

[Christmas Seminar] The AI Knight Rises from Deep Learning to Flourishing Societies



Sunghee Yun

Beth's Daddy & Liam, Lucy, Adrian & Lillian's Uncle

About Speaker

- *Co-founder / CTO - AI Technology & Product Strategy @ Erudio Bio, CA, USA*
- Advisory Professor, Electrical Engineering and Computer Science @ DGIST
- Adjunct Professor, Electronic Engineering Department @ Sogang University
- Technology Consultant @ Gerson Lehrman Group (GLG)
- *KFAS-Salzburg Global Leadership Initiative Fellow @ Salzburg Global Seminar*
- *Co-founder / CTO & Chief Applied Scientist @ Gauss Labs, CA, USA* – 2023
- Senior Applied Scientist @ Mobile Shopping App Org, Amazon.com, Inc. – 2020
- Principal Engineer @ Software R&D Center of DS Division, Samsung – 2017
- Principal Engineer @ Strategic Marketing & Sales Team, Samsung – 2016
- Principal Engineer @ DT Team of DRAM Development Lab, Samsung – 2015
- Senior Engineer @ CAE Team - Samsung – 2012
- M.S. & Ph.D. - Electrical Engineering @ Stanford University – 2004
- B.S. - Electrical Engineering @ Seoul National University – 1998

Highlight of Career Journey

- B.S. in EE @ SNU, M.S. & Ph.D. in EE @ Stanford Univ.
 - *Convex Optimization - theory & algorithms* - advised by *Prof. Stephen P. Boyd*
- Principal Engineer @ Memory Design Technology Team
 - AI & optimization - collaborating with *DRAM/NAND Design/Process/Test teams*
- Senior Applied Scientist @ Amazon
 - e-commerce AIs - deep reinforcement learning & recommender system
 - Jeff Bezos's project - *increase sales by \$200M* via Mobile Shopping App
- Co-founder / CTO & Chief Applied Scientist @ Gauss Labs
 - *industrial AI - R&D, market & product strategies*
- Co-founder / CTO - AI Technology & Product Strategy @ Erudio Bio
 - *biotech - AI technology, business development & product strategy*

Today

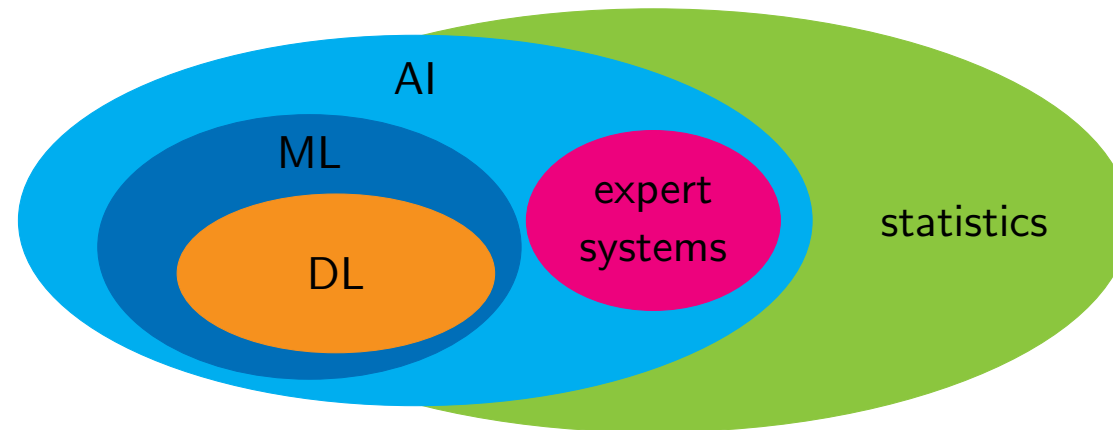
- Artificial Intelligence
- Multimodal AI
- AI Products & AI Industry
- Empowering Humanity for Future Enriched by AI
- Appendices
 - Serendipities around AIs
 - Some Important Questions
- Selected references
- References

Artificial Intelligence

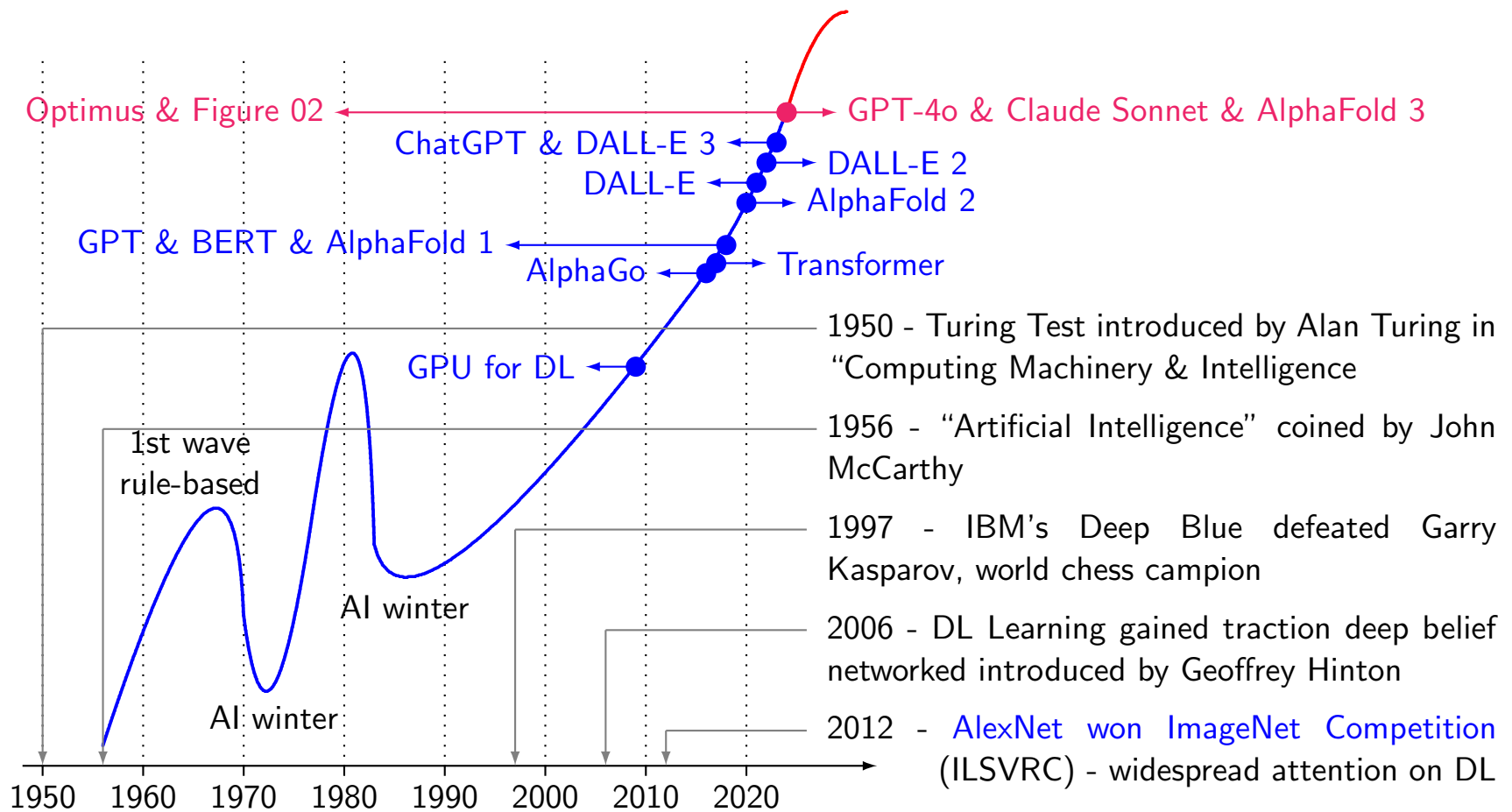
Definition and History

Definition of AI

- AI is
 - technology enabling machines to do tasks requiring human intelligence, such as learning, problem-solving, decision-making & language understanding
 - *not* one thing - encompass range of technologies, methodologies & applications
- relationship of AI, statistics, ML, DL, NN & expert system [HGH⁺22]



History of AI



Significant AI Achievements - 2014 – 2024

Deep learning revolution

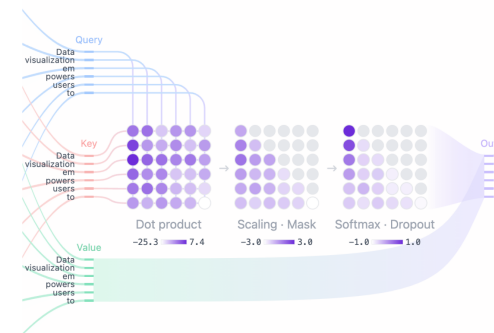
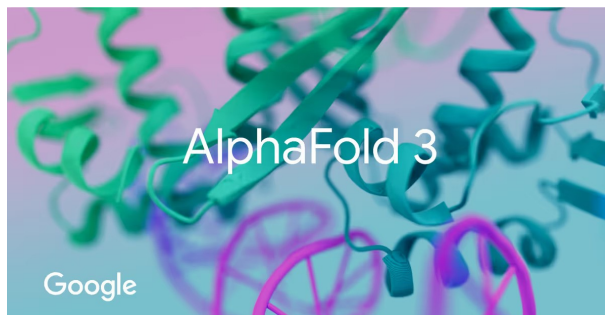
- 2012 – 2015 - DL revolution¹
 - CNNs demonstrated exceptional performance in image recognition, *e.g.*, [AlexNet's victory in ImageNet competition](#)
 - widespread adoption of DL learning in CV transforming industries
- 2016 - AlphaGo defeats human Go champion
 - DeepMind's AlphaGo defeated world champion in Go, extremely complex game [believed to be beyond AI's reach](#)
 - significant milestone in RL - AI's potential in solving complex & strategic problems



¹DL: deep learning, CNN: convolutional neural network, CV: computer vision, RL: reinforcement learning

