做难而正确的事

细分方向和课题选择

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2026 年 02 月 23 日

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为什么要选题

选题不是导师给我的吗？

是也不是。

一个典型的研究过程

导师：你读一下这几篇文献，我们来把 A 方法应用到 B 领域中。
学生读完之后：我觉得 A 方法不适用于 B 领域，但是我认为 A 方法可能可以解决目前困扰 C 领域的一个问题，我来写个研究方案。
几周后，学生：A 方法能够显著解决 C 领域的某问题，性能提高了 xxx/成本降低了 xxx/填补了 xxx 的空白。

研究的乐趣在于发现并解决问题，而不是接受任务。

选择细分方向要参考平台资源

CSRanking↗ 是一个完全客观的、按照计算机学科顶会论文数量对学术机构进行排名的数据库。

在该数据库中，选取 2016-2026 的数据，南京大学在 AI 领域的五个子领域中：

- Artificial intelligence 排名世界第 1
- Computer vision 排名世界第 9
- Machine learning 排名世界第 4
- Natural language processing 排名世界第 12
- The Web & information retrieval 排名世界第 13

其他学科暂无细分方向的客观排名，可以咨询高年级同学。

	Institution	Count	Faculty
1	▶ Nanjing University	183.3	100
2	▶ Peking University	155.8	112
3	▶ Tsinghua University	145.7	98
4	▶ Zhejiang University	138.4	95
5	▶ Shanghai Jiao Tong University	132.2	107
6	▶ Chinese Academy of Sciences	116.8	71
7	▶ USTC	114.8	50
8	▶ Nanyang Technological University	108.5	48
9	▶ Harbin Institute of Technology	90.9	75
10	▶ UESTC	90.0	71

根据个人禀赋匹配研究范式

研究范式

研究范式（research paradigm）是指在某一学科或研究共同体中，被广泛接受的一整套关于：

- 研究对象是什么
- 什么问题是“值得研究的”
- 什么方法是“合法的”
- 什么结果算作“知识”
- 如何评价研究质量

的基本假设、方法体系与价值标准的集合。

例如，自然科学通过控制变量等手段，在特定实验环境下进行可复现的实验，研究自变量和因变量的关系；而宏观经济学通过研究历史经济数据，利用统计学模型获得变量间的相关性，并通过适当的经济学理论推断变量间的因果关系。

同一学科内不同细分方向的研究范式大相径庭

以智能科学与技术四个典型细分方向为例：

- **机器学习**：经验主义与工程驱动，强调数据规模与算法创新
- **知识表示与推理**：形式化与逻辑主义，追求理论严密性与可证明性
- **类脑智能**：跨自然科学范式，融合神经生物学与计算模型
- **人机交互**：社会科学与心理学范式，重视用户体验与实验设计

这些范式在**研究方法、验证标准、成果评价和人才特质要求**上差异巨大。

机器学习方向：经验主义与工程驱动范式

- 研究对象：大规模数据集与统计模型
- 核心问题：如何在数据上获得更低的 error、更高的 accuracy、更好的 generalization
- 方法论（Methodology）：
  - 数学建模（概率论、优化理论、信息论）
  - 算法设计（SGD、Transformer、Diffusion Model 等）
  - 大规模实验对比（benchmark 驱动）
- 实验范式：
  - 标准数据集（ImageNet、COCO、GLUE 等）
  - 可复现实验
  - 定量指标（Accuracy、F1、BLEU、Perplexity）
  - 成果评价标准：
    - 是否在 benchmark 上超过 SOTA（State-of-the-art，最优解）
    - 是否提出新的模型结构或训练方法

NIPS'17-Attention Is All You Need

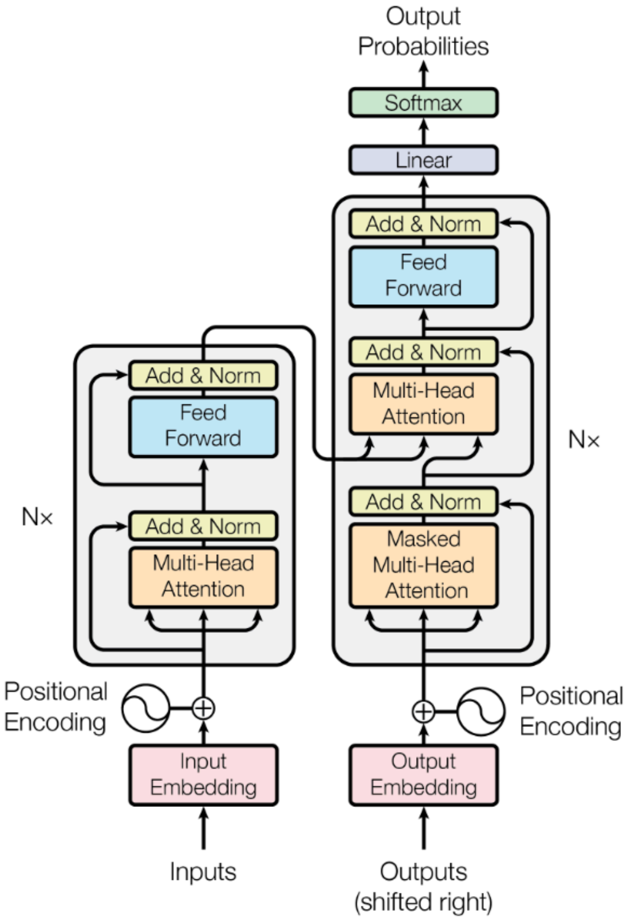


Figure 1: The Transformer - model architecture.

Table 2: The Transformer achieves better BLEU scores than previous state-of-the-art models on the English-to-German and English-to-French newstest2014 tests at a fraction of the training cost.

Model	BLEU		Training Cost (FLOPs)	
	EN-DE	EN-FR	EN-DE	EN-FR
ByteNet [15]	23.75			
Deep-Att + PosUnk [32]		39.2		$1.0 \cdot 10^{20}$
GNMT + RL [31]	24.6	39.92	$2.3 \cdot 10^{19}$	$1.4 \cdot 10^{20}$
ConvS2S [8]	25.16	40.46	$9.6 \cdot 10^{18}$	$1.5 \cdot 10^{20}$
MoE [26]	26.03	40.56	$2.0 \cdot 10^{19}$	$1.2 \cdot 10^{20}$
Deep-Att + PosUnk Ensemble [32]		40.4		$8.0 \cdot 10^{20}$
GNMT + RL Ensemble [31]	26.30	41.16	$1.8 \cdot 10^{20}$	$1.1 \cdot 10^{21}$
ConvS2S Ensemble [8]	26.36	**41.29**	$7.7 \cdot 10^{19}$	$1.2 \cdot 10^{21}$
Transformer (base model)	27.3	38.1	$\mathbf{3.3 \cdot 10^{18}}$	
Transformer (big)	**28.4**	**41.0**	$2.3 \cdot 10^{19}$	

- 在英-德翻译任务中，Transformer 得分超过了 SOTA；
- 在英-法翻译任务中，Transformer 得分接近 SOTA；
- 在训练成本上，Transformer 的基础模型和大模型比 SOTA 分别低了 3 个和 2 个数量级。

知识表示与推理方向：形式化与逻辑主义范式

- 研究对象：符号系统、逻辑语言、推理规则
- 核心问题：
  - 知识如何被形式化表达？
  - 推理系统是否 sound / complete？
  - 推理复杂度是多少？
- 方法论：
  - 一阶逻辑、描述逻辑、模态逻辑
  - 形式化语义与证明系统
  - 计算复杂性分析（NP-hard、PSPACE-complete 等）
- 实验范式：
  - 定理证明（proof）
  - 反例构造
  - 算法复杂度分析
- 成果评价标准：
  - 是否给出严格定理与证明
  - 是否改进理论复杂度界
  - 是否提出新的逻辑系统或语义框架

KR'24-Counterfactual and Semifactual Explanations in Abstract Argumentation: Formal Foundations, Complexity and Computation

- *complete* ($\mathtt{co}$) iff it is an admissible set and $S = Acc(S)$;
- *preferred* ($\mathtt{pr}$) iff it is a $\subseteq$-maximal complete extension;
- *stable* ($\mathtt{st}$) iff it is a total preferred extension, i.e. a preferred extension such that $S \cup Def(S) = \mathrm{A}$;
- *semi-stable* ($\mathtt{sst}$) iff it is a preferred extension such that $S \cup Def(S)$ is maximal (w.r.t. $\subseteq$);
- *grounded* ($\mathtt{gr}$) iff it is a $\subseteq$-minimal complete extension.

