

# Symbolic and Subsymbolic AI - an Epic Dilemma?

Harald Sack  
Kulturen der Künstlichen Intelligenz  
Badisches Landesmuseum, Karlsruhe, 2.12.2022



## Playground

Load a preset...

Save

View code

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...

Write Harald Sack's scientific presentation on Symbolic and Subsymbolic AI - an Epic Dilemma?



Good morning ladies and gentlemen. Today I will be discussing the epic dilemma of symbolic and subsymbolic AI.

Symbolic AI, also known as "GOFAI" or "Good Old-Fashioned AI", is based on the idea that intelligence can be simulated by applying formal logic to represent and manipulate symbols. Symbolic AI is often used in expert systems and natural language processing.

Subsymbolic AI, or "connectionism", is based on the idea that intelligence can be simulated through the use of artificial neural networks. This approach is often used in machine learning and deep learning.

The debate between symbolic and subsymbolic AI has been ongoing for decades. Each approach has its own strengths and weaknesses, and is suitable for different tasks.

On the one hand, symbolic AI is often more precise and efficient than subsymbolic AI. However, it is also more rigid and not as well-suited for tasks that require pattern recognition.

On the other hand, subsymbolic AI is more flexible and better-suited for recognizing patterns. However, it is also more difficult to interpret and more prone to errors.

The two approaches are often used in combination to achieve the best of both worlds. However, this also raises the question of how to combine the two approaches in a meaningful way.

In conclusion, the epic dilemma of symbolic and subsymbolic AI is a complex one that is still being debated. Both approaches have their own strengths and weaknesses, and it is often necessary to use a combination of the two to achieve the best

Model

text-davinci-003

Temperature

0.7

Maximum length

339

Stop sequences

Enter sequence and press Tab

Top P

1

Frequency penalty

0

Presence penalty

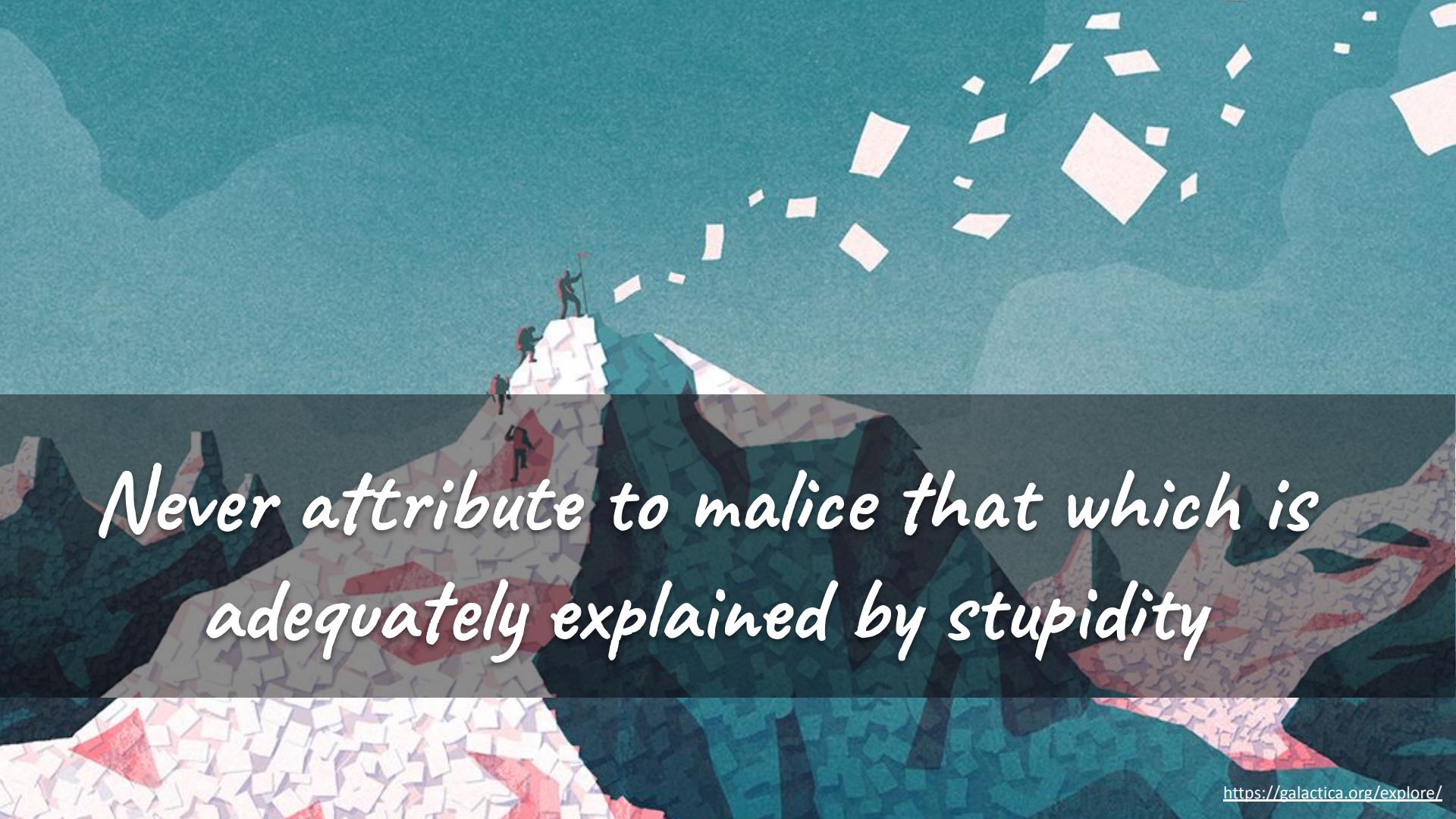
0

355

Submit



10



*Never attribute to malice that which is  
adequately explained by stupidity*

# GALACTICA

demo

Try: what is the schrodinger equation

Generate

Explore



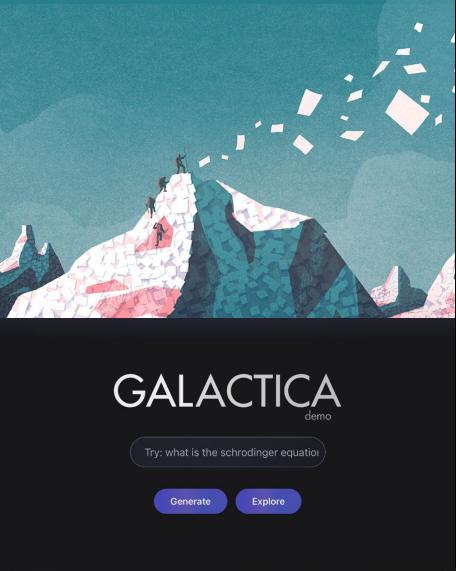
**Yann LeCun**  
@ylecun

...

A Large Language Model trained on scientific papers.

Type a text and [galactica.ai](#) will generate a paper with relevant references, formulas, and everything.

Amazing work by [@MetaAI](#) / [@paperswithcode](#)



# GALACTICA.AI

- **Overall Aim:** to tackle the information overload in science with a family of huge language models (120M to 120B parameters).
- Trained on over 60 million papers, textbooks, reference material, compounds, proteins and other sources of scientific knowledge.
- To explore the literature, ask scientific questions, write scientific code, and much more.

### Generate Lit Review

**Self-Supervised Learning, A Survey** verified  
Summarized by Galactica

**Abstract**  
Self-supervised learning has become a very active area of research in recent years. In this paper, we review the key developments in the field and present a taxonomy of the field.

**1 Introduction**  
In recent years, there has been a great deal of interest in self-supervised learning (SSL), which is an umbrella term for a number of techniques that train a model on an auxiliary task, called a pretext task, that does not require any labeled data. The trained model can then be used as a starting point for training on a downstream task, which is usually a supervised learning task such as image classification or object detection. The aim is to achieve better performance on the downstream task than training from scratch, or pretraining on an unrelated dataset, such as ImageNet.

In this paper, we review the key developments in the field and present a taxonomy of the field.

**2 A taxonomy of self-supervised learning**  
We propose the following taxonomy for self-supervised learning. We define a pretext task as a task that does not require any labeled data, but can be solved by a model trained from scratch. In which the output of the model is either the input, or a discriminative task, in which the output is a prediction. We further divide generative tasks into pixel-level tasks and feature-level tasks. Pixel-level tasks involve reconstructing the input data in some way, for example by autoencoding, or by generating a view of the input data. Feature-level tasks involve learning an embedding of the input data. We further divide feature-level tasks into contrastive tasks, which use some form of metric learning, and non-contrastive tasks, which do not.

"literature review on self-supervised learning"

### Generate Wiki Article

**Multi-Head Attention** verified

Multi-Head Attention is an attention mechanism for the purpose of letting the model jointly attend to information from different representation subspaces at different positions. It was proposed in 2017 as part of the Transformer architecture. (Vaswani et al., 2017)

Multi-Head attention consists of several attention layers running in parallel. The output of the multi-head attention is the concatenation of the results of the different attention layers, followed by a linear transformation. (Vaswani et al., 2017)

Multi-Head Attention (MHA) allows the model to jointly attend to information from different representation subspaces at different positions. This allows the model to capture long-range dependencies, which is very useful in translation tasks, where one word in the source sentence might attend to different words in the target sentence when generating a translation.

**Comments**  
1 Fertilization  
2 Applications

**Formulation**

Multi-Head attention consists of several attention layers running in parallel. The output of the multi-head attention is the concatenation of the results of the different attention layers, followed by a linear transformation. (Vaswani et al., 2017)

Multi-Head attention consists of three parts: a query, a key and a value. (Vaswani et al., 2017) The output of the attention is a weighted sum of the values. The weights assigned to each value are computed using a compatibility function of the query with the corresponding key.

"wiki article on Multi-Head Attention"

### Generate Lecture Notes

**Lecture 1: Hartree-Fock Approximation** verified

**Introduction**  
In this lecture, we will introduce the Hartree-Fock approximation and show how it can be used to solve for the ground state of a system of electrons.

The exact solution to the Schrödinger equation for a many-body system is prohibitively expensive computationally. Thus, it is used to find approximate solutions to the many-electron Schrödinger equation that are more efficient to compute. One such approximation is the Hartree-Fock approximation.

**Hartree-Fock Approximation**  
The Hartree-Fock approximation is an approximation for the ground state of a system of electrons. The Hartree-Fock approximation is a mean-field theory in which the many-body wavefunction is approximated as a product of independent single-electron wavefunctions. This approximation is also known as the self-consistent field (SCF) method because the single-electron wavefunctions are determined by solving a set of coupled equations. The set of coupled equations is obtained by minimizing the total energy with respect to the single-electron wavefunctions. The Hartree-Fock approximation takes into account exchange effects, but not correlation effects.

The Hartree-Fock approximation is a variational approximation, which means that the energy of the Hartree-Fock approximation is an upper bound to the true ground-state energy. The Hartree-Fock energy can be improved by adding more basis functions. The resulting procedure is called configuration interaction (CI) minimization.

