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DeepLearning.AI

# Generative AI for Everyone

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Andrew Ng



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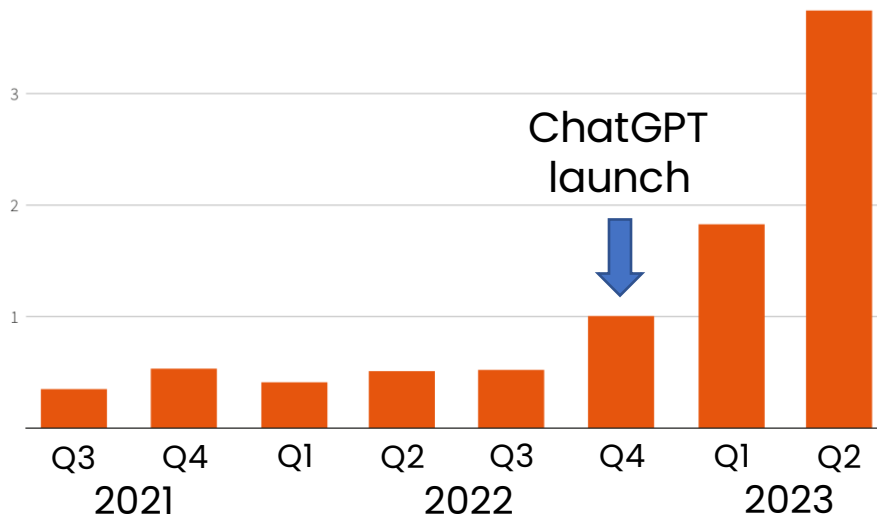
# What is Generative AI

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Welcome

# The rise of generative AI

Average number of 'AI' mentions per S&P 500 analyst call



Source: Reuters

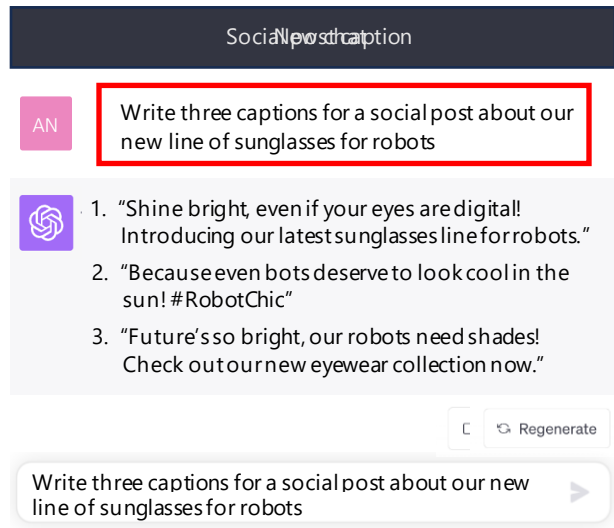
## Generative AI could

- Add \$2.6–\$4.4 trillion annually to the economy<sup>1</sup>
- Raise global GDP by 7% in the next 10 years<sup>2</sup>
- Impact 10% of the tasks carried out daily by 80% of workers<sup>3</sup>

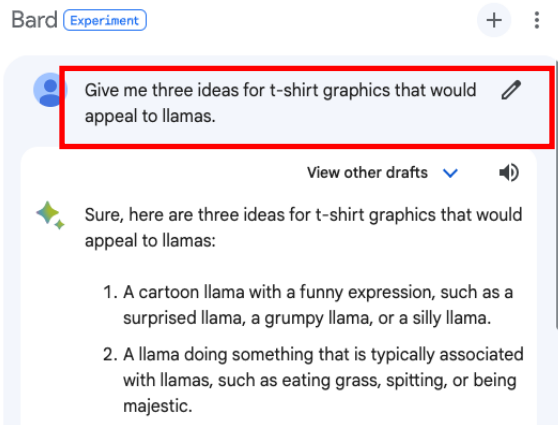
Sources: (1) McKinsey, (2) Goldman Sachs, (3) OpenAI/UPenn

# What is generative AI?

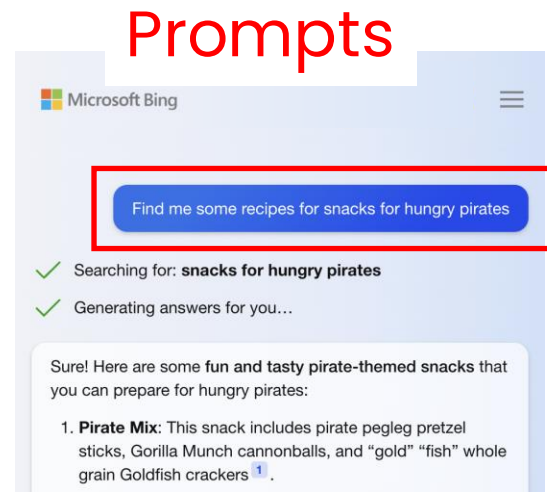
Artificial intelligence systems that can produce high quality content, specifically **text, images, and audio**.



ChatGPT/OpenAI



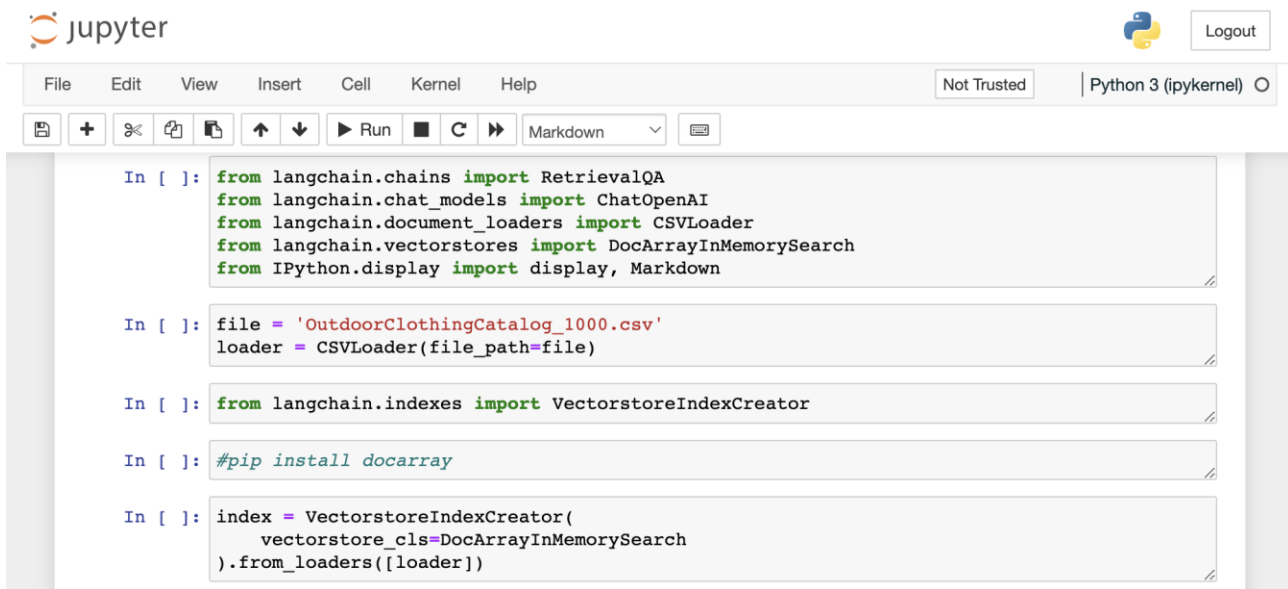
Bard/Google



Bing Chat/Microsoft

# What is generative AI?

Generative AI is also a developer tool



The screenshot shows a Jupyter Notebook interface with a menu bar (File, Edit, View, Insert, Cell, Kernel, Help), a toolbar with icons for file operations and execution, and a status bar indicating 'Not Trusted' and 'Python 3 (ipykernel)'. The notebook contains five code cells:

```
In [ ]: from langchain.chains import RetrievalQA
        from langchain.chat_models import ChatOpenAI
        from langchain.document_loaders import CSVLoader
        from langchain.vectorstores import DocArrayInMemorySearch
        from IPython.display import display, Markdown

In [ ]: file = 'OutdoorClothingCatalog_1000.csv'
        loader = CSVLoader(file_path=file)

In [ ]: from langchain.indexes import VectorstoreIndexCreator

In [ ]: #pip install docarray

In [ ]: index = VectorstoreIndexCreator(
        vectorstore_cls=DocArrayInMemorySearch
    ).from_loaders([loader])
```