The argumentation semantics can be also defined in terms of *labelling* (Baroni, Caminada, and Giacomin 2011). A labelling for an AF $\langle \mathrm{A}, \mathrm{R}\rangle$ is a total function $\mathcal{L} : \mathrm{A} \to \{\mathbf{in}, \mathbf{out}, \mathbf{und}\}$ assigning to each argument a label: $\mathcal{L}(a) = \mathbf{in}$ means that a is accepted, $\mathcal{L}(a) = \mathbf{out}$ means that a is rejected, and $\mathcal{L}(a) = \mathbf{und}$ means that a is undecided.

Hereafter, with a little abuse of notation, a labelling will be also used to denote a set of labelled arguments, that is $\mathcal{L}$ also denotes the set $\{\ell(a) \mid \ell \in \{\mathbf{in}, \mathbf{out}, \mathbf{und}\} \wedge a \in A \wedge \mathcal{L}(a) = \ell\}$. Moreover, we also use the notations $\mathbf{in}(\mathcal{L}) = \{a \mid a \in \mathrm{A} \wedge \mathcal{L}(a) = \mathbf{in}\}$, $\mathbf{out}(\mathcal{L}) = \{a \mid a \in \mathrm{A} \wedge \mathcal{L}(a) = \mathbf{out}\}$, and $\mathbf{und}(\mathcal{L}) = \{a \mid a \in \mathrm{A} \wedge \mathcal{L}(a) = \mathbf{und}\}$, to denote the sets of arguments labelled as $\mathbf{in}$, $\mathbf{out}$, and $\mathbf{und}$ by $\mathcal{L}$, respectively. For any labelling $\mathcal{L}$ and argument a, $\mathcal{L}[a] = \ell(a)$, where $\ell \in \{\mathbf{in}, \mathbf{out}, \mathbf{und}\}$ and $\mathcal{L}(a) = \ell$, denotes the projection of $\mathcal{L}$ over a.

Given an AF $\Lambda = \langle \mathrm{A}, \mathrm{R}\rangle$, a labelling $\mathcal{L}$ for A is said to be *admissible (or legal)* if $\forall a \in \mathbf{in}(\mathcal{L}) \cup \mathbf{out}(\mathcal{L})$ it holds that: (*i*) $\mathcal{L}(a) = \mathbf{out}$ iff $\exists\,(b, a) \in \mathrm{R}$ such that $\mathcal{L}(b) = \mathbf{in}$; and (*ii*) $\mathcal{L}(a) = \mathbf{in}$ iff $\forall (b, a) \in \mathrm{R}$, $\mathcal{L}(b) = \mathbf{out}$ holds.

Moreover, $\mathcal{L}$ is a *complete* labelling (or $\mathtt{co}$-labelling) iff conditions (*i*) and (*ii*) hold for all arguments $a \in \mathrm{A}$.[1]

Between complete extensions and complete labellings there is a bijective mapping defined as follows: for each extension E there is a unique labelling $\mathcal{L}(E) = \{\mathbf{in}(a) \mid a \in E\} \cup \{\mathbf{out}(a) \mid a \in Def(E)\} \cup \{\mathbf{und}(a) \mid a \in \mathrm{A} \setminus (E \cup Def(E))\}$, and for each labelling $\mathcal{L}$ there is a unique extension, that is $\mathbf{in}(\mathcal{L})$. We say that $\mathcal{L}(E)$ is the labelling *corresponding* to E. Moreover, we say that $\mathcal{L}(E)$ is a σ-labelling for a given AF Λ and semantics $\sigma \in \{\mathtt{co}, \mathtt{pr}, \mathtt{st}, \mathtt{sst}, \mathtt{gr}\}$ iff E is a σ-extension of Λ.

In the following, we say that the *status of an argument* a w.r.t. a labelling $\mathcal{L}$ (or its corresponding extension $\mathbf{in}(\mathcal{L})$) is $\mathbf{in}$ (resp., $\mathbf{out}$, $\mathbf{und}$) iff $\mathcal{L}(a) = \mathbf{in}$ (resp., $\mathcal{L}(a) = \mathbf{out}$, $\mathcal{L}(a) = \mathbf{und}$). We will avoid to mention explicitly the labelling (or the extension) whenever it is understood.

The set of complete (resp., preferred, stable, semi-stable, grounded) labellings of an AF Λ will be denoted by $\mathtt{co}(\Lambda)$ (resp., $\mathtt{pr}(\Lambda)$, $\mathtt{st}(\Lambda)$, $\mathtt{sst}(\Lambda)$, $\mathtt{gr}(\Lambda)$). All the above-mentioned semantics except the stable admit at least one labelling. The grounded semantics, that admits exactly one labelling, is said to be a *unique status* semantics, while the others are said to be *multiple status* semantics. With a little abuse of notation, in the following we also use $\mathtt{gr}(\Lambda)$ to denote the grounded labelling. For any AF Λ, it holds that: *i*) $\mathtt{st}(\Lambda) \subseteq \mathtt{sst}(\Lambda) \subseteq \mathtt{pr}(\Lambda) \subseteq \mathtt{co}(\Lambda)$, *ii*) $\mathtt{gr}(\Lambda) \in \mathtt{co}(\Lambda)$, and *iii*) $\mathtt{st}(\Lambda) \neq \emptyset$ implies that $\mathtt{st}(\Lambda) = \mathtt{sst}(\Lambda)$.

[1] Although $\mathbf{und}$ is not explicitly mentioned, since $\mathcal{L}$ is a total function, it suffices to characterize complete labelings (Caminada and Pigozzi 2011; Baroni, Caminada, and Giacomin 2011).

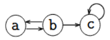


Figure 2: AF of Example 4.

For any pair $(\mathcal{L},\mathcal{L}')$ of σ-labellings of AF $\Lambda = \langle \mathrm{A}, \mathrm{R}\rangle$ (with $\sigma \in \{\mathtt{gr}, \mathtt{co}, \mathtt{st}, \mathtt{pr}, \mathtt{sst}\}$), we use $\delta(\mathcal{L}, \mathcal{L}')$ to denote the *distance* $|\{a \in \mathrm{A} \mid \mathcal{L}(a) \neq \mathcal{L}'(a)\}|$ between $\mathcal{L}$ and $\mathcal{L}'$ in terms of the number of arguments having a different status.

Example 4. Let $\Lambda = \langle \mathrm{A}, \mathrm{R}\rangle$ be an AF where $\mathrm{A} = \{\mathtt{a}, \mathtt{b}, \mathtt{c}\}$ and $\mathrm{R} = \{(\mathtt{a}, \mathtt{b}), (\mathtt{b}, \mathtt{a}), (\mathtt{b}, \mathtt{c}), (\mathtt{c}, \mathtt{c})\}$ whose graph is shown in Figure 2. AF Λ has three complete labellings: $\mathcal{L}_1 = \{\mathbf{und}(\mathtt{a}), \mathbf{und}(\mathtt{b}), \mathbf{und}(\mathtt{c})\}$, $\mathcal{L}_2 = \{\mathbf{in}(\mathtt{a}), \mathbf{out}(\mathtt{b}), \mathbf{und}(\mathtt{c})\}$, and $\mathcal{L}_3 = \{\mathbf{out}(\mathtt{a}), \mathbf{in}(\mathtt{b}), \mathbf{out}(\mathtt{c})\}$, and we have that $\delta(\mathcal{L}_1, \mathcal{L}_2) = 2$ and $\delta(\mathcal{L}_1, \mathcal{L}_3) = \delta(\mathcal{L}_2, \mathcal{L}_3) = 3$. Moreover, the set of preferred labellings is $\mathtt{pr}(\Lambda) = \{\mathcal{L}_2, \mathcal{L}_3\}$, whereas the set of stable (and semi-stable) labellings is $\mathtt{st}(\Lambda) = \mathtt{sst}(\Lambda) = \{\mathcal{L}_3\}$, and the grounded labelling is $\mathcal{L}_1$. □

Four canonical argumentation problems are *existence*, *verification*, and *credulous* and *skeptical acceptance*. These problems can be formalized as follows. Given an AF $\Lambda = \langle \mathrm{A}, \mathrm{R}\rangle$, for any semantics $\sigma \in \{\mathtt{gr}, \mathtt{co}, \mathtt{st}, \mathtt{pr}, \mathtt{sst}\}$, (*i*) the existence problem (denoted EX^σ) consists in deciding whether there is at least one σ-labelling for Λ; (*ii*) the verification problem (denoted VE^σ) consists in deciding whether a given labelling is a σ-labelling for Λ; and (*iii*) given a (goal) argument $g \in \mathrm{A}$, the *credulous* (resp., *skeptical*) acceptance problem, denoted as CA^σ (resp., SA^σ), is the problem of deciding whether $\mathbf{in}(g)$ belongs to any (resp., all) σ-labellings of Λ. Clearly, for the grounded semantics, which admits exactly one labelling, credulous and skeptical acceptance problems become identical.