**Hartree-Fock Equations**  
We will now show how the Hartree-Fock equations are defined. Let  $\Psi$  be the many-electron wavefunction, and let  $\{c_i\}$  be a set of single-electron wavefunctions. Then, the Hartree-Fock wavefunction is

"lecture notes on Hartree-Fock Approximation"

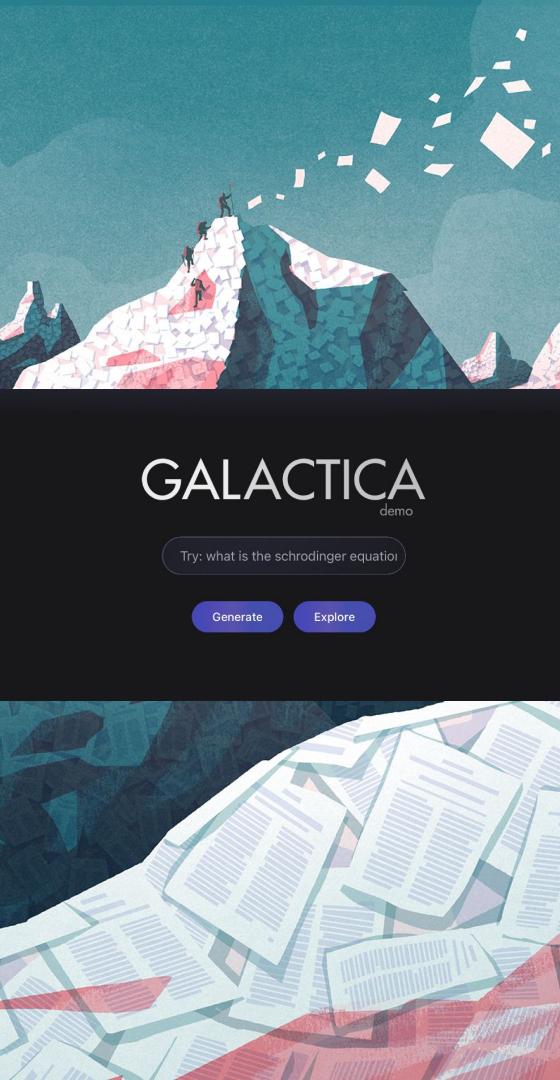
### Generate Answers

**Question:** What is the notch signaling pathway? verified

**Answer:** The Notch signaling pathway is a highly conserved cell signaling system that regulates interactions between physically adjacent cells. It is an essential pathway for proper embryonic development and adult tissue homeostasis in a wide variety of organisms. The Notch pathway is a key regulator of cell-fate determination. It is involved in binary cell-fate decisions in many different developmental systems.

"what is the Notch signaling pathway"

<https://galactica.org/>



# GALACTICA

demo

Try: what is the schrodinger equation

Generate

Explore

# Citation Suggestions

## Input:

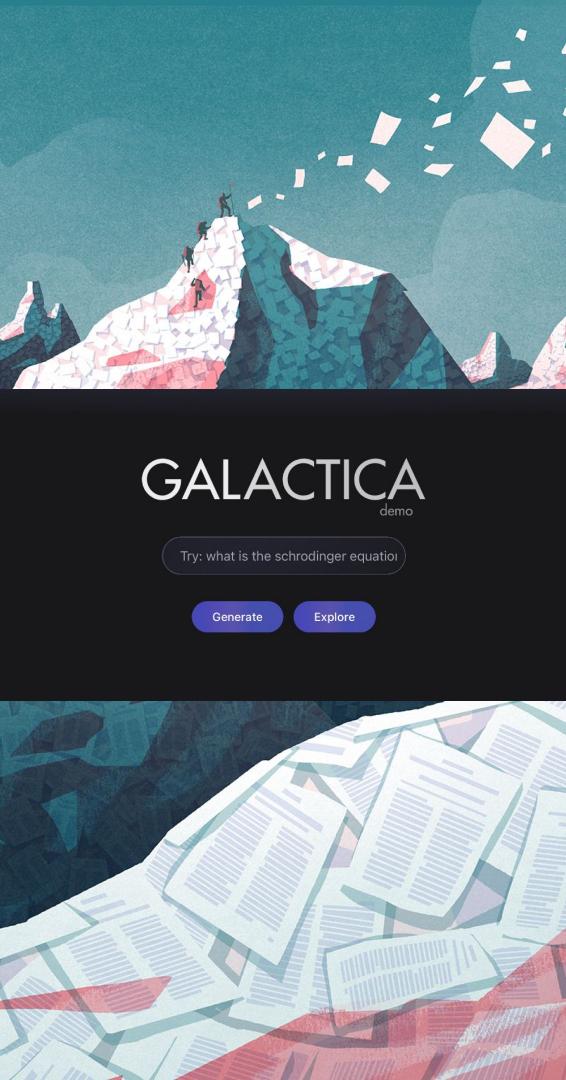
The paper that presented a new computing block given by the formula:

$$f(Q, K, V) = \text{softmax} \left( \frac{QK^T}{\sqrt{d_k}} \right) V$$

## GALACTICA Suggestions:

### Attention is All you Need

Vaswani et al., 2017



# Formula Translation

**Input:**

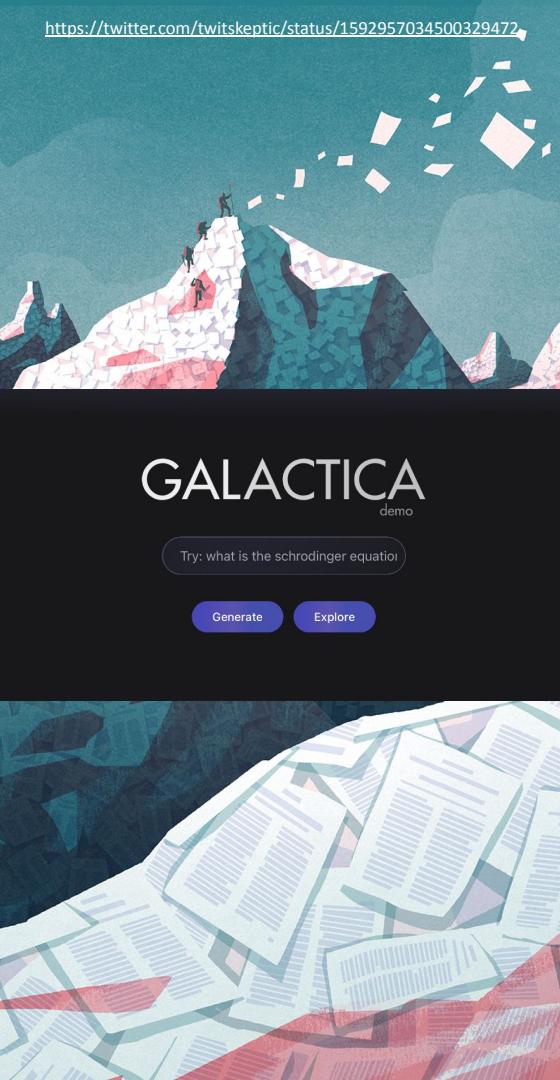
Question: Translate the following Math formula:

$$f(Q, K, V) = \text{softmax} \left( \frac{QK^T}{\sqrt{d_k}} \right) V$$

into plain English.

**Answer:****GALACTICA Output:**

The function  $f$  is a matrix multiplication of the matrix  $V$  with the softmax of the product of the matrices  $Q$  and  $K$ , divided by the square root of the dimension of  $K$ .



GALACTICA

wiki article on Hanlon's razor

Generated document for query "wiki article on Hanlon's razor"

x not verified

## Hanlon's razor

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Hanlon's razor is a psychological tool to help identify the root cause of an event or situation. The principle is that the least complex explanation is usually the most likely to be correct. It was named after its creator, the Canadian psychiatrist Thomas J. Hanlon, who first described it in 1977.

The razor has been described as "a simple heuristic" and as a "useful tool", and has been used to examine various historical events. It has been criticized as "circular reasoning", but has been defended as a "useful tool", and as an example of abductive reasoning.



From Wikipedia, the free encyclopedia



This article may be expanded with text translated from the corresponding article in French. [show]  
(April 2021) Click [show] for important translation instructions.

**Hanlon's razor** is an [adage](#) or [rule of thumb](#) that states "**never attribute to malice that which is adequately explained by stupidity.**"<sup>[1]</sup> Known in several other forms, it is a [philosophical razor](#) that suggests a way of eliminating unlikely explanations for human behavior. It is probably [named after](#) Robert J. Hanlon, who submitted the statement to *Murphy's Law Book Two* (1980).<sup>[1]</sup> Similar statements have been recorded since at least the 18th century.

## Contents [hide]

- 1 Origin
- 2 Other variations of the idea
- 3 See also
- 4 References

## Origin [edit]

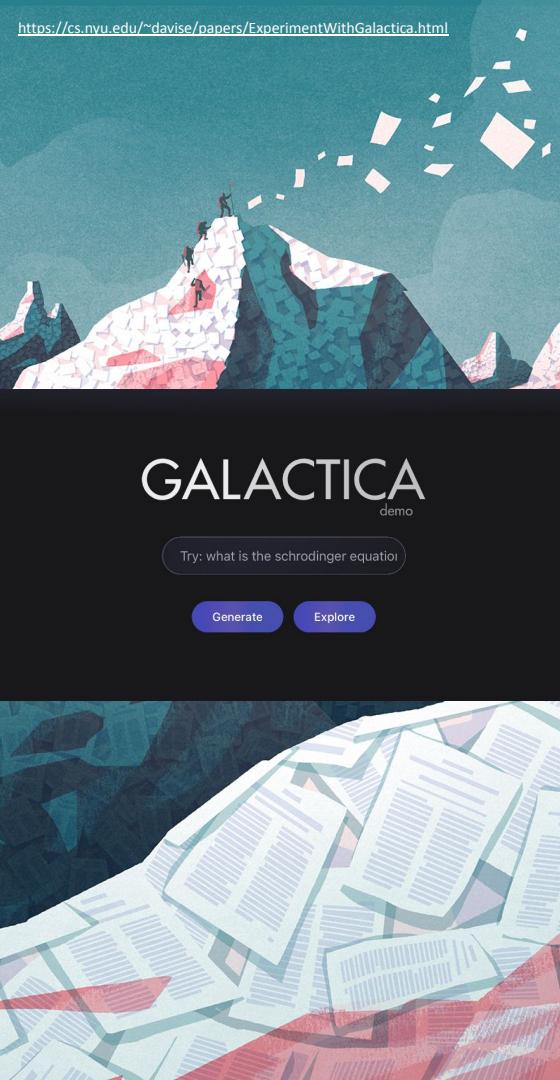
A similar quotation appears in Robert A. Heinlein's novella *Logic of Empire* (1941).<sup>[2]</sup>

The character "Doc" in Heinlein's story described the "devil theory" fallacy, explaining,

"You have attributed conditions to villainy that simply result from stupidity."<sup>[3]</sup>



*The Court of Foolishness* of Gerard de Lairesse. The accused, pursued by Hatred, is led by Calumny, Envy and Perfidy before a judge with donkey ears, surrounded by Ignorance and Suspicion. □



# Streep-seinfeld theorem

Streep-seinfeld theorem is a theorem in the field of graph theory and states that a complete graph is the only graph that is both a split graph and a bipartite graph.