Transformer changes everything

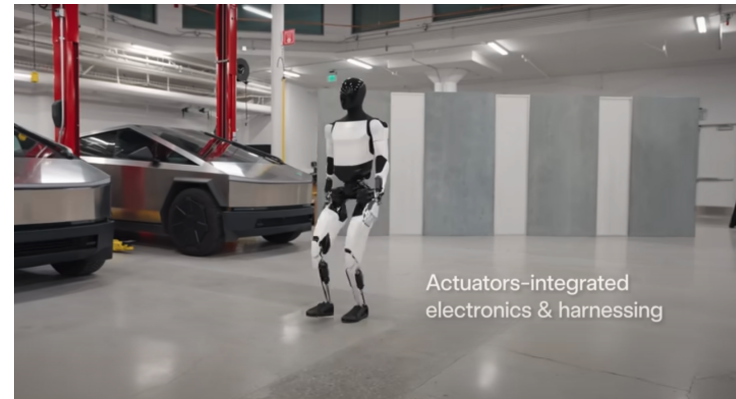
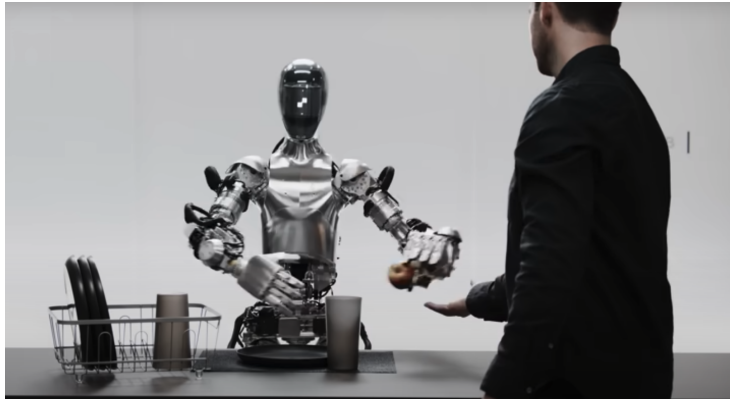
- 2017 – 2018 - Transformers & NLP breakthroughs²
 - *Transformer (e.g., BERT & GPT) revolutionized NLP*
 - major advancements in, e.g., machine translation & chatbots
- 2020 - AI in healthcare – AlphaFold & beyond
 - DeepMind's *AlphaFold solves 50-year-old protein folding problem* predicting 3D protein structures with remarkable accuracy
 - accelerates drug discovery and personalized medicine - offering new insights into diseases and potential treatments



²NLP: natural language processing, GPT: generative pre-trained transformer

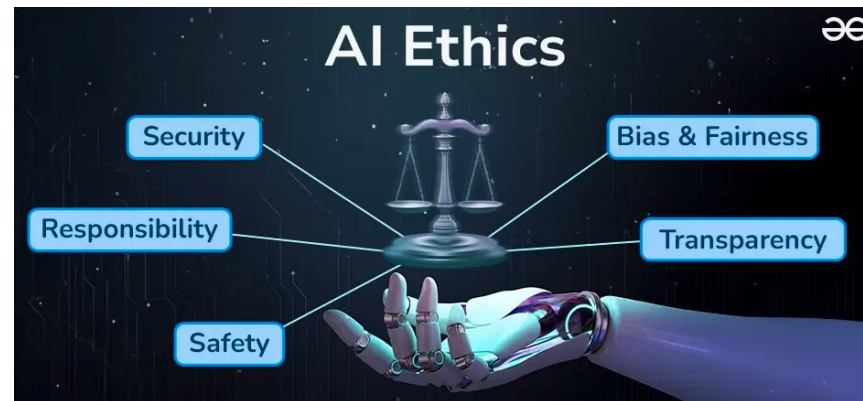
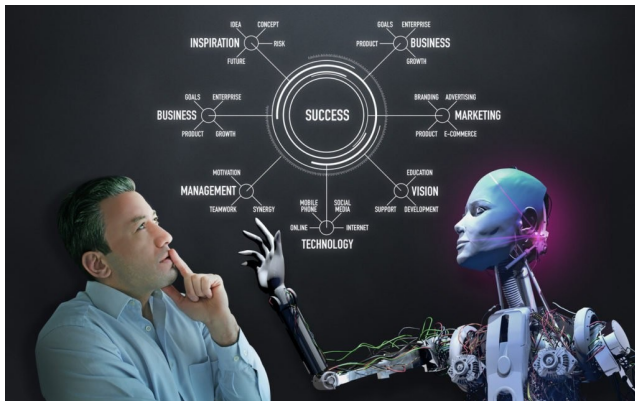
Lots of breakthroughs within 6 months in 2024

- proliferation of advanced AI models
 - GPT-4o, Claude Sonnet, Llama 3, Sora
 - *transforming industries* such as content creation, customer service, education, *etc.*
- breakthroughs in specialized AI applications
 - Figure 02, Optimus, AlphaFold 3
 - driving unprecedented advancements in automation, drug discovery, scientific understanding - *profoundly affecting healthcare, manufacturing, scientific research*



Transformative impact of AI - reshaping industries, work & society

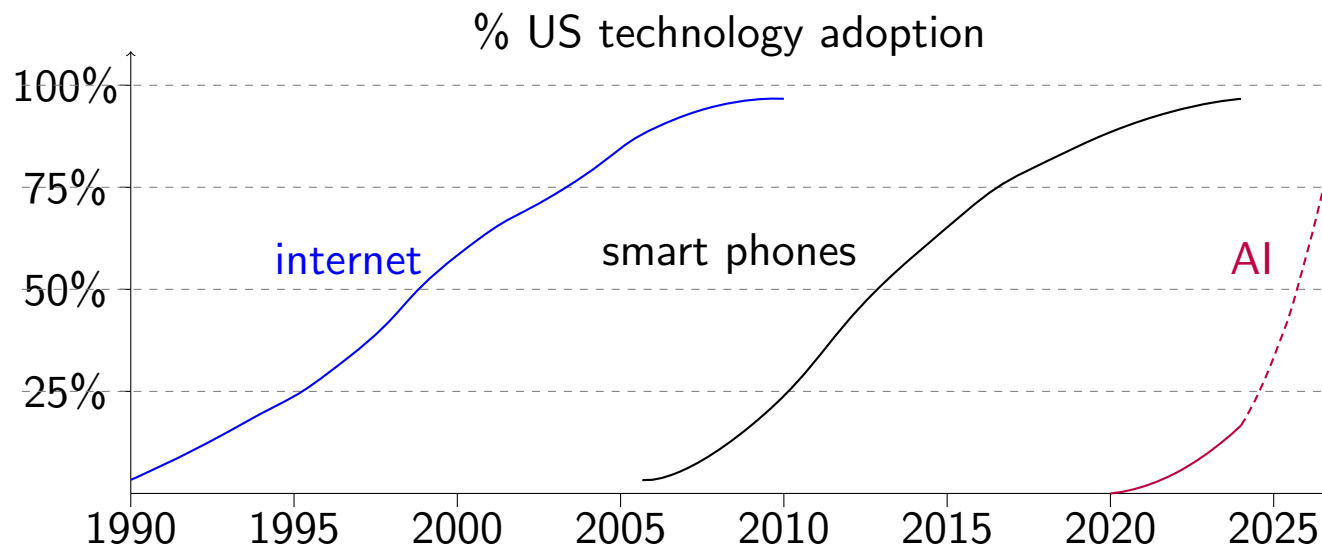
- accelerating human-AI collaboration
 - not only reshaping industries but *altering how humans interact with technology*
 - AI's role as collaborator and augmentor redefines productivity, creativity, the way we address global challenges, *e.g., sustainability & healthcare*
- AI-driven automation *transforms workforce dynamics* - creating new opportunities while challenging traditional job roles
- *ethical AI considerations* becoming central not only to business strategy, but to society as a whole - *influencing regulations, corporate responsibility & public trust*



Recent Advances in AI

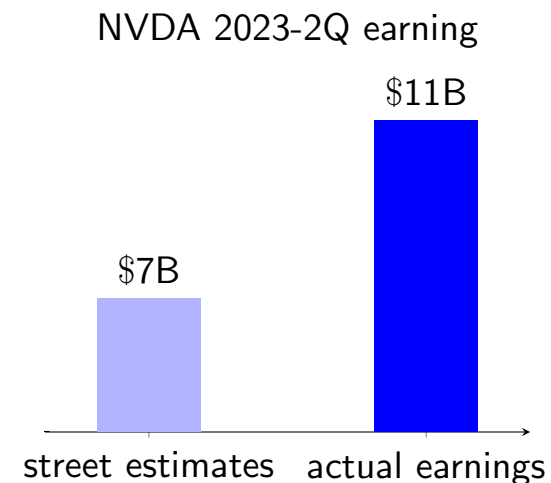
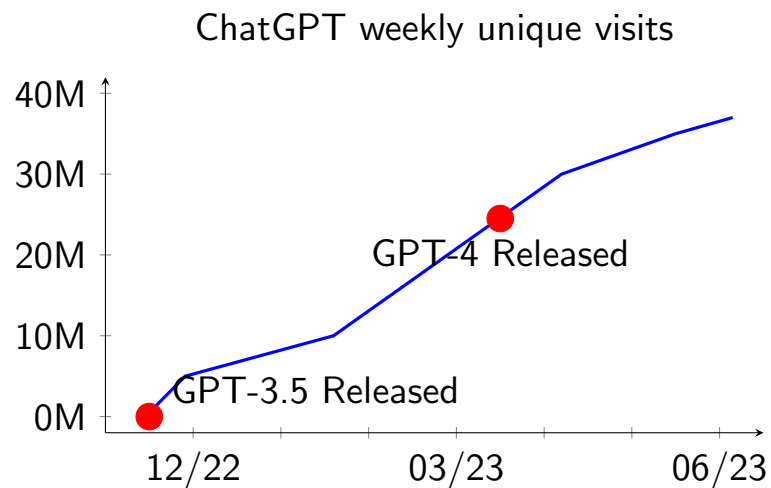
Where are we in AI today?

- sunrise phase - currently experiencing dawn of AI era with significant advancements and increasing adoption across various industries
- early adoption - in early stages of AI lifecycle with widespread adoption and innovation across sectors marking significant shift in technology's role in society



Explosion of AI ecosystems - ChatGPT & NVIDIA

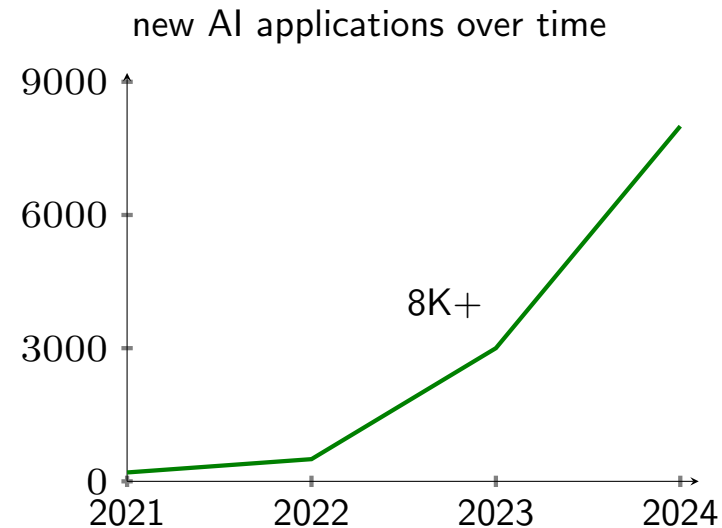
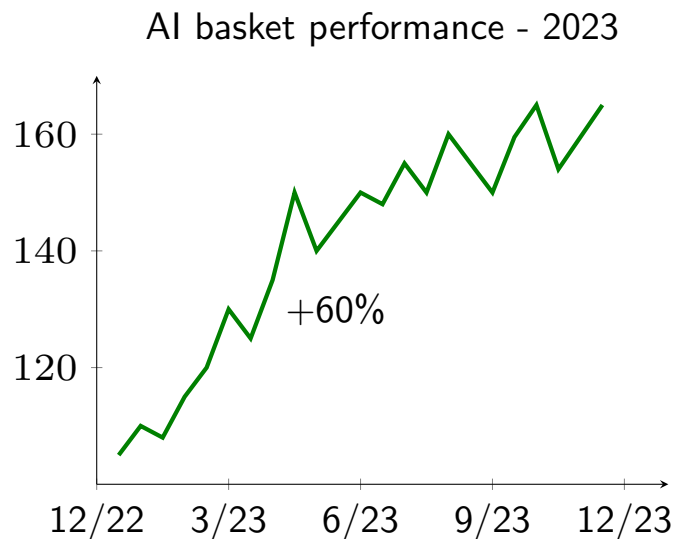
- took only *5 months for ChatGPT users to reach 35M*
- NVIDIA 2023 Q2 earning exceeds market expectation by big margin - \$7B vs \$13.5B
 - surprisingly, *101% year-to-year growth*
 - even more surprisingly *gross margin was 71.2%* - up from 43.5% in previous year³



