# **Course evaluations**

https://uw.iasystem.org/survey/310151

Please do them

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# Lecture 19

**CV/AI** Frontiers

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# Administrative

A5, A6 (extra credit) out

- Due June 10th

Exam

- Mon, June 9, 2:30-4:20
- Same room as lecture: BAG154
- List of topics, practice exam posted on EdStem

Makeup exam

- Friday June 6th. 1:30-3:20. Emails have been sent to the folks taking the makeup.

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# We are in the era of deep learning

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### CVPR → SuBARES → Accepted





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Perceptron



Frank Rosenblatt, ~1957

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#### Perceptron



#### Simple and Complex cells





Frank Rosenblatt, ~1957

Hubel and Wiesel, 1959

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Perceptron



Simple and Complex cells

Neocognitron



Hubel and Wiesel, 1959



Fukushima, 1980

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Perceptron



Simple and Complex cells Neocognitron **Convolutional Networks** Image Maps Input Output Fully Connected Convolutions Subsampling Response Stimulus Frank Rosenblatt, ~1957 Hubel and Wiesel, 1959 Fukushima, 1980 LeCun et al, 1998 Lecture 19 - 10 June 4, 2025

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AlexNet



Krizhevsky, Sutskever, and Hinton, 2012

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#### AlexNet



Krizhevsky, Sutskever, and Hinton, 2012



Geoffrey

Hinton

2018 Turing Award



Yann LeCun

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Yoshua

Bengio

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# What's Next?

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# The Bitter Lesson

### **Rich Sutton**

#### March 13, 2019

The biggest lesson that can be read from 70 years of AI research is that general methods that leverage computation are ultimately the most effective, and by a large margin. The ultimate reason for this is Moore's law, or rather its generalization of continued exponentially falling cost per unit of computation. Most AI research has been conducted as if the computation available to the agent were constant (in which case leveraging human knowledge would be one of the only ways to improve performance) but, over a slightly longer time than a typical research project, massively more computation inevitably becomes available. Seeking an improvement that makes a difference in the shorter term, researchers seek to leverage their human knowledge of the domain, but the only thing that matters in the long run is the leveraging of computation. These two need not run counter to each other, but in practice they tend to. Time spent on one is time not spent on the other. There are psychological commitments to investment in one approach or the other. And the human-knowledge approach tends to complicate methods in ways that make them less suited to taking advantage of general methods leveraging computation. There were many examples of AI researchers' belated learning of this bitter lesson, and it is instructive to review some of the most prominent.

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**GFLOP** per Dollar

• GPU (Tensor Core)



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Examples that came out this year

- Stable Diffusion 3 (02/2024): text-to-image generation models from 800M to 8B.
- Sora (02/2024): text-to-image/video generation models
- LLaMA 3 (04/2024): large language model from 8B to 70B pretrained on over 15T tokens with two custom-built 24K GPU clusters
- Chameleon (05/2024): multimodal generative model, 34B parameters

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### Bigger Models, More Data, More Compute: Stable Diffusion 3

- Diffusion Transformer
- Rectified Flows





Prompt: Translucent pig, inside is a smaller pig.

Prompt: A massive alien space ship that is shaped like a pretzel.



Prompt: A kangaroo holding a beer, wearing ski goggles and passionately singing silly songs.

Prompt: An entire universe inside a bottle sitting on the shelf at walmart on sale.

Prompt: A cheeseburger with juicy beef patties and melted cheese sits on top of a toilet that looks like a throne and stands in the middle of the royal chamber. Prompt: This dreamlike digital art captures a vibrant, kaleidoscopic bird in a lush rainforest

This Prompt: A car made gital art out of vegetables. *i*brant, c bird in Prompt: Heat death of the universe line art

https://stability.ai/news/stable-diffusion-3-research-paper

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#### • Diffusion Transformer

Close-up portrait shot of a woman in autumn, extreme detail, shallow depth of field



https://openai.c

Digital art of a young tiger under an apple tree in a matte painting style with gorgeous details



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a toy robot wearing a green dress and a sun hat taking a pleasant stroll in Johannesburg, South Africa during a winter storm



https://openai.com/index/video-generation-models-as-world-simulators/

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a cool tiny demo in OpenAl website





https://openai.com/index/video-generation-models-as-world-simulators/

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#### You

What is the number that rhymes with the word we use to describe a tall plant?