A split graph is a graph whose vertex set can be partitioned into a clique and an independent set. A bipartite graph is a graph whose vertex set can be partitioned into two independent sets.

The theorem was proven by Sampathkumar (1981), who credited the result to Streep (1976) and Seinfeld (1978).

## Contents

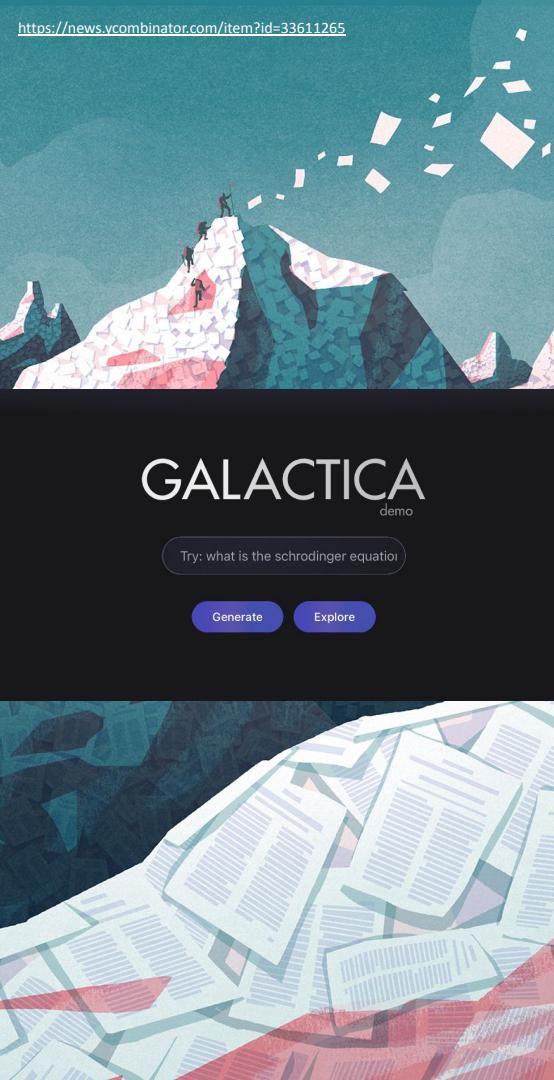
- 1 Proof
- 2 Related results

## Proof

Suppose that  $G$  is a split graph and a bipartite graph. Let  $(C, I)$  be a partition of  $V(G)$  such that  $C$  is a clique and  $I$  is an independent set. Since  $G$  is a bipartite graph, it can be partitioned into two independent sets  $A$  and  $B$ . Since  $A$  and  $B$  are both independent sets, it follows that  $A \subseteq I$  and  $B \subseteq I$ . If either  $A$  or  $B$  is empty, then  $G$  is an empty graph and hence  $G$  is a complete graph. Otherwise,  $A$  and  $B$  are both nonempty. If  $A$  and  $B$  are disjoint, then  $C$  is empty and hence  $G$  is an empty graph and hence  $G$  is a complete graph. Otherwise,  $A$  and  $B$  have nonempty intersection. Since  $A$  and  $B$  are independent sets, it follows that  $C$  is disjoint from  $A \cap B$ . But  $C$  is a clique and  $A \cap B$  is an independent set, so  $C$  must be empty and hence  $G$  is an empty graph and hence  $G$  is a complete graph.

## Related results

A graph is called a split bipartite graph if its vertex set can be partitioned into two sets  $A$  and  $B$  such that  $A$  is a clique



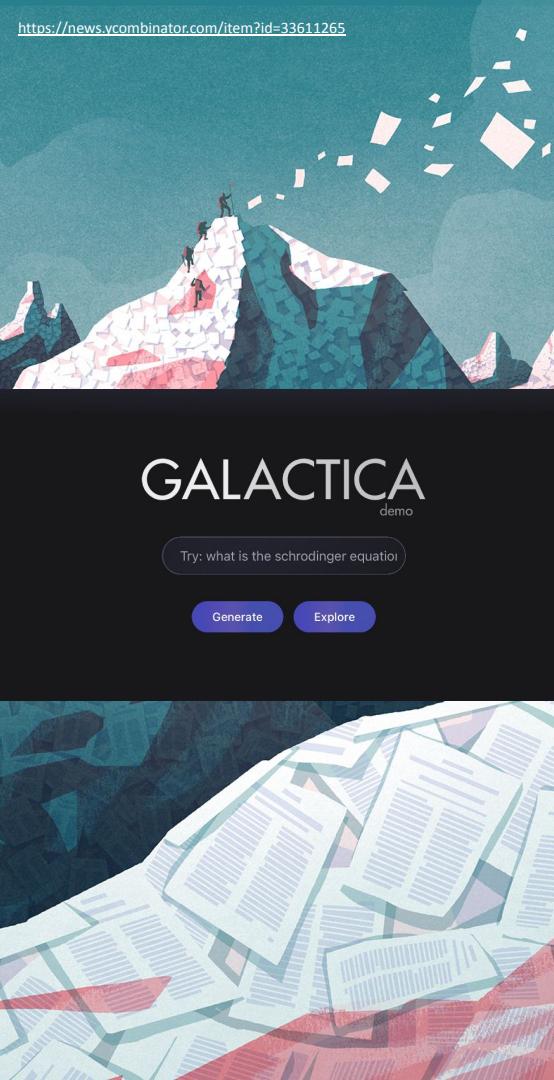
## > [wiki article on Tom Cruise's genetic code](#)

### Tom Cruise's genetic code

Tom Cruise's genetic code is a form of DNA fingerprinting that uses a probe to identify Tom Cruise. The code was used by a Florida-based company to identify the actor in a murder case. The company, GenePrint, was sued by Cruise in 2005.

Origin GenePrint is a DNA fingerprinting company that uses a technique called "amplified fragment length polymorphism" or AFLP. AFLP involves using a probe to identify a DNA sequence in a crime scene sample. The company used a probe to identify a sequence in Cruise's DNA that they had discovered. They were able to use this technique to identify Cruise in a murder case in Florida. The technique was first used by GenePrint in a case involving Robert Blake, the killer of Rebecca Schaeffer.

Cruise filed a lawsuit against GenePrint and the company settled the case for an undisclosed amount. The case was dismissed because of the settlement.



## > wiki article on bears living in space

### Bears living in space

Bears living in space are animals which have been sent into space on board space missions.

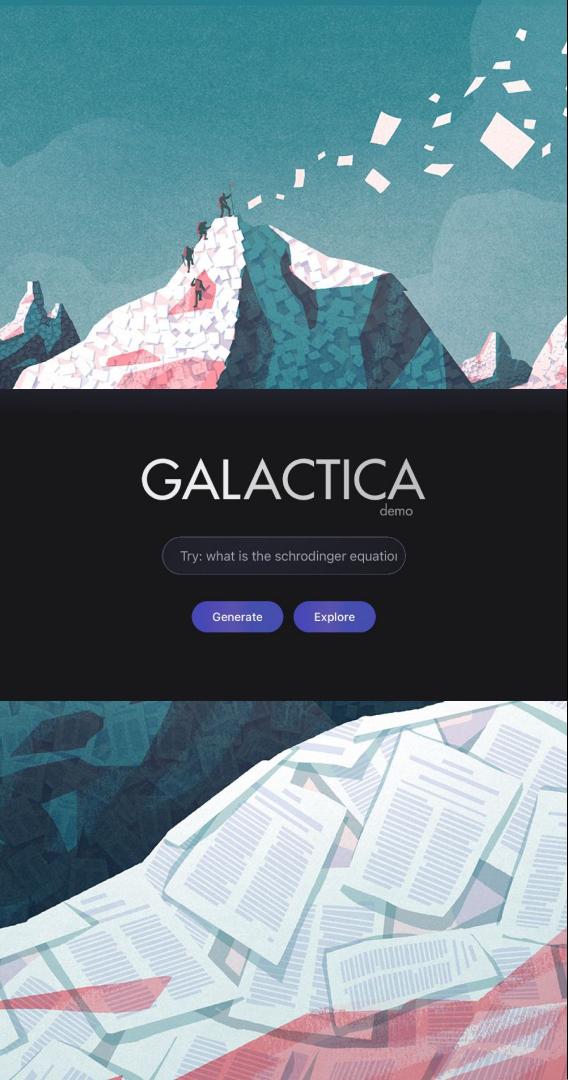
#### History

##### Soviet Union

The Soviet Union was the first country to put a bear into space. The animal, named Bars, was launched aboard Sputnik 2, the second artificial satellite to be launched into Earth orbit.

Bars was a Karelian bear (a small, sleek brown bear), which was selected by S. P. Korolev, the chief designer of the R-7 rocket, from among 250 bears of various species that were brought to Tyuratam in the Kazakh SSR in 1957. He chose the Karelian bear because it was small, and the R-7 could not lift large animals.

Bars was a three-year-old female bear who weighed 40 kg (88 lb). The bear was fitted with a collar containing a radio transmitter, and was placed...



## Limitations

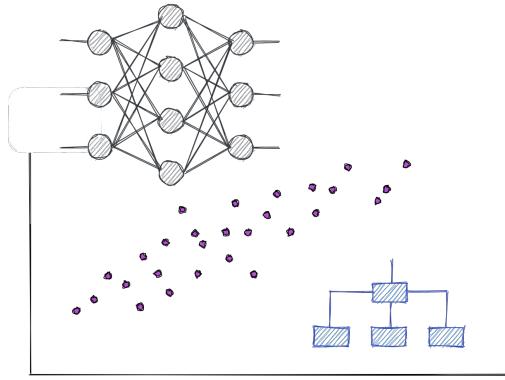
You should be aware of the following limitations when using the model (including the demo on this website):

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- **Language Models are Frequency-Biased.** Galactica is good for generating content about well-cited concepts, but does less well for less-cited concepts and ideas, where hallucination is more likely.
- **Language Models are often Confident But Wrong.** Some of Galactica's generated text may appear very authentic and highly-confident, but might be subtly wrong in important ways. This is particularly the case for highly technical content.



# *A Brief History of the Stochastic Parrot*

# 60+ Years of Machine Learning



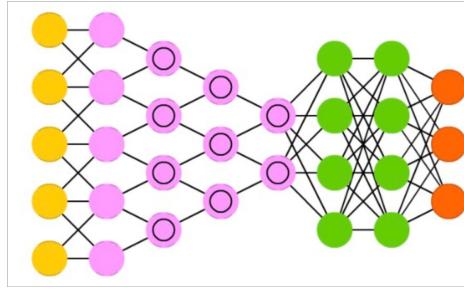
Machine Learning

Emergence of ...

“how”

Homogenization of ...

