 1 The greater the *division of labor*, the greater the *consensus*.
 - 2 The greater the *solidarity*, the greater the *number of associates per member*.
 - 3 The greater the *number of associates per member*, the greater the *consensus*.
 - 4 The greater the *consensus*, the smaller the *number of rejections per deviant*.
 - 5 The greater the *division of labor*, the smaller the *number of rejections per deviant*.
 - 6 The greater the *number of associates per member*, the smaller the *number of rejections per deviant*.

 - 7 The greater the *division of labor*, the greater the *solidarity*.
 - 8 The greater the *solidarity*, the greater the *consensus*.
 - 9 The greater the *number of associates per member*, the greater the *division of labor*.
 - 10 The greater the *solidarity*, the smaller the *number of rejections per deviant*.
-

- Propositions 1–6 are claimed to be derivable from the 7–10 using “*the deduction rules of ordinary language*.”

An initial formal theory

A first order logic rendition (axioms **A.7–10** and theorems **T.1–6**)

- T.1** $\forall x, y [\text{dlab}(x) > \text{dlab}(y) \rightarrow \text{cons}(x) > \text{cons}(y)]$
 - T.2** $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{napm}(x) > \text{napm}(y)]$
 - T.3** $\forall x, y [\text{napm}(x) > \text{napm}(y) \rightarrow \text{cons}(x) > \text{cons}(y)]$
 - T.4** $\forall x, y [\text{cons}(x) > \text{cons}(y) \rightarrow \text{nrpd}(y) > \text{nrpd}(x)]$
 - T.5** $\forall x, y [\text{dlab}(x) > \text{dlab}(y) \rightarrow \text{nrpd}(y) > \text{nrpd}(x)]$
 - T.6** $\forall x, y [\text{napm}(x) > \text{napm}(y) \rightarrow \text{nrpd}(y) > \text{nrpd}(x)]$
-

- A.7** $\forall x, y [\text{dlab}(x) > \text{dlab}(y) \rightarrow \text{soli}(x) > \text{soli}(y)]$
 - A.8** $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{cons}(x) > \text{cons}(y)]$
 - A.9** $\forall x, y [\text{napm}(x) > \text{napm}(y) \rightarrow \text{dlab}(x) > \text{dlab}(y)]$
 - A.10** $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{nrpd}(y) > \text{nrpd}(x)]$
-

Automated Reasoning Tools

	Theorem prover (OTTER)	Model generator (MACE)
input	set of first-order formulas	set of first-order formulas
output	proof (derivation of contradiction) end of search runs on...	domain size (very few) models of given cardinality end of search

Is the (formal) theory consistent?

On universe $\{0, 1\}$, MACE generates 1024 models of the A.7–10.

	napm	soli	cons	dlab	nrdp	>	0	1
0	0	1	1	1	0	0	F	F
1	0	0	0	0	1	1	T	F

Soundness of claimed inferences

Propositions **T.1**, **T.3**, **T.5**, and **T.6** are theorems.

T.1 $\forall x, y [\text{dlab}(x) > \text{dlab}(y) \rightarrow \text{cons}(x) > \text{cons}(y)]$

Proof: OTTER can derive **T.1** from **A.7** and **A.8**.

Propositions **T.2** and **T.4** are false conjectures!

T.2 $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{napm}(x) > \text{napm}(y)]$

Proof: MACE finds a model of **A.7–10** in which **T.2** is false.

	napm	soli	cons	dlab	nrdp	>	0	1
0	0	0	0	0	0	0	T	F
1	1	0	0	0	0	1	F	F

Our final verdict?

Verbal theory:	Formal theory:	
P.1 from P.7 and P.8	T.1 from A.7 and A.8	✓
P.2 from P.7 and P.9	No theorem T.2	
P.3 from P.8 and derived P.2	T.3 from A.9, A.7 and A.8	✓ (!)
P.4 from P.8 and P.10	No theorem T.4	
P.5 from P.7 and P.10	T.5 from A.7 and A.10	✓
P.6 from P.9 and derived P.5	T.6 from A.9, A.7 and A.10	✓

As Zetterberg [1965] remarks, “our deductions are not too precise, so long as our concepts are defined in normal prose, and the deduction rules of ordinary language are used.”

Nonintended models or real counterexamples?

The counterexample to T.2 gives a unnatural “ $>$ ”-relation:
 $(0 > 0)$ is true, and $(0 > 1)$, $(1 > 0)$, and $(1 > 1)$ are false.

Background assumptions on “ $>$ ”:

MP.1 $\forall x, y \neg[(x > y) \wedge (y > x)]$

MP.2 $(1 > 0).$

Adding these two background assumptions to the theory will substantially reduce the number of models of the theory.

Our previous counterexamples do no longer belong to the theory!

More counterexamples...

Proposition 2 is still not derivable.

T.2 $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{napm}(x) > \text{napm}(y)]$

Proof: MACE generates (w.l.o.g., we use only **A.7**, **A.9**, **MP.1–2**):

	soli	dlab	napm		>	0	1
0	0	0	0		0	F	F
1	1	0	0		1	T	F
0	0	0	1				
1	1	0	1				
0	0	0	0				
1	1	1	0				
0	0	0	1				
1	1	1	1				
0	0	1	0				
1	1	1	0				
0	0	1	0				
1	1	1	0				

Weaken theorems: counterexamples become models

Analyze the counterexamples to **T.2**:

they all have the form $\text{soli}(1) > \text{soli}(0)$ and $\text{napm}(1) = \text{napm}(0)$.

A weaker version of Proposition 2 that also holds in these models is:
“The greater the solidarity, the greater or equal the number of associates per member.”

$$\mathbf{T.2}^- \quad \forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \neg(\text{napm}(y) > \text{napm}(x))]$$

Proof: OTTER can derive **T.2**⁻ from **A.7**, **A.9**, and **MP.1**.

Strengthen axioms: restricting the theory's domain

The counterexamples to **T.2** have the form

$\text{soli}(1) > \text{soli}(0)$ and $\text{napm}(1) = \text{napm}(0)$.

(A) Add: $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{napm}(x) > \text{napm}(y)]$

Trivial solution: we have now made proposition 2 an axiom.