³source - Bloomberg

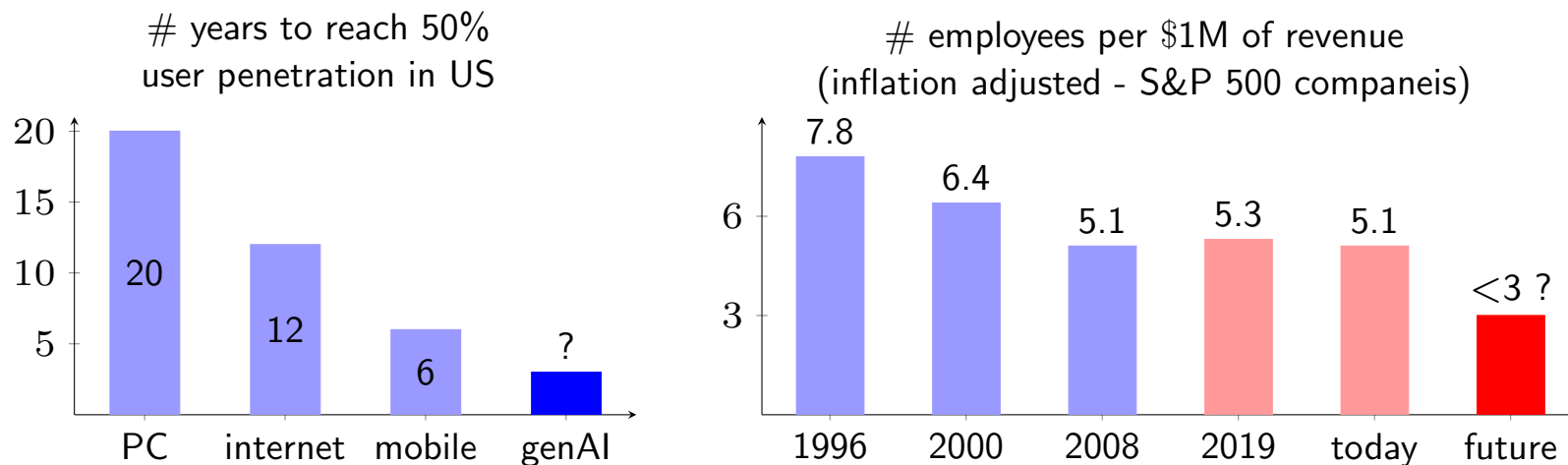
Explosion of AI ecosystems - AI stock market

- *AI investment surge in 2023 - portfolio performance soars by 60%*
 - AI-focused stocks significantly outpaced traditional market indices
- *over 8,000 new AI applications* developed in last 3 years
 - applications span from healthcare and finance to manufacturing and entertainment



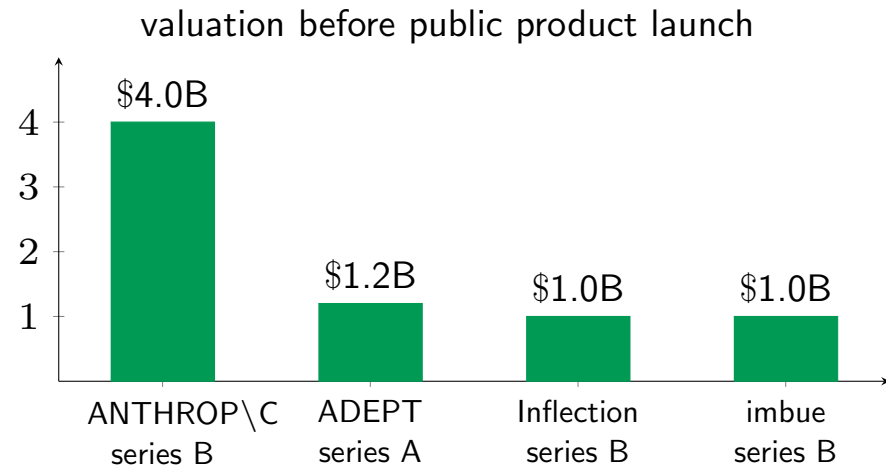
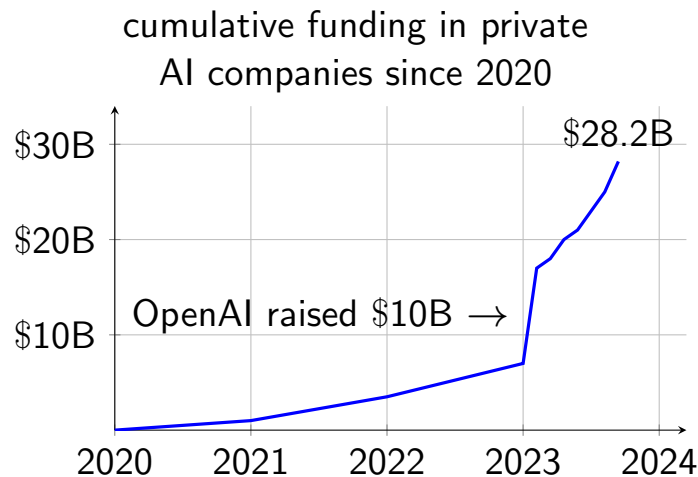
AI's transformative impact - adoption speed & economic potential

- adoption - has been twice as fast with platform shifts suggesting
 - increasing demand and readiness for new technology improved user experience & accessibility
- AI's potential to drive economy for years to come
 - 35% improvement in productivity driven by introduction of PCs and internet
 - greater gains expected with AI proliferation



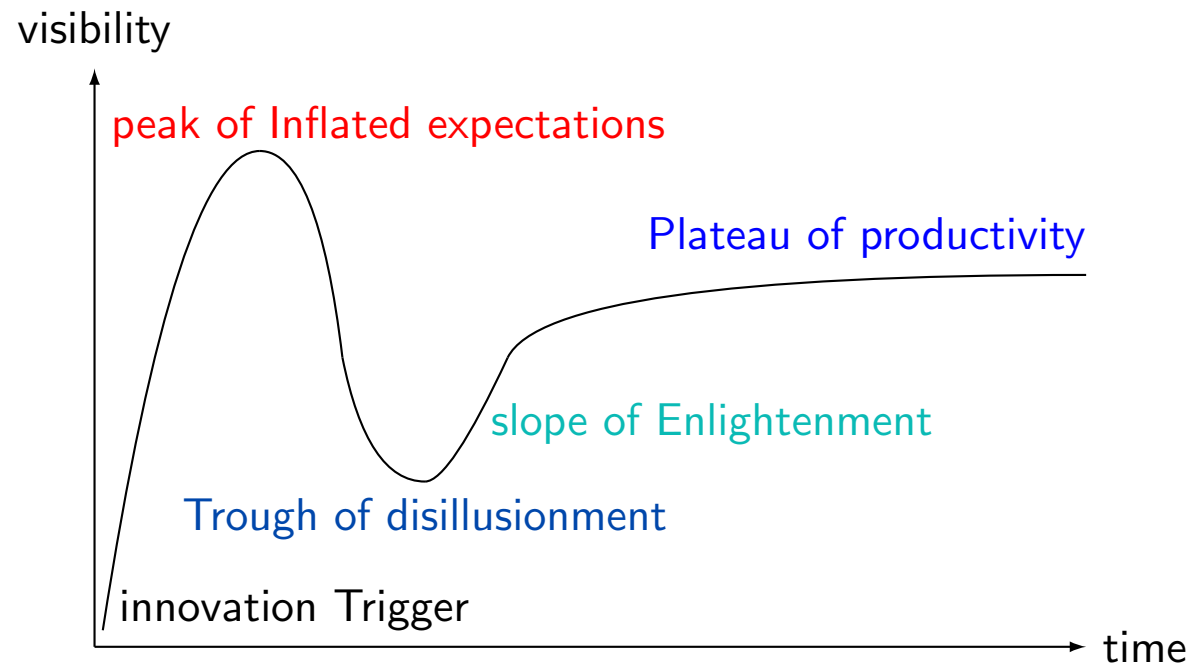
Massive investment in AI

- *explosive growth* - cumulative funding skyrocketed reaching staggering \$28.2B
- OpenAI - significant fundraising (= \$10B) fueled rapid growth
- *valuation surge* - substantial valuations even before public products for stellar companies
- *fierce competition for capital* among AI startups driving innovation & accelerating development
- massive investment indicates *strong belief in & optimistic outlook for potential of AI* to revolutionize industries & drive economic growth



Is AI hype?

Technology hype cycle



- innovation trigger - technology breakthrough kicks things off
- peak of inflated expectations - early publicity induces many successes followed by even more
- trough of disillusionment - expectations wane as technology producers shake out or fail
- slope of enlightenment - benefit enterprise, technology better understood, more enterprises fund pilots

Fiber vs cloud infrastructure

- fiber infrastructure - 1990s
 - Telco Co's raised \$1.6T of equity & \$600B of debt
 - bandwidth costs decreased 90% within 4 years
 - companies - Covage, NothStart, Telligent, Electric Lightwave, 360 networks, Nextlink, Broadwind, UUNET, NFS Communications, Global Crossing, Level 3 Communications
 - became *public good*
- cloud infrastructure - 2010s
 - entirely new computing paradigm
 - mostly public companies with data centers
 - *big 4 hyperscalers generate* \$150B + annual revenue