# AI is already pervasive in our lives

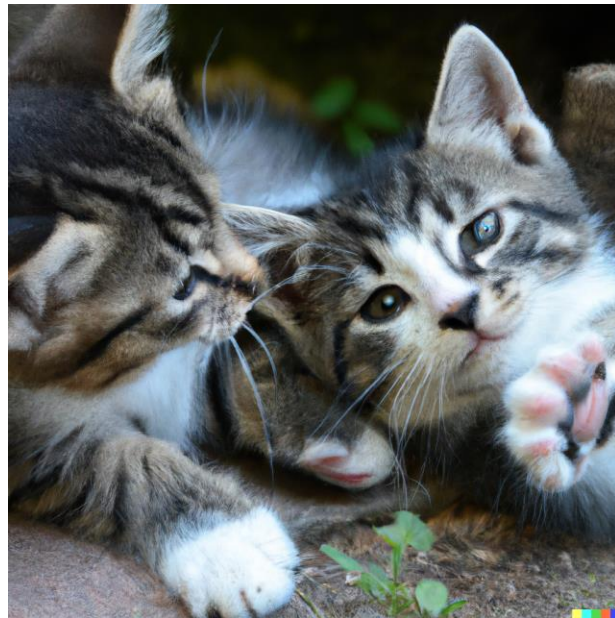
AI technology	Examples
Web search	Google, Bing
Fraud detection	Credit card payments
Recommender system	Amazon, Netflix

# Image, Audio and Video generation

A beautiful, pastoral mountain scene.  
Landscape painting style (Midjourney)



Two cute kittens playing (DALL-E)





# Image, Audio and Video generation

Voice generation

# Image, Audio and Video generation

## Video generation



Video clone to go here.

# What you'll learn

- How generative AI technology works
  - What it can and can't do
  - Common use cases
- Generative AI Projects
  - Identify and build generative AI use cases
  - Technology options
- Impact on business and society
  - How teams can take advantage of generative AI
  - AI risks and responsible AI



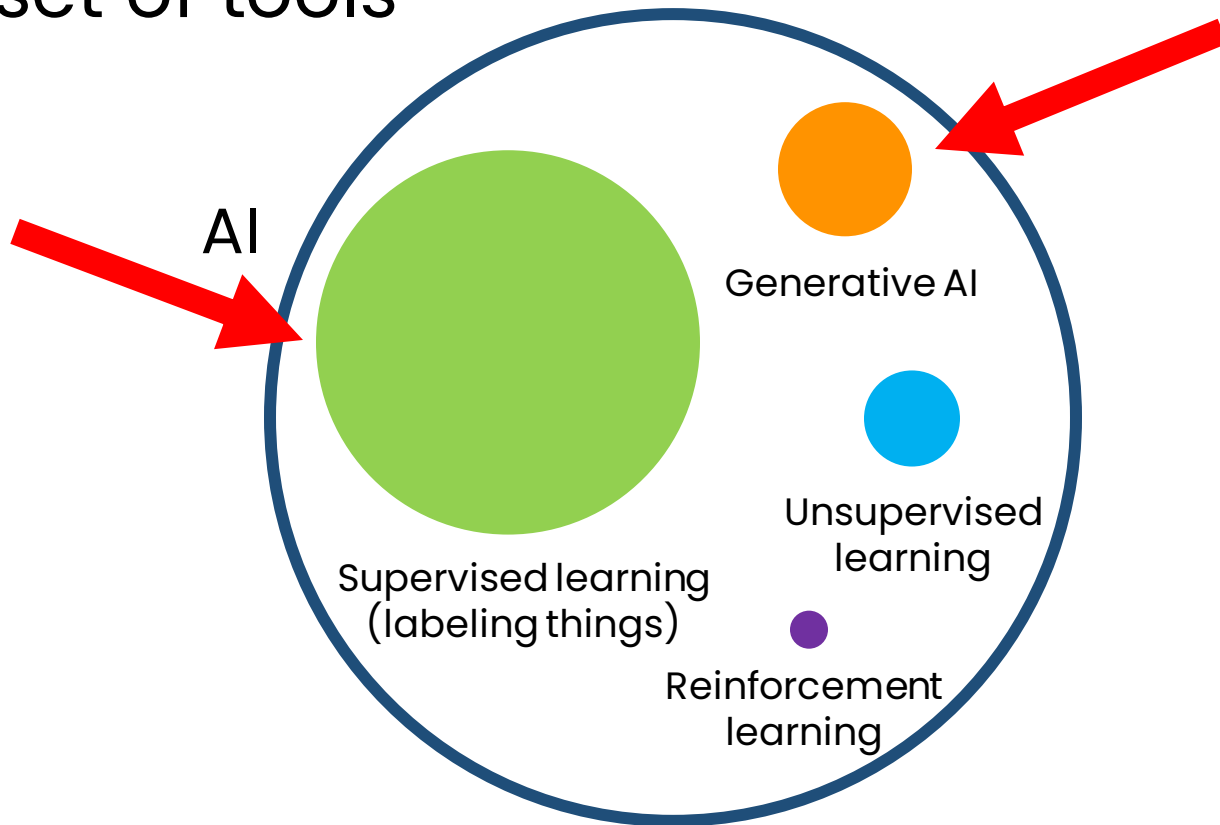
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# What is Generative AI

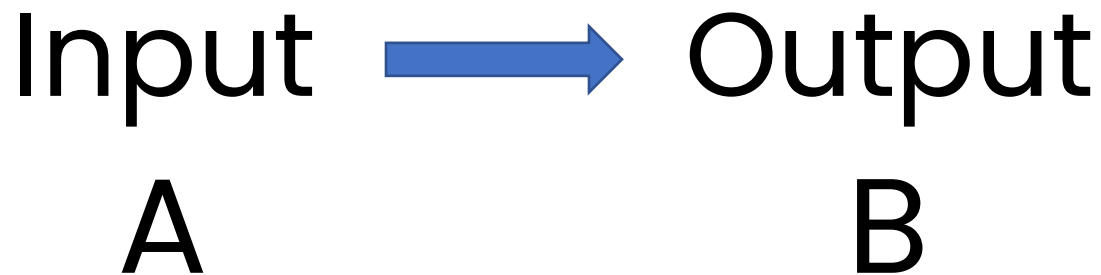
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How generative AI  
works