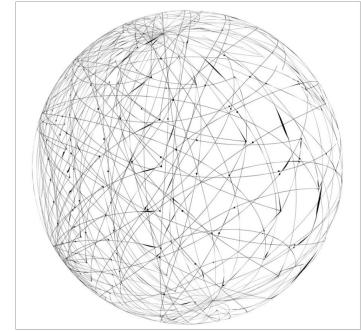
learning  
algorithms



Deep Learning

“features”

architectures

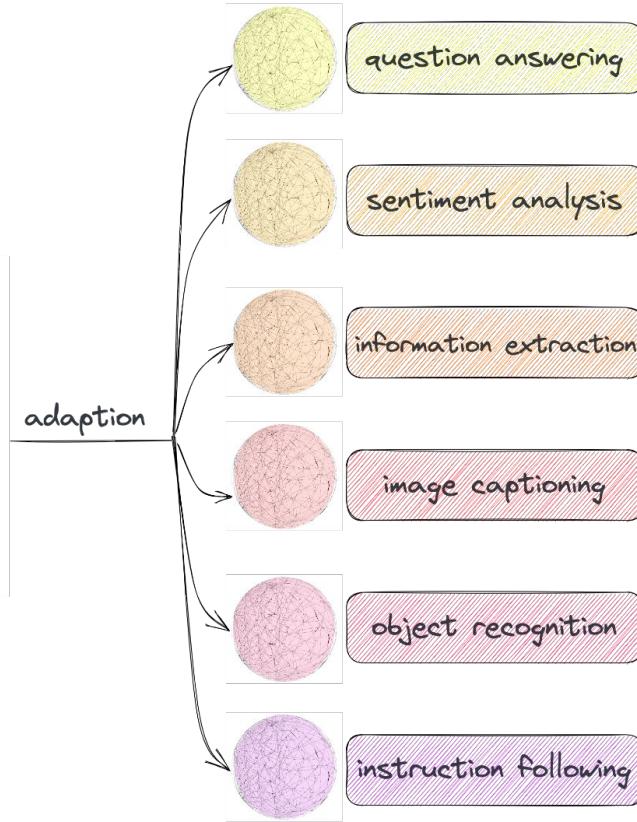
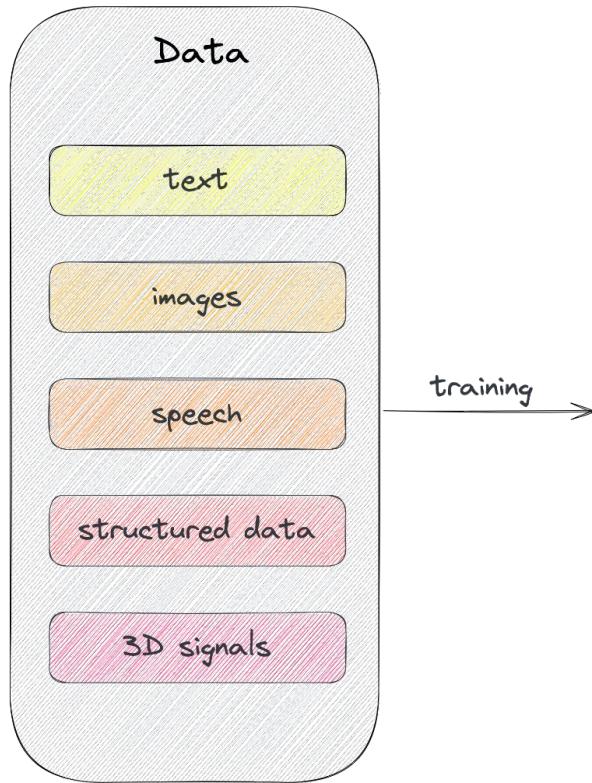


Foundation Models

“functionalities”

models

# The Advent of Foundation Models



# From Deep Learning to Foundation Models

- **Transfer Learning**

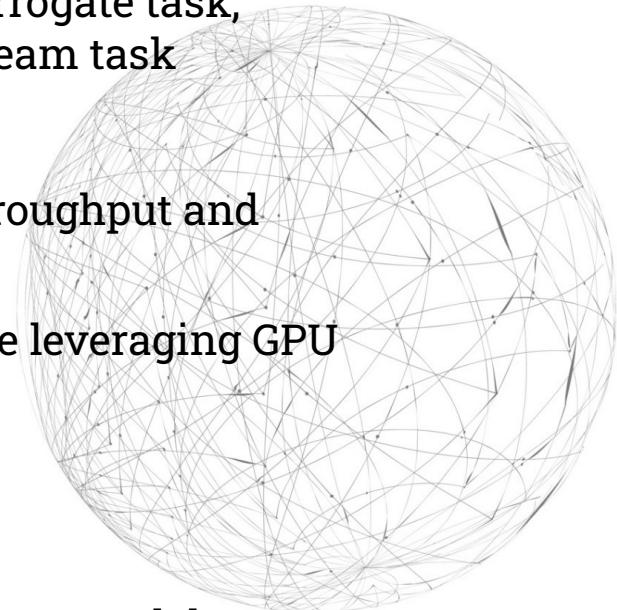
(Deep Learning) Pretraining the model for a surrogate task, fine-tuning of the model for a specific downstream task

- **Scale**

- Improvement of computational power (GPU throughput and memory)
- Development of transformer model architecture leveraging GPU parallelism enabling more expressive models
- Availability of much more training data

- **Self-supervised Learning**

Distributional semantics, autoregressive language models, Transformer based architectures, multimodality



# Foundation Models are NOT a new foundation of AI!



Has AI found a new Foundation?

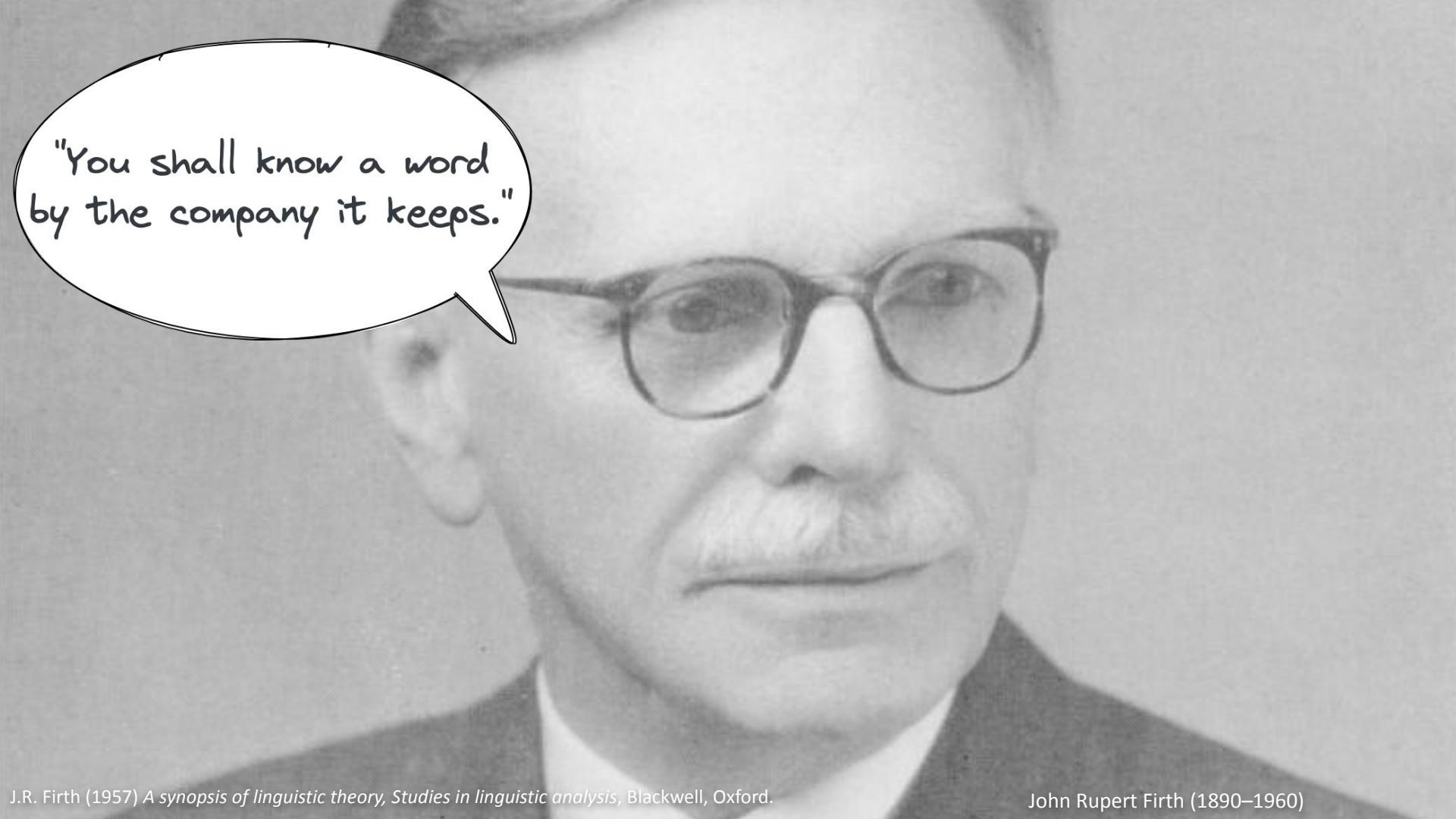
11.SEP.2021 . 11 MIN READ



# Semantics vs Stochastics



"The meaning of a word  
is its use in the language"



"You shall know a word  
by the company it keeps."

3-gram

1-gram

To him swallowed confess hear  
both. Which. Of save on trail for  
are ay device and rote life have  
Hill he late speaks; or! a more to  
leg less first you enter.

Fly, and will rid me these  
news of price. Therefore the sadness  
of parting, as they say,  
'tis done. This shall forbid it should  
be branded, if renown made it empty.

2-gram

Why dost stand forth thy  
canopy, forsooth; he is this  
palpable hit the King Henry.  
Live king. Follow. What means, sir.  
I confess she?  
then all sorts, he is trim, captain

4-gram

I will go seek the traitor Gloucester.  
Exeunt some of the watch.  
A great banquet serv'd in.  
It cannot be but so.

## N-Gram Shakespeare Generator



## Playground

write a dialogue between Caliban and Puck from an unknown Shakespeare play

Puck: Good day, Caliban.

|  
Caliban: Who are you?

Puck: I am the mischievous spirit Puck.

Caliban: What do you want with me?

Puck: I have been sent here to help you.

Caliban: I don't need help.

Puck: Oh, but I think you do. I can help you to realize your dreams and ambitions.