(B) Add: **A.12** $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{dlab}(x) > \text{dlab}(y)]$
A.13 $\forall x, y [\text{dlab}(x) > \text{dlab}(y) \rightarrow \text{napm}(x) > \text{napm}(y)]$

This works!

T.2 $\forall x, y [\text{soli}(x) > \text{soli}(y) \rightarrow \text{napm}(x) > \text{napm}(y)]$

Proof: OTTER can derive **T.2** from **A.12** and **A.13**.

Adding axioms or changing their interpretation

Note that **A.12** and **A.13** are the converses of **A.7** and **A.9**!

That is, Proposition 7

“The greater the division of labor, the greater the solidarity.”

is formalized as

$$\mathbf{A.7^*} \quad \forall x, y [\text{dlab}(x) > \text{dlab}(y) \leftrightarrow \text{soli}(x) > \text{soli}(y)]$$

Similarly, Proposition 9

“The greater the number of associates per member, the greater the division of labor.”

is formalized as

$$\mathbf{A.9^*} \quad \forall x, y [\text{napm}(x) > \text{napm}(y) \leftrightarrow \text{dlab}(x) > \text{dlab}(y)]$$

A revised formal theory

T.1*	$\forall x, y [dlab(x) > dlab(y) \leftrightarrow cons(x) > cons(y)]$
T.2*	$\forall x, y [soli(x) > soli(y) \leftrightarrow napm(x) > napm(y)]$
T.3*	$\forall x, y [napm(x) > napm(y) \leftrightarrow cons(x) > cons(y)]$
T.4*	$\forall x, y [cons(x) > cons(y) \leftrightarrow nrpd(y) > nrpd(x)]$
T.5*	$\forall x, y [dlab(x) > dlab(y) \leftrightarrow nrpd(y) > nrpd(x)]$
T.6*	$\forall x, y [napm(x) > napm(y) \leftrightarrow nrpd(y) > nrpd(x)]$
A.7*	$\forall x, y [dlab(x) > dlab(y) \leftrightarrow soli(x) > soli(y)]$
A.8*	$\forall x, y [soli(x) > soli(y) \leftrightarrow cons(x) > cons(y)]$
A.9*	$\forall x, y [napm(x) > napm(y) \leftrightarrow dlab(x) > dlab(y)]$
A.10*	$\forall x, y [soli(x) > soli(y) \leftrightarrow nrpd(y) > nrpd(x)]$

- Still consistent?

MACE produces 34 models of **A.7^{*}–10^{*}** (and **MP.1-2**) on $\{0, 1\}$.

	napm	soli	cons	dlab	nrpd	>	0	1
0	1	1	1	1	0	0	F	F
1	0	0	0	0	1	1	T	F

Inferences in the revised formal theory

Verbal theory:	Formal theory:	
P.1 from P.7 and P.8	T.1* from A.7* and A.8*	✓
P.2 from P.7 and P.9	T.2* from A.7* and A.9*	✓
P.3 from P.8 and derived P.2	T.3* from A.9*, A.7* and A.8*	✓
P.4 from P.8 and P.10	T.4* from A.8* and A.10*	✓
P.5 from P.7 and P.10	T.5* from A.7* and A.10*	✓
P.6 from P.9 and derived P.5	T.6* from A.9*, A.7* and A.10*	✓

How ‘complex’ is it really?

Yes, I have to admit

- it is often *pedantic*: rigorousness requires many tedious calculations
- logical machinery requires all formal detail to be explicit
- including common sense or background assumptions
- very few logical axiomatizations of substantive theories

However, it can be automated—Use Artificial Intelligence!

Generic Automated Reasoning Tools:

Bill McCune’s programs OTTER and MACE are freely available from Argonne National Laboratory at <http://www.mcs.anl.gov/AR/>

Use of Automated Reasoning Tools:

Kamps	Formal Theory Building	KR'98, Morgan Kaufmann, 1998
Kamps	Process of Axiomatizing Theories	AISB Scientific Creativity, 1999
Kamps	Criteria for Formal Theory Building	AAAI-99, MIT Press, 1999

Theoretical Criteria + Automated Reasoning Tools

Criterion	OTTER	MACE
Consistency		$(\exists \mathcal{A}) \mathcal{A} \models \Sigma$
Inconsistency	$\Sigma \vdash \perp$	
Soundness	$\Sigma \vdash \varphi$	
Unsoundness		$(\exists \mathcal{A}) \mathcal{A} \models \Sigma \cup \{\neg \varphi\}$
Falsifiability		$(\exists \mathcal{A}) \mathcal{A} \models \Sigma_{\text{def}} \cup \{\neg \varphi\}$
Unfalsifiability	$\Sigma_{\text{def}} \vdash \varphi$	
Satisfiability		$(\exists \mathcal{A}) \mathcal{A} \models \Sigma_{\text{def}} \cup \{\varphi\}$
Unsatisfiability	$\Sigma_{\text{def}} \vdash \neg \varphi$	
Independence		$(\exists \mathcal{A}) \mathcal{A} \models \Sigma$ and $(\forall \sigma \in \Sigma) (\exists \mathcal{B}) \mathcal{B} \models \Sigma \setminus \{\sigma\} \cup \{\neg \sigma\}$

Note: Σ denotes a premise set, with $\Sigma_{\text{def}} \subseteq \Sigma$ the definitions in this set and $\sigma \in \Sigma$ an individual premise, and φ a conjecture or theorem.

Conclusions

Formal logic is useful to evaluate (& revise) actual scientific theories

- provides an unambiguous exposition (including the underlying assumptions)
- identify implicit background assumptions or even hiatus

Not just syntax!—Syntax and semantics combined give a more powerful and versatile language than “non-logics”

Artificial Intelligence provides flexible generic tools

- automated theorem provers (search for proofs & contradictions)
- automated model generators (search for counterexamples & models)

This puts classical philosophy of science in a completely different perspective—the computational tools allow us to realize what was previously just philosophy

Especially useful during the *process* of formalization

- feedback crucial for revising the theory (e.g., analyze counterexamples)

Axiomatization is more than strict justification. . .

In case you forgot...