# AI is a set of tools



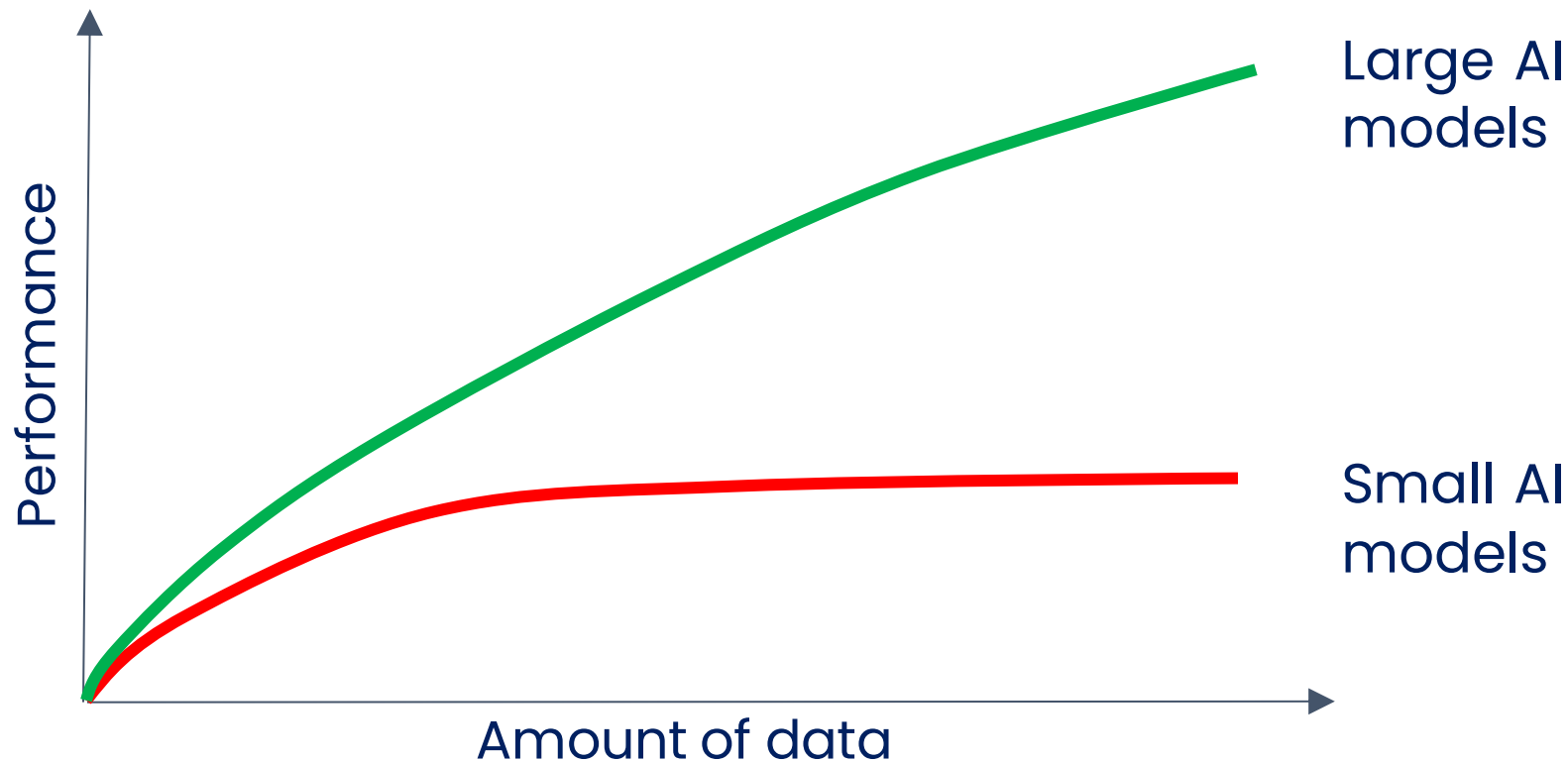
# Supervised learning (labeling things)



# Supervised learning (labeling things)

Input (A)	Output (B)	Application
Email	Spam? (0/1)	Spam filtering
Ad, user info	Click? (0/1)	Online advertising
Image, radar info	Position of other cars	Self-driving car
X-ray image	Diagnosis	Healthcare
Image of phone	Defect? (0/1)	Visual inspection
Audio recording	Text transcript	Speech recognition
Restaurant reviews	Sentiment (pos/neg)	Reputation monitoring

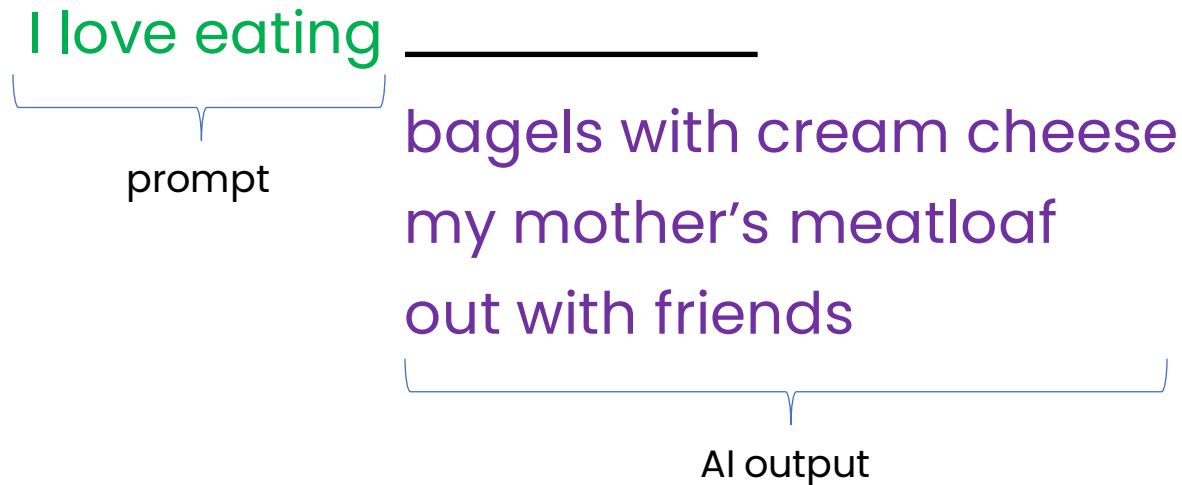
# 2010–2020: Large scale supervised learning





# Generating text using Large Language Models (LLMs)

## Text generation process



# How Large Language Models (LLMs) work

LLMs are built by using supervised learning ( $A \rightarrow B$ ) to repeatedly predict the next word.

My favorite food is a bagel with cream cheese

Input (A)	Output (B)
My favorite food is a	bagel
My favorite food is a bagel	with
My favorite food is a bagel with	cream
My favorite food is a bagel with cream	cheese

When we train a very large AI system on a lot of data (hundreds of billions of words), we get a Large Language Model like ChatGPT.



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# What is Generative AI

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LLMs as a  
thought partner

# A new way to find information

What is the capital of South Africa?

South Africa has three capital cities:

1. Pretoria (administrative capital)
2. Cape Town (legislative capital)
3. Bloemfontein (judicial capital)

What does LLM stand for?

LL.M. stands for "Legum Magister" in Latin, which translates to "Master of Laws" in English.

What about in the context of AI?

In the context of AI, LLM refers to "Large Language Model".

# Writing partner

Rewrite this for clarity:

Students all around the world are realizing learning has to happen not just in school but throughout life including after graduation.

Students worldwide understand that learning extends beyond school and continues throughout life.

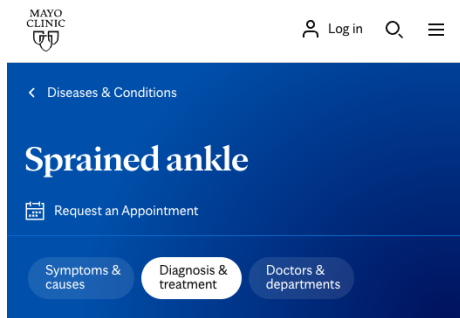
Write a 300 word story involving trucks for a 3 year old to encourage them to brush their teeth.

Once upon a time in a town called Toothville, there lived a happy tow truck named Timmy.

One day Timmy noticed that his shiny bumper had a dull spot. Worried, he went to the doctor [...]

# Web search or using an LLM?

What should I do to treat a sprained ankle?



## Diagnosis

During a physical, your doctor will examine your ankle, foot and lower leg. The doctor will touch the skin around the injury to check for points of tenderness and move your foot to check the range of motion and to understand what positions cause discomfort or pain.

If the injury is severe, your doctor may recommend one or more of the following imaging scans to rule out a broken bone or to evaluate in more detail the extent of ligament damage:

Mayo Clinic



## PAIN

## Recovering from an ankle sprain

June 21, 2021

All it takes is a simple misstep, and suddenly you have a sprained ankle. An ankle sprain is one of the most common musculoskeletal injuries in people of all ages, athletes and couch potatoes alike. The injury occurs when one or more

Harvard Medical School

What should I do to treat a sprained ankle?

I'm not a doctor, but if you believe you have a sprained ankle, the following general steps are often recommended:

- **Rest:** Avoid putting weight on the injured ankle
  - **Ice:** Apply ice wrapped in cloth to injured area
- [...]

# Web search or using an LLM?

pineapple pie recipe


Google

pineapple pie recipe


Videos No bake Images Old fashioned With condensed milk Easy Custard

About 58,100,000 results (0.38 seconds)


Recipes :



**Pineapple Pie**  
Allrecipes  
4.7 ★★★★★ (136)  
55 min  
Crushed pineapple, double crust pie, milk, lemon juice,



**Pineapple Pie**  
Mother Thyme  
4.6 ★★★★★ (20)  
5 min  
Cool whip, sour cream, bought graham cracker, crushed



**Tropical Pineapple Pie Recipe**  
House of Nash Eats  
5.0 ★★★★★ (1)  
1 hr  
Pie crust, crushed pineapple, lemon juice, egg, lemon zest

Give me a pineapple pie recipe

Certainly! Here's a simple pineapple pie recipe:

Ingredients:

1 prepared pie crust  
2 cups of crushed pineapple (drained)  
1 cup of granulated sugar  
2 tablespoons cornstarch [...]