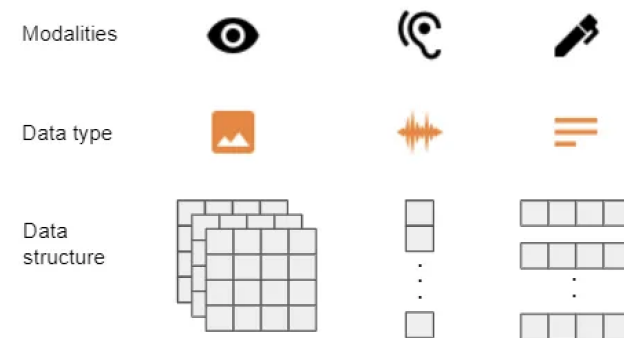
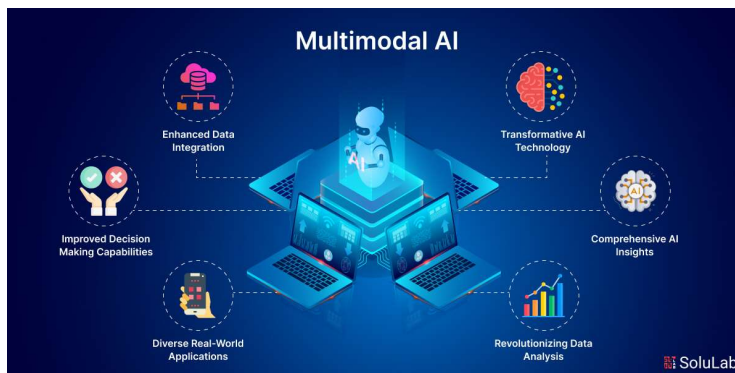
Yes & No

characteristics of hype cycles	speaker's views
value accrual misaligned with investment	<ul style="list-style-type: none">● OpenAI still operating at a loss; business model <i>still</i> not clear● gradual value creation across broad range of industries and technologies (<i>e.g.</i>, CV, LLMs, RL) unlike fiber optic bubble in 1990s
overestimating timeline & capabilities of technology	<ul style="list-style-type: none">● self-driving cars delayed for over 15 years, with limited hope for achieving level 5 autonomy● AI, however, has proven useful within a shorter 5-year span, with enterprises eagerly adopting
lack of widespread utility due to technology maturity	<ul style="list-style-type: none">● AI already providing significant utility across various domains● vs quantum computing remains promising in theory but lacks widespread practical utility

Multimodal AI

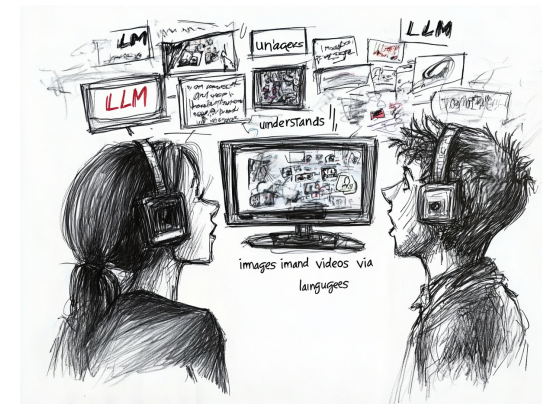
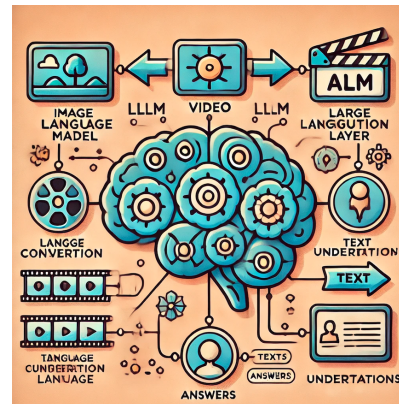
Multimodal learning

- understand information from multiple modalities, *e.g.*, text, images, audio & video
- representation learning methods
 - combine two representations, *e.g.*, language + image
 - learn multimodal representations simultaneously
- applications
 - images from text prompt, captions from images, videos with narration, musics with lyrics
- collaboration among different modalities
 - understand image world (open system) using language (closed system)



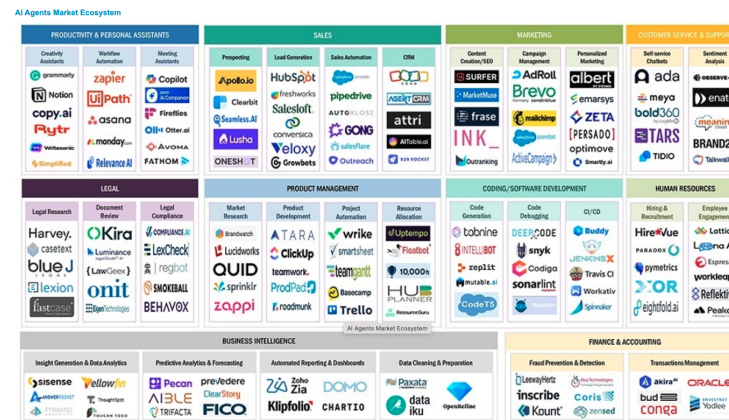
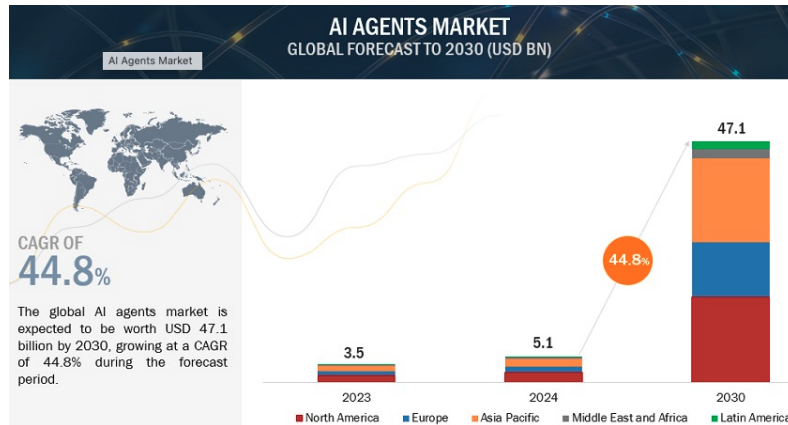
Implications of success of LLMs

- (very) many researchers change gears towards LLM
 - from computer vision (CV), speech, music, video, even reinforcement learning
- *LLM is not (only) about NLP . . .* humans have . . .
 - evolved and optimized (natural) language structures for eons
 - handed down knowledge using (this) natural languages for thousands of years
 - (internal structure or representation of) natural language optimized via evolution through *thousands of generation by evolution*
- LLM (can) *connect non-linguistic world (open system) via languages (closed system)*



Multimodal AI (mmAI) - definition & history

- definition - systems processing & integrating data from multiple sources & modalities, *e.g.*, text, images, audio, video, to generate unified response / decision
- 1990s – 2000s - early systems - initial research combining basic text & image data
- 2010s - CNNs & RNNs enabling more sophisticated handling of multimodality
- 2020s - modern multimodal models - Transformer-based architectures (*e.g.*, CLIP and GPT-4 Vision) handling complex multi-source data at highly advanced level
- mmAI *mimics human cognitive ability* to interpret and integrate information from various sources, leading to holistic decision-making



mmAI Technology

- core components
 - data preprocessing - images, text, audio & video
 - architectures - unified Transformer-based (*e.g.*, ViT) & cross-attention mechanisms / hybrid architectures (*e.g.*, CNNs + LLMs)
 - integration layers - fusion methods for combining data representations from different modalities
- technical challenges
 - data alignment - accurate alignment of multimodal data
 - computational demand - high-resource requirements for training and inferencing
 - diverse data quality - manage variations in data quality across modalities
- advancements
 - multimodal embeddings - shared feature spaces interaction between modalities
 - self-supervised learning - leverage unlabeled data to learn representations across modalities

mmAI - current and future industries

- industries
 - healthcare - enhanced diagnostic combining imaging, *e.g.*, MRI, with patient history
 - customer experience - virtual assistants understanding spoken language & visual cues
 - autonomous vehicles - integration of visual, radar & audio data
- future
 - ubiquitous mmAI - seamless integration into everyday devices
 - advances in edge computing - low-power & real-time mm processing for IoT apps
 - highly tailored personalized experience - in education, entertainment & healthcare



AI Products

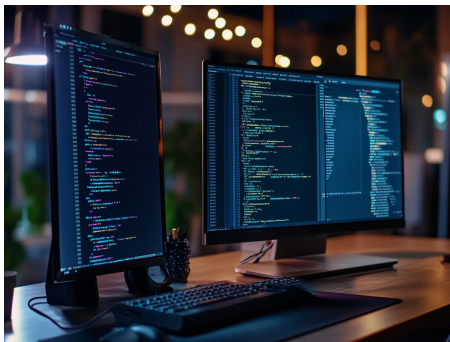
AI product development - trend and characteristics

- *rapid pace* of innovation - new AI models & products being released at unprecedented rate, improvements coming in weeks or months (rather than years)
- *LLMs dominating* - models like GPT-4 & Claude pushing boundaries in NLP & genAI
- *multimodal AI* gaining traction - models processing & generating text, images & even video becoming more common, *e.g.*, Grok, GPT-4, Gemini w/ vision capabilities
- *open-source* AI movement - growing trend of open-source AI models and tools, challenging dominance of proprietary systems
- *AI integration in everyday products* - from smartphones to home appliances, AI being integrated into wide array of consumer products



AI product development - trend and characteristics

- *ethical AI & regulatory focus* - increased attention on ethical implications of AI & calls for regulation of AI development and deployment
- AI in enterprise - businesses across industries rapidly adopting AI for various applications
- *specialized AI models* - development of AI models tailored for specific industries or tasks, *e.g.*, healthcare, biotech, financial analysis
- AI-assisted *coding and development* - help software developers write code more efficiently & tools becoming increasingly sophisticated
- *concerns about AI safety & existential risk* - growing debate about potential short & long-term risks of advanced AI



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ChatGPT 4o with o1-mini -
that there are no misplaced \hline
commands. Specifically, ensure that
\\ does not follow an \hline or a
multi-line call without careful
placement. Let me know if you need
more help with this

how can I align every text
centered

Edited
I've updated the table to center all the
text within each cell. Let me know if
there's anything else you'd like to
adjust

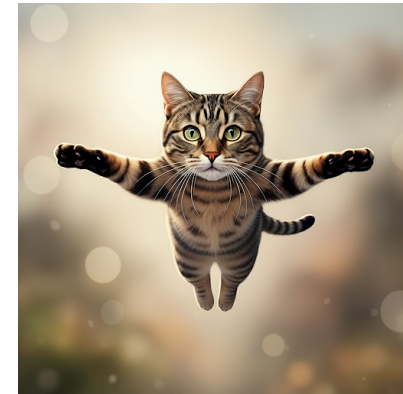
Message ChatGPT
ChatGPT can make mistakes. Check important
info.