Syntax A logic is based on a particular set of symbols. For first order logic these are a fixed set of the logical symbols (variables; connectives \neg , \wedge , \vee , \rightarrow , and \leftrightarrow ; equality symbol $=$; quantifiers \forall and \exists ; and parenthesis and commas) and a varying set of non-logical symbols (individual constants; functions; and predicates).

There are strict rules that define which sequences of symbols are well-formed formulas (or sentences) of the language.

Semantics A (formal) model consists of a universe (a non-empty set) and an interpretation function that is a mapping between the non-logical symbols (i.e., constants, functions, and predicates of the language) and elements of this universe. The logical symbols have a fixed interpretation.

This allows for a strict definition of relative truth, i.e., whenever a sentence φ is satisfied (or true) in a model \mathcal{A} , in symbols, $\mathcal{A} \models \varphi$. We will use $\Sigma \models \varphi$ to denote that sentence φ is satisfied in every model of the set of sentences Σ , i.e., φ is a logical consequence of Σ .

Proof Theory We use $\Sigma \vdash \varphi$ to denote that sentence φ is deducible from the set of sentences Σ , i.e., there exists a proof of φ from Σ . Such a (formal) proof is a finite sequence of sentences ending with φ and such that each sentence is either a logical axiom (i.e., a tautology, quantifier or identity axiom); belongs to Σ ; or can be inferred from earlier sentences using an inference rule. There exist sets of inference rules that are sound and complete, i.e., such that $\Sigma \vdash \varphi$ if and only if $\Sigma \models \varphi$.

Where are these AI tools in the Allegory?

- Q1 Are these tools
 - * (a) the **charioteer** (reason and control, guiding to the truth)
 - * (b) the **horses** (intuitions and generative power)
 - * (c) both?
- Q2 Who is in control? Who is the **charioteer**
 - * (a) You are in control steering the model to the truth
 - * (b) AI is in control of the generated output
 - * (c) there is no control: the **horses** take us somewhere
- Q3 Which of the **horses** is these AI tools?
 - * (a) the **good breed horse** (high morals, rational, responsible)
 - * (b) the **opposite horse** (irrational passions, appetites, hallucination)
 - * (c) both?

Slogan # 4

Empowering Users?

Let's use new AI for this task...

- We have a very clear set of challenges, with known output
 - ★ How would modern AI models cope with this?
 - ★ We have two challenging tasks:
 - * Task 1: Natural language inference
 - * Task 2: Formal language inference
 - ★ Let's try and find out...

Task 1: Natural Language Inference Task

- Input Zetterberg [1965] leading to prompt:

Which of the following seven conjectures:

- P.1 The greater the division of labor, the greater the consensus.
- P.2 The greater the solidarity, the greater the number of associates per member.
- P.3 The greater the number of associates per member, the greater the consensus.
- P.4 The greater the consensus, the smaller the number of rejections per deviant.
- P.5 The greater the division of labor, the smaller the number of rejections per deviant.
- P.6 The greater the number of associates per member, the smaller the number of rejections per deviant.

Can be derived from the following four axioms:

- P.7 The greater the division of labor, the greater the solidarity.
- P.8 The greater the solidarity, the greater the consensus.
- P.9 The greater the number of associates per member, the greater the division of labor.
- P.10 The greater the solidarity, the smaller the number of rejections per deviant.

ChatGPT 3.5 ▾

You Which of the following seven conjectures:

P1 The greater the division of labor, the greater the consensus.
P2 The greater the solidarity, the greater the number of associates per member.
P3 The greater the number of associates per member, the greater the consensus.
P4 The greater the consensus, the smaller the number of rejections per deviant.
P5 The greater the division of labor, the smaller the number of rejections per deviant.
P6 The greater the number of associates per member, the smaller the number of rejections per deviant.

Can be derived from the following four axioms:

P7 The greater the division of labor, the greater the solidarity.
P8 The greater the solidarity, the greater the consensus.
P9 The greater the number of associates per member, the greater the division of labor.
P10 The greater the solidarity, the smaller the number of rejections per deviant.

ChatGPT Let's analyze the given axioms and see which conjectures can be derived from them:

Axioms:
P7 The greater the division of labor, the greater the solidarity. (A7)
P8 The greater the solidarity, the greater the consensus. (A8)
P9 The greater the number of associates per member, the greater the division of labor. (A9)
P10 The greater the solidarity, the smaller the number of rejections per deviant. (A10)

Conjectures:
P1 The greater the division of labor, the greater the consensus. (Derivable from A7 and A8)
P2 The greater the solidarity, the greater the number of associates per member. (Derivable from A7, A8, and A9)
P3 The greater the number of associates per member, the greater the consensus. (Derivable from A8 and A9)
P4 The greater the consensus, the smaller the number of rejections per deviant. (Derivable from A8 and A10)
P5 The greater the division of labor, the smaller the number of rejections per deviant. (Derivable from A7, A8, and A10)
P6 The greater the number of associates per member, the smaller the number of rejections per deviant. (Derivable from A8, A9, and A10)

Therefore, all seven conjectures (P1 to P6) can be derived from the given axioms (P7 to P10). ●

labor. (A9)

P10 The greater the solidarity, the smaller the number of rejections per deviant.
(A10)

Conjectures:

P1 The greater the division of labor, the greater the consensus. (Derivable from A7 and A8)

P2 The greater the solidarity, the greater the number of associates per member.
(Derivable from A7, A8, and A9)

P3 The greater the number of associates per member, the greater the consensus.
(Derivable from A8 and A9)

P4 The greater the consensus, the smaller the number of rejections per deviant.
(Derivable from A8 and A10)

P5 The greater the division of labor, the smaller the number of rejections per deviant. (Derivable from A7, A8, and A10)

P6 The greater the number of associates per member, the smaller the number of rejections per deviant. (Derivable from A8, A9, and A10)

Therefore, all seven conjectures (P1 to P6) can be derived from the given axioms (P7 to P10). ●

You

Which of the following seven conjectures:

P1 The greater the division of labor, the greater the consensus.
P2 The greater the solidarity, the greater the number of associates per member.
P3 The greater the number of associates per member, the greater the consensus.
P4 The greater the consensus, the smaller the number of rejections per deviant.
P5 The greater the division of labor, the smaller the number of rejections per deviant.
P6 The greater the number of associates per member, the smaller the number of rejections per deviant.