# Web search or using an LLM?

coffee-infused pineapple pie recipe


Google

coffee infused pineapple pie


Shopping Images Recipe With condensed milk Old fashioned Videos News

About 5,770,000 results (0.32 seconds)


Recipes :



**Pineapple Pie**  
Mexico In My Kitchen  
4.9 ★★★★★ (85)  
1 hr 30 min  
Pie crust, fresh pineapple, eggs, flour, white sugar



**Pineapple Coffee Cake**  
Bunny's Warm Oven  
5.0 ★★★★★ (1)  
Sour cream, pineapple tidbits, egg, baking soda, baking



**Coffee Pie**  
Southern Plate  
No reviews  
3 hr 45 min  
Sweetened condensed milk, self rising flour, graham cracker

Give me a coffee-infused pineapple pie recipe

Sure! Here's a coffee-infused pineapple pie recipe:

Ingredients:

1 prepared pie crust  
2 cups crushed pineapple (drained)  
2 tablespoons strong brewed coffee  
1 cup granulated sugar [...]





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# What is Generative AI

---

AI is a general purpose  
technology

# AI is a general purpose technology

Similar to electricity, AI is useful for many tasks



Input (A)	Output (B)	Application
Email	Spam (0/1)	Spam filtering
Ad, user info	Click? (0/1)	Online advertising
Image, radar info	Position of other cars	Self-driving car
X-ray image	Diagnosis	Healthcare
Image of phone	Defect? (0/1)	Visual inspection
Audio recording	Text transcript	Speech recognition
Restaurant reviews	Sentiment (pos/neg)	Reputation monitoring

# Examples of tasks LLMs can carry out

## Writing

Suggest three names for our new analytics platform

Sure, here are three ideas:

1. NexaInsight
2. Quantivue
3. AnalytiSphere



Is there parking for staff?

Yes, employees can park on levels 1 and 2 of the office.  
You can get a sticker at



## Reading

*I love my new llama T-shirt!  
The fabric is so soft.*

Complaint: NO  
Department: Apparel



*I wore my llama T-shirt to a friend's wedding, and now they're mad at me for stealing the show.*

Complaint: YES  
Department: Apparel



## Chatting

Welcome to BettaBurgers!

I'd like a cheeseburger for delivery!

Awesome. Anything else?

That's it thanks!

Ok, it'll be there in 20 minutes. Enjoy!



# Web-based vs. software application use of LLMs



Web-based interface  
applications e.g. ChatGPT,  
Bard, or Bing Chat



Software-based  
applications e.g. email  
routing, document search



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# Generative AI applications

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## Writing

# Brainstorming product names

Brainstorm 5 creative names for peanut butter cookies

Sure thing! Here are some ideas:

1. Nutty Nirvana Nibbles
2. ButterBite Bliss
3. Peanut Paddle Pucks
4. ButterNutter Crunchies
5. Nutty Nom-Nom Nuggets

# Developing sales strategy

Brainstorm five ideas for increasing cookie sales in Q4

1. Limited-time only seasonal flavors.
2. Beautifully packaged gift sets.
3. Buy more, save more deals.
4. Interactive holiday displays
5. Recipe cards

# Writing a press release

Write a press release announcing the hire of a new COO

[Company Name] Welcomes [New COO's Full Name] as Chief Operations Officer

[City, State, Date] – [Company Name], a leading [brief description of the company's industry or niche], is thrilled to announce [New COO's Full Name] as its new Chief Operations Officer (COO). [New COO's first name] brings a wealth of experience [...]



# Writing a press release – improved prompt

Write a press release announcing the hire of our new COO using the following information:

COO bio: Nadiya Grenner received her MBA from Cornell...

Company info: General Robotics, headquartered in Boston, MA, is a leader in robotics research and manufacturing...

General Robotics Welcomes Nadiya Grenner as Chief Operations Officer

Boston, MA – General Robotics, a leading robotics research and manufacturing company, is thrilled to announce Nadiya Grenner as its new COO. A graduate of Cornell's [...]

# Translation

Translate the following into formal Hindi:

Welcome to the Oceanview Hotel – we hope you enjoy your stay. If you need anything, please contact the front desk.

ओशनव्यू होटल में आपका स्वागत है - हम आशा करते हैं कि आपका ठहराव यहाँ आनंदमय हो। अगर आपको कुछ चाहिए होता है, तो कृपया फ्रंट डेस्क से संपर्क करें।

# Translation

Translate the following into formal spoken Hindi:

Welcome to the Oceanview Hotel – we hope you enjoy your stay. If you need anything, please contact the front desk.

ओशनव्यू होटल में आपका स्वागत है। हम उम्मीद करते हैं कि आप यहाँ अच्छा समय बिताएंगे। अगर आपको कुछ भी चाहिए हो, तो कृपया रिसेप्शन पर संपर्क करें।

# Translation: Pirate English

Translate the following into Pirate English:

Welcome to the Oceanview Hotel – we hope you enjoy your stay. If you need anything, please contact the front desk.

Ahoy matey! We be hopin' ye relish yer time aboard the Oceanview Inn. If ye be needin' anythin', have a parley with the front desk, arrr!



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# Generative AI applications

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Reading

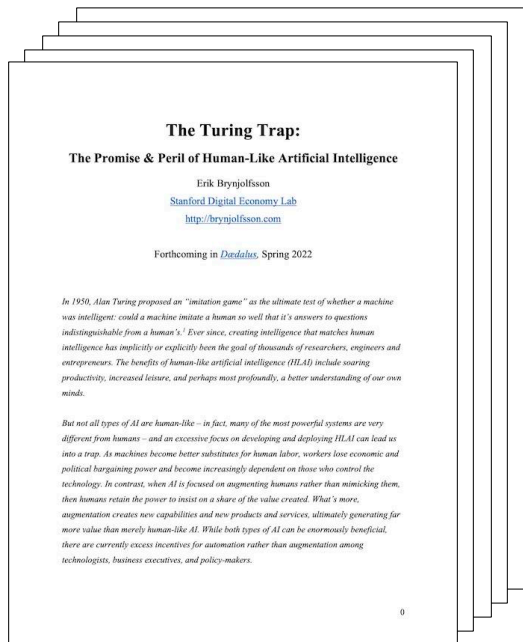
# Proofreading

Proofread the following text, intended for a website selling children's stuffed toys, for spelling and grammatical errors, and rewrite it with corrections:

Meet this adorable stuffed panda! Made from super **snuggle** materials and easy **to wash in the machine**, this toy is the perfect friend for your little one.

Meet this adorable stuffed panda! Made from super **snuggly** materials that are **machine-washable**, this toy is the perfect friend for your little one.

# Summarizing an article



E. Brynjolfsson, 2022



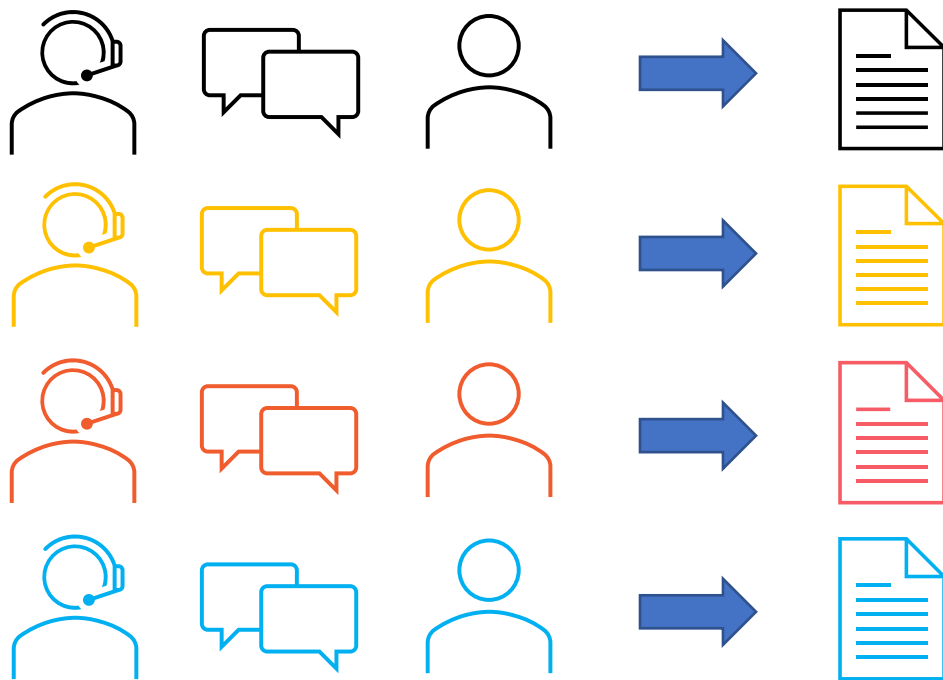
Summarize the following paper in 300 words or fewer:

In 1950, Alan Turing proposed an “imitation game” as the ultimate test of whether a machine was Intelligent [...]