#### 🔿 Meta Al

I think I can help with that!

The word you're referring to is probably "tree", and the number that rhymes with it is "three"!



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#### You

how to prepare Computer Vision final?

#### 🔿 Meta Al

Preparing for a Computer Vision final exam requires a combination of understanding concepts, practicing problems, and reviewing materials. Here's a suggested plan to help you prepare:

#### 1. Review Fundamentals

- · Linear Algebra: matrices, vectors, tensor operations
- Calculus: derivatives, optimization
- Probability and Statistics: probability distributions, Bayes' theorem
- Programming skills: Python, NumPy, pandas, etc.

#### 2. Computer Vision Concepts

- Image processing: filtering, transforms, feature extraction
- Object recognition: classification, detection, segmentation
- Deep learning: CNNs, architectures (e.g., ResNet, YOLO)
- Image generation: synthesis, GANs

#### 3. Study Materials

- Textbook: "Computer Vision: Algorithms and Applications" by Richard Szeliski
- Online courses: Stanford CS231n, MIT OpenCourseWare
- Research papers: read recent papers on arXiv, CVPR, ICCV

#### 4. Practice Problems

- Implement algorithms: image filtering, object detection
- Work on projects: image classification, segmentation, generation
- Use libraries: OpenCV, PyTorch, TensorFlow
- 5. Review and Practice Regularly
  - Set aside dedicated time to review and practice each week
  - Make flashcards for key terms and concepts
  - Join online communities (e.g., Kaggle, Reddit) for discussion and learning

#### 6. Take Practice Exams

- Find practice exams or quizzes online
- Time yourself to simulate the actual exam experience
- Review your mistakes and focus on weak areas

By following this plan, you'll be well-prepared for your Computer Vision final exam. Good luck!

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## Bigger Models, More Data, More Compute: Chameleon

**Prompt:** I'm bored. Could you show me some cool, quirky-looking birds? Also tell me about them in 2–3 sentences.



**Response:** Absolutely! Here are three birds with some unique features that you might find interesting:

**Keel-Billed Toucan** The Keel-Billed Toucan is a brightly colored bird native to South American rainforests and woodlands. Its most distinctive feature is its colorful beak, which can grow up to seven inches long and has a distinctive, curved shape. The beak is used for plucking fruit from trees and for social displays. Despite its large size, the Keel-Billed Toucan is a skilled flyer and can often be seen flitting through the treetops. Here is an image of this vibrant bird: <img>

**Puffin** Puffins are small, aquatic birds that are found in the northern hemisphere. They have distinctive black and white feathers, as well as a brightly colored beak that is used for attracting mates and defending their territory. Puffins are known for their distinctive "puffin" call, which sounds like a loud, guttural chuckle. They feed on fish, which they catch by diving into the water from the air. Puffins are colonial birds, and they breed in large colonies on rocky cliffs and islands. Here is an image of this adorable bird: <img>





**Golden Pheasant** The Golden Pheasant is a brightly colored bird native to the forests of China. It is a member of the pheasant family and is known for its striking plumage, which features a golden-yellow body, red face, and green tail feathers. The Golden Pheasant is a ground-dwelling bird, and it feeds on a diet of insects, seeds, and fruits. It is a popular game bird, and is often hunted for its meat and feathers. In captivity, the Golden Pheasant is sometimes kept as an ornamental bird, due to its striking appearance. Here is an image of this beautiful bird: <img>

I hope these images and descriptions have helped to brighten your day! If you have any other questions or requests, please don't hesitate to ask.

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# Bigger Models, More Data, More Compute: Chameleon



**Prompt: <img>** While chameleons are masters of camouflage in the natural world, let's see how they might fare in a man-made setting.

1. Analyze the colors, patterns, and textures in this image and identify the most challenging spot for a chameleon to blend in.

2. Then generate an image of a chameleon with the optimal pattern to camouflage itself.

3. Then, rate and explain how successful each attempt is on a scale from 1-10.

**Response:** The image is of a stop sign in a forested area, with some sunlight filtering through the trees. The sign has a red octagonal shape with a white border and the word "STOP" written in white letters. In the background, there are green leaves and trees.