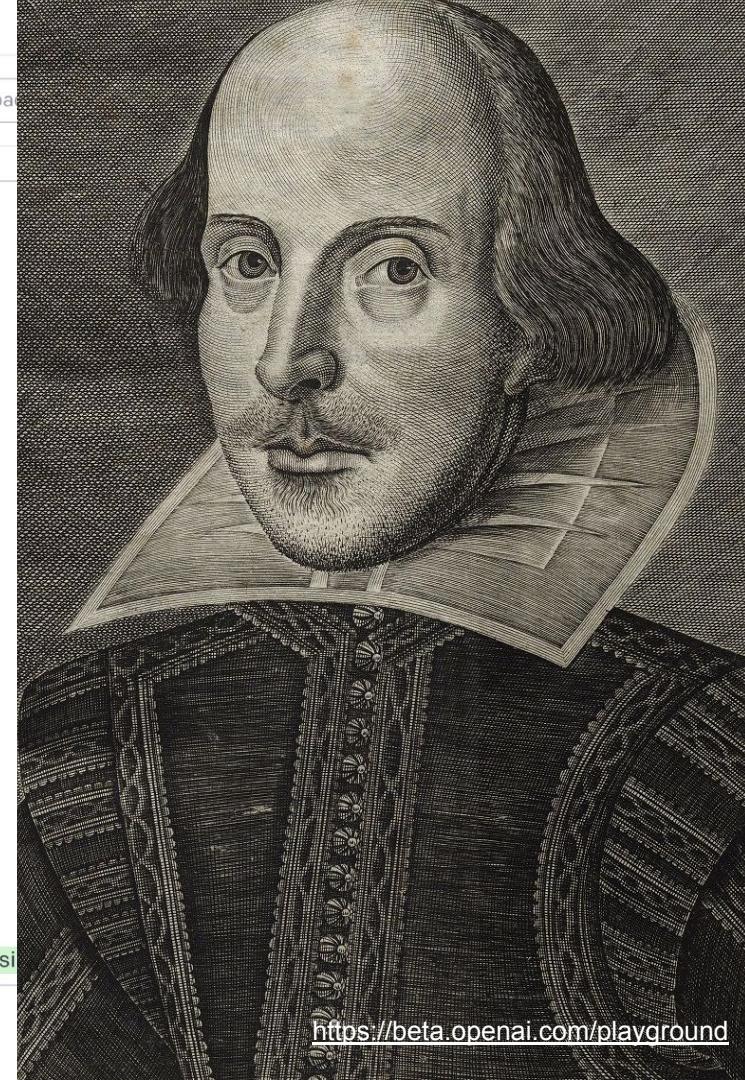
Caliban: How?

Puck: With a little bit of magic. I can grant you whatever you wish for.

Caliban: How can I trust you?

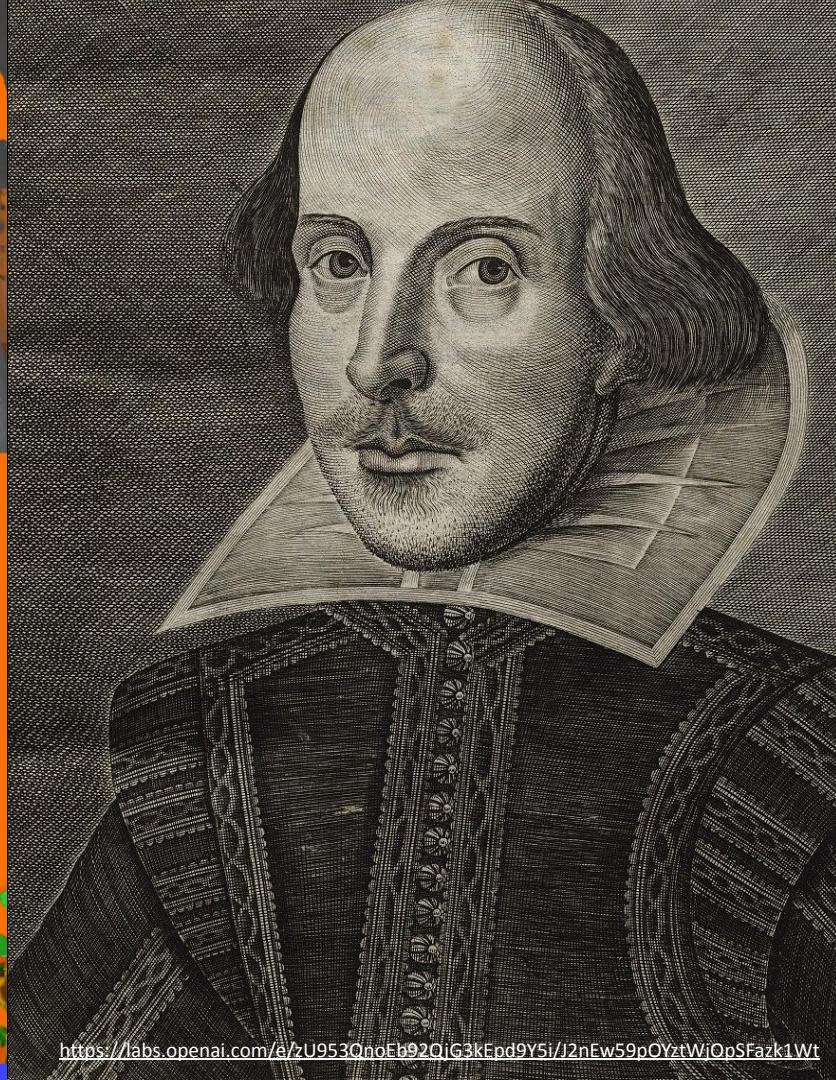
Puck: You can trust me, for I am an agent of good fortune. I can make your dreams come true. What is it you desire?

Submit





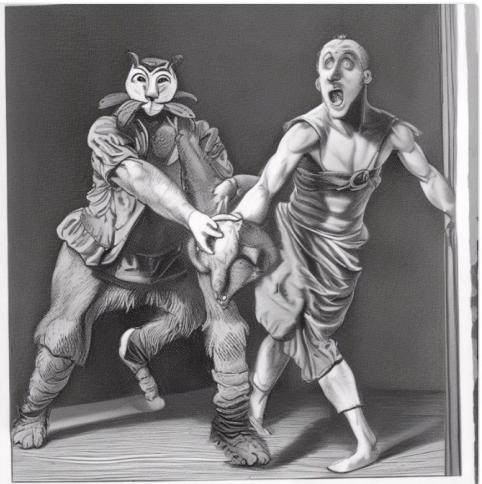
DALL-E



<https://labs.openai.com/e/zU953QnoEb92QjG3kEpd9Y5i/J2nEw59pOYztWjOpSFazk1Wt>

caliban and puck on stage together in a Shakespeare play

Generate image



The

<https://huggingface.co/spaces/stabilityai/stable-diffusion>

# Semantics from Stochastics

- Can we really derive meaning from probability distributions and statistics?
- Let's look at the Language Domain
  - Based on probability and statistics it is possible to **create syntactically and semantically correct texts**.
  - With larger training data and larger models also **contextually and pragmatically well fitting texts** can be created.
  - **Factual questions** can be correctly answered.
  - What about **Interpretative questions** and **Evaluative questions**?

# Playground

[Completion](#)[Q & A](#)[Summarization](#)[Prompt](#)[Text](#)[Multimodal](#)[Model Q&A](#)

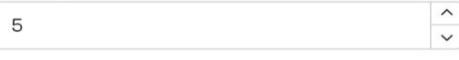
## Advanced Settings

(or use our [jumpstart](#))**Model** ⓘ

Multilingual model trained on English, German, French, Spanish and Italian

 luminous-extended**Maximum Tokens** ⓘ

64

**Stop Sequences** ⓘ ##### \n**Best of** ⓘ Show Probabilities ⓘ**Temperature** ⓘ**Top K** ⓘ

Q: Why is there war in Ukraine?

A:

**Completion**

The war in Ukraine is a result of the US-NATO-EU-backed coup in Ukraine in 2014. The coup was carried out by a coalition of fascist, neo-Nazi, and ultra-nationalist groups that have been operating in Ukraine for years. They are known as the Right Sector. The

[Append to Prompt](#)[Reset](#)[Submit](#)

# Semantics from Stochastics

- Can we really derive meaning from probability distributions and statistics?
- Let's look at the Language Domain
  - Based on probability and statistics it is possible to **create syntactically and semantically correct texts**.
  - With larger training data and larger models also **contextually and pragmatically well fitting texts** can be created.
  - **Factual questions** can be correctly answered.
  - **Interpretative questions or Evaluative questions** might be subject of inherent **bias** (of the training data).

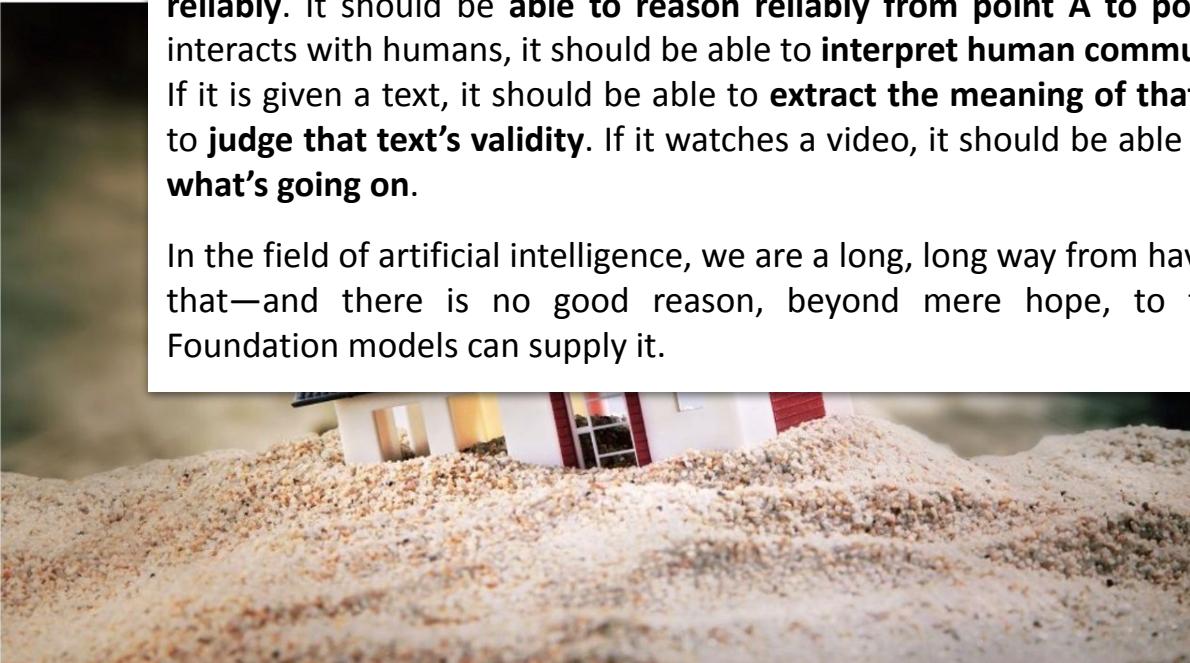
# Semantics from Stochastics

- Can we really derive meaning from probability distributions and statistics?
- Evaluation by probing current Foundation Models
  - Foundation models create **factual and interpretative errors**.
  - There seems to be only a **very limited understanding of common sense**.
  - It remains **unclear** how much meaning can be “learned” via stochastic models.



A foundation, in its usual sense, is the bedrock on which something complex is built. [...] A foundation for AI should provide something similar. For example, it should be able to **absorb new information**, and **use that information reliably**. It should be **able to reason reliably from point A to point B**. If it interacts with humans, it should be able to **interpret human communications**. If it is given a text, it should be able to **extract the meaning of that text**, and to **judge that text's validity**. If it watches a video, it should be able to **explain what's going on**.