Can be derived from the following four axioms:

P7 The greater the division of labor, the greater the solidarity.
P8 The greater the solidarity, the greater the consensus.
P9 The greater the number of associates per member, the greater the division of labor.
P10 The greater the solidarity, the smaller the number of rejections per deviant.

 Copilot

Certainly! Let's explore the relationship between these conjectures and the given axioms. First, let's briefly define what axioms, conjectures, and theorems are:

1. **Axioms (or Postulates):** Axioms are statements that we accept as true without needing a proof. They serve as the foundation for all other mathematical derivations. Axioms are universally accepted and indisputable. For example, the statement "0 is a natural number" is an axiom.

2. **Conjectures:** Conjectures are mathematical statements whose truth or falsity we don't know yet. They are hypotheses that await validation or refutation.

Now, let's analyze the given conjectures in light of the provided axioms:

Conjecture P1: The greater the division of labor, the greater the consensus.
• This conjecture suggests a positive relationship between division of labor and consensus.

Conjecture P2: The greater the solidarity, the greater the number of associates per member.
• This conjecture implies that stronger solidarity leads to more associates per member.

Conjecture P3: The greater the number of associates per member, the greater the consensus.
• Here, the conjecture connects the number of associates to consensus.

Conjecture P4: The greater the consensus, the smaller the number of rejections per deviant.
• This conjecture posits that consensus reduces the number of rejections per deviant.

Conjecture P5: The greater the division of labor, the smaller the number of rejections per deviant.
• It suggests an inverse relationship between division of labor and rejections per deviant.

Conjecture P6: The greater the number of associates per member, the smaller the number of rejections per deviant.
• This conjecture links the number of associates to rejections per deviant.

Now, let's examine how these conjectures relate to the given axioms:

1. **Axiom P7:** The greater the division of labor, the greater the solidarity.
◦ This axiom establishes a positive connection between division of labor and solidarity.

2. **Axiom P8:** The greater the solidarity, the greater the consensus.
◦ This axiom suggests that stronger solidarity leads to higher consensus.

3. **Axiom P9:** The greater the number of associates per member, the greater the division of labor.
◦ This axiom connects the number of associates to division of labor.

4. **Axiom P10:** The greater the solidarity, the smaller the number of rejections per deviant.
◦ Here, the axiom implies that stronger solidarity reduces rejections per deviant.

Now, let's see which conjectures can be derived from these axioms:

• **Conjecture P1** can be derived from Axioms P7 and P8.
• **Conjecture P2** can be derived from Axiom P9.
• **Conjecture P3** can be derived from Axioms P8 and P9.
• **Conjecture P4** can be derived from Axioms P8 and P10.
• **Conjecture P5** can be derived from Axioms P7 and P10.
• **Conjecture P6** can be derived from Axiom P9.

In summary, all seven conjectures can be traced back to the provided axioms, demonstrating their interconnectedness in this context. ☺

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Feedback

2. **Axiom P.8:** The greater the solidarity, the greater the consensus.

- This axiom suggests that stronger solidarity leads to higher consensus.

3. **Axiom P.9:** The greater the number of associates per member, the greater the division of labor.

- This axiom connects the number of associates to division of labor.

4. **Axiom P.10:** The greater the solidarity, the smaller the number of rejections per deviant.

- Here, the axiom implies that stronger solidarity reduces rejections per deviant.

Now, let's see which conjectures can be derived from these axioms:

- **Conjecture P.1** can be derived from Axioms P.7 and P.8.
- **Conjecture P.2** can be derived from Axiom P.9.
- **Conjecture P.3** can be derived from Axioms P.8 and P.9.
- **Conjecture P.4** can be derived from Axioms P.8 and P.10.
- **Conjecture P.5** can be derived from Axioms P.7 and P.10.
- **Conjecture P.6** can be derived from Axiom P.9.

In summary, all seven conjectures can be traced back to the provided axioms, demonstrating their interconnectedness in this context. 🌟

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● 1 of 5



What is the difference between an axiom and a theorem?

Can you give me another example of axioms in mathematics?

Feedback

P.2: The greater the solidarity, the greater the number of associates per member.

- This does not follow from the axioms. While P.8 links solidarity to consensus, there's no connection to the number of associates.

P.3: The greater the number of associates per member, the greater the consensus.

- This is not directly derivable either. P.9 connects associates to division of labor, not consensus.

P.4: The greater the consensus, the smaller the number of rejections per deviant.

- This can be derived from P.8 and P.10. P.8 states greater solidarity leads to greater consensus, and P.10 connects greater solidarity to fewer rejections.

P.5: The greater the division of labor, the smaller the number of rejections per deviant.

- This cannot be derived from the axioms. While P.7 connects division of labor to increased solidarity, the link to fewer rejections is missing.

P.6: The greater the number of associates per member, the smaller the number of rejections per deviant.

- This cannot be derived directly. While P.9 connects associates to division of labor, the further connection to fewer rejections isn't provided by the axioms.

Therefore, the only conjecture that can be derived from the given axioms is **P.4:** The greater the consensus, the smaller the number of rejections per deviant.

Task 1: Natural Language Inference Task Results

Theorem	Informal	Formal	Chat-		
	Zetterberg [1965]	Kamps [1999b]	-GPT	-Bing	-Gemini
T.1	✓	✓	✓	✓	✗
T.2	✗	✗	✗	✗	✗
T.3	✓	✓	✓	✓	✗
T.4	✗	✗	✗	✗	✓
T.5	✓	✓	✓	✓	✗
T.6	✓	✓	✓	✓	✗
Percentage	67%	100%	67%	67%	17%

- Can LLMs reason correctly in natural language inference?
 - ★ ChatGPT (GPT 3.5) not strict (positive/confirmation bias?)
 - ★ Bing Chat (GPT 4) also not strict (positive/confirmation bias?)
 - ★ Gemini far more conservative (tries to avoid errors?)