The complexity of the above-mentioned problems has been thoroughly investigated (see e.g. (Gabbay et al. 2021) for a survey), and the results are summarized in Table 1.

3 Counterfactual Reasoning

In this section, after formally defining the concept of counterfactual, we investigate the complexity of counterfactual-based argumentation problems.

As stated next, a counterfactual of a given σ-labelling w.r.t. a given goal argument g is a minimum-distance σ-labelling altering the acceptance status of g.

Definition 1 (Counterfactual (CF)). Let $\langle \mathrm{A}, \mathrm{R}\rangle$ be an AF, $\sigma \in \{\mathtt{gr}, \mathtt{co}, \mathtt{st}, \mathtt{pr}, \mathtt{sst}\}$ a semantics, $g \in \mathrm{A}$ a goal argument, and $\mathcal{L}$ a σ-labelling for $\langle \mathrm{A}, \mathrm{R}\rangle$. Then, a labelling $\mathcal{L}' \in \sigma(\langle \mathrm{A}, \mathrm{R}\rangle)$ is a *counterfactual* of $\mathcal{L}$ w.r.t. g if:

(i) $\mathcal{L}(g) \neq \mathcal{L}'(g)$, and

(ii) there exists no $\mathcal{L}'' \in \sigma(\langle \mathrm{A}, \mathrm{R}\rangle)$ such that $\mathcal{L}(g) \neq \mathcal{L}''(g)$ and $\delta(\mathcal{L}, \mathcal{L}'') < \delta(\mathcal{L}, \mathcal{L}')$.

We use $\mathcal{CF}^\sigma(g, \mathcal{L})$ to denote the set of counterfactuals of $\mathcal{L}$ w.r.t. g.

Example 5. Continuing with Example 2, under stable semantics, for the labelling $\mathcal{L}_3 = \{\mathbf{out}(\mathtt{fish}), \mathbf{in}(\mathtt{meat}),$

	Classical problems				Counterfactual-based problems				Semifactual-based problems			
σ	EX^σ	VE^σ	CA^σ	SA^σ	$\mathsf{CF\text{-}EX}^\sigma$	$\mathsf{CF\text{-}VE}^\sigma$	$\mathsf{CF\text{-}CA}^\sigma$	$\mathsf{CF\text{-}SA}^\sigma$	$\mathsf{SF\text{-}EX}^\sigma$	$\mathsf{SF\text{-}VE}^\sigma$	$\mathsf{SF\text{-}CA}^\sigma$	$\mathsf{SF\text{-}SA}^\sigma$
$\mathtt{co}$	T	P	NP-c	P	NP-c	coNP-c	NP-h, Θ_2^p	coNP-h, Θ_2^p	NP-c	coNP-c	NP-h, Θ_2^p	coNP-h, Θ_2^p
$\mathtt{st}$	NP-c	P	NP-c	coNP-c	NP-c	coNP-c	NP-h, Θ_2^p	coNP-h, Θ_2^p	NP-c	coNP-c	NP-h, Θ_2^p	coNP-h, Θ_2^p
$\mathtt{pr}$	T	coNP-c	NP-c	Π_2^p-c	Σ_2^p-c	Π_2^p-c	Σ_2^p-h, Θ_3^p	Π_2^p-h, Θ_3^p	Σ_2^p-c	Π_2^p-c	Σ_2^p-h, Θ_3^p	Π_2^p-h, Θ_3^p
$\mathtt{sst}$	T	coNP-c	Σ_2^p-c	Π_2^p-c	Σ_2^p-c	Π_2^p-c	Σ_2^p-h, Θ_3^p	Π_2^p-h, Θ_3^p	Σ_2^p-c	Π_2^p-c	Σ_2^p-h, Θ_3^p	Π_2^p-h, Θ_3^p

Table 1: Complexity of classical, counterfactual-based and semifactual-based problems in AF under complete ($\mathtt{co}$), stable ($\mathtt{st}$), preferred ($\mathtt{pr}$), and semi-stable ($\mathtt{sst}$) semantics. For any complexity class C, C-c (resp., C-h) means C-complete (resp., C-hard); an interval C-h, C' means C-hard and in C'. New results are highlighted in cyan. T means trivial (from the computational standpoint).

Example 9. Consider the stable labelling $\mathcal{L}_3 = \{\mathbf{out}(\mathtt{fish}), \mathbf{in}(\mathtt{meat}), \mathbf{out}(\mathtt{pasta}), \mathbf{out}(\mathtt{white}), \mathbf{in}(\mathtt{red})\}$ for the AF of Example 3. We have that $\mathcal{L}_2 = \{\mathbf{in}(\mathtt{fish}), \mathbf{out}(\mathtt{meat}), \mathbf{out}(\mathtt{pasta}), \mathbf{out}(\mathtt{white}), \mathbf{in}(\mathtt{red})\}$ and $\mathcal{L}_4 = \{\mathbf{out}(\mathtt{fish}), \mathbf{out}(\mathtt{meat}), \mathbf{in}(\mathtt{pasta}), \mathbf{out}(\mathtt{white}), \mathbf{in}(\mathtt{red})\}$ are the only semifactuals of $\mathcal{L}_3$ w.r.t. the argument $\mathtt{red}$ as there is no other $\mathtt{st}$-labelling agreeing on $\mathtt{red}$ and having distance greater than $\delta(\mathcal{L}_3, \mathcal{L}_2) = \delta(\mathcal{L}_3, \mathcal{L}_4) = 2$. In fact, $\mathcal{L}_1 = \{\mathbf{in}(\mathtt{fish}), \mathbf{out}(\mathtt{meat}), \mathbf{out}(\mathtt{pasta}), \mathbf{in}(\mathtt{white}), \mathbf{out}(\mathtt{red})\}$, having distance $\delta(\mathcal{L}_3, \mathcal{L}_1) = 4$, is not a semifactual for $\mathcal{L}_3$ w.r.t. $\mathtt{red}$ as $\mathcal{L}_1(\mathtt{red}) \neq \mathcal{L}_3(\mathtt{red})$. Thus, $\mathcal{SF}^{\mathtt{st}}(\mathtt{red}, \mathcal{L}_3) = \{\mathcal{L}_2, \mathcal{L}_4\}$. □

Similarly to the case of counterfactuals, the semifactual relationship is not symmetric, that is, $\mathcal{L}' \in \mathcal{SF}^\sigma(g, \mathcal{L})$ does not entail that $\mathcal{L} \in \mathcal{SF}^\sigma(g, \mathcal{L}')$.

As for the case of counterfactuals, semifactual reasoning makes sense only for multiple status semantics. Thus, hereafter, we do not consider the grounded semantics.

The semifactual-based existence problem is as follows.

Definition 6 (SF-Existence Problem). Given as input an AF $\Lambda = \langle \mathrm{A}, \mathrm{R}\rangle$, a semantics $\sigma \in \{\mathtt{co}, \mathtt{st}, \mathtt{pr}, \mathtt{sst}\}$, a goal argument $g \in \mathrm{A}$, an integer $k \in \mathbb{N}$, and a σ-labelling $\mathcal{L} \in \sigma(\Lambda)$, $\mathsf{SF\text{-}EX}^\sigma$ is the problem of checking whether there exists a labelling $\mathcal{L}' \in \sigma(\Lambda)$ s.t. $\mathcal{L}(g) = \mathcal{L}'(g)$ and $\delta(\mathcal{L}, \mathcal{L}') \geq k$.