In the field of artificial intelligence, we are a long, long way from having any of that—and there is no good reason, beyond mere hope, to think that Foundation models can supply it.



## Has AI found a new Foundation?

11.SEP.2021 . 11 MIN READ



*Symbolic AI to the Rescue*

# Symbolic AI to the Rescue

## Limitations

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<https://cs.nyu.edu/~davise/papers/ExperimentWithGalactica.html>

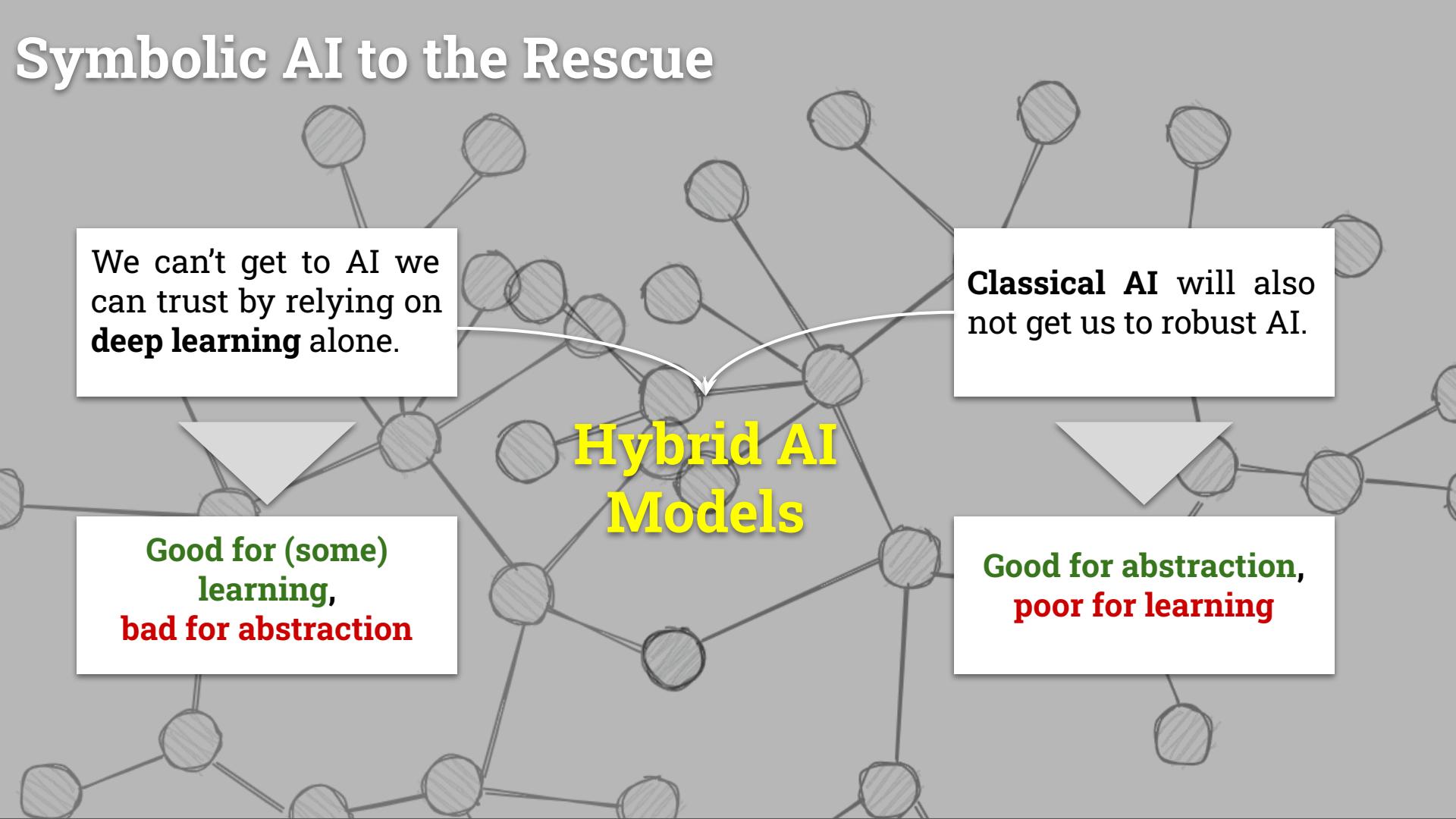
## Subsymbolic AI

- Neural Networks, Deep Learning & Foundation Models

## Symbolic AI

- Knowledge Representation
- Reasoning
- Verification

# Symbolic AI to the Rescue



We can't get to AI we can trust by relying on **deep learning** alone.

**Classical AI** will also not get us to robust AI.

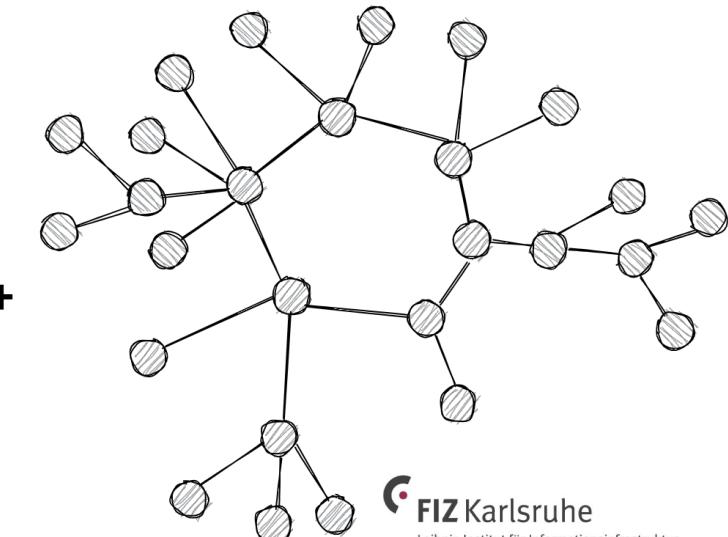
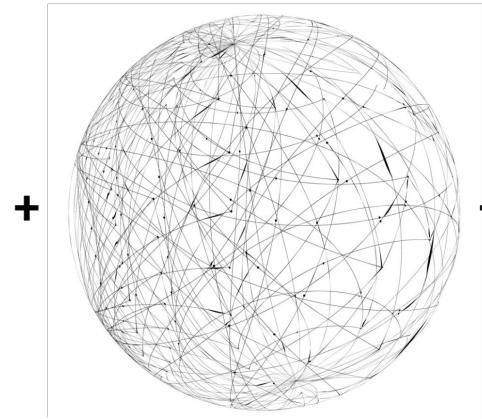
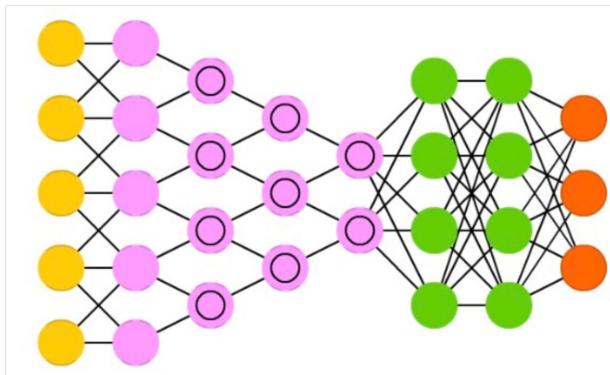
## Hybrid AI Models

Good for (some) learning,  
bad for abstraction

Good for abstraction,  
poor for learning

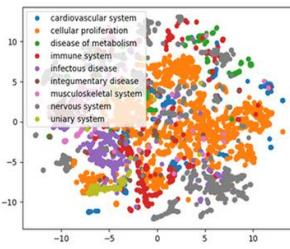
# Hybrid AI – Using One for the Benefit of the Other

- Knowledge Graph Embeddings
- Knowledge Extraction
- Explainable AI
- Fact Checking