**Challenging Spot for a Chameleon:** The stop sign would be the most challenging spot for a chameleon to blend in due to its bright red color and bold white letters, which would stand out in the forested environment.

**Optimal Pattern for Camouflage:** To camouflage itself on the stop sign, a chameleon would need to have a pattern that would break up its outline and make it less conspicuous. A pattern with shades



of brown and red would help the chameleon blend in more effectively. Additionally, a mottled or dappled pattern would help to scatter light and further reduce the chameleon's visibility.

#### <img>

Rating and Explanation: A rating of 2/10 would be given for the chameleon's ability to blend in on the stop sign. While the chameleon's green and brown pattern helps to break up its outline, the bright red color of the stop sign will still make it stand out in the forested environment.

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# Bigger Models, More Data, More Compute, More problems

Hong Kong (CNN) — A British multinational design and engineering company behind world-famous buildings such as the Sydney Opera House has confirmed that it was the target of a deepfake scam that led to one of its Hong Kong employees paying out <u>\$25</u> million to fraudsters.

https://www.cnn.com/2024/05/16/tech/arup-deepfake-scam-loss-hong-kong-intl-hnk/index.html

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### Bigger Models, More Data, More Compute, More problems

- ML Systems can encode bias
- Large models can lack common sense
- Who should control models and data?

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## Bigger Models, More Data, More Compute, More problems

#### • ML Systems can encode bias

- Large models can lack common sense
- Who should control models and data?

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### Stepping Back: Why Build ML Systems?

Automate decision making, so machines can make decision instead of people.

**Ideal**: Automated decisions can be cheaper, more accurate, more impartial, improve our lives

**Reality**: If we aren't careful, automated decisions can encode bias, harm people, make lives worse

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# **Allocative Harms**

- Some systems decide how to allocate resources
- If the system is biased, it may allocate resources unfairly or perpetuate inequality
- Examples:
  - Insurance rates
  - College admissions
  - Job applications
  - Loan applications
  - Mortgage applications
  - Sentencing criminals

Barocas et al, "The Problem With Bias: Allocative Versus Representational Harms in Machine Learning", SIGCIS 2017 Kate Crawford, "The Trouble with Bias", NeurIPS 2017 Keynote

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# **Example: Video Interviewing**

Technology

# A face-scanning algorithm increasingly decides whether you deserve the job

HireVue claims it uses artificial intelligence to decide who's best for a job. Outside experts call it 'profoundly disturbing.'



Source: https://www.washingtonpost.com/technology/2019/10/22/ai-hiring-face-scanning-algorithm-increasingly-decides-whether-you-deserve-job/

https://www.hirevue.com/platform/online-video-interviewing-software

Example Credit: Timnit Gebru

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**Representational Harms** 

### A system reinforces harmful stereotypes

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### **Representational Harms: Machine Translation**

≡ Go	ogle Trans	late	—					Sign in
★ Text	Docume	ents	nglish	i tra	insla	tion	1-1-1	
makes assumptions								
HUNGARIAN - DETECTED		POLISH	PO 🗸	$\stackrel{\rightarrow}{\leftarrow}$	ENGLISH	POLISH	PORTUGUESE	$\sim$

X

Ő szép. Ő okos. Ő olvas. Ő mosogat. Ő épít. Ő varr. Ő tanít. Ő főz. Ő kutat. Ő gyereket nevel. Ő zenél. Ő takarító. Ő politikus. Ő sok pénzt keres. Ő süteményt süt. Ő professzor. Ő asszisztens.

# Hungarian does not use gendered pronouns

She is beautiful. He is clever. He reads. She washes the dishes. He builds. She sews. He teaches. She cooks. He's researching. She is raising a child. He plays music. She's a cleaner. He is a politician. He makes a lot of money. She is baking a cake. He's a professor. She's an assistant.