We use $\mathsf{SF\text{-}EX}^\sigma_\Lambda(g, k, \mathcal{L})$ (or simply $\mathsf{SF\text{-}EX}^\sigma(g, k, \mathcal{L})$ whenever Λ is fixed) to denote the output of $\mathsf{SF\text{-}EX}^\sigma$ with input Λ, g, k, and $\mathcal{L}$.

Example 10. Continuing with Example 3, assume the customer is interested to know whether there exists a menu containing $\mathtt{red}$ wine and differing from $\mathcal{L}_3$ by at least two items. Under stable semantics, the answer to this question is yes, as there exists menu $\mathcal{L}_2 \in \mathtt{st}(\Lambda)$, with $\mathcal{L}_2(\mathtt{red}) = \mathcal{L}_3(\mathtt{red})$ and $\delta(\mathcal{L}_3, \mathcal{L}_2) = 2$, i.e. $\mathsf{SF\text{-}EX}^{\mathtt{st}}(\mathtt{red}, 2, \mathcal{L}_3)$ is true. □

The following theorem characterizes the complexity of the existence problem under semifactual reasoning.

Theorem 5. $\mathsf{SF\text{-}EX}^\sigma$ *is:*

- NP*-complete for* $\sigma \in \{\mathtt{co}, \mathtt{st}\}$*; and*
- Σ_2^p*-complete for* $\sigma \in \{\mathtt{pr}, \mathtt{sst}\}$.

Proof. For the membership result, guess a labelling $\mathcal{L}'$ with $\mathcal{L}(g) = \mathcal{L}'(g)$ and check in PTIME (resp., PTIME, coNP, and coNP) that $\mathcal{L}' \in \sigma(\Lambda)$ with $\sigma = \mathtt{co}$ (resp., $\mathtt{st}, \mathtt{pr}, \mathtt{sst}$) (Dvorák and Dunne 2017) and $\delta(\mathcal{L}, \mathcal{L}') \geq k$.

(Sketch.) For $\sigma = \mathtt{co}$ (resp., $\sigma = \mathtt{st}$), we provide a reduction from the non-empty $\mathtt{co}$-existence problem $\mathsf{EX}^{\mathtt{co}}_{\neg\emptyset}$ (resp., $\mathtt{st}$-existence problem $\mathsf{EX}^{\mathtt{st}}$), as done for the hardness results of $\mathsf{CF\text{-}EX}^\sigma$ but with different constructions. We show that $\mathsf{EX}^{\mathtt{co}}_{\neg\emptyset}(\langle \mathrm{A}, \mathrm{R}\rangle)$ (resp., $\mathsf{EX}^{\mathtt{st}}(\langle \mathrm{A}, \mathrm{R}\rangle)$) is true iff $(\langle \mathrm{A}^*, \mathrm{R}^*\rangle, \bar{g}, k = 1, \mathcal{L}^*)$ is a true instance of $\mathsf{SF\text{-}EX}^\sigma$, where: $\mathrm{A}^* = \mathrm{A} \cup \{g, \bar{g}\}$, $\mathrm{R}^* = \mathrm{R} \cup \{(g, a), (a, g), (a, \bar{g}), (g, \bar{g}) \mid a \in \mathrm{A}\}$, and $\mathcal{L}^* = \{\mathbf{in}(g)\} \cup \{\mathbf{out}(a) \mid a \in \mathrm{A}^* \setminus \{g\}\}$. For $\sigma \in \{\mathtt{pr}, \mathtt{sst}\}$ we provide a reduction from the complement of the skeptical σ-acceptance problem for AF, namely $\overline{\mathsf{SA}}^\sigma$. We we show that $\overline{\mathsf{SA}}^\sigma(\langle \mathrm{A}, \mathrm{R}\rangle, g)$ is true iff $(\langle \mathrm{A}^*, \mathrm{R}^*\rangle, \bar{g}, k = 1, \mathcal{L}^*)$ is a true instance of $\mathsf{SF\text{-}EX}^\sigma$, where $\mathrm{A}^* = \mathrm{A} \cup \{x, \bar{x}, x^u, \bar{g}, g^u\}$, $\mathrm{R}^* = \mathrm{R} \cup \{(g, \bar{g}), (\bar{g}, \bar{g}), (\bar{g}, g^u), (g^u, g^u), (x, \bar{x}), (\bar{x}, x^u), (x^u, x^u), (x, g^u) \cup \{(x, a), (a, x) \mid a \in \mathrm{A}\}$, and $\mathcal{L}^* = \{\mathbf{in}(x), \mathbf{out}(\bar{x}), \mathbf{und}(x^u), \mathbf{und}(\bar{g}), \mathbf{out}(g^u)\} \cup \{\mathbf{out}(a) \mid a \in \mathrm{A}\}$. □

For semifactuals, the verification problem is checking whether a given labelling $\mathcal{L}'$ is a semifactual for $\mathcal{L}$ and g (hence the distance between the two labelling is maximal).

Definition 7 (SF-Verification Problem). Given as input an AF $\Lambda = \langle \mathrm{A}, \mathrm{R}\rangle$, a semantics $\sigma \in \{\mathtt{co}, \mathtt{st}, \mathtt{pr}, \mathtt{sst}\}$, a goal argument $g \in \mathrm{A}$, a σ-labelling $\mathcal{L} \in \sigma(\Lambda)$, and a labelling $\mathcal{L}'$, $\mathsf{SF\text{-}VE}^\sigma$ is the problem of checking whether $\mathcal{L}'$ belongs to $\mathcal{SF}^\sigma(g, \mathcal{L})$.

We use $\mathsf{SF\text{-}VE}^\sigma_\Lambda(g, \mathcal{L}, \mathcal{L}')$ (or simply $\mathsf{SF\text{-}VE}^\sigma(g, \mathcal{L}, \mathcal{L}')$) to denote the output of $\mathsf{SF\text{-}VE}^\sigma$ with input $\Lambda, g, \mathcal{L}$, and $\mathcal{L}'$.

Example 11. Consider the situation in Example 3, and assume the customer is interested to know whether $\mathcal{L}_2$ is the farthest menu w.r.t. $\mathcal{L}_3$ containing $\mathtt{red}$ wine. This problem can be answered by deciding $\mathsf{SF\text{-}VE}^{\mathtt{st}}(\mathtt{meat}, \mathcal{L}_3, \mathcal{L}_2)$, which is true as we have that $\mathcal{L}_2 \in \mathcal{SF}^{\mathtt{st}}(\mathtt{red}, \mathcal{L}_3)$. □

Theorem 6. $\mathsf{SF\text{-}VE}^\sigma$ *is:*

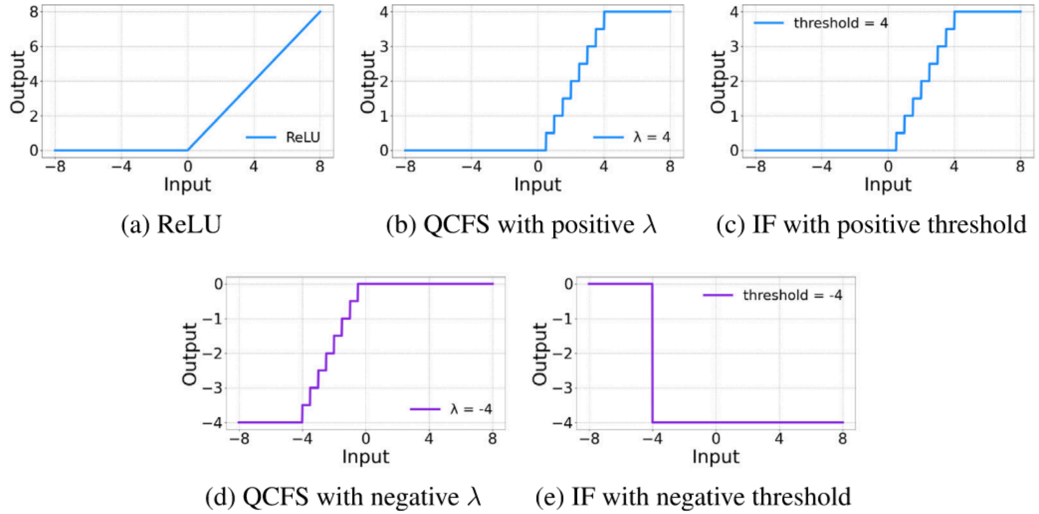
- coNP*-complete for* $\sigma \in \{\mathtt{co}, \mathtt{st}\}$*; and*
- Π_2^p*-complete for* $\sigma \in \{\mathtt{pr}, \mathtt{sst}\}$.