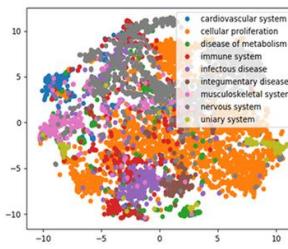


# Hybrid AI – Knowledge Graph Embeddings

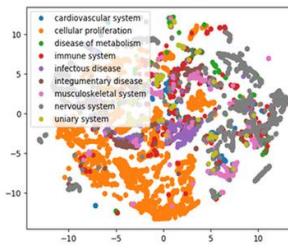
A. Walking RDF/OWL



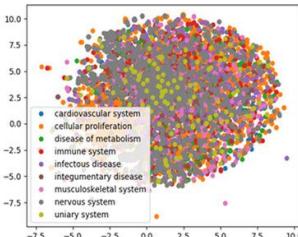
B. TransE embeddings



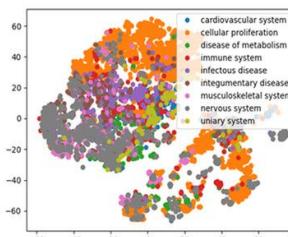
C. Poincare embeddings



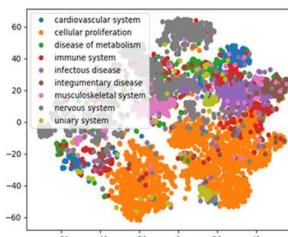
D. Rescal embeddings



E. SimpLE embeddings



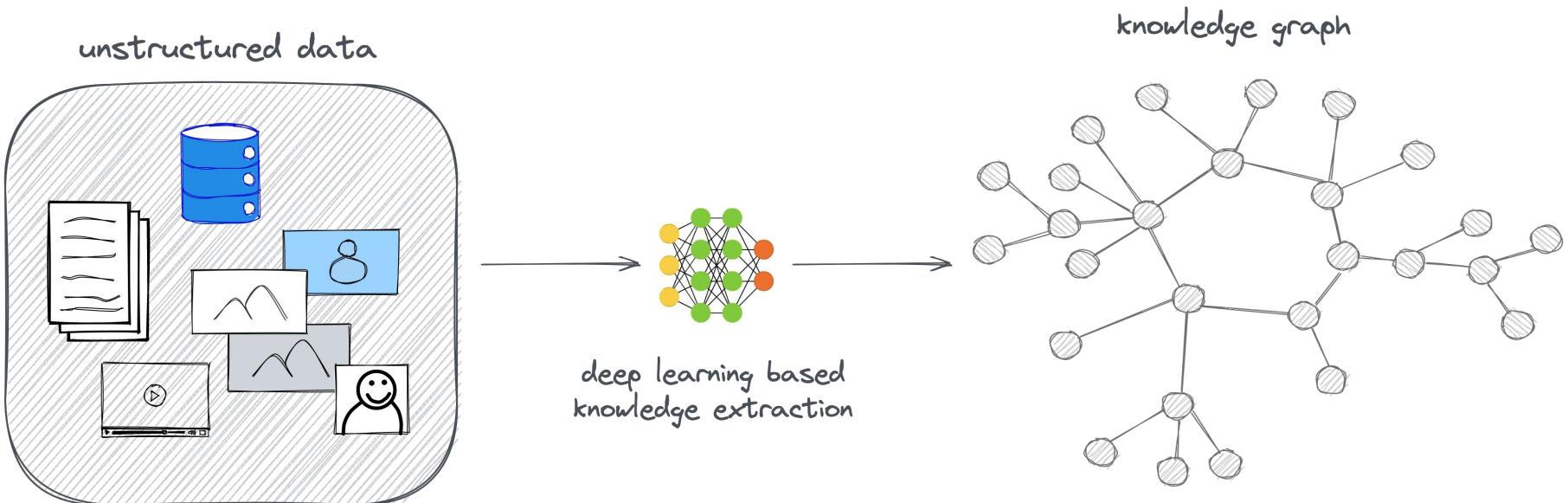
F. R-GCN embeddings



- Knowledge Graph Completion
- Link Prediction

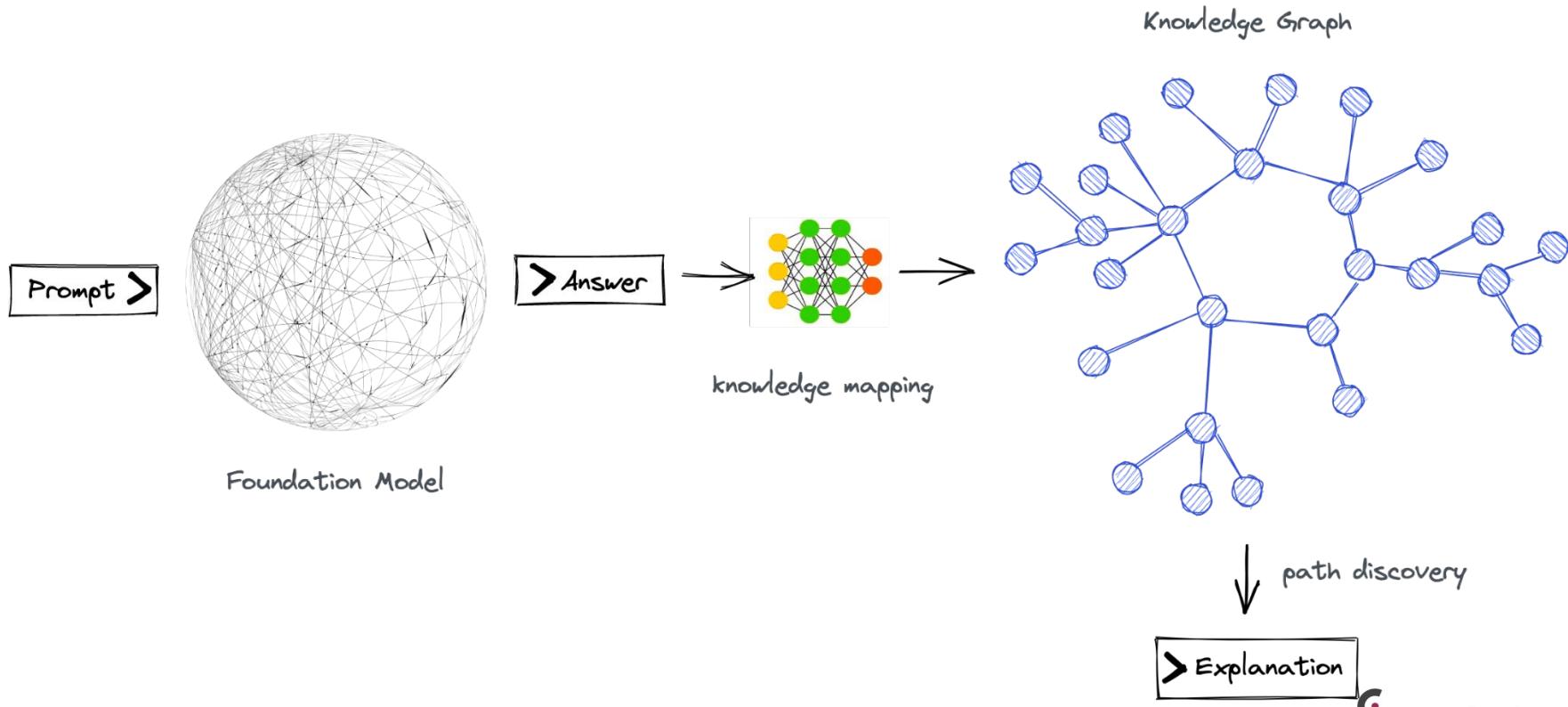
- Ontology Mapping
- Entity / Knowledge Graph Alignment

# Hybrid AI – Knowledge Extraction

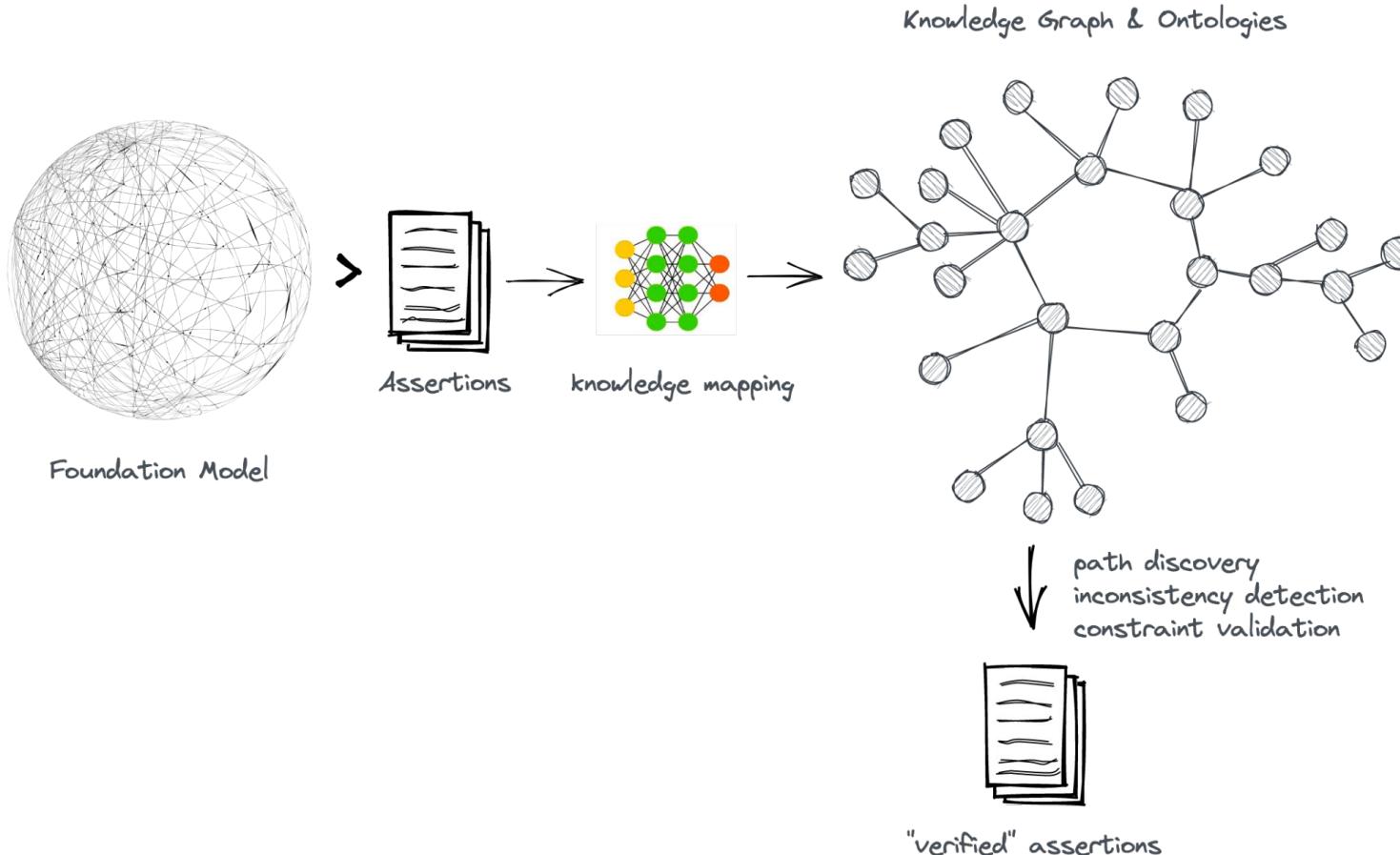


- Knowledge Graph Population
- Ontology Learning
- Entity Recognition & Linking
- Relation Extraction

# Hybrid AI – Explainable AI

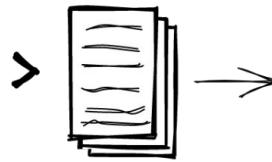
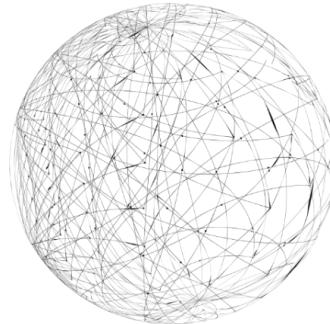


# Hybrid AI – Fact Checking

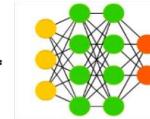


# Hybrid AI – Fact Checking and Human Intelligence

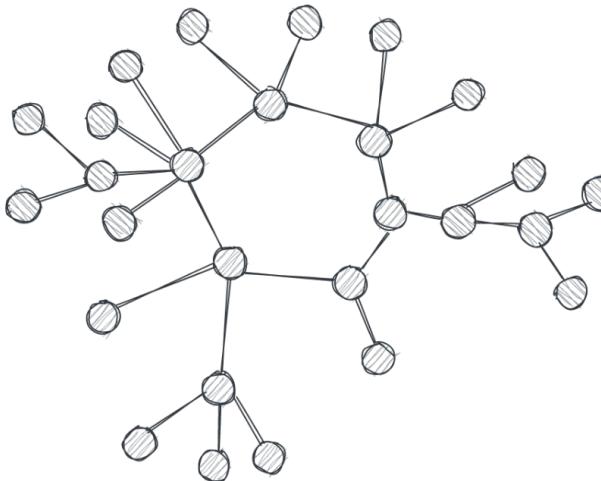
Knowledge Graph & Ontologies



Assertions



knowledge mapping



Foundation Model

domain knowledge  
common sense knowledge  
world knowledge  
experience, best practices,  
tacit knowledge,  
a priori/a posteriori knowledge,  
known/unknown unknown,  
meta knowledge,  
situated knowledge,  
...



