0. ORGANIZATION
1. DIGITAL TECHNOLOGIES
2. SENSORS
3. ACTUATORS
4. COMPUTER VISION
5. GENERATIVE AI
6. NATURAL LANGUAGE PROCESSING
7. USER INTERFACES
8. CLOUD SERVICES
9. DATABASES

The slides are meant as visual support for the lecture.
They are neither a documentation nor a script.

Please do not print the slides.

Comments and feedback at n.meseth@hs-osnabrueck.de

ORGANIZATION

BACK

ILIAS
Microsoft Teams

sessions

group work

examination

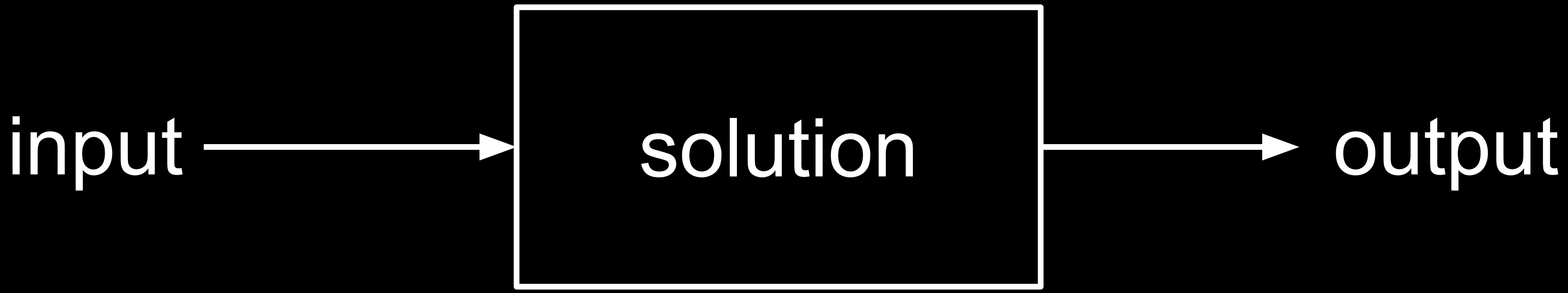
working environment

visual studio code
python
tinkerforge
git

DIGITAL TECHNOLOGIES

BACK

a model for solving problems



input