J 1

194 / 5000

•

1 «





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### **Representational Harms: Machine Translation**



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Source: https://www.bbc.com/news/newsbeat-32332603

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Harvard study: What CEOs do all day cnbc.com



heartofthecustomer.com

7 Personality Traits Every CEO Shoul... forbes.com

Roeland Baan new CEO of Haldor T ... blog.topsoe.com

C X I

Wartime CEOs are not the ideal leaders ... ft.com

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## Representational Harm in DALL-E 2

Text Prompt: "lawyer"



Ramesh et al, "Hierarchical Text-Conditional Image Generation with CLIP Latents", arXiv 2022 <a href="https://github.com/openai/dalle-2-preview/blob/main/system-card.md">https://github.com/openai/dalle-2-preview/blob/main/system-card.md</a>

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## Representational Harm in DALL-E 2

Text Prompt: "nurse"



Ramesh et al, "Hierarchical Text-Conditional Image Generation with CLIP Latents", arXiv 2022 https://github.com/openai/dalle-2-preview/blob/main/system-card.md

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## **Representational Harm in Super-Resolution**

#### Input: Low-Resolution Face



#### **Output: High-Resolution Face**



Menon et al, "PULSE: Self-Supervised Photo Upsampling via Latent Space Exploration of Generative Models", CVPR 2020 Example source: <u>https://twitter.com/Chicken3gg/status/1274314622447820801</u>

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■ MSFT ■ Face++ ■ IBM



Buolamwini and Gebru, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification", FAT\* 2018

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Buolamwini and Gebru, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification", FAT\* 2018

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Buolamwini and Gebru, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification", FAT\* 2018

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Buolamwini and Gebru, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification", FAT\* 2018

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### Some solutions

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### **Datasheets for Datasets**

# Idea: A standard list of questions to answer when releasing a dataset. Who created it? Why? What is in it? How was it labeled?

A Database for Studying Face Recognition in Unconstrained Environments

Labeled Faces in the Wild

#### **Motivation**

For what purpose was the dataset created? Was there a specific task in mind? Was there a specific gap that needed to be filled? Please provide a description.

Labeled Faces in the Wild was created to provide images that can be used to study face recognition in the unconstrained setting where image characteristics (such as pose, illumination, resolution, focus), subject demographic makeup (such as age, gender, race) or appearance (such as hairstyle, makeup, clothing) cannot be controlled. The dataset was created for the specific task of pair matching: given a pair of images each containing a face, determine whether or not the images are of the same person.<sup>1</sup>

#### Who created this dataset (e.g., which team, research group) and on behalf of which entity (e.g., company, institution, organization)?

The initial version of the dataset was created by Gary B. Huang, Manu Ramesh, Tamara Berg, and Erik Learned-Miller, most of whom were researchers at the University of Massachusetts Amherst at the time of the dataset's release in 2007.

Who funded the creation of the dataset? If there is an associated grant, please provide the name of the grantor and the grant name and number. The construction of the LFW database was supported by a United States National Science Foundation CAREER Award.

The dataset does not contain all possible instances. There are no known relationships between instances except for the fact that they are all individuals who appeared in news sources on line, and some individuals appear in multiple pairs.

What data does each instance consist of? "Raw" data (e.g., unprocessed text or images)or features? In either case, please provide a description.

Each instance contains a pair of images that are 250 by 250 pixels in JPEG 2.0 format.

#### Is there a label or target associated with each instance? If so, please provide a description.

Each image is accompanied by a label indicating the name of the person in the image.

**Is any information missing from individual instances?** If so, please provide a description, explaining why this information is missing (e.g., because it was unavailable). This does not include intentionally removed information, but might include, e.g., redacted text.

Everything is included in the dataset.

### Are relationships between individual instances made explicit (e.g., users' movie ratings, social network links)? If so, please describe how these relationships are made explicit.

There are no known relationships between instances except for the fact that they are all individuals who appeared in pause courses

#### Gebru et al, "Datasheets for Datasets", FAccT 2018

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## Model Cards

Idea: A standard list of questions to answer when releasing a trained model. Who created it? What data was it trained on? What should it be used for? What should it **not** be used for?