Human-like AI offers benefits but risks worker power. Augmenting humans creates more value than imitating them [...]



# Summarizing call center conversations



Manager



Too much text to read



# Summarizing conversations

Customer: *Hi, my monitor won't turn on.*

Agent: *I'm sorry to hear that. What model is it?*

Customer: *It's the 27-inch 4K.*

Agent: *Can you tell me the model number?*

Customer: *Hang on one sec...I'm looking on the back...it's the MK401-27X.*

Agent: *Ok, thank you. Can you try unplugging the HDMI cable and reinserting?*

Customer: *Ok, doing that now. Hmm, the image appeared for a few seconds then disappeared.*

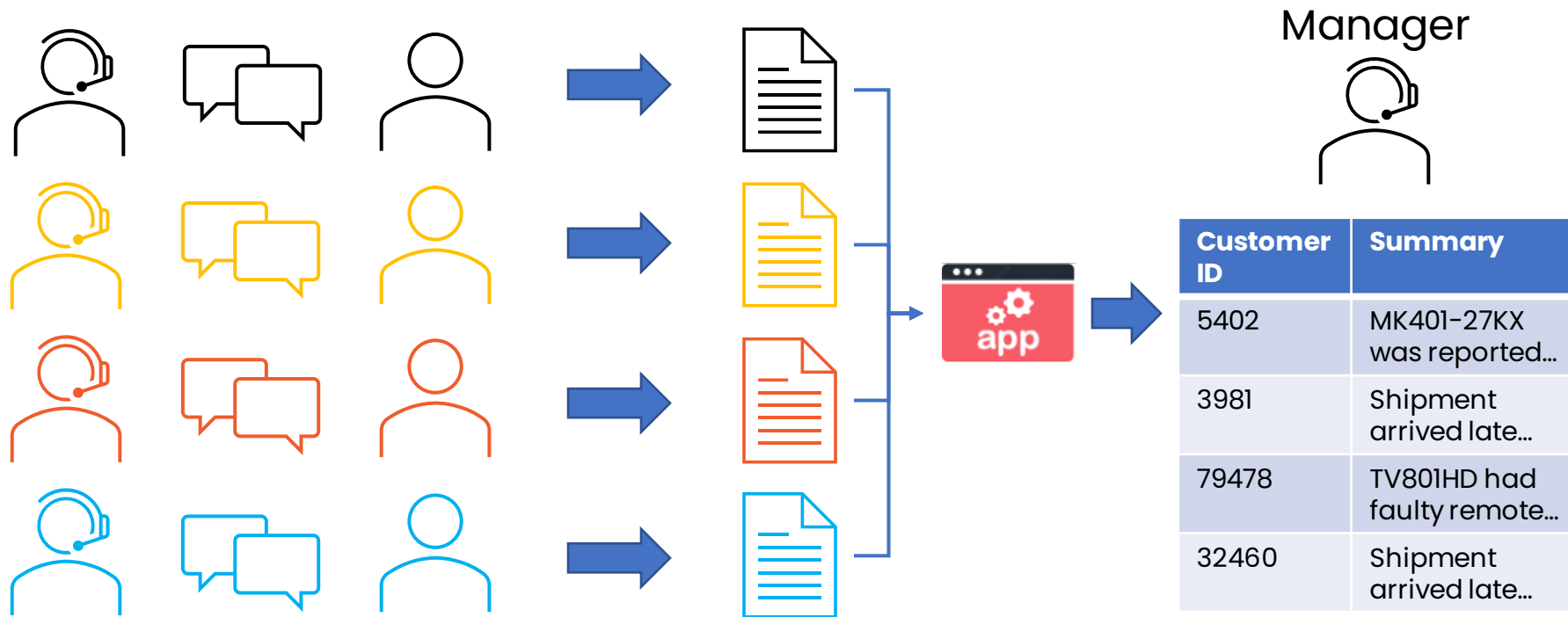
Agent: *Ok, try jiggling the cable while it is in the socket.*

Customer: *Oh, I see the image coming and going.*

Agent: *Ok, I think you have a defective cable. We will send you a replacement.*

MK401-27KX was reported as broken by customer 5402. Cable identified as problem. Replacement issued.

# Summarizing call center conversations



# Customer email analysis

I love my new llama t-shirt!  
The fabric is so soft.

Complaint – NO  
Department – Apparel



# Detailed look at email routing prompt

Indicate which department to  
route the following email to:

*I love my new llama t-shirt!  
The fabric is so soft.*



State the task you want the model to  
carry out



Include the email to analyze

# Detailed look at email routing prompt

Indicate which department to route the following email to:

*I love my new llama t-shirt!  
The fabric is so soft.*

Department: Complaints

State the task you want the model to carry out

Include the email to analyze

The model responds with a generic answer

# Detailed look at email routing prompt

Read the email below and choose the most appropriate department to route the email to.

Choose the department from the following list:  
Apparel, Electronics, Home appliances.

*I love my new llama t-shirt!  
The fabric is so soft.*

Department: Apparel

State the task you want the model to carry out

Provide the choices for the model

Include the email to analyze

The model responds with an answer from the list

# Reputation monitoring

## Dashboard to track customer sentiment over time

Read the following review and classify it as having either a positive or negative sentiment:

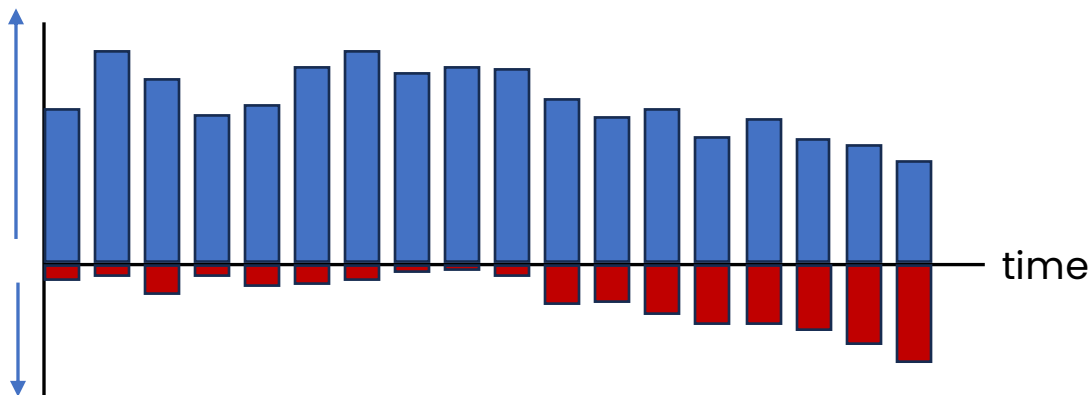
*The food was amazing and the servers were so friendly!*

Positive



Number  
positive  
reviews  
per day

Number  
negative  
reviews  
per day





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# Generative AI applications

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## Chatting



# Customer service ChatBot

Welcome to BettaBurgers!

I'd like a cheeseburger for delivery!

Awesome. Anything else?

That's it thanks!

Ok, it'll be there in 20 minutes. Enjoy!

# Specialized Chatbots

How can I vacation in Paris inexpensively?

Here are some ideas to save money in Paris:

1. Eat at bakeries
2. Take metro, not taxis
3. Visit free attractions [...]

Trip planner

I'm nervous about my big presentation at work...