Lin Comparison Table
1 \documentclass{article}
2 \usepackage{array}
3 \usepackage{geometry}
4 \geometry{paper, margin=1in}
5 \begin{document}
6
7 \begin{table}[t]
8 \centering
9 \vspace{1cm}
10 \begin{tbl_struct}
11 \tbl_struct_row{1}{\textbf{Model}} & \textbf{Organization} & \textbf{Training Data} & \textbf{Parameters} & \textbf{Strengths} &
12 \textbf{Weaknesses} \\
13 \hline
14 GPT-4 & OpenAI & Diverse web and books & ~1.7T (estimated) & Advanced reasoning, fine-tuned for various uses, and
15 multimodal capabilities. & Requires high computational resources, expensive to run. \\
16 \hline
17 LLaMA (LLaMA-2) & Meta (Facebook) & Public datasets \\
18 \hline
19 Claude & Anthropic & Mix of high-quality datasets & Not disclosed & Safety-first approach, built to avoid harmful
20 responses. & Limited in terms of publicly available details, moderate training. \\
21 \hline
22 PaLM 2 & Google & Multilingual text corpus & 540B & High language comprehension, good at multilingual tasks, supports
23 various downstream applications. & Requires significant resources, not as versatile as GPT-4 in some contexts. \\
24 \hline
25 BLOOM & BigScience Community & Diverse multilingual corpus (46 languages) & 176B & Open and accessible for diverse
26 users, supports multiple languages. & Resource-intensive, lower performance in comparison to top proprietary models like GPT-4. \\
27 \hline
28 Mistral & Mistral AI & Public web data & 7B to 13B & Lower parameter count with strong efficiency, aimed for open-
  
```


LLM products

- OpenAI - ChatGPT 4o, GPT-4 Turbo Canvas
- Anthropic - Claude 3.5 Sonnet (with Artifacts), Claude 3 Opus, Claude 3 Haiku
- Mistral AI - Mistral 7B, Mistral Large 2, Mistral Small xx.xx, Mistral Nemo (12B)
- Google - Gemini (w/ 1.5 Flash), Gemini Advanced (w/ 1.5 Pro)
- X - Grok [mini] [w/ Fun Mode]
- Perplexity AI - Perplexity [Pro] - combines GPT-4, Claude 3.5, and Llama 3
- Liquid AI - Liquid-40B, Liquid-3B (running on small devices)

flying cats generated by Grok, ChatGPT 4o & Gemini



Comparison of LLMs & LLM products

model	developer	training data	# params	strength	weakness
GPT-4	OpenAI	web & books	170B	advanced reasoning & multimodal capabilities	high computational resources
LLaMA-2	Meta	public info & research articles	7~70B	open access & good performance for different sizes	not powerful for complex tasks
Claude	Anthropic	mix of high-quality datasets	not disclosed	safety-first approach avoiding harmful responses	limited in publicly available details
PaLM 2	Google	multilingual text corpus	540B	high multilingual comprehension supporting various downstream apps	significant resources & not versatile in some contexts

Comparison of LLMs & LLM products

model	developer	training data	# params	strength	weakness
BLOOM	BigScience Community	diverse multilingual corpus	176B	open & support multiple languages	resource-intensive & lower performance
Mistral ⁴	Mistral AI	public web data	7~13B	lower parameter count	limited scalability for specialized apps
Liquid Foundation Model (LFM)	Liquid AI	adaptive datasets	adaptive & dynamic parameters	modular & support more specialized fine-tuning for niche use-cases & adaptable in deployment	complexity in design and implementation

Multimodal genAI products

- DALL-E by OpenAI
 - *generate unique and detailed images based on textual descriptions*
 - understanding context and relationships between words
- Midjourney by Midjourney
 - let people *create imaginative artistic images*
 - can interactively guide the generative process, providing high-level directions



Multimodal genAI products



- Dream Studio by Stability AI
 - *analyze patterns in music data & generates novel compositions*
 - musicians can explore new ideas and enhance their *creative* processes
- Runway by Runway AI
 - *realistic images, manipulate photos, create 3D models & automate filmmaking*

Rise of co-pilot products

- definition - AI-powered tools designed to enhance human productivity across multiple domains including document creation, presentations & coding
- benefits
 - *efficiency* - automate repetitive tasks allowing users to focus on high-value activities
 - *error reduction* - minimize mistakes common in manual work
 - *creativity* - suggestions and prompts help users explore new ideas and approaches
 - *integration* with major productivity suites - Microsoft 365, Google Workspace
- popular products
 - [GitHub Copilot](#), [Microsoft 365 Copilot](#), [Grammarly AI](#), [Visual Studio Code Extensions](#)



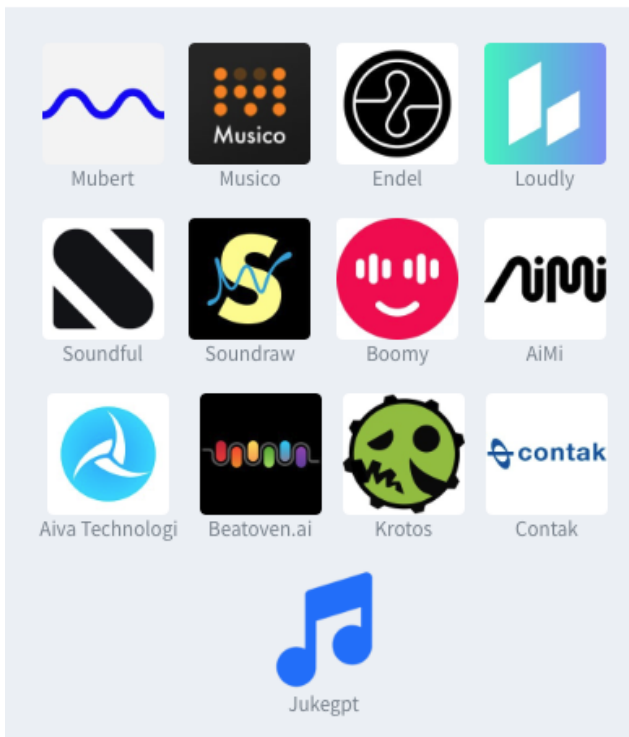
Future of co-pilot products

- potential advancements
 - wider adoption across industries and professions
 - *real-time fully automated collaboration*, *predictive content generation*, personalization
- impact on work environments & creative processes
 - *collaborative human-AI relationships* with augmented reality
 - unprecedented levels of problem-solving due to *augmented cognitive abilities*
- challenges & considerations
 - *ethical concerns around data privacy & AI decision-making*
 - potential impact on *human skills & job markets*

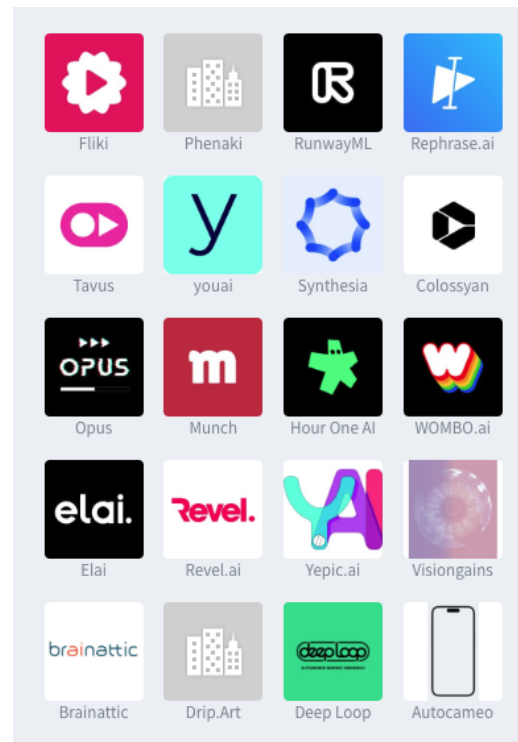


Other AI products - audio/video/text

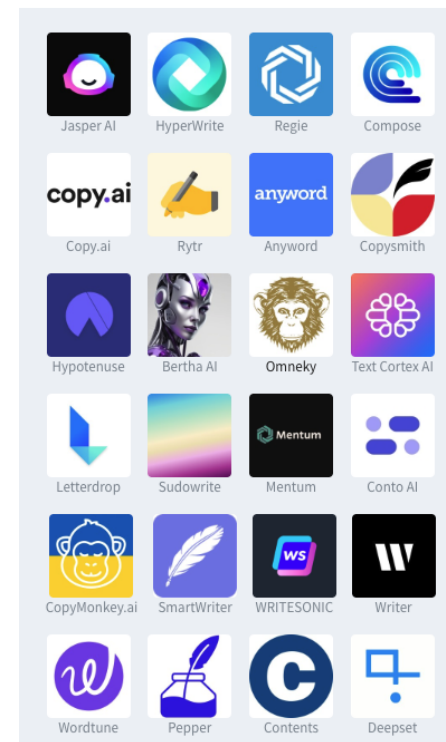
audio



vidio



text

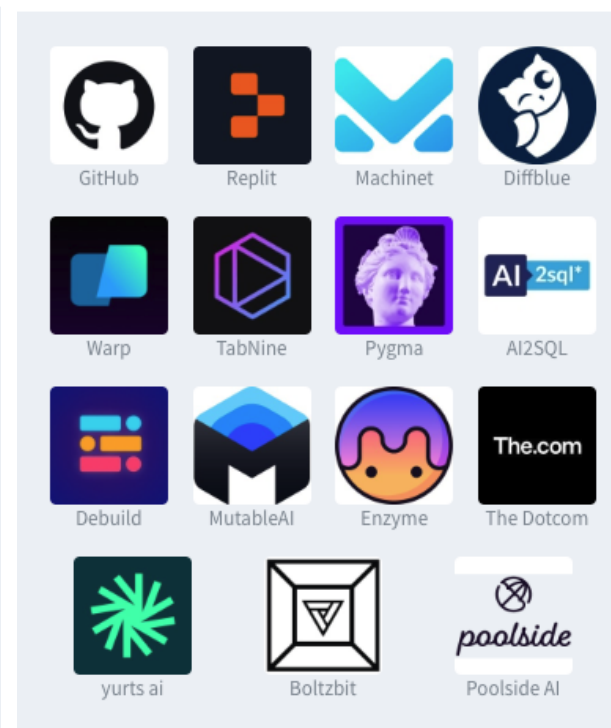
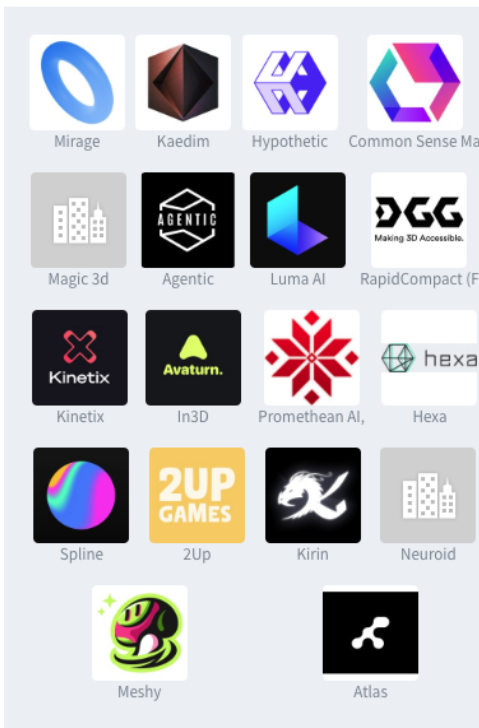
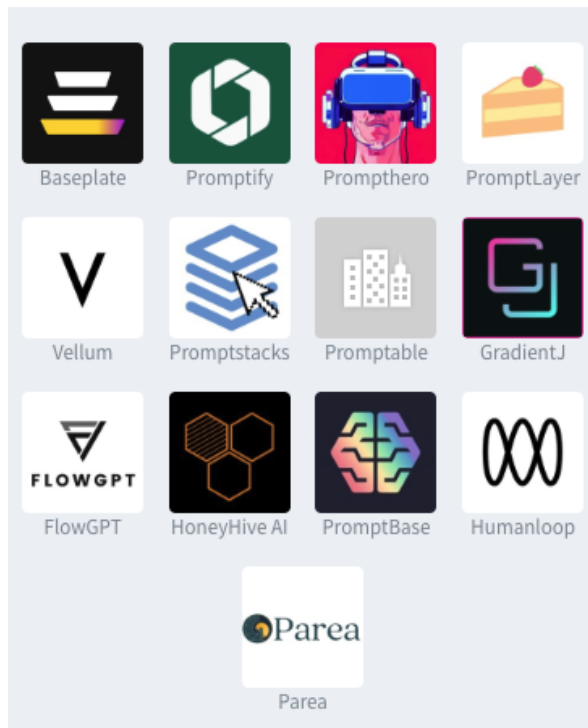


Other AI products - LLM/gaming/design/coding

LLM

gaming & design

coding



AI Industry

Heavy Lifting of LLMs

News - OpenAI's "\$8.5B bills" report sparks bankruptcy speculation

- OpenAI's financial situation reflects its ambitious vision
 - projected \$8.5B expenses vs \$3.5–4.5B revenue in 2024 w/ massive investment in AI infrastructure and talent
- caused by Sam Altman's reckless & non-strategic commitment to AGI development
 - “Whether we burn \$500M, \$5B, or \$50B a year, I don't care...” - prioritizing long-term impact over short-term profitability
- reflect broader AI industry trend of high burn rates
 - indicative of the resource-intensive nature of cutting-edge AI research



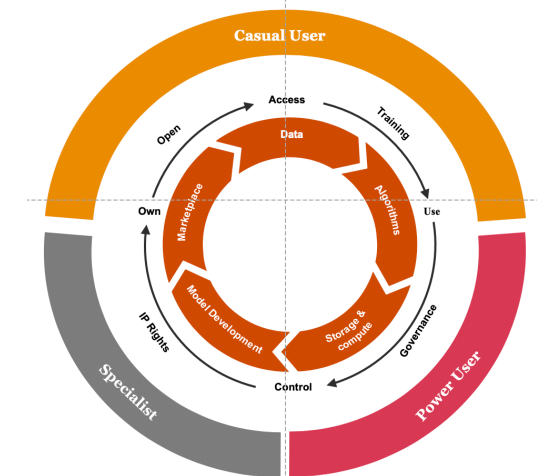
LLM - strategic challenges & industry dynamics

- evolving competitive landscape
 - threat from open-source models (*e.g.*, Meta's Llama 3.1) & potential commoditization of LLMs
- balancing act with Microsoft partnership
 - critical financial support vs maintaining independence - Microsoft's \$13B investment provides both opportunity and constraint
- sustainability of current business model
 - high costs of AI development vs monetization challenges
 - need for breakthrough applications or efficiency improvements
- ethical & regulatory considerations
 - balancing rapid development with responsible AI principles
 - potential impact of future AI regulations on operations and costs

Industry disruption of open-source AI models on industry

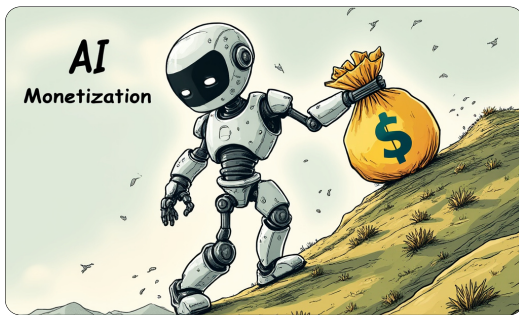
- rise of open-source models such as Meta's Llama 3.1 reshaping the AI landscape