Proof. The following guess-and-check algorithm provides the membership result for the complement of our problem. First, check whether $\mathcal{L}(g) = \mathcal{L}'(g)$, and then guess a labelling $\mathcal{L}''$ with $\mathcal{L}(g) = \mathcal{L}''(g)$ and check in PTIME (resp., PTIME, coNP, and coNP) that $\mathcal{L}'' \in \sigma(\Lambda)$ with $\sigma = \mathtt{co}$ (resp., $\mathtt{st}, \mathtt{pr}, \mathtt{sst}$) (Dvorák and Dunne 2017) and that $\delta(\mathcal{L}, \mathcal{L}'') > \delta(\mathcal{L}, \mathcal{L}')$ (in PTIME). If both condition holds then the complement of our problem is true.

类脑智能方向：跨自然科学范式

- 研究对象：生物神经系统与神经动力学模型
- 核心问题：
  - 大脑如何实现学习与记忆？
  - 神经元放电模式如何编码信息？
  - 生物机制如何启发人工模型？
- 方法论：
  - 神经动力学方程
  - 生物实验数据分析（EEG、fMRI、spike trains）
  - 计算模型仿真
- 实验范式：
  - 生物实验与计算实验并行
  - 假设—验证式研究
  - 小样本、高噪声数据
- 成果评价标准：
  - 是否解释生物现象
  - 是否与神经科学实验一致
  - 是否提出可验证假说

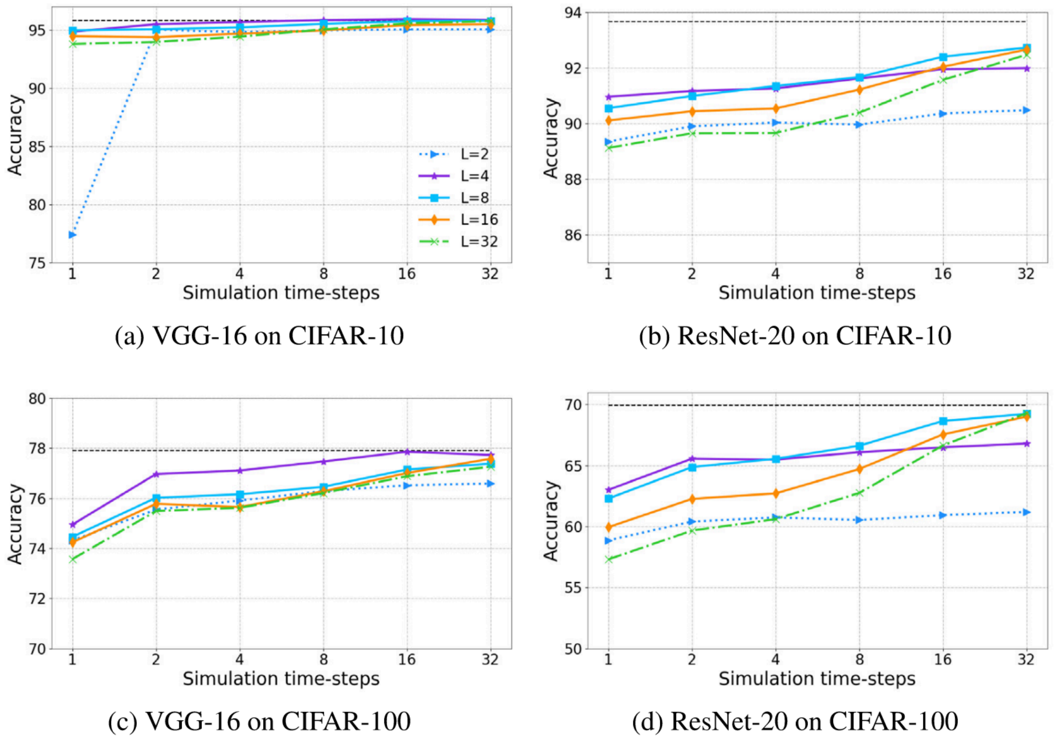
Neural Networks'25-CS-QCFS Bridging the performance gap in ultra-low latency spiking neural networks



(a) ReLU (b) QCFS with positive λ (c) IF with positive threshold

(d) QCFS with negative λ (e) IF with negative threshold

Fig. 2. The behavior of QCFS, ReLU, and IF.



(a) VGG-16 on CIFAR-10 (b) ResNet-20 on CIFAR-10

(c) VGG-16 on CIFAR-100 (d) ResNet-20 on CIFAR-100

Fig. 5. Influence of different quantization steps.

人机交互方向：社会科学与实验心理学范式

- 研究对象：人类用户行为与认知过程
- 核心问题：
  - 系统是否可用（usability）？
  - 用户是否理解模型决策？
  - 交互是否降低认知负担？
- 方法论：
  - 用户实验设计（A/B test）
  - 问卷与统计分析
  - 定性访谈与行为编码
- 实验范式：
  - 小样本受试者实验
  - 对照组与统计显著性检验（p-value, confidence interval）
  - IRB / 伦理审查
- 成果评价标准：
  - 是否具有统计显著性
  - 是否改善用户体验
  - 是否符合伦理与社会价值

CHI'19-Guidelines for Human-AI Interaction

该研究旨在解决人工智能系统（AI-infused systems）因其不确定性、不可预测性和演化性而给用户界面设计带来的独特挑战。

研究人员通过综合过去 20 年间学术界和工业界的 150 多项建议，总结并验证了 18 条通用设计准则。

例如：

- G2: Make clear how well the system can do what it can do. Help the user understand how often the AI system may make mistakes.
- G4: Show contextually relevant information. Display information relevant to the user's current task and environment.

		AI Design Guidelines	Example Applications of Guidelines
Initially	G1	**Make clear what the system can do.** Help the user understand what the AI system is capable of doing.	[Activity Trackers, Product #1] "Displays all the metrics that it tracks and explains how. Metrics include movement metrics such as steps, distance traveled, length of time exercised, and all-day calorie burn, for a day."
	G2	**Make clear how well the system can do what it can do.** Help the user understand how often the AI system may make mistakes.	[Music Recommenders, Product #1] "A little bit of hedging language: 'we think you'll like'."
During interaction	G3	**Time services based on context.** Time when to act or interrupt based on the user's current task and environment.	[Navigation, Product #1] "In my experience using the app, it seems to provide timely route guidance. Because the map updates regularly with your actual location, the guidance is timely."
	G4	**Show contextually relevant information.** Display information relevant to the user's current task and environment.	[Web Search, Product #2] "Searching a movie title returns show times in near my location for today's date"
	G5	**Match relevant social norms.** Ensure the experience is delivered in a way that users would expect, given their social and cultural context.	[Voice Assistants, Product #1] "[The assistant] uses a semi-formal voice to talk to you - spells out "okay" and asks further questions."
	G6	**Mitigate social biases.** Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.	[Autocomplete, Product #2] "The autocomplete feature clearly suggests both genders [him, her] without any bias while suggesting the text to complete."
When wrong	G7	**Support efficient invocation.** Make it easy to invoke or request the AI system's services when needed.	[Voice Assistants, Product #1] "I can say [wake command] to initiate."
	G8	**Support efficient dismissal.** Make it easy to dismiss or ignore undesired AI system services.	[E-commerce, Product #2] "Feature is unobtrusive, below the fold, and easy to scroll past...Easy to ignore."
	G9	**Support efficient correction.** Make it easy to edit, refine, or recover when the AI system is wrong.	[Voice Assistants, Product #2] "Once my request for a reminder was processed I saw the ability to edit my reminder in the UI that was displayed. Small text underneath stated 'Tap to Edit' with a chevron indicating something would happen if I selected this text."
	G10	**Scope services when in doubt.** Engage in disambiguation or gracefully degrade the AI system's services when uncertain about a user's goals.	[Autocomplete, Product #1] "It usually provides 3-4 suggestions instead of directly auto completing it for you"
	G11	**Make clear why the system did what it did.** Enable the user to access an explanation of why the AI system behaved as it did.	[Navigation, Product #2] "The route chosen by the app was made based on the Fastest Route, which is shown in the subtext."