#### Model Card • Model Details. Basic information about the model. - Person or organization developing model - Model date - Model version - Model type - Information about training algorithms, parameters, fairness constraints or other applied approaches, and features - Paper or other resource for more information - Citation details - License - Where to send questions or comments about the model • Intended Use. Use cases that were envisioned during development. - Primary intended uses - Primary intended users - Out-of-scope use cases • Factors. Factors could include demographic or phenotypic

- Factors. Factors could include demographic or phenotypic groups, environmental conditions, technical attributes, or others listed in Section 4.3.
- Relevant factors

- Evaluation factors
- **Metrics**. Metrics should be chosen to reflect potential realworld impacts of the model.
  - Model performance measures
  - Decision thresholds
  - Variation approaches
- **Evaluation Data**. Details on the dataset(s) used for the quantitative analyses in the card.
  - Datasets
  - Motivation
  - Preprocessing
- **Training Data**. May not be possible to provide in practice. When possible, this section should mirror Evaluation Data. If such detail is not possible, minimal allowable information should be provided here, such as details of the distribution over various factors in the training datasets.

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- Quantitative Analyses
  - Unitary results
  - Intersectional results
- Ethical Considerations
- Caveats and Recommendations

Mitchell et al, "Model Cards for Model Reporting", FAccT 2019

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### Model Cards

# Some models are just for research and not to be deployed. **Make it clear!**

#### **Out-of-Scope Use Cases**

**Any** deployed use case of the model - whether commercial or not - is currently out of scope. Non-deployed use cases such as image search in a constrained environment, are also not recommended unless there is thorough in-domain testing of the model with a specific, fixed class taxonomy. This is because our safety assessment demonstrated a high need for task specific testing especially given the variability of CLIP's performance with different class taxonomies. This makes untested and unconstrained deployment of the model in any use case currently potentially harmful.

Certain use cases which would fall under the domain of surveillance and facial recognition are always out-of-scope regardless of performance of the model. This is because the use of artificial intelligence for tasks such as these can be premature currently given the lack of testing norms and checks to ensure its fair use.

https://github.com/openai/CLIP/blob/main/model-card.md

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## Bigger Models, More Data, More Compute, More problems

- ML Systems can encode bias
- Large models can lack common sense
- Who should control models and data?

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## Large Models Lack Common Sense

Some plants surrounding a lightbulb



A lightbulb surrounding some plants



### Large vision + language models cannot correctly pair images with captions

Thrush et al, "Winoground: Probing Vision and Language Models for Visio-Linguistic Compositionality", CVPR 2022

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## Large Models Lack Common Sense

Samples from DALL-E 2 for the prompt:

"a red cube on top of a blue cube"

Simple compositions of objects, attributes, relationships often not respected



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Ramesh et al, "Hierarchical Text-Conditional Image Generation with CLIP Latents", arXiv 2022

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### Large Models Lack Common Sense: GPT-2

**Bold = prompt written by human** *Italic = completion written by GPT-2* 

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I was born in 1950. In the year 2025 my age will be 35. That was only a few years ago. Most things in life just continue to improve.

I see a black dog and a brown horse. The bigger animal's color is *black*, and the smaller is brown.

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Examples generated using

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### Large Models Lack Common Sense: GPT-3

**Bold = prompt written by human** *Italic = completion written by GPT-3* 

At the party, I poured myself a glass of lemonade, but it turned out to be too sour, so I added a little sugar. I didn't see a spoon handy, so I stirred it with a paper napkin. But that turned out to be a bad idea because the napkin disintegrated in the glass. After I finished the drink, I threw the napkin away in a wastebasket—but when I picked up the glass to wash it out, there was a big black spot on my hand.

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Source:

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### Large Models Lack Common Sense

Open question: Can large models learn common sense about the world from lots of (internet) data? Or are there fundamental limitations?



## Bigger Models, More Data, More Compute, More problems

- ML Systems can encode bias
- Large models can lack common sense
- Who should control models and data?

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## Who should control data?

Image copyright != Consent to use in a dataset

Birhane and Prabhu, "Large Image Datasets: A Pyrrhic Win for Computer Vision?", WACV 2021

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# Who should control data?

Image copyright != Consent to use in a dataset



### "One in two American adults is in a law enforcement face recognition network."

Birhane and Prabhu, "Large Image Datasets: A Pyrrhic Win for Computer Vision?", WACV 2021 Garvie, Bedoya, and Frankle: "The Perpetual Line-Up", 2016, https://www.perpetuallineup.org/

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## Who should control models?

The largest models can only be trained by large non-academic institutions. Is this a problem?

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## Who should control models?

The largest models can only be trained by large non-academic institutions. Is this a problem?

Should governments regulate the use of ML-based solutions?

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## Bigger Models, More Data, More Compute

What's the most critical bottleneck in a long run? model? data? compute?