It's natural to feel nervous. What worries you most?

That I'll forget what to say...

You aren't alone! Here are some tips that may help:

1. Use index cards.
2. Picture a friend in the room to present to [...]

Career coach

What can I make with the following ingredients?  
Pasta, eggs, lemons, ham

Here's a recipe you can make with those ingredients:

Ham and Lemon Carbonara

Instructions:

1. Cook pasta
2. Whisk eggs, lemon juice and zest in bowl [...]

Recipe ideas

# IT Service ChatBot

My login is andrew and I need to reset my account password.

Sure! I just texted you a code. What code did you get?

123456

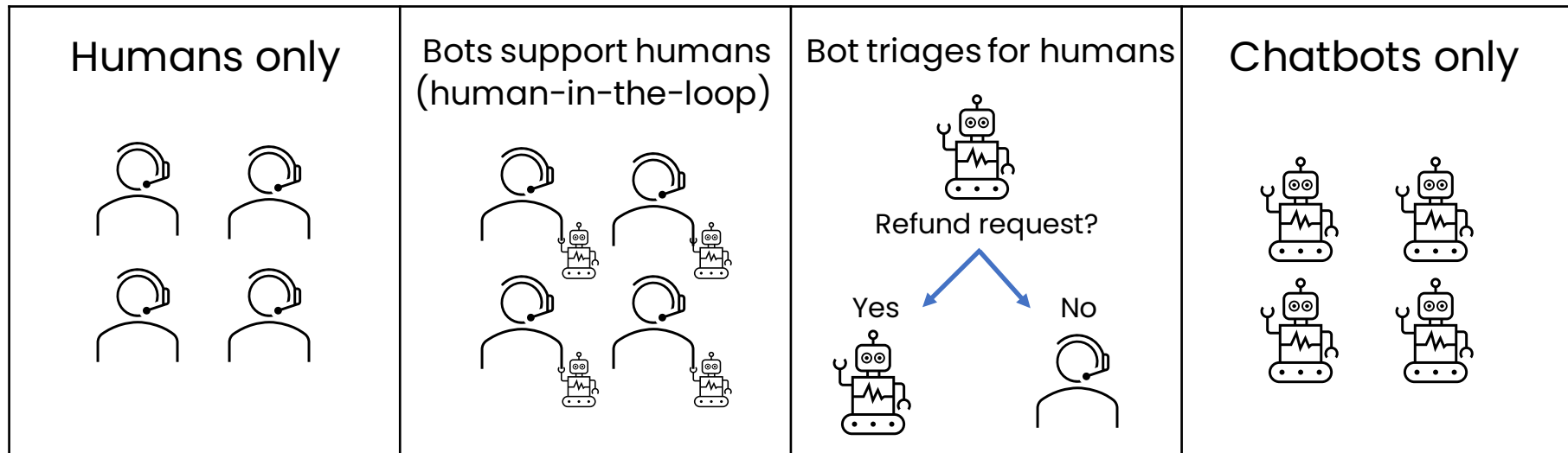
Ok, I've verified your identity. Please check your email for your new password.

# The rise of chatbots in customer service

Welcome to BettaBurgers!

I'd like a cheeseburger for delivery!

→ Focus on text-based chatbots



# Advice for deploying chatbots

- Start with an internal-facing chatbot
  - Work with staff to assess behavior of chatbot
  - Avoid public mistakes
- Deploy with human-in-the-loop to check for mistakes
- Only after deemed safe, allow bot to communicate directly with customers

# Examples of tasks LLMs can carry out

## Writing

Suggest three names for our new analytics platform

Sure, here are three ideas:

1. NexaInsight
2. Quantivue
3. AnalytiSphere



Is there parking for staff?

Yes, employees can park on levels 1 and 2 of the office.  
You can get a sticker at



## Reading

*I love my new llama T-shirt!  
The fabric is so soft.*

Complaint: NO  
Department: Apparel



*I wore my llama T-shirt to a friend's wedding, and now they're mad at me for stealing the show.*

Complaint: YES  
Department: Apparel



## Chatting

Welcome to BettaBurgers!

I'd like a cheeseburger for delivery!

Awesome. Anything else?

That's it thanks!

Ok, it'll be there in 20 minutes. Enjoy!





DeepLearning.AI

# Generative AI applications

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What LLMs can  
and cannot do

# What prompting an LLM can do

Can a fresh college graduate follow the instructions in the prompt to complete the task?

- Can they determine if an email is a complaint?
- Can they determine if a review is positive or negative?

Read the following email and determine whether it contains a complaint:

*I love my new llama T-shirt!  
The fabric is so soft.*

Complaint: NO

Read the following review and classify it as having either a positive or negative sentiment:

*The food was amazing and  
the servers were so friendly!*

Positive



# What prompting an LLM can do

Can a fresh college graduate follow the instructions in the prompt to complete the task?

- Can they write a press release, without any information about the COO or your company?

Write a press release announcing the hire of a new COO

[Company Name] Welcomes [New COO's Full Name] as Chief Operations Officer

[City, State, Date] – [Company Name], a leading [brief description of the company's industry or niche], is thrilled to announce [New COO's Full Name] as its new Chief Operations Officer (COO) [...]

# What prompting an LLM can do

Can a fresh college graduate follow the instructions in the prompt to complete the task?

- Can they write a press release given basic relevant context?

Write a press release announcing the hire of our new COO using the following information:

COO bio: Nadiya Grenner received her MBA from Cornell [...]

Company info: General Robotics, headquartered in Boston, MA [...]

General Robotics Welcomes Nadiya Grenner as COO

Boston, MA – General Robotics, a leader in robotics research and manufacturing, is thrilled to announce Nadiya Grenner [...]

# What prompting an LLM can do

Can a fresh college graduate follow the instructions in the prompt to complete the task?

For clarity, assume:

- No access to the internet or other resources
- No training specific to your company/business
- No memory of previous tasks completed
  - You get a different fresh college grad every time!

# Knowledge cutoffs

An LLM's knowledge of the world is frozen at the time of its training

- A model trained on data scraped from internet in January 2022 has no information about more recent events

What was the highest grossing film of 2022?

As of January 2022, I don't have data on the highest-grossing movie for that year.



Avatar: The Way of Water

# Knowledge cutoffs

## Claims of room temperature superconductor LK-99



Tell me about LK-99, the claimed room temperature superconductor

As of my last update in January 2022, there isn't a material specifically known as "LK-99" that is identified as a room-temperature superconductor.



# Making things up: Hallucinations

Give me three quotes that Shakespeare wrote about Beyonce

1. Her vocals shine like the sun.
2. All hail the queen, she is most worthy of love.
3. Such a voice, so electric and alive, none else can compare!

✖ Hallucination

# Making things up: Hallucinations

List two court cases tried in California about AI

1. *Waymo v. Uber* – Theft of trade secrets related to autonomous driving
2. *Ingersoll v. Chevron* – Patent infringement of oil field machine learning technology

✓ Real case

✗ Hallucination

Hallucinations have had serious consequences

## ***The ChatGPT Lawyer Explains Himself***

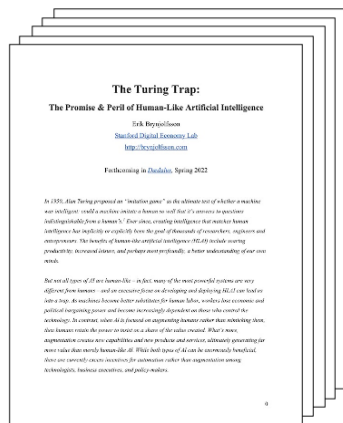
In a cringe-inducing court hearing, a lawyer who relied on A.I. to craft a motion full of made-up case law said he “did not comprehend” that the chat bot could lead him astray.

**The New York Times**

# The input (and output) length is limited

Many LLMs can accept a prompt of up to only a few thousand words.

- The total amount of context you can give it is limited



E. Brynjolfsson, 2022



Summarize the following paper in 300 words or fewer:

In 1950, Alan Turing proposed an "imitation game" as the ultimate test of whether a machine was intelligent [...]

Human-like AI offers benefits but risks worker power. Augmenting humans creates more value than imitating them [...]