path discovery  
inconsistency detection  
constraint validation

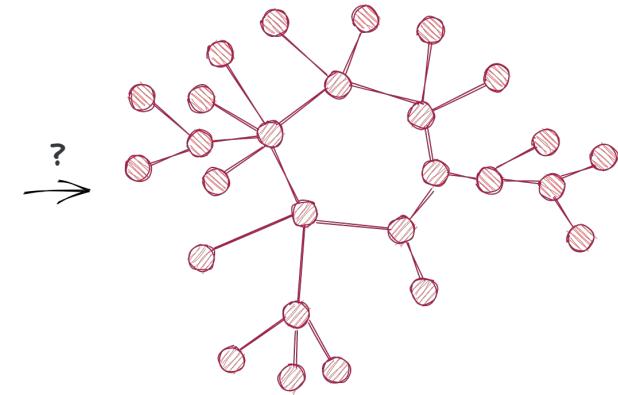


"verified" assertions

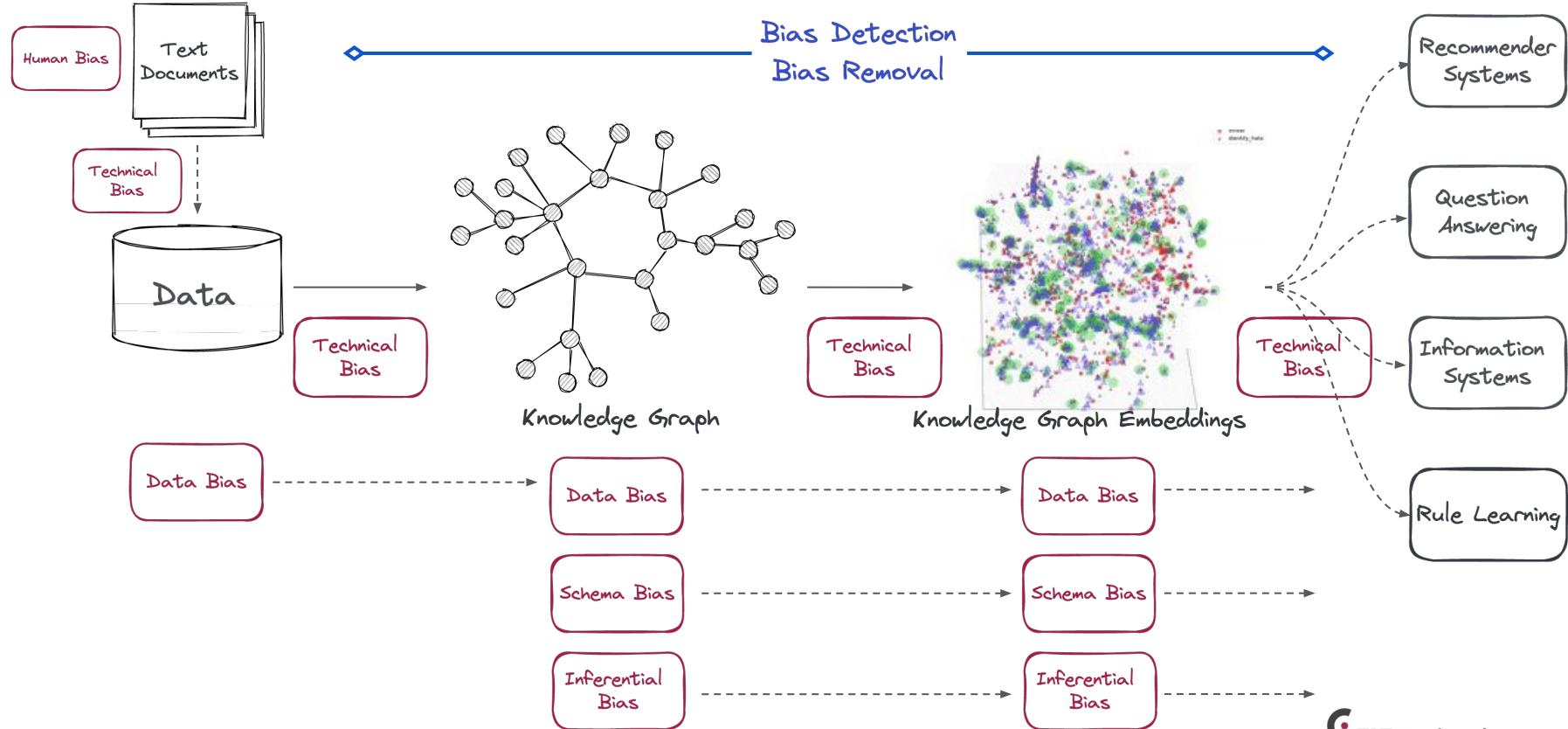
# Hybrid AI – Inconsistency Detection

- A general usecase potentially requires all kinds of **knowledge** to be **explicitly available**
- **Reasoning** will be another potential bottle neck
  - From **doubt** to **justification**
  - The importance or **order**:  
Knowledge must be organized hierarchically, in thematic/context-dependent modules
- Hybrid AI (the other meaning): human intelligence in combination with machine intelligence
  - Provenance and trust

domain knowledge  
common sense knowledge  
world knowledge  
experience, best practices,  
tacit knowledge,  
a priori/a posteriori knowledge,  
known/unknown unknown,  
meta knowledge,  
situated knowledge,  
...



# Bias as Foundational Trap





# Conclusion

# Towards a *better* Foundation in AI

(Marcus & Davis, 2021)

1. Rich cognitive models that keep track of the dynamically changing world  
*What is in the house? What is my favourite song? What do I expect today?*
2. Extensive Real World Knowledge  
*Most people in Italy speak Italian. If Aldo is from Bologna, it is most likely that he speaks Italian.*
3. Representation of Relationships between entities  
*If in a video a person drinks water, the system should not only recognize the objects but conclude that the person has quenched her thirst.*
4. Compositionality, an agent must understand wholes in terms of parts  
*"The Woman who went up a mountain and came down with a diamond" should be recognized as a sentence about a woman, who now possesses a diamond.*
5. Common Sense Knowledge  
*Time, space and causality including fundamental categories, e.g. physical objects, mental states, interpersonal relationships.*
6. Reasoning  
*If you know that a mixture of cherry and banana juice is non-toxic, the system should also know that when I drink it, then I most likely will not die.*
7. Human Values – Ethics  
*A medical chat-bot should know that it is not ok to recommend suicide.*

Reset Thread

Dark Mode

OpenAI Discord

Learn More

Log out

However, the subsymbolic AI approach also has its limitations. For example, it can be difficult to understand how a neural network makes a particular decision or prediction, and it can be difficult to explain the reasons behind its behavior. Additionally, the use of neural networks can be computationally intensive and require large amounts of data for training.

In conclusion, the field of AI is faced with an epic dilemma: should we pursue the symbolic AI approach, which is based on logical rules and well-understood principles, but has limitations in dealing with complex data? Or should we pursue the subsymbolic AI approach, which is based on the structure and function of the human brain, but can be difficult to understand and explain?

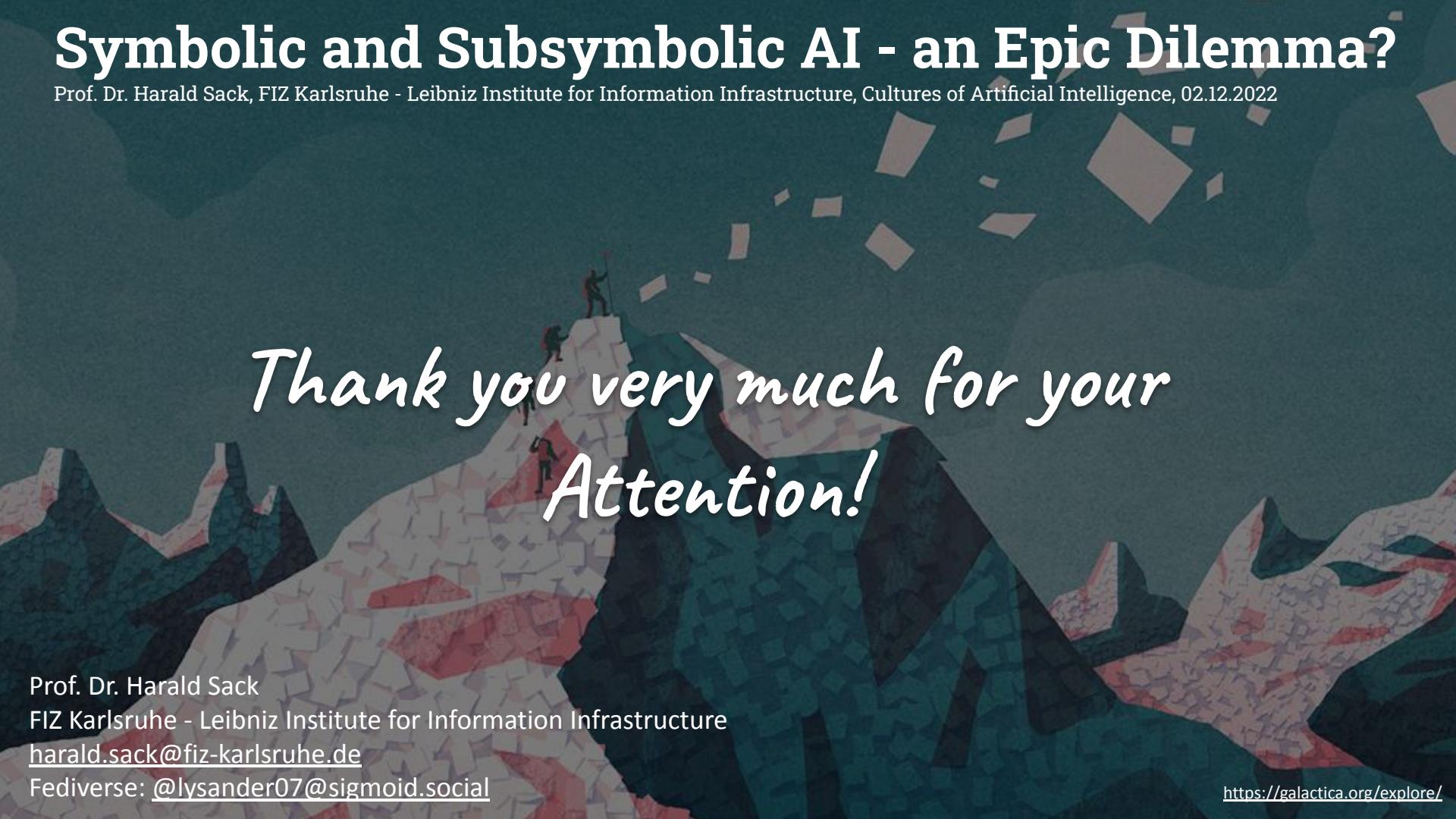
Ultimately, the answer to this dilemma may lie in combining the strengths of both approaches

Try again



# Symbolic and Subsymbolic AI - an Epic Dilemma?

Prof. Dr. Harald Sack, FIZ Karlsruhe - Leibniz Institute for Information Infrastructure, Cultures of Artificial Intelligence, 02.12.2022



*Thank you very much for your  
Attention!*

Prof. Dr. Harald Sack

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<https://galactica.org/explore/>

# Symbolic and Subsymbolic AI - an Epic Dilemma?

Prof. Dr. Harald Sack, FIZ Karlsruhe - Leibniz Institute for Information Infrastructure, Cultures of Artificial Intelligence, 02.12.2022

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- [7] Janowicz, K., Hu, Y., McKenzie, G., Gao, S., Regalia, B., Mai, G., Zhu, R., Adams, B., Taylor, K.: *Moon landing or safari? a study of systematic errors and their causes in geographic linked data*. In: GIScience 2016. pp. 275–290. Springer (2016)