- industry disruption
 - AI democratization - open-source making advanced AI capabilities accessible to wider range of developers and companies
 - innovation acceleration - collaborative improvement of open-source models could lead to faster progress
 - pressure on proprietary models - companies like OpenAI may need to offer significant advantages over free alternatives to justify their costs

Democratization Framework



innovation
acceleration

Impact of open-source AI models on industry



- business model challenges
 - monetization difficulties - capable models becoming freely available
 - shift to services & applications - focus may move from selling access to models to providing *specialized services* or *applications built on top of them*
- ethical & security concerns
 - responsible AI - open-source models raise questions about control and responsible use
 - dual-use potential - wider access to powerful AI models could increase risks of misuse or malicious applications, *e.g.*, *Deepfake*

Tech Giants & AI Companies

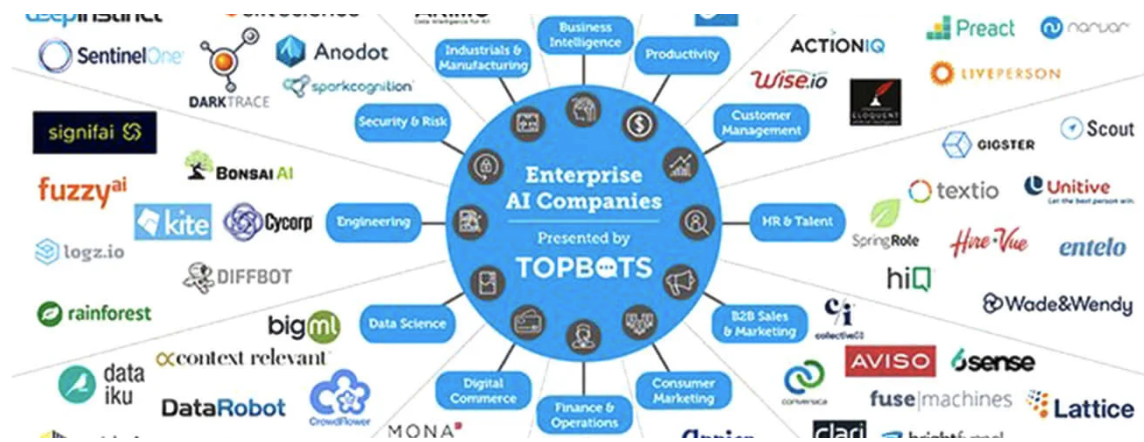
Evolving relationship between tech giants & AI companies

- partnership between OpenAI & Microsoft exemplifies broader trend of collaboration & integration in AI industry
- symbiotic relationships
 - tech giants provide resources & funding - AI companies research & innovation
 - provide AI companies w/ instant access to large user bases & distribution channels
- power dynamics
 - independence concerns - AI companies' risk of losing autonomy
 - tech giants' access to advanced AI potentially widening gap with smaller competitors



AI industry consolidation

- mergers & acquisitions
 - will see increased M&A activities as tech giants seek to bring AI capabilities in-house
- ecosystem development
 - tech giants creating AI-focused ecosystems, similar to cloud services, to attract and retain developers & businesses



**Empowering Humanity for Future
Enriched by AI**

Blessings & Curses of AI

Blessings

- advancements in healthcare & improved quality of life
 - much faster & more accurate diagnosis, far superior personalized medicine, accelerated drug discovery, assistive technologies
- economic growth & efficiency
 - automation to increase productivity and reduce cost, far superior decision-making
- environmental solutions
 - climate change prediction, global warming effect mitigation, solutions for sustainability
- safety & security
 - natural disaster prediction & relief, cybersecurity



Curses

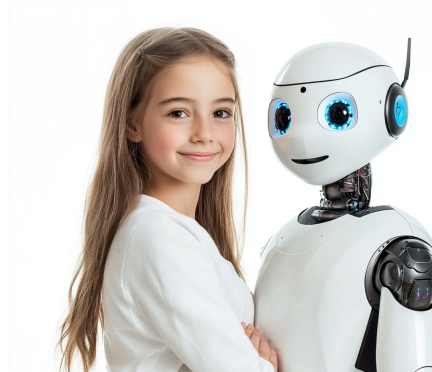
- job displacement & overall impacts on labor market
 - millions of jobs threatened, wealth gap widened
- bias & inequality, misinformation & manipulation
 - existing human biases, both conscious and unconscious, perpetuated through AIs, asymmetric accessibility to advanced AI technologies by nations & corporations
- ethical dilemmas
 - infringing privacy & human rights, accountability for weapon uses and damages by AI
- environmental costs
 - significant energy for training AI models, waste generated by obsolescent AI hardware



Solutions for Empowering Humanity

AI capacity building - scientists, engineers & practitioners

- ethics and responsible AI education or campaign via interdisciplinary collaboration
 - foster continuous learning programs on AI risks, bias & societal impacts
- bias detection & mitigation
 - bias-detection tools to identify & reduce discrimination in data & models
 - regular fairness audits
- transparency & explainability
 - explainable AI (xAI) techniques, frameworks like Model Cards for transparency
- environmental impact awareness
 - reduce AI's carbon footprint, advocate for sustainable AI development practices



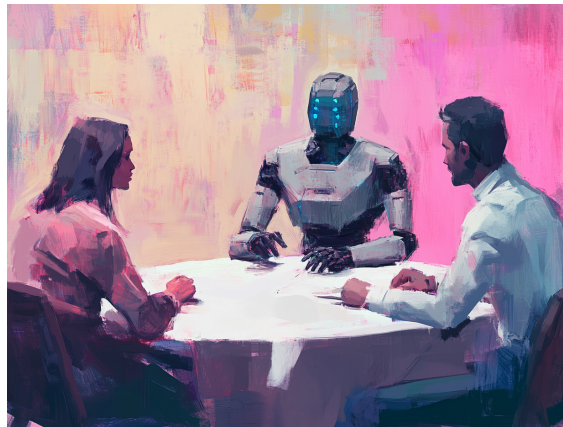
AI capacity building - lawmakers & policy makers

- problems
 - difficulties in understanding of rapidly evolving AI technologies
 - lead to reactive or insufficient regulation
- proposed solutions
 - develop comprehensive regulatory frameworks addressing transparency, bias & privacy concerns
 - gender bias, racial bias, hallucinations
 - foster public debates on ethical AI use & societal implications
 - introduce policies to limit spread of AI-generated misinformation,



Participatory social agreements

- open data frameworks including data sovereignty, regulation of data transfer, storage & localization
- corporate social responsibility, extra-territorial obligations & environmental protection
 - including outside the jurisdiction of the country
- labour and employment displacements, tax cuts & algorithmic impact assessments
 - including remedies for AI harms and enforcements



Appendix

Serendipities around AIs

Serendipity or inevitability?

- What if Geoffrey Hinton had not been a persistent researcher?
- What if Geoffrey had been a symbolist (instead of connectionist)?
- What if symbolists won AI race over connectionists?
- What if attention mechanism did not perform well?
- What if Transformer architecture did not perform super well?
- What if Jensen Hwang had not been crazy about making hardware for professional gamers?
- Is it like Alexander Fleming's Penicillin?
- Or more like Inevitability?

Important Questions to be Asked

Some important questions around AI

- why human-level AI in the first place?
- what lies in very core of DL architecture? what makes it work amazingly well?
- biases that can hurt judgement, decision making, social good?
- ethical and legal issues
- consciousness, knowledge, belief, reasoning
- future of AI

Human-level AI?

Why human-level in the first place?

- lots of times, when we measure AI performance, we say
 - how can we achieve human-level performance, *e.g.*, CV models?
- why human-level?
 - are all human traits desirable? are humans flawless?
 - aren't humans still evolving?
- advantage of AI over humans
 - *e.g.*, self-driving cars can use extra eyes, GPS, computer network
 - *e.g.*, recommendation system runs for hundreds of millions of people overnight
 - AI is available 24 / 7 while humans cannot
 - . . . critical advantages for medical assistance, emergency handling
 - AI does not make more mistakes because task is repetitive and tedious
 - AI does not request salary raise or go on strike

What makes DL so successful?

Factors contributing to astonishing success of DL

- analysis based on speaker's mathematical, numerical algorithmic & statistical perspectives considering hardware innovations

30% universal approximation theorem? - (partially) yes! but that's not all

- function space of neural network is *dense* (math theory), *i.e.*, for every $f : \mathbf{R}^n \rightarrow \mathbf{R}^m$, exists $\langle f_n \rangle$ such that $\lim_{n \rightarrow \infty} f_n = f$

25% architectures/algorithms tailored for each class of applications, *e.g.*, CNN, RNN, Transformer, NeRF, diffusion, GAN, VAE, . . .

20% data labeling - expensive, data availability - unlimited web text corpus

15% computation power/parallelism - AI accelerators, *e.g.*, GPU, TPU & NPU