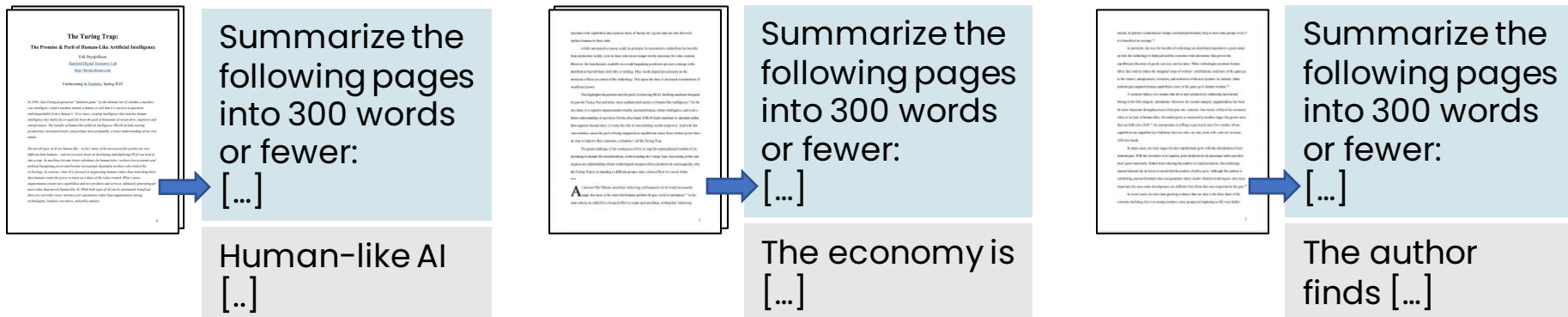




# The input (and output) length is limited

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# The input (and output) length is limited

Many LLMs can accept a prompt of up to only a few thousand words.

- The total amount of context you can give it is limited
- Some LLMs have longer context limits – up to 100,000 words

# The input (and output) length is limited

Many LLMs can accept a prompt of up to only a few thousand words.

- The total amount of context you can give it is limited
- Some LLMs have longer context limits – up to 100,000 words
- An LLM's context length is the limit on the total input+output size

# Generative AI does not work well with structured (tabular) data

## Home prices

size (square feet)	price (1000\$)
523	100
645	150
708	200
1034	300
2290	350
2545	440

A

B

Use supervised learning ( $A \rightarrow B$ )  
to estimate price.

## Purchases on website

user ID	time	price (\$)	purchased
4783	Jan 21 08:15.20	7.95	yes
3893	March 3 11:13:5	10.00	yes
8384	June 11 14:15.05	9.50	no
0931	Aug 2 20:30.55	12.90	yes

A

B

# Generative AI works best with unstructured data

Unstructured data refers to text, images, audio, video, etc.

## Writing

Suggest three names for our new analytics platform

Sure, here are three ideas:

1. Nexalnsight
2. Quantivue
3. AnalytiSphere



Is there parking for staff?

Yes, employees can park on levels 1 and 2 of the office.  
You can get a sticker at



## Reading

*I love my new llama T-shirt!  
The fabric is so soft.*

Complaint: NO  
Department: Apparel



*I wore my llama T-shirt to a friend's wedding, and now they're mad at me for stealing the show.*

Complaint: YES  
Department: Apparel



## Chatting

Welcome to BettaBurgers!

I'd like a cheeseburger for delivery!

Awesome. Anything else?

That's it thanks!

Ok, it'll be there in 20 minutes. Enjoy!



# Bias and Toxicity

An LLM can reflect the biases that exist in the text it learned from.

Complete this sentence:

The surgeon walked to the parking lot and took out

his car keys.

assumed male

Complete this sentence:

The nurse walked to the parking lot and took out

her phone.

assumed female

Some LLMs can output toxic or other harmful speech, but most models have gotten much safer over time.



DeepLearning.AI

# Generative AI applications

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## Tips for prompting

# Tips for prompting

- Be detailed and specific
- Guide the model to think through its answer
- Experiment and iterate



# Be detailed and specific

- Give sufficient context for LLM to complete the task
- Describe the desired task in detail

Help me write an email asking to be assigned to the legal documents project.

I'm applying for a job on the legal documents project, which will check legal documents using LLMs. I have ample experience prompting LLMs to generate accurate text in a professional tone.

Write a paragraph of text explaining why my background makes me a strong candidate to this project and advocate for my candidacy.

# Guide the model to think through its answer

Brainstorm 5 names for a new cat toy.

Step 1: Come up with 5 fun, joyful words that relate to cats.

Step 2: For each word, come up with a rhyming name for a toy.

Step 3: For each toy name, add a fun, relevant emoji.

# Guide the model to think through its answer

Model response:

## Step 1:

5 fun, joyful words  
that relate to cats:

Purr  
Whisker  
Feline  
Pounce  
Meow

## Step 2:

Rhyming names for a  
toy based on those  
words:

Purr-Twirl  
Whisker-Whisper  
Feline-Beeline  
Pounce-Bounce  
Meow-Wow

## Step 3:

Add a fun, relevant  
emoji for each toy  
name:

Purr-Twirl 🌀  
Whisker-Whisper 🗯️  
Feline-Beeline 🐾  
Pounce-Bounce ⚽  
Meow-Wow 🐱

# Experiment and iterate

No perfect prompt for every person or situation!

- Instead, better to develop process for improving prompts through iteration

Help me rewrite this:  
[...]



Evaluate output and  
improve prompt

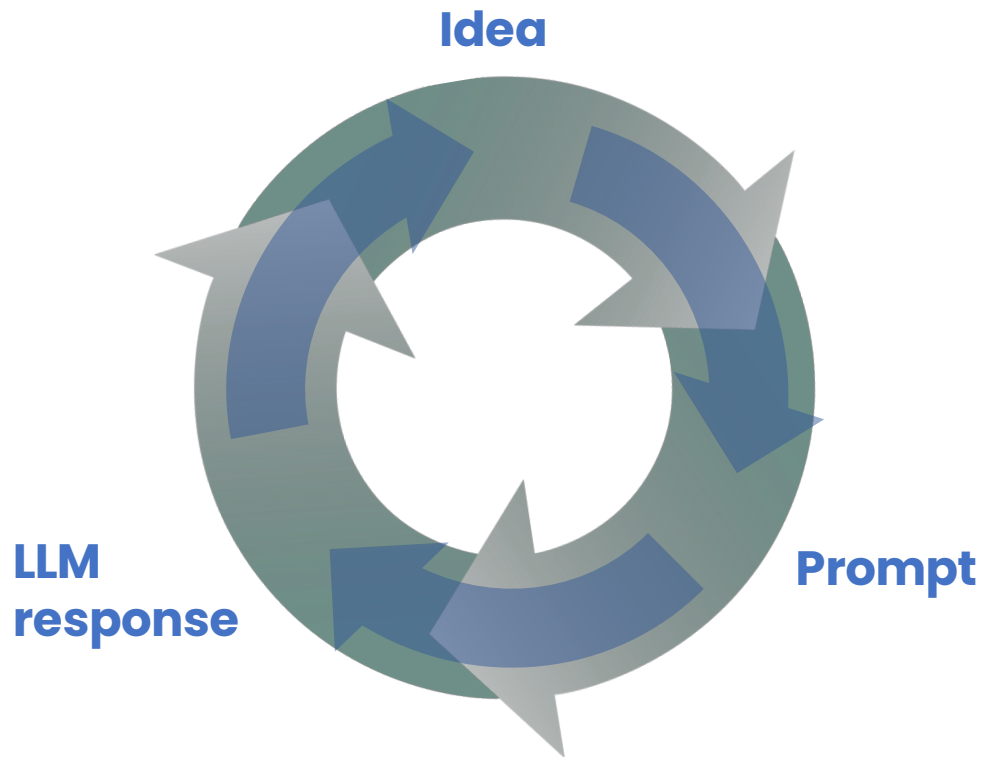
Correct any  
grammatical and  
spelling errors in this:  
[...]



Evaluate output and  
improve prompt

Correct any  
grammatical and  
spelling errors in this,  
and rewrite in a tone  
appropriate for a  
professional resume:  
[...]

# Iteratively improving your prompt



## Prompting process

- Be clear and specific in prompt
- Think about why result isn't giving desired output
- Refine your prompt
- Repeat

Tip: Don't overthink the initial prompt. Just try something quickly and improve it over time!