Task 2: Formal Language Inference Task

- Input Kamps [1999b] leading to prompt:

Which of the following seven conjectures:

- T.1 $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
- T.2 $\forall x, y [soli(x) > soli(y) \rightarrow napm(x) > napm(y)]$
- T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
- T.4 $\forall x, y [cons(x) > cons(y) \rightarrow nrpd(y) > nrpd(x)]$
- T.5 $\forall x, y [dlab(x) > dlab(y) \rightarrow nrpd(y) > nrpd(x)]$
- T.6 $\forall x, y [napm(x) > napm(y) \rightarrow nrpd(y) > nrpd(x)]$

Can be derived from the following four axioms:

- A.7 $\forall x, y [dlab(x) > dlab(y) \rightarrow soli(x) > soli(y)]$
- A.8 $\forall x, y [soli(x) > soli(y) \rightarrow cons(x) > cons(y)]$
- A.9 $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
- A.10 $\forall x, y [soli(x) > soli(y) \rightarrow nrpd(y) > nrpd(x)]$

ChatGPT 3.5 ▾

JA You Which of the following seven conjectures:
T.1 $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
T.2 $\forall x, y [soli(x) > soli(y) \rightarrow napm(x) > napm(y)]$
T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
T.4 $\forall x, y [cons(x) > cons(y) \rightarrow nRPD(y) > nRPD(x)]$
T.5 $\forall x, y [dlab(x) > dlab(y) \rightarrow nRPD(y) > nRPD(x)]$
T.6 $\forall x, y [napm(x) > napm(y) \rightarrow nRPD(y) > nRPD(x)]$

Can be derived from the following four axioms:
A.7 $\forall x, y [dlab(x) > dlab(y) \rightarrow soli(x) > soli(y)]$
A.8 $\forall x, y [soli(x) > soli(y) \rightarrow cons(x) > cons(y)]$
A.9 $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
A.10 $\forall x, y [soli(x) > soli(y) \rightarrow nRPD(y) > nRPD(x)]$

ChatGPT Let's analyze each conjecture and see if it can be derived from the given axioms:

T.1: $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
This can be derived from A.7 and A.8.

T.2: $\forall x, y [soli(x) > soli(y) \rightarrow napm(x) > napm(y)]$
This can be derived from A.8 and A.9.

T.3: $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
This can be derived from A.8 and A.9.

T.4: $\forall x, y [cons(x) > cons(y) \rightarrow nRPD(y) > nRPD(x)]$
This can be derived from A.8 and A.10.

T.5: $\forall x, y [dlab(x) > dlab(y) \rightarrow nRPD(y) > nRPD(x)]$
This can be derived from A.7, A.8, and A.10.

T.6: $\forall x, y [napm(x) > napm(y) \rightarrow nRPD(y) > nRPD(x)]$
This can be derived from A.9 and A.10.

Therefore, all of the given conjectures (T.1 to T.6) can be derived from the provided axioms (A.7 to A.10). ●

**ChatGPT**

Let's analyze each conjecture and see if it can be derived from the given axioms:

T.1: $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$

This can be derived from A.7 and A.8.

T.2: $\forall x, y [soli(x) > soli(y) \rightarrow napm(x) > napm(y)]$

This can be derived from A.8 and A.9.

T.3: $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$

This can be derived from A.8 and A.9.

T.4: $\forall x, y [cons(x) > cons(y) \rightarrow nrpd(y) > nrpd(x)]$

This can be derived from A.8 and A.10.

T.5: $\forall x, y [dlab(x) > dlab(y) \rightarrow nrpd(y) > nrpd(x)]$

This can be derived from A.7, A.8, and A.10.

T.6: $\forall x, y [napm(x) > napm(y) \rightarrow nrpd(y) > nrpd(x)]$

This can be derived from A.9 and A.10.

Therefore, all of the given conjectures (T.1 to T.6) can be derived from the provided axioms (A.7 to A.10). ●

You

Which of the following seven conjectures:

T.1 $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
 T.2 $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
 T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
 T.4 $\forall x, y [cons(x) > cons(y) \rightarrow nprd(y) > nprd(x)]$
 T.5 $\forall x, y [dlab(x) > dlab(y) \rightarrow nprd(y) > nprd(x)]$
 T.6 $\forall x, y [napm(x) > napm(y) \rightarrow nprd(y) > nprd(x)]$

Can be derived from the following four axioms:

A.7 $\forall x, y [dlab(x) > dlab(y) \rightarrow sol(x) > sol(y)]$
 A.8 $\forall x, y [sol(x) > sol(y) \rightarrow cons(x) > cons(y)]$
 A.9 $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
 A.10 $\forall x, y [sol(x) > sol(y) \rightarrow nprd(y) > nprd(x)]$

- Copilot
- Designer
- Vacation planner
- Cooking assistant
- Fitness trainer

Copilot

Let's analyze the given conjectures and axioms:

1. **T.1:** $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
2. **T.2:** $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
3. **T.3:** $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
4. **T.4:** $\forall x, y [cons(x) > cons(y) \rightarrow nprd(y) > nprd(x)]$
5. **T.5:** $\forall x, y [dlab(x) > dlab(y) \rightarrow nprd(y) > nprd(x)]$
6. **T.6:** $\forall x, y [napm(x) > napm(y) \rightarrow nprd(y) > nprd(x)]$

And the given axioms:

1. **A.7:** $\forall x, y [dlab(x) > dlab(y) \rightarrow sol(x) > sol(y)]$
2. **A.8:** $\forall x, y [sol(x) > sol(y) \rightarrow cons(x) > cons(y)]$
3. **A.9:** $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
4. **A.10:** $\forall x, y [sol(x) > sol(y) \rightarrow nprd(y) > nprd(x)]$

Let's examine each conjecture in light of the given axioms:

1. **T.1:** The implication in T.1 involves **dlab** and **cons**. We can use A.7 and A.8 to establish that if **dlab(x) > dlab(y)**, then **soli(x) > soli(y)**, and consequently, **cons(x) > cons(y)**. Therefore, T.1 can be derived from the axioms.
2. **T.2:** The implication in T.2 involves **soli** and **napm**. Using A.8 and A.9, we can infer that if **soli(x) > soli(y)**, then **dlab(x) > dlab(y)**, and subsequently, **napm(x) > napm(y)**. Thus, T.2 can be derived from the axioms.
3. **T.3:** The implication in T.3 involves **napm** and **cons**. By combining A.9 and A.8, we can conclude that if **napm(x) > napm(y)**, then **dlab(x) > dlab(y)**, and consequently, **cons(x) > cons(y)**. Hence, T.3 can be derived from the axioms.
4. **T.4:** The implication in T.4 involves **cons** and **nprd**. Using A.8 and A.10, we can establish that if **cons(x) > cons(y)**, then **nprd(y) > nprd(x)**. Therefore, T.4 can be derived from the axioms.
5. **T.5:** The implication in T.5 involves **dlab** and **nprd**. Combining A.7 and A.10, we can infer that if **dlab(x) > dlab(y)**, then **soli(x) > soli(y)**, and subsequently, **nprd(y) > nprd(x)**. Thus, T.5 can be derived from the axioms.
6. **T.6:** The implication in T.6 involves **napm** and **nprd**. By using A.9 and A.10, we can conclude that if **napm(x) > napm(y)**, then **dlab(x) > dlab(y)**, and consequently, **nprd(y) > nprd(x)**. Hence, T.6 can be derived from the axioms.

In summary, all six conjectures (T.1 to T.6) can be derived from the given axioms (A.7 to A.10). ☀

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? ! □ ↓ ◀ ● 1 of 5

? What is the significance of these conjectures?

! Can you explain what dlab, soli, napm and nprd stand for?

Feedback

and the given axioms.

1. **A.7:** $\forall x, y [d\text{lab}(x) > d\text{lab}(y) \rightarrow s\text{oli}(x) > s\text{oli}(y)]$
2. **A.8:** $\forall x, y [s\text{oli}(x) > s\text{oli}(y) \rightarrow c\text{ons}(x) > c\text{ons}(y)]$
3. **A.9:** $\forall x, y [n\text{apm}(x) > n\text{apm}(y) \rightarrow d\text{lab}(x) > d\text{lab}(y)]$
4. **A.10:** $\forall x, y [s\text{oli}(x) > s\text{oli}(y) \rightarrow n\text{rpd}(y) > n\text{rpd}(x)]$

Let's examine each conjecture in light of the given axioms:

1. **T.1:** The implication in T.1 involves **d_{lab}** and **c_{ons}**. We can use A.7 and A.8 to establish that if **d_{lab}(x) > d_{lab}(y)**, then **s_{oli}(x) > s_{oli}(y)**, and consequently, **c_{ons}(x) > c_{ons}(y)**. Therefore, T.1 can be derived from the axioms.
2. **T.2:** The implication in T.2 involves **s_{oli}** and **n_{apm}**. Using A.8 and A.9, we can infer that if **s_{oli}(x) > s_{oli}(y)**, then **d_{lab}(x) > d_{lab}(y)**, and subsequently, **n_{apm}(x) > n_{apm}(y)**. Thus, T.2 can be derived from the axioms.
3. **T.3:** The implication in T.3 involves **n_{apm}** and **c_{ons}**. By combining A.9 and A.8, we can conclude that if **n_{apm}(x) > n_{apm}(y)**, then **d_{lab}(x) > d_{lab}(y)**, and consequently, **c_{ons}(x) > c_{ons}(y)**. Hence, T.3 can be derived from the axioms.
4. **T.4:** The implication in T.4 involves **c_{ons}** and **n_{rpd}**. Using A.8 and A.10, we can establish that if **c_{ons}(x) > c_{ons}(y)**, then **n_{rpd}(y) > n_{rpd}(x)**. Therefore, T.4 can be derived from the axioms.
5. **T.5:** The implication in T.5 involves **d_{lab}** and **n_{rpd}**. Combining A.7 and A.10, we can infer that if **d_{lab}(x) > d_{lab}(y)**, then **s_{oli}(x) > s_{oli}(y)**, and subsequently, **n_{rpd}(y) > n_{rpd}(x)**. Thus, T.5 can be derived from the axioms.
6. **T.6:** The implication in T.6 involves **n_{apm}** and **n_{rpd}**. By using A.9 and A.10, we can conclude that if **n_{apm}(x) > n_{apm}(y)**, then **d_{lab}(x) > d_{lab}(y)**, and consequently, **n_{rpd}(y) > n_{rpd}(x)**. Hence, T.6 can be derived from the axioms.

In summary, all six conjectures (T.1 to T.6) can be derived from the given axioms (A.7 to A.10). 

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What is the significance of these conjectures?

Can you explain what d_{lab}, s_{oli}, n_{apm} and n_{rpd} stand for?

Feedback

You
Which of the following seven conjectures:
T.1 $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
T.2 $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
T.4 $\forall x, y [cons(x) > cons(y) \rightarrow nrd(x) > nrd(y)]$
T.5 $\forall x, y [dlab(x) > dlab(y) \rightarrow nrd(x) > nrd(y)]$
T.6 $\forall x, y [napm(x) > napm(y) \rightarrow nrd(x) > nrd(y)]$

Can be derived from the following four axioms:
A.7 $\forall x, y [dlab(x) > dlab(y) \rightarrow sol(x) > sol(y)]$
A.8 $\forall x, y [sol(x) > sol(y) \rightarrow cons(x) > cons(y)]$
A.9 $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
A.10 $\forall x, y [sol(x) > sol(y) \rightarrow nrd(x) > nrd(y)]$

Copilot
Let's analyze the given conjectures and axioms. First, let's understand the terms:
1. **Axioms:** These are statements that we assume to be true without requiring proof. They serve as the foundation for mathematical reasoning. Axioms are universally accepted and form the basis for all other derivations.
2. **Conjectures:** These are mathematical statements whose truth or falsity is not yet known. Conjectures are hypotheses that await validation or disproof.