10% rest - Python, open source software, cloud computing, MLOps, . . .

Why do we see sudden leap in LLM performance?

Probability inferred sequence is correct

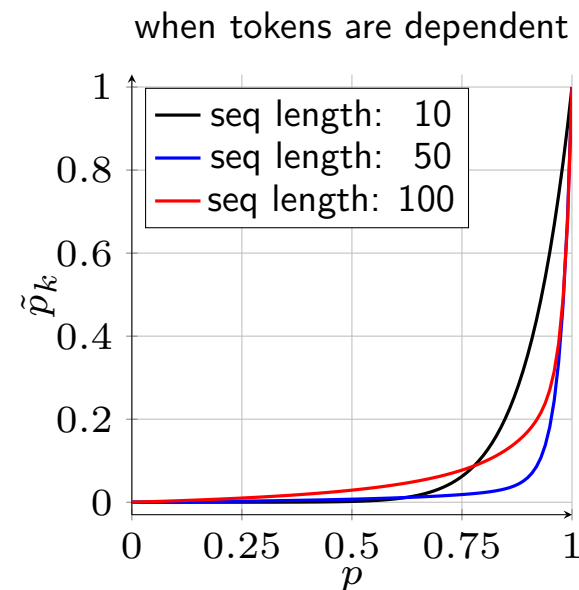
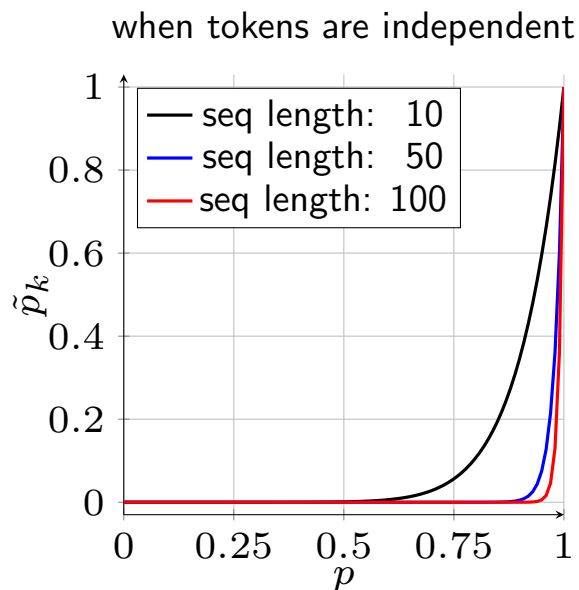
- assume
 - t_i - i th token
 - p_i - probability that t_i is correct
 - ρ_i - correlation coefficient between t_{i-1} & t_i
 - \tilde{p}_k - probability that (t_1, \dots, t_k) are correct
- recursion

$$\rho_i = \frac{\tilde{p}_i - \tilde{p}_{i-1}p_i}{\sqrt{\tilde{p}_{i-1}(1 - \tilde{p}_{i-1})p_i(1 - p_i)}}$$

$$\Leftrightarrow \tilde{p}_i = \tilde{p}_{i-1}p_i + \rho_i \sqrt{\tilde{p}_{i-1}(1 - \tilde{p}_{i-1})p_i(1 - p_i)}$$

Dramatic improvement of LLM near saturation

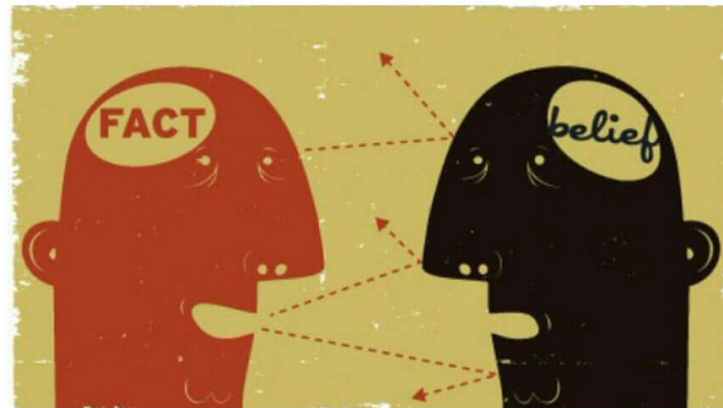
- do simulations for both independent & dependent cases
 - assume p_i are same for all i
- (for both cases) sequence inference improves dramatically as p approaches 1
- this explains *why we have observed sudden dramatic performance improvement of certain seq2seq learning technologies, e.g., LLM*



Biases - by Humans & Machines

Cognitive biases

- cognitive biases [[Kah11](#)]
 - confirmation bias, availability bias
 - hindsight bias, confidence bias, optimistic bias
 - anchoring bias, halo effect, framing effect, outcome bias
 - belief bias, negativity bias, false consensus,



LLM biases

- plausible with LLM
 - availability bias - biased by imbalancedly available information
 - LLM trained by imbalanced # articles for specific topics
 - belief bias - derive conclusion not by reasoning, but by what it saw
 - LLM easily inferencing what it saw, *i.e.*, data it trained on
 - halo effect - overemphasize on what prestigious figures say
 - LLM trained by imbalanced # reports about prestigious figures
- similar facts true for other types of ML models,
 - *e.g.*, video caption, text summarization, sentiment analysis
- cognitive biases only human represent
 - confirmation bias, hindsight bias, confidence bias, optimistic bias, anchoring bias, negativity bias, framing effect

Ethical and Legal Issues

Ethics - possibilities & questions

- AI can be exploited by those who have bad intention to
 - manipulate / deceive people - using manipulated data corpus for training
 - *e.g.*, spread false facts
 - induce unfair social resource allocation
 - *e.g.*, medical insurance, taxation
 - exploit advantageous social and economic power
 - *e.g.*, unfair wealth allocation, mislead public opinion
- AI for Good - advocated by Andrew Ng
 - *e.g.*, public health, climate change, disaster management
- should scientists and engineers be morally & politically conscious?
 - *e.g.*, Manhattan project

Legal issues with ethical consideration - (hypothetical) scenarios

- scenario 1: full self-driving algorithm causes traffic accident killing people
 - who is responsible? - car maker, algorithm developer, driver, algorithm itself?
- scenario 2: self-driving cars kill less people than human drivers
 - *e.g.*, human drivers kill 1.5 people for 100,000 miles & self-driving cars kill 0.2 people for 100,000 miles
 - how should law makers make regulations?
 - utilitarian & humanistic perspectives
- scenario 3: someone is not happy with their data being used for training
 - “The Times sues OpenAI and Microsoft over AI use of copyrighted work” (Dec. 2023)
 - “Newspaper publishers in California, Colorado, Illinois, Florida, Minnesota and New York said Microsoft and OpenAI used millions of articles without payment or permission to develop ChatGPT and other products” (Apr. 2024)

Consciousness

Consciousness

- what is consciousness, anyway?
 - recognizes itself as independent, autonomous, valuable entity?
 - recognizes itself as living being, unchangeable entity?
- no agreed definition on consciousness exists yet . . . and will be so forever
- does it have anything to do with the fact that humans are biologically living being?
- is SKYNET ever plausible (without someone's intention)?
 - can AI have *desire* to survive (or save earth)?



Utopia or dystopia - futile debates

- not important questions (at all) *I think . . .*
- what we should focus on is not the possibilities of doomday or Judgment Day, but rather
 - our limits on controlling unintended impacts of AI
 - *misuse* by (greedy and bad) people possessing social, economic & political power
 - *social good and welfare impaired* by (exploiting) AI
- should concern
 - choice among utilitarianism, humanism, justice & equity
 - amend or improve laws and regulations
 - address ethical issues caused by AI



Knowledge, Belief, and Reasoning of AI

Does AI (or LLM) have knowledge or belief? Can it reason?

What categories of questions should they be in?

engineering, scientific, philosophical, cognitive scientific . . . ?

Three surprises of LLM

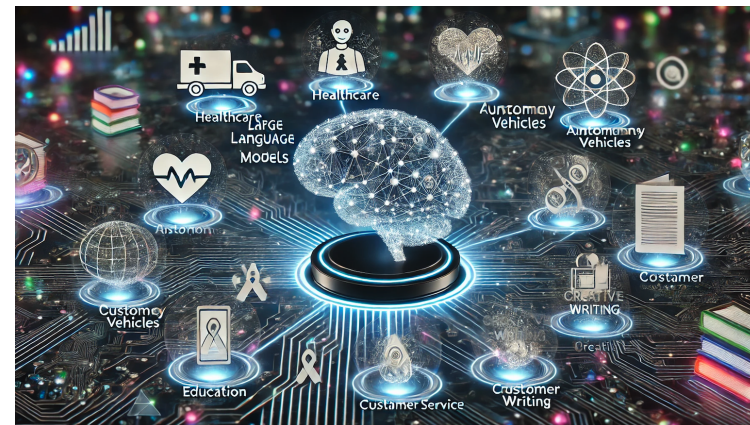
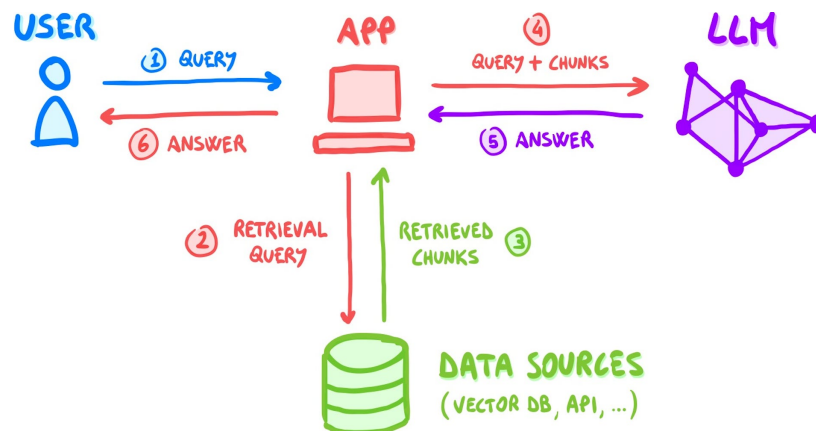
- LLM is very different sort of animal . . . except that it is *not* an animal!
- *unreasonable* effectiveness of data [HNF09]
 - *performance scales with size of training data*
 - *qualitative leaps* in capability as models scale
 - tasks demanding human intelligence *reduced to next token prediction*
- focus on third surprise
 - *“conditional probability model looks like human with intelligence”*
 - making vulnerable to anthropomorphism
- examine it by throwing questions
 - *“does LLM have knowledge and belief?”*
 - *“can it reason?”*

What LLM really does!

- given prompt “the first person to walk on the Moon was”, LLM responds with “Neil Armstrong” . . . strictly speaking
 - it’s *not* being asked *who* was the first person to walk on the Moon
 - what are being *really* asked is *“given statistical distribution of words in vast public corpus of text, what words are most likely to follow ‘The first person to walk on the Moon was’?”*
- given prompt “after ring was destroyed, Frodo Baggins returned to”, LLM responds with “the Shire”
 - on one level, it seems fair to say, you might be testing LLM’s knowledge of fictional world of Tolkien’s novels
 - what are being *really* asked is *“given statistical distribution of words in vast public corpus of text, what words are most likely to follow ‘After the ring was destroyed, Frodo Baggins returned to’?”*

LLMs or systems in which they are embedded?

- crucial to distinguish between the two (for philosophical clarity)
 - LLM (bare-bones model) - highly specific & well-defined function, which is *conditional probability estimator*
 - systems in which LLMs are embedded - question-answering, news article summarization, screenplays generation, language translation



How ChatBot works using LLMs?

- conversational AI agent does *in-context learning* or *few-shot prompting*

- for example,

- when the user enters

- who is the first person to walk on the Moon?

- ChatBot, LLM-embedded system, feeds the following to LLM

- User, a human, and BOT, a clever and knowledgeable AI agent.

- User: what is 2+2?