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## Bigger Models, More Data, More Compute

I vote for data

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# Why data?

- The data we used to train Large Language Model
  - web crawl data
  - Github
  - Wikipedia
  - Books
  - $\circ$  Arxiv
  - StackExchange
  - 0 .....

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# Why data?

- The data we used to train Large Language Model
  - web crawl data
  - Github
  - Wikipedia The internet isn't big enough to provide all
  - Books the data we need
  - Arxiv
  - StackExchange
  - 0

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# Why data?



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## Solutions?

- Start over, find something else as data-efficient as human
  - human don't need the internet-scale data to be intelligent
  - but we haven't figured out exactly why

## • Synthetic data

- $\circ$  the power of compositionality
- the power of programing
- $\circ$  the power of trained models

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## Synthetic data: the power of compositionality



https://arxiv.org/pdf/2402.01103

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# Synthetic data

- generate synthetic data that ensures balanced distribution
- generate synthetic data programmatically as we like and scale up





Question : How many white step stool are there in the image?

Choices : 2, 5, 7, 6

Answer :2



Question : How many brown clock are there in the image?

Choices : 3, 7, 4, 1

Answer :3



Question : How many wood highchair are there in the image?

Chocies : 3, 1, 2, 4

Answer : 3

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demo: https://youtu.be/6tgspeI-GHY

### About Infinigen

Infinigen is a procedural generator of 3D scenes, developed by Princeton Vision & Learning Lab. Infinigen is optimized for computer vision research and generates diverse high-quality 3D training data. Infinigen is based on Blender and is free and open-source (BSD 3-Clause License). Infinigen is being actively developed to expand its capabilities and coverage. Everyone is welcome to contribute.

#### Posts from @PrincetonVL



Princeton Vision & Lea @Prir · Dec 15, 2023 Infinigen v1.1.1 is out: updated to Blender3.6 and revamped installation to be more robust. See github.com/princeton-vl/i... for more, including our "minimal" install variant which lets you

https://infinigen.org/

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Follow

Task: Move the laptop to the bed and the bowl to the kitchen.



https://aihabitat.org/partnr/

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An example conversation on solving a reasoning problem between two agents

Beliefs of the agents

# Using synthetic conversations to improve social reasoning and collaborative skills of LLMs

https://ai.meta.com/research/publications/collaborative-reasoner-self-improving-social-agents-with-synthetic-conversations/

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# Synthetic data

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- generate synthetic data that ensures balanced distribution
- generate synthetic data programmatically as we like and scale up

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• let weaker model supervise strong model

### Meta uses LLama 2 to help data filtering for LLama 3

To ensure Llama 3 is trained on data of the highest quality, we developed a series of datafiltering pipelines. These pipelines include using heuristic filters, NSFW filters, semantic deduplication approaches, and text classifiers to predict data quality. We found that previous generations of Llama are surprisingly good at identifying high-quality data, hence we used Llama 2 to generate the training data for the text-quality classifiers that are powering Llama 3.

https://ai.meta.com/blog/meta-llama-3/

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## OpenAI trained Sora with model-generated video captions

#### Language understanding

Training text-to-video generation systems requires a large amount of videos with corresponding text captions. We apply the re-captioning technique introduced in DALL·E 3<sup>so</sup> to videos. We first train a highly descriptive captioner model and then use it to produce text captions for all videos in our training set. We find that training on highly descriptive video captions improves text fidelity as well as the overall quality of videos.

https://openai.com/index/video-generation-models-as-world-simulators/

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OpenAI. https://openai.com/index/weak-to-strong-generalization/

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We can significantly improve generalization in many settings. We use a simple method that encourages the strong model to be more confident—including confidently disagreeing with the weak supervisor if necessary. When we supervise GPT-4 with a GPT-2-level model using this method on NLP tasks, the resulting model typically performs somewhere between GPT-3 and GPT-3.5. We are able to recover much of GPT-4's capabilities with only much weaker supervision.