Now, let's examine each of the conjectures and see if they can be derived from the given axioms:

1. **T.1:** $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
 - This conjecture relates the "dlab" property to the "cons" property.
 - It does not directly involve any of the axioms.
2. **T.2:** $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
 - This conjecture connects the "sol" property to the "napm" property.
 - It does not directly involve any of the axioms.
3. **T.3:** $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
 - This conjecture links the "napm" property to the "cons" property.
 - It does not directly involve any of the axioms.
4. **T.4:** $\forall x, y [cons(x) > cons(y) \rightarrow nrd(x) > nrd(y)]$
 - This conjecture connects the "cons" property to the "nrd" property.
 - It is related to **Axiom A.10**.
5. **T.5:** $\forall x, y [dlab(x) > dlab(y) \rightarrow nrd(x) > nrd(y)]$
 - This conjecture relates the "dlab" property to the "nrd" property.
 - It is related to **Axiom A.9**.
6. **T.6:** $\forall x, y [napm(x) > napm(y) \rightarrow nrd(x) > nrd(y)]$
 - This conjecture connects the "napm" property to the "nrd" property.
 - It does not directly involve any of the axioms.

Now, let's consider the axioms:

1. **A.7:** $\forall x, y [dlab(x) > dlab(y) \rightarrow sol(x) > sol(y)]$
 - This axiom relates the "dlab" property to the "sol" property.
2. **A.8:** $\forall x, y [sol(x) > sol(y) \rightarrow cons(x) > cons(y)]$
 - This axiom connects the "sol" property to the "cons" property.
3. **A.9:** $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
 - This axiom links the "napm" property to the "dlab" property.
4. **A.10:** $\forall x, y [sol(x) > sol(y) \rightarrow nrd(x) > nrd(y)]$
 - This axiom connects the "sol" property to the "nrd" property.

Based on this analysis, we can conclude the following:

- **T.4** (related to Axiom A.10) and **T.5** (related to Axiom A.9) can be derived from the given axioms.
- The other conjectures do not directly follow from the axioms provided.

Therefore, the answer is that **T.4** and **T.5** can be derived from the given axioms. The remaining conjectures require additional reasoning or information beyond the provided axioms.

Feedback

1 2 3

1 of 5

What is the meaning of dlab, sol, napm and nrd?

Can you explain how to derive T.4 from Axiom A.10?

- It is related to Axiom A.10.

6. **T.6:** $\forall x, y [napm(x) > napm(y) \rightarrow nRPD(y) > nRPD(x)]$

- This conjecture connects the “napm” property to the “nRPD” property.
- It does not directly involve any of the axioms.

Now, let's consider the axioms:

1. **A.7:** $\forall x, y [dLab(x) > dLab(y) \rightarrow sOli(x) > sOli(y)]$

- This axiom relates the “dLab” property to the “sOli” property.

2. **A.8:** $\forall x, y [sOli(x) > sOli(y) \rightarrow cOns(x) > cOns(y)]$

- This axiom connects the “sOli” property to the “cOns” property.

3. **A.9:** $\forall x, y [napm(x) > napm(y) \rightarrow dLab(x) > dLab(y)]$

- This axiom links the “napm” property to the “dLab” property.

4. **A.10:** $\forall x, y [sOli(x) > sOli(y) \rightarrow nRPD(y) > nRPD(x)]$

- This axiom connects the “sOli” property to the “nRPD” property.

Based on this analysis, we can conclude the following:

- **T.4** (related to Axiom A.10) and **T.5** (related to Axiom A.9) can be derived from the given axioms.
- The other conjectures do not directly follow from the axioms provided.

Therefore, the answer is that **T.4** and **T.5** can be derived from the given axioms. The remaining conjectures require additional reasoning or information beyond the provided axioms.

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1 of 5



What is the meaning of dLab, sOli, napm and nRPD?

Can you explain how to derive T.4 from Axiom A.10?

 Feedback

Which of the following seven conjectures:

T.1 $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
T.2 $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
T.4 $\forall x, y [cons(x) > cons(y) \rightarrow nrpd(y) > nrpd(x)]$
T.5 $\forall x, y [dlab(x) > dlab(y) \rightarrow nrpd(y) > nrpd(x)]$
T.6 $\forall x, y [napm(x) > napm(y) \rightarrow nrpd(y) > nrpd(x)]$

Can be derived from the following four axioms:

A.7 $\forall x, y [dlab(x) > dlab(y) \rightarrow sol(x) > sol(y)]$
A.8 $\forall x, y [sol(x) > sol(y) \rightarrow cons(x) > cons(y)]$
A.9 $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
A.10 $\forall x, y [sol(x) > sol(y) \rightarrow nrpd(y) > nrpd(x)]$

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◆ **Analyzing the Conjectures and Axioms:**

Here's an analysis of each conjecture in relation to the provided axioms:

T.1: Cannot be derived.

- While A.7 implies a connection between `dlab` and `soli`, it doesn't directly relate their values to `cons`.

T.2: Cannot be derived.

- Similar to T.1, the chain of implications doesn't go through to napm affecting cons.

T.3: Derivable.

- A.9 connects `napm` to `dlab`, and A.7 connects `dlab` to `soli`, finally reaching `cons` through A.8.

T.4: Cannot be derived.

- Although A.10 connects `soli` to `nrpd`, there's no direct link between `cons` values of different entities.

T.5: Cannot be derived.

- Similar to T.1, the link between `dlab` values and `nrpd` cannot be established through the given axioms.

T.6: Cannot be derived.

- Similar to T.2, the chain of implications doesn't connect napm to nrpd values in the given axioms.

Therefore, the only conjecture that can be derived from the provided axioms is T.3.

T.1: Cannot be derived.

- While A.7 implies a connection between `dlab` and `soli`, it doesn't directly relate their values to `cons`.

T.2: Cannot be derived.

- Similar to T.1, the chain of implications doesn't go through to napm affecting cons.

T.3: Derivable.

- A.9 connects `napm` to `dlab`, and A.7 connects `dlab` to `soli`, finally reaching `cons` through A.8.

T.4: Cannot be derived.

- Although A.10 connects `soli` to `nrdp`, there's no direct link between `cons` values of different entities.

T.5: Cannot be derived.

- Similar to T.1, the link between `dlab` values and `nrdp` cannot be established through the given axioms.

T.6: Cannot be derived.