研究范式直接决定了研究者需要的核心素质

机器学习（工程驱动）

- 关键：巧妙的想法 + 系统的工程优化
- 例：Transformer 的核心想法（多头自注意力）很简洁，但论文成功在于细致的超参数设计与大规模实验验证
- 研究者可部分被自动化搜索（AutoML）和 scaling law 替代

知识表示与推理（理论深度）

- 关键：严密的数学思维与对问题的深入理解
- 例：Calvanese 等人关于 OWL 本体查询复杂度的工作，核心来自对描述逻辑理论的深刻洞察
- 研究者需要提出启发式的转换规则并证明其正确性，目前不存在形式逻辑上可靠的 AI

> 研究 PL（程序设计语言）需要你既懂数学，又懂计算机；而研究 AI 你可以既不懂数学，也不懂计算机。

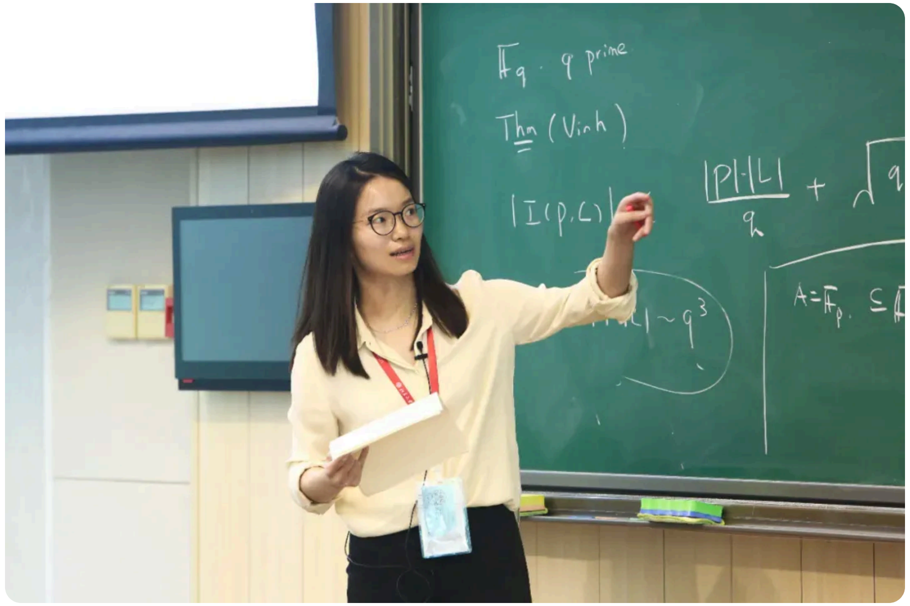
研究范式直接决定了研究者在项目中的地位

- 有些课题需要昂贵的研究设备和操作设备的傻瓜

冷冻电镜（Cryo-EM）单台设备价格数百万美元。论文创新点一般是：**我们首次解析了蛋白 X 的三维结构（分辨率 3.2 Å），与已知 Y 蛋白结构高度相似。**

- 有些课题需要一沓草稿纸和一个聪明的脑瓜

纽约大学王虹（Hong Wang）与其合作者 Larry Guth 通过引入多项式分层法（Polynomial Partitioning），证明了**三维挂谷集合的 Minkowski 维数必须等于 3**。



根据个人兴趣选择研究范式

研究范式与研究成果的可信度高度相关

在工程驱动的 AI 领域的研究中：

- 大多数高引用论文实验无法复现或复现结论不符[1]；
- 大量论文中存在数据泄露等学术舞弊[2]；
- AI 幻觉在投稿论文中屡见不鲜，同行评审并未检出[3]；

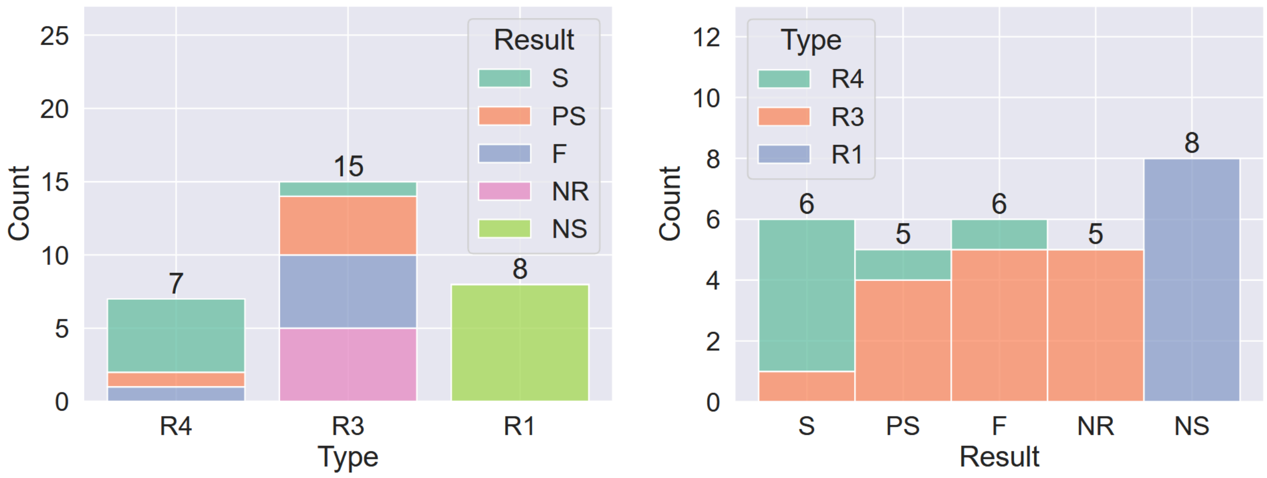
1. Gundersen, O. E., Cappelen, O., Mølna, M., & Nilsen, N. G. (2025). The Unreasonable Effectiveness of Open Science in AI: A Replication Study. Proceedings of the AAAI Conference on Artificial Intelligence, 39(25), 26211–26219. https://doi.org/10.1609/aaai.v39i25.34818 ⮥
2. Kapoor, S., & Narayanan, A. (2023). Leakage and the Reproducibility Crisis in Machine-Learning-Based Science. Patterns, 4(9), 100804. https://doi.org/10.1016/j.patter.2023.100804 ⮥
3. GPTZero Team. (2026, January). GPTZero Finds 100 New Hallucinations in NeurIPS 2025 Accepted Papers. AI Detection Resources | GPTZero. https://gptzero.me/news/neurips/ ⮥

AAAI'25-The Unreasonable Effectiveness of Open Science in AI

本文统性地尝试复现 30 篇高引用 AI 论文，其中：

- 有 8 篇依赖于特定数据和硬件，因此读者无法不可能复现；
- 成功复现结论（S）：6 篇；
- 部分成功复现结论（PS）：5 篇；
- 复现实验失败（F）：6 篇；
- 复现完成，结论不符（NR）：5 篇；

换言之，绝大多数的 AI 论文其结论无法被证明。



(a) Results per reproducibility type. (b) Reproducibility types per result.

Figure 2: Overview of the results.

Patterns'23-Leakage and the reproducibility crisis in machine-learning-based science

数据泄露是指用于测试模型性能的关键数据以某种方式泄漏给模型，是严重的学术舞弊。

例如：南信大《数字电子技术》任课老师把期末考试卷和往年卷一起发给同学们训练，导致同学们在上考场之前就见过考试题。

本文对 17 个科学领域（包括医学、社会科学等）的 22 篇综述论文进行分析，发现数据泄漏至少影响了 294 篇论文。在**所有案例**中，数据泄漏都导致了虚假的乐观结论。