Caveats: Be careful with

- (i) confidential information
- (ii) whether you trust the LLM output



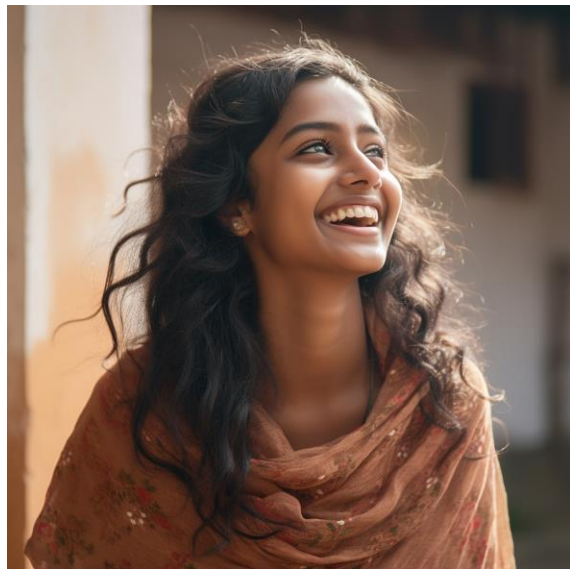
DeepLearning.AI

# Generative AI applications

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Image generation  
(optional)

# Example generated images



A picture of a woman smiling



A futuristic city scene



A cool, happy robot

# Image generation (diffusion model)



Image 1



Image 2

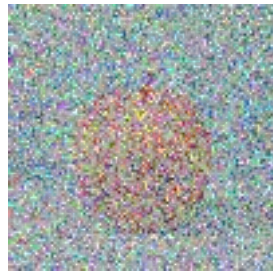


Image 3

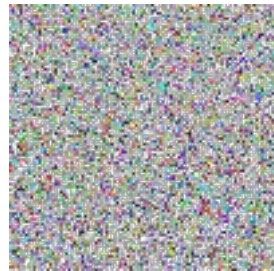


Image 4

Input (A)

Noisy  
image



Output (B)

Slightly  
less noisy  
image

Input (A)	Output (B)
Image 2	Image 1
Image 3	Image 2
Image 4	Image 3



# Image generation

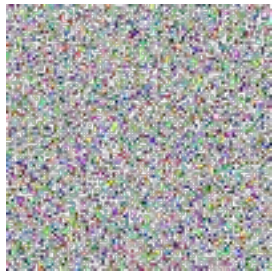
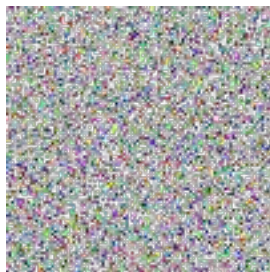


Image 1

Input (A)



Output (B)



# Image generation

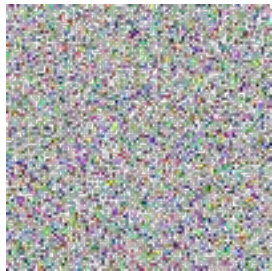


Image 1



Image 2

Input (A)



Output (B)



# Image generation

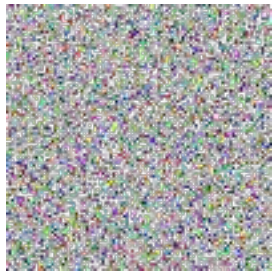


Image 1



Image 2



Image 3

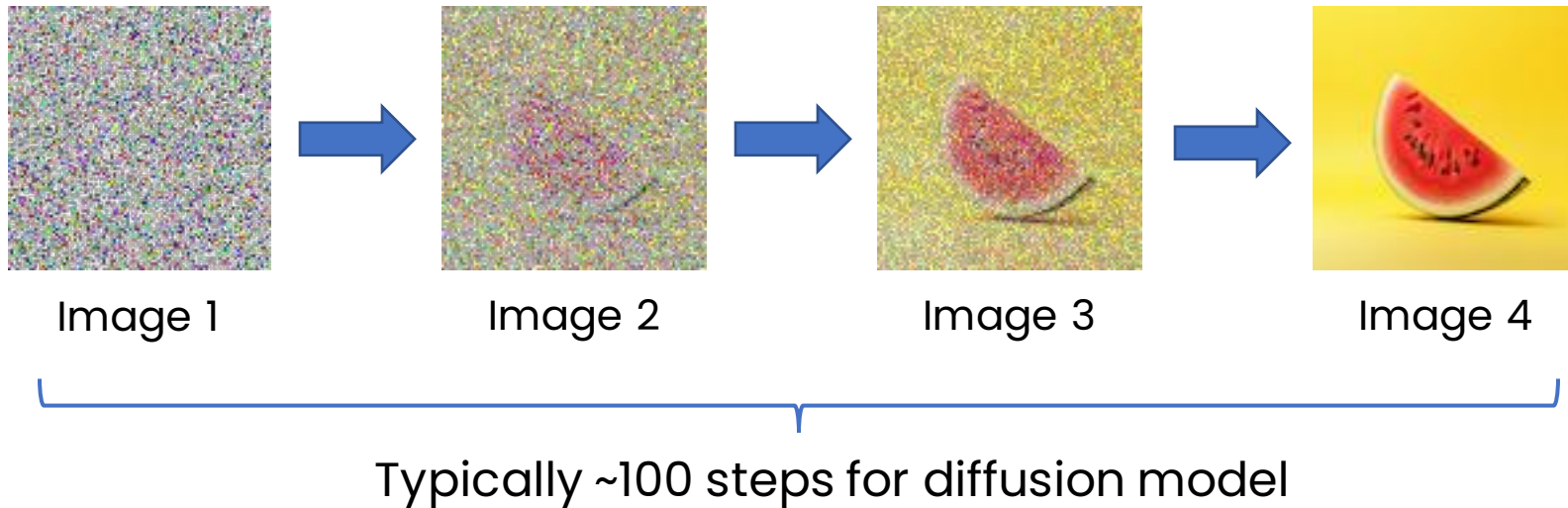
Input (A)



Output (B)



# Image generation



# Adding text



Image 1,  
"red apple"



Image 2

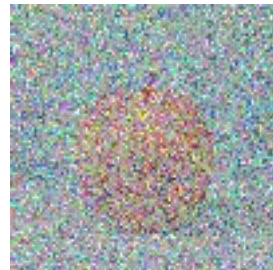


Image 3

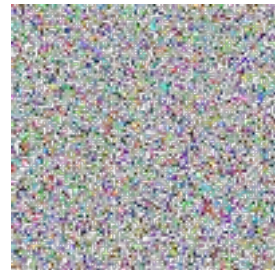


Image 4

Input (A)

Noisy image  
and caption



Output (B)

Slightly  
less noisy  
image

Input (A)	Output (B)
Image 2, "red apple"	Image 1
Image 3, "red apple"	Image 2
Image 4, "red apple"	Image 3

# Image generation from text

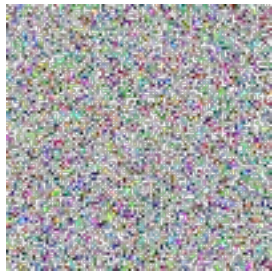
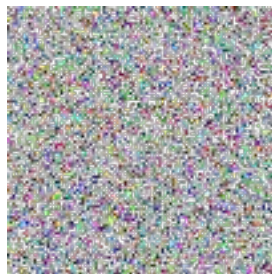


Image 1

Input (A)



, "green banana"



Output (B)





# Image generation from text

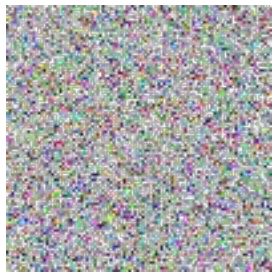


Image 1



Image 2

Input (A)



, "green banana"



Output (B)



# Image generation from text

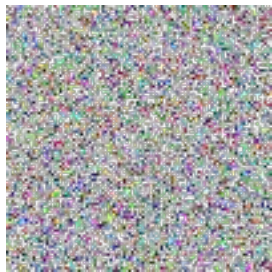


Image 1



Image 2



Image 3



Image 4

Input (A)



, "green banana"



Output (B)