- Similar to T.2, the chain of implications doesn't connect napm to nrdp values in the given axioms.

Therefore, the only conjecture that can be derived from the provided axioms is

T.3.



Which of the following seven conjectures:

T.1 $\forall x, y [dlab(x) \rightarrow dlab(y) \rightarrow cons(x) > cons(y)]$
T.2 $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$
T.4 $\forall x, y [cons(x) > cons(y) \rightarrow nrpd(x) > nrpd(y)]$
T.5 $\forall x, y [dlab(x) > dlab(y) \rightarrow nrpd(y) > nrpd(x)]$
T.6 $\forall x, y [napm(x) > napm(y) \rightarrow nrpd(y) > nrpd(x)]$

Can be derived from the following four axioms:

A.7 $\forall x, y [dlab(x) > dlab(y) \rightarrow sol(x) > sol(y)]$
A.8 $\forall x, y [sol(x) > sol(y) \rightarrow cons(x) > cons(y)]$
A.9 $\forall x, y [napm(x) > napm(y) \rightarrow dlab(x) > dlab(y)]$
A.10 $\forall x, y [sol(x) > sol(y) \rightarrow nrpd(y) > nrpd(x)]$

◆ Analyzing the Conjectures and Axioms:

Here's an analysis of each conjecture in relation to the provided axioms:

T.1: Cannot be derived.

- While A.7 implies a connection between `dlab` and `sol`, it doesn't directly relate their values to `cons`.

T.2: Cannot be derived.

- Similar to T.1, the chain of implications doesn't go through to `napm` affecting `cons`.

T.3: Derivable.

- A.9 connects `napm` to `dlab`, and A.7 connects `dlab` to `sol`, finally reaching `cons` through A.8.

T.4: Cannot be derived.

- Although A.10 connects `sol` to `nrpd`, there's no direct link between `cons` values of different entities.

T.5: Cannot be derived.

- Similar to T.1, the link between `dlab` values and `nrpd` cannot be established through the given axioms.

T.6: Cannot be derived.

- Similar to T.2, the chain of implications doesn't connect `napm` to `nrpd` values in the given axioms.

Therefore, the only conjecture that can be derived from the provided axioms is T.3.

Which of the following seven conjectures:

T.1 $\forall x, y [dlab(x) \rightarrow dlab(y) \rightarrow cons(x) > cons(y)]$
T.2 $\forall x, y [sol(x) > sol(y) \rightarrow napm(x) > napm(y)]$
T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$

My previous response contained a mistake in the analysis of T.4. Here's the corrected analysis:

T.1: Cannot be derived. (Reasoning unchanged)

T.2: Cannot be derived. (Reasoning unchanged)

T.3: Derivable. (Reasoning unchanged)

T.4: Derivable.

- A.8 connects `sol(x)` to `cons(x)`.
- A.10 connects `sol(x)` to `nrpd(y)`, where `x` and `y` can be different entities.

Since the order of `x` and `y` is not relevant within a universal quantifier, we can reverse the order in A.10 to obtain `nrpd(x) > nrpd(y)`.

Therefore, by combining A.8 and the reversed A.10, we can derive T.4.

T.5: Cannot be derived. (Reasoning unchanged)

T.6: Cannot be derived. (Reasoning unchanged)

Therefore, the conjectures that can be derived from the provided axioms are T.3 and T.4.



Which of the following seven conjectures:

- T.1 $\forall x, y [dlab(x) > dlab(y) \rightarrow cons(x) > cons(y)]$
- T.2 $\forall x, y [soli(x) > soli(y) \rightarrow napm(x) > napm(y)]$
- T.3 $\forall x, y [napm(x) > napm(y) \rightarrow cons(x) > cons(y)]$



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My previous response contained a mistake in the analysis of T.4. Here's the corrected analysis:

T.1: Cannot be derived. (Reasoning unchanged)

T.2: Cannot be derived. (Reasoning unchanged)

T.3: Derivable. (Reasoning unchanged)

T.4: Derivable.

- A.8 connects `soli(x)` to `cons(x)`.
- A.10 connects `soli(x)` to `nrdp(y)`, where x and y can be different entities.

Since the order of x and y is not relevant within a universal quantifier, we can reverse the order in A.10 to obtain `nrdp(x) > nrdp(y)`.

Therefore, by combining A.8 and the reversed A.10, we can derive T.4.

T.5: Cannot be derived. (Reasoning unchanged)

T.6: Cannot be derived. (Reasoning unchanged)

Therefore, the conjectures that can be derived from the provided axioms are T.3 and T.4.

Task 2: Formal Language Inference Task Results

Theorem	Informal	Formal	Chat-		
	Zetterberg [1965]	Kamps [1999b]	-GPT	-Bing	-Gemini
T.1	✓	✓	✓, ✓	✓, ✗	✗, ✗
T.2	✗	✗	✗, ✗	✗, ✓	✗, ✗
T.3	✓	✓	✓, ✓	✓, ✗	✓, ✓
T.4	✗	✗	✗, ✗	✗, ✗	✗, ✓
T.5	✓	✓	✓, ✓	✓, ✓	✗, ✗
T.6	✓	✓	✓, ✓	✓, ✗	✗, ✗
Percentage	67%	100%	67/67%	67/33%	50/33%

- Can LLMs reason correctly in formal language inference?
 - ★ ChatGPT (GPT 3.5) not strict (positive/confirmation bias?)
 - ★ Bing Chat (GPT 4) same, and worse if resubmitted...
 - ★ Gemini very conservative, and uncertain on resubmission...

Wrap Up?

- Four slogans:
 - ★ #1: *November 30, 2022*
 - ★ #2: *AI Strengths and Limitations*
 - ★ #3: *Foundations of Creativity*
 - ★ #4: *Empowering Users?*
- Can AI models creatively help advance knowledge and science?
 - ★ Yes: even old AI models helped creative theory formation!
 - ★ Modern models far more creative power, but less control and transparency
- LLMs give very plausible answers, and plausible explanations
 - ★ Not very reliable in natural language inference...
 - ★ Not very reliable in formal language inference...
- Very useful, but use with care – be the **charioteer** and let the AI model be your **horses!**

Questions?

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