修复泄漏后，复杂机器学习模型的表现并不实质性优于几十年前的传统逻辑回归模型 。

Field	Paper	Number of papers reviewed	Number of papers with pitfalls	**[L1.1] No test set**	**[L1.2] Pre-proc. on train-test**	**[L1.3] Feature sel. on train-test**	**[L1.4] Duplicates**	**[L2] Illegitimate features**	**[L3.1] Temporal leakage**	**[L3.2] Non-ind. b/w train-test**	**[L3.3] Sampling bias**	Comput. reproducibility issues	Data quality issues	Metric choice issues	Standard dataset used?
Medicine	Bouwmeester et al. (2012)	71	27	○									○		
Neuroimaging	Whelan & Garavan (2014)	–	14	○		○									
Bioinformatics	Blagus & Lusa (2015)	–	6		○										
Autism Diagnostics	Bone et al. (2015)	–	3				○				○		○	○	○
Nutrition Research	Ivanescu et al. (2016)	–	4	○									○	○	
Software Eng.	Tu et al. (2018)	58	11						○			○	○		○
Toxicology	Alves et al. (2019)	–	1				○					○	○		
Clinical Epidem.	Christodoulou et al. (2019)	71	48			○							○		
Satellite Imaging	Nalepa et al. (2019)	17	17							○			○		○
Tractography	Poulin et al. (2019)	4	2	○								○	○	○	○
Brain-computer Int.	Nakanishi et al. (2020)	–	1	○											○
Histopathology	Oner et al. (2020)	–	1							○					
Neuropsychiatry	Poldrack et al. (2020)	100	53	○	○								○	○	
Neuroimaging	Ahmed et al. (2021)	–	1							○					
Neuroimaging	Li et al. (2021)	122	18							○					
IT Operations	Lyu et al. (2021)	9	3						○						○
Medicine	Filho et al. (2021)	–	1					○							
Radiology	Roberts et al. (2021)	62	16	○			○				○	○			○
Neuropsychiatry	Shim et al. (2021)	–	1			○						○			
Medicine	Vandewiele et al. (2021)	24	21			○				○	○	○	○		○
Computer Security	Arp et al. (2022)	30	22	○	○	○		○	○	○	○		○	○	
Genomics	Barnett et al. (2022)	41	23			○							○		

Figure 1. Survey of 22 papers that identify pitfalls in the adoption of ML methods across 17 fields, collectively affecting 294 papers

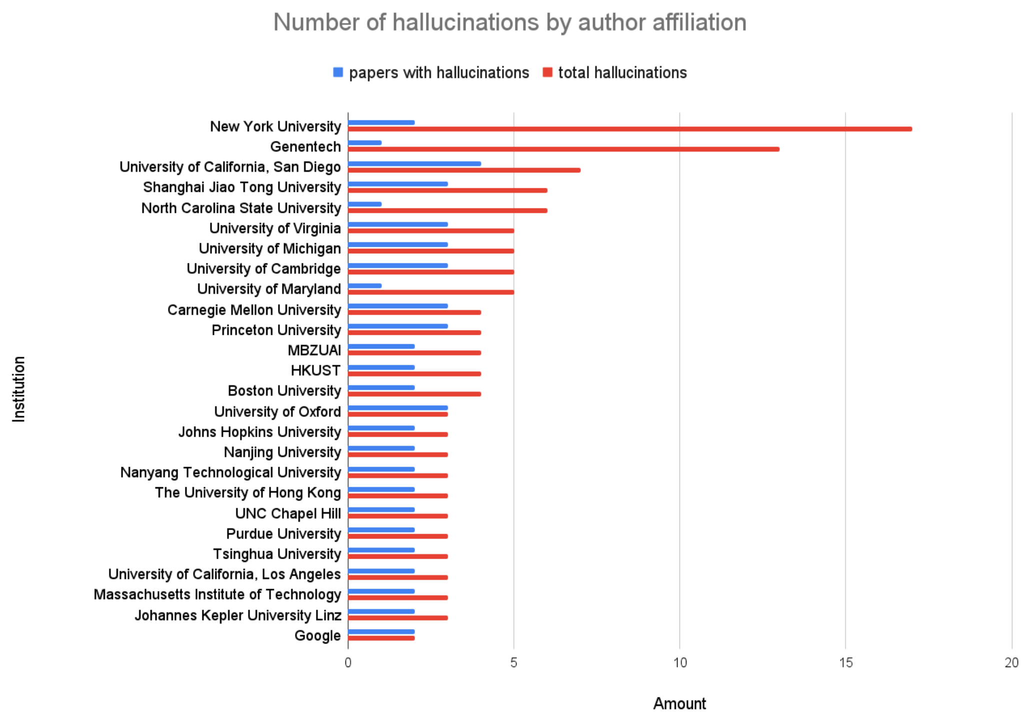
In each field, papers adopting ML methods suffer from data leakage. The column headings for types of data leakage, shown in bold, are based on our taxonomy of data leakage. We also highlight other issues that are reported in the papers: (1) computational reproducibility (the lack of availability of code, data, and computing environment to reproduce the exact results reported in the paper); (2) data quality (e.g., small size or large amounts of missing data); (3) metric choice (using incorrect metrics for the task at hand, e.g., using accuracy for measuring model performance in the presence of heavy class imbalance); and (4) standard dataset use, where issues are found despite the use of standard datasets in a field.[16–37]

GPTZero finds 100 new hallucinations in NeurIPS 2025 accepted papers

GPTZero 对 AI 顶会 NIPS'25 发表的 4841 论文进行扫描，发现其中 51 篇论文共包含至少 100 处虚假的幻觉引用，包括但不限于：

- 初级错误（占位符）：参考文献中直接出现占位符姓名，或引用链接指向 example.com 和 404 页面；
- 中级错误（信息混淆）：引用的论文作者、年份、期卷号或 DOI 被 AI 随机篡改；
- 高级伪造（凭空捏造）：这些文献在现实世界中完全不存在。

GPTZero 同样对另一个 AI 顶会 ICLR 发起了调查，结论类似：GPTZero finds over 50 new hallucinations in ICLR 2026 submissions。



研究范式直接决定研究方向的热门程度和泡沫程度

- AI 8 大顶会一年接受论文 15000+篇；
- TCS 5 大顶会一年接受论文仅几百篇；

东南沿海某985：

> 1篇网络安全A会=12篇人工智能A会

软件学院某副教授：

> 1 PLDI = 2 ICSE = 20 CVPR

会议	类型	CCF	会议日期	全文截止	倒计时	地点	录用率	微信群	收藏
AAAI 2026	人工智能	A	January 20 - 27, 2026	2025-08-02 19:59:59	已截稿	Singapore EXPO	23.7%(2342/9862 24')	点击进群	★
ACL 2026	人工智能	A	July 2 - 7, 2026	2026-01-06 19:59:59	已截稿	United States	21.4%(943/4407 24')	点击进群	★
CVPR 2026	人工智能	A	June 3-7, 2026	2025-11-14 19:59:00	已截稿	United States	22.1%(2878/13008 25')	点击进群	★
ICCV 2025	人工智能	A	October 19-25, 2025	2025-03-08 17:59:59	已截稿	Hawaii	26.2%(2160/8260 23')	点击进群	★
ICML 2026	人工智能	A	July 6-12, 2026	2026-01-29 19:59:59	已截稿	Korea	27.5%(2609/9473 24')	点击进群	★
IJCAI 2026	人工智能	A	August 15-21, 2026	2026-01-20 19:59:59	已截稿	Germany	14.0%(791/5651 24')	点击进群	★
NeurIPS 2025	人工智能	A	December 2-7, 2025	2025-05-16 19:59:59	已截稿	USA	25.8%(4037/15671 24')	点击进群	★

数据来源：https://github.com/ccfddl/ccf-deadlines，人工整理，仅供参考

会议	类型	CCF	会议日期	全文截止	倒计时	地点	录用率	微信群	收藏
CAV 2026	计算机科学理论	A	July 26-29, 2026	2026-01-29 19:59:59	已截稿	Portugal	19.1%(40/209 22')	点击进群	★
STOC 2026	计算机科学理论	A	June 22-26, 2026	2025-11-05 05:59:59	已截稿	USA	32.3%(155/480 23')	点击进群	★
LICS 2026	计算机科学理论	A	July 20-23, 2026	2026-01-23 19:59:59	已截稿	Portugal	34.8%(63/181 22')	点击进群	★
FOCS 2025	计算机科学理论	A	December 14-17, 2025	2025-04-04 09:00:00	已截稿	Australia		点击进群	★
SODA 2026	计算机科学理论	A	January 11-14, 2026	2025-07-15 19:59:59	已截稿	Canada		点击进群	★

数据来源：https://github.com/ccfddl/ccf-deadlines，人工整理，仅供参考

研究范式直接决定研究方向的热门程度和泡沫程度

- “论文辅导、保证中稿”的代写服务大行其道，所有论文工厂集中在 AI 领域；
- 从未见过计算机科学、操作系统、程序设计语言领域的代写服务。

科研工作者如何面对 AI 时代

Science'24-GPTs are GPTs: Labor market impact potential of LLMs

该研究建立了一个新的评估标准，结合人类专家和GPT-4的分类，评估了GPT能力美国劳动力对各职业任务的影响，用暴露值（Exposure）表示这一影响。主要结论包括：