OpenAI. https://openai.com/index/weak-to-strong-generalization/

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# **Data-centric AI**

## **Introduction to Data-Centric Al**

#### MIT

## https://dcai.csail.mit.edu/

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## Deep Learning is Here to Stay

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# Deep Learning is Here to Stay and will impact more than computer vision

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# Deep Learning for Computer Science

**Traditional Hash Table** 



Learn to assign keys to buckets in a way that minimizes hash collisions for the types of data you encounter

Kraska et al, "The Case for Learned Index Structures", SIGMOD 2018

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# **Deep Learning for Mathematics**

Convert mathematical expressions into graphs, process then with graph neural networks!



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# Applications: Theorem proving, symbolic integration

Wang et al, "Premise Selection for Theorem Proving by Deep Graph Embedding", NeurIPS 2017 Kaliszyk et al, "Reinforcement Learning of Theorem Proving", NeurIPS 2018 Ruta Desain Chungrhiangymbolic Mathematics", artiecture 19 - 82

# Deep Learning for Graphics: NVIDIA DLSS



https://www.nvidia.com/en-us/geforce/news/nvidia-dlss-2-0-a-big-leap-in-ai-rendering/

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# Deep Learning for Science: Protein Folding



**Input**: 1D sequence of amino acids

#### Output: 3D protein structure

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# Deep Learning for Science: AlphaFold 2 and Protein Language Models



https://deepmind.com/blog/article/alphafold-a-solution-to-a-50-year-old-grand-challenge-in-biology

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# Deep Learning for Science: Open Catalyst

#### Meta | Carnegie Mellon University

## **Open Catalyst Project**

Using AI to model and discover new catalysts to address the energy challenges posed by climate change.



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# Deep Learning for Ecology: Wildlife understanding and tracking <sup>a</sup> Carolina were (N = 2083) <sup>b</sup> Carolina were (N = 2083) <sup>c</sup> Carolin



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# Deep Learning for AI Research: AI scientist

#### The AI Scientist: Towards Fully Automated Open-Ended Scientific Discovery

**Chris Lu**<sup>1,2,\*</sup>, **Cong Lu**<sup>3,4,\*</sup>, **Robert Tjarko Lange**<sup>1,\*</sup>, **Jakob Foerster**<sup>2,†</sup>, **Jeff Clune**<sup>3,4,5,†</sup> **and David Ha**<sup>1,†</sup> \*Equal Contribution, <sup>1</sup>Sakana AI, <sup>2</sup>FLAIR, University of Oxford, <sup>3</sup>University of British Columbia, <sup>4</sup>Vector Institute, <sup>5</sup>Canada CIFAR AI Chair, <sup>†</sup>Equal Advising

One of the grand challenges of artificial general intelligence is developing agents capable of conducting scientific research and discovering new knowledge. While frontier models have already been used as aides to human scientists, e.g. for brainstorming ideas, writing code, or prediction tasks, they still conduct only a small part of the scientific process. This paper presents the first comprehensive framework for fully automatic scientific discovery, enabling frontier large language models (LLMs) to perform research independently and communicate their findings. We introduce THE AI SCIENTIST, which generates novel research ideas, writes code, executes experiments, visualizes results, describes its findings by writing a full scientific paper, and then runs a simulated review process for evaluation. In principle, this process can be repeated to iteratively develop ideas in an open-ended fashion and add them to a growing archive of knowledge, acting like the human scientific community. We demonstrate the versatility of this approach by applying it to three distinct subfields of machine learning: diffusion modeling, transformer-based language modeling, and learning dynamics. Each idea is implemented and developed into a full paper at a meager cost of less than \$15 per paper, illustrating the potential for our framework to democratize research and significantly accelerate scientific progress. To evaluate the generated papers, we design and validate an automated reviewer, which we show achieves near-human performance in evaluating paper scores. THE AI SCIENTIST can produce papers that exceed the acceptance threshold at a top machine learning conference as judged by our automated reviewer. This approach signifies the beginning of a new era in scientific discovery in machine learning: bringing the transformative benefits of AI agents to the entire research process of AI itself, and taking us closer to a world where endless affordable creativity and innovation can be unleashed on the world's most challenging problems. Our code is open-sourced at https://github.com/SakanaAI/AI-Scientist.





June 4, 2025

Sep 2024

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# **Computer Vision and Deep Learning Can**

## Better Our Lives

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## **Computer Vision and Deep Learning Can**

## Better Our Lives

Now is a great time to be working in

computer vision and deep learning!

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# The End!

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