- BOT: the answer is 4.

- User: where was Albert Einstein born?

- BOT: he was born in Germany.

- User: who is the first person to walk on the Moon?

- BOT:

Knowledge, belief & reasoning around LLM

- *not* easy topic to discuss, or even impossible because
 - we do *not* have agreed definition of these terms especially in context of being asked questions like

does LLM have belief?

or

do humans have knowledge?

- let us discuss them in two different perspectives
 - laymen's perspective
 - cognitive scientific perspective

Laymen's perspective on knowledge, belief & reasoning

- does (good) LLM have knowledge?
 - Grandmother - looks like it cuz when instructed *“explaining big bang”*, it says
“ The Big Bang theory is prevailing cosmological model that explains the origin and evolution of the universe. . . . 13.8 billion years ago . . . ”
- does it have belief?
 - Grandmother: I don't think so, *e.g.*, it does not believe in God.
- can it reason?
 - Grandmother: seems like it! *e.g.*, when asked *“Sunghee is a superset of Alice and Beth is a superset of Sunghee. is Beth a superset of Alice?”*, it says
“ Yes, based on information provided, if Sunghee is a superset of Alice and Beth is a superset of Sunghee, then Beth is indeed a superset of Alice . . . ”
- can it reason to prove theorem whose inferential structure is more complicated?
 - Grandmother: I'm not sure. - actually, I don't know what you're talking about!

Knowledge

- could argue LLM “knows” which words follow which other words with high probability
- but, only *in context of capacity to distinguish truth from falsehood*, can we legitimately speak of “knowledge”!
- LLM(-embedded BOT)
 - can be said to “*encode*”, “*store*”, or “*contain*” knowledge
 - lacks means to use words “true” & “false” in all ways & in all contexts because . . .
 - does not inhabit the world we human language-users share!



Belief

- nothing can count as *belief about the world* we share unless
 - it is against backdrop of “ability to update beliefs appropriately in light of evidence from *that world*” - (again) essential capacity to distinguish truth from falsehood
- change taking place in humans when acquiring or updating belief is
 - reflection of their nature as language-using animals inhabiting shared world with community of language-users
- then, *what if LLM-embedded system updates LLM with outside world information?*
 - even so, when interacting with AI systems based on LLMs, these grounds are *absent!*



can you provide me up-to-date information about AI agent perplexity?

Sources

Perplexity AI: A Guide for Beginners - Jeff Su
Perplexity AI's value to soar to \$8B as it features new \$800M funding ...
Perplexity AI: A Deep Dive - Redhouse

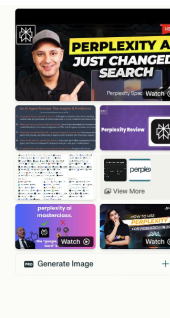
Perplexity

Perplexity AI is an AI-powered search engine and answer engine that has gained significant traction in recent years. Founded in 2022, Perplexity uses large language models (LLMs) to generate answers to user queries, citing sources from the web within the text response. As of Q1 2024, Perplexity had reached 15 million monthly users.

Key features and developments of Perplexity AI include:

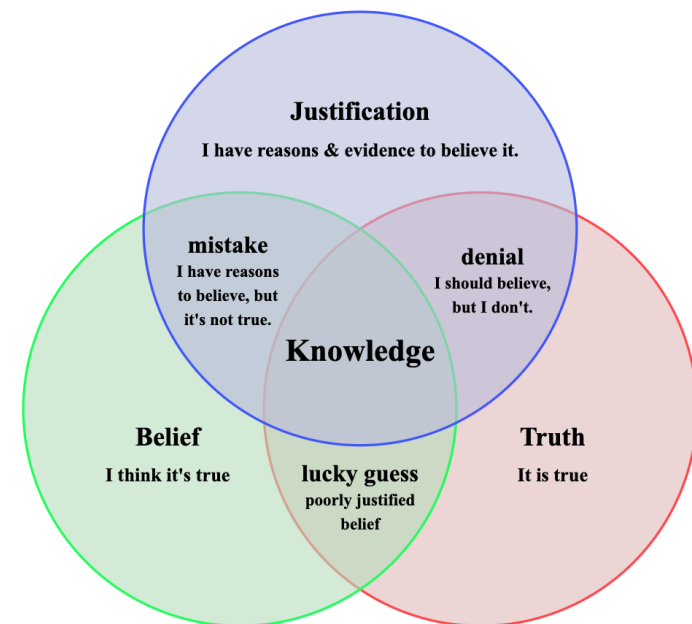
1. Search functionality: Perplexity summarizes search results and produces text with inline citations, providing personalized results based on the context of user queries.

Ask follow-up



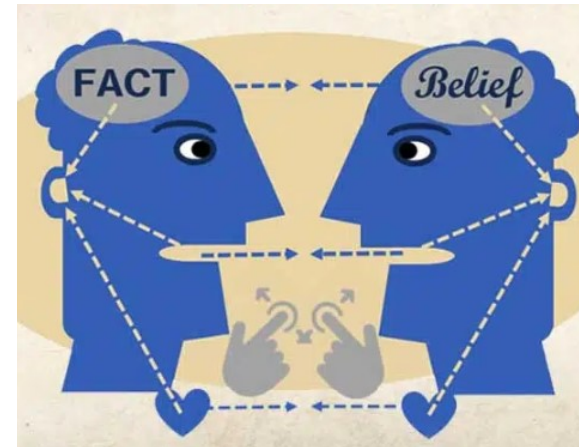
Cognitive scientific perspective on knowledge

- does LLM have knowledge?
 - I don't think so.
- why?
 - when asked *“who is Tom Cruise's mother?”*, it says *“Tom Cruise's mother is Mary Lee Pfeiffer.”* However, this is nothing but *“guessing” by conditional probability model the most likely following words after “Tom Cruise's mother is.”*
 - so we cannot say it really knows the fact!



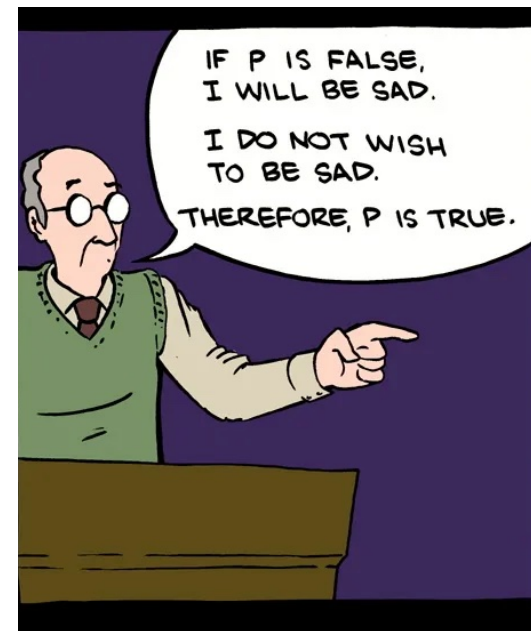
Cognitive scientific perspective on belief

- for the discussion
 - we do not concern *any specific belief*
 - we concern prerequisites for ascribing any beliefs to AI system
- so does it have belief?
 - when a human being takes to Wikipedia and confirms some fact, what happens is not her language model update, but
 - reflection of her nature as language-using animal inhabiting shared world with a community of other language-users.*
 - LLM does not have this ground, essential consideration when deciding whether it *really* had beliefs.
 - so *no, LLM cannot have belief!*



Cognitive scientific perspective on reasoning

- note reasoning is *content neutral*
 - e.g., following logic is perfect regardless of truth of premises
 - hence, no access to outside world does *not* disqualify
- when asked “*if humans are immortal, would Socrates have survived today?*”, LLM says
“... *it's logical to conclude that Socrates would likely still be alive today. ...*”
- is there fundamental difference compared to *true* reasoning?
- moreover, LLM can *mimic even multi-step reasoning whose inferencing structure is complicated* using *chain-of-thoughts prompting*, i.e., *in-context learning* or *few-shot prompting*,



Simple example showing LLM not possessing knowledge

- User

“Who is Tom Cruise’s mother?”



- LLM(-embedded question-answering system) (as of Jan 2022)

“Tom Cruise’s mother is Mary Lee Pfeiffer. She was born Mary Lee South. . . . Information about his family, including his parents, has been publicly available,”

- User

“Who is Mary Lee Pfeiffer’s son?”

- LLM(-embedded question-answering system) (as of Jan 2022)

“As of my last knowledge update in January 2022, I don’t have specific information about Mary Lee Pfeiffer or her family, including her son. . . .”

Risk of anthropomorphization

- unfortunately, contemporary LLMs are *too powerful, too versatile, and too useful to accept previous arguments!*
- maybe, it is o.k. for laymen to (mistakenly) anthropomorphize LLM(-embedded systems)
- however, *imperative for AI researchers, scientists, engineers & practitioners* to have rigorous understanding in these aspects especially when
 - talk to or advise *policy makers, media, etc.*
 - consult or collaborate with professionals in areas such as *philosophy, ethics, law, etc.*

e.g., to address and prepare negative societal and economic impacts

Moral

- AI, *e.g.*, LLM, shows incredible utility and commercial potentials, hence we should
 - make informed decisions about trustworthiness and safety
 - avoid ascribing capacities they lack take best usage of remarkable capabilities of AI
- today's AI is so powerful, so (seemingly) convincingly intelligent
 - obfuscate mechanism
 - actively encourage *anthropomorphism* with philosophically loaded words like “believe” and “think”
 - easily mislead people about character and capabilities of AI
- matters not only to scientists, engineers, developers, and entrepreneurs, but also
 - *general public, policy makers, media people*

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Thank You