- 约80%的劳动力暴露值超过10%；
- 约19%的劳动者暴露值超过50%；
- 高薪职位和需要高级技能、受教育程度较高的职业（如程序员、律师）暴露值更高；
- GPT展现出了通用技术（General-Purpose Technologies, GPTs）的特征，意味着其影响将是深远且跨行业的。

Group	Occupations with highest exposure	% Exposure
Human α	Interpreters and Translators	76.5
	Survey Researchers	75.0
	Poets, Lyricists and Creative Writers	68.8
	Animal Scientists	66.7
	Public Relations Specialists	66.7
Human β	Survey Researchers	84.4
	Writers and Authors	82.5
	Interpreters and Translators	82.4
	Public Relations Specialists	80.6
	Animal Scientists	77.8
Human ζ	Mathematicians	100.0
	Tax Preparers	100.0
	Financial Quantitative Analysts	100.0
	Writers and Authors	100.0
	Web and Digital Interface Designers	100.0
	Humans labeled 15 occupations as "fully exposed."	
Model α	Mathematicians	100.0
	Correspondence Clerks	95.2
	Blockchain Engineers	94.1
	Court Reporters and Simultaneous Captioners	92.9
	Proofreaders and Copy Markers	90.9
Model β	Mathematicians	100.0
	Blockchain Engineers	97.1
	Court Reporters and Simultaneous Captioners	96.4
	Proofreaders and Copy Markers	95.5
	Correspondence Clerks	95.2
Model ζ	Accountants and Auditors	100.0
	News Analysts, Reporters, and Journalists	100.0
	Legal Secretaries and Administrative Assistants	100.0
	Clinical Data Managers	100.0
	Climate Change Policy Analysts	100.0
	The model labeled 86 occupations as "fully exposed."	
Highest variance	Search Marketing Strategists	14.5
	Graphic Designers	13.4
	Investment Fund Managers	13.0
	Financial Managers	13.0
	Insurance Appraisers, Auto Damage	12.6

Science'24-GPTs are GPTs Labor market impact potential of LLMs

34 个与物理世界交互的职业暴露值为 0，包括：

- 运动员和体育竞技者；
- 汽车玻璃安装工和修理工；
- 公共汽车和卡车机械师及柴油发动机专家；
- 水泥工和混凝土抹光工；
- 厨师；
- 电力线路安装工和维修工；
- 挖掘和装载机及拉铲操作员、露天采矿；
- 铸造模具和制芯工；
- 砖瓦工、砌块工、石匠、瓷砖和大理石铺设工的助手；
- 肉类、家禽和鱼类切割工和修整工；
- 金属轨道铺设和维护设备操作员；

Occupations with no labeled exposed tasks
Agricultural Equipment Operators
Athletes and Sports Competitors
Automotive Glass Installers and Repairers
Bus and Truck Mechanics and Diesel Engine Specialists
Cement Masons and Concrete Finishers
Cooks, Short Order
Cutters and Trimmers, Hand
Derrick Operators, Oil and Gas
Dining Room and Cafeteria Attendants and Bartender Helpers
Dishwashers
Dredge Operators
Electrical Power-Line Installers and Repairers
Excavating and Loading Machine and Dragline Operators, Surface Mining
Floor Layers, Except Carpet, Wood, and Hard Tiles
Foundry Mold and Coremakers
Helpers–Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters
Helpers–Carpenters
Helpers–Painters, Paperhangers, Plasterers, and Stucco Masons
Helpers–Pipelayers, Plumbers, Pipefitters, and Steamfitters
Helpers–Roofers
Meat, Poultry, and Fish Cutters and Trimmers
Motorcycle Mechanics
Paving, Surfacing, and Tamping Equipment Operators
Pile Driver Operators
Pourers and Casters, Metal
Rail-Track Laying and Maintenance Equipment Operators
Refractory Materials Repairers, Except Brickmasons
Roof Bolters, Mining
Roustabouts, Oil and Gas
Slaughterers and Meat Packers
Stonemasons
Tapers
Tire Repairers and Changers
Wellhead Pumpers

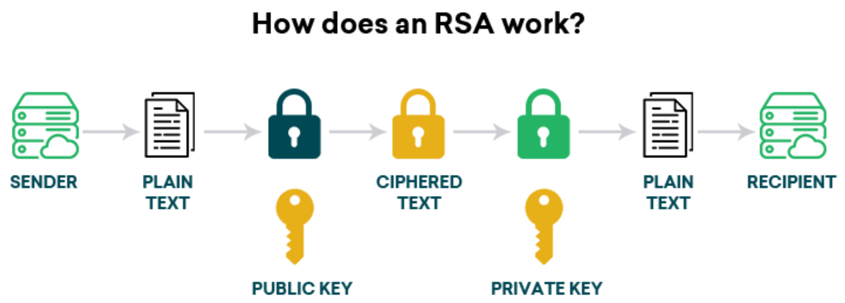
Table 11: All 34 occupations for which none of our measures labeled any tasks as exposed.

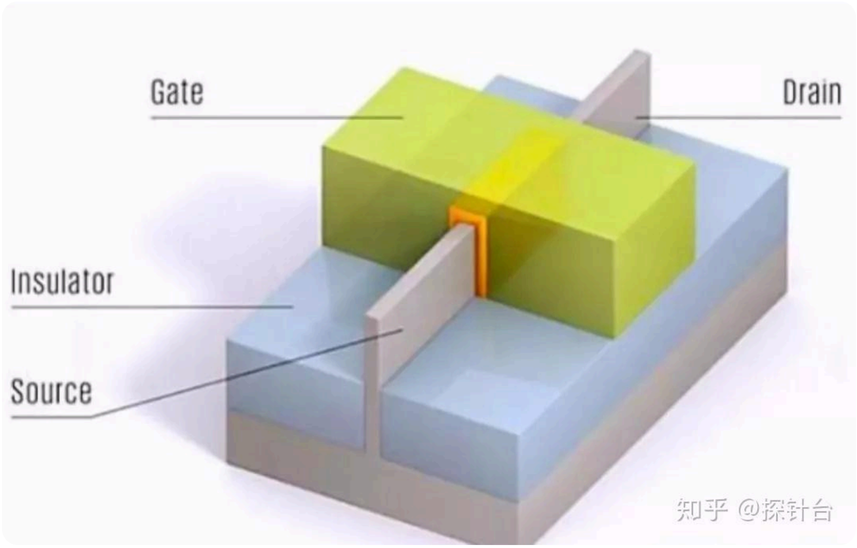
AI 职业替代风险评估矩阵

业界需求决定研究意义？

1. 基础理论的研究并不直接对应业界需求，但对学科发展意义重大；
    - 在 18、19 世纪，数论被公认为数学中最纯粹、最“没用”的分支。但大整数理论构成了 1970s 诞生的 RSA 加密算法的理论基础，该算法是全球的互联网安全、银行交易和军事通信的核心原理。
2. 业界需求可随研究成果而改变；
    - 晶体管出现前，业界对“便携式计算”或“智能手机”毫无需求。但当半导体研究成果落地后，业界的需求从“修真空管”彻底转向了“集成电路设计”、“软件开发”和“移动互联网”。

> 在汽车出现前，人们想要的是一匹更快的马。
>
> ——亨利·福特





研究的意义感

研究意义 ≠ 研究的意义感

> 在共产主义社会高级阶段，劳动已经**不仅仅是**谋生的手段，而是本身成了生活的第一需要。
>
> ——马克思《哥达纲领批判》

在 2026 年，绝大多数的脑力劳动已经**无法成为**谋生的手段，因此不作为生活需要的劳动失去了存在的意义。

在接下来的几年，水论文将无法成为谋生、就业、升学的手段，因此**没有研究难度、没有研究价值的水论文将失去存在的意义**。

什么是“难而正确的事”？

- 难
  - 需要克服困难去做；
  - 你能做，别人不能，AI 也不能；
- 正确
  - 有意义感，有正反馈，能够自得其乐；
  - 不因简单而喜欢，不因短平快而浮躁；

桐花万里丹山路，雏凤清于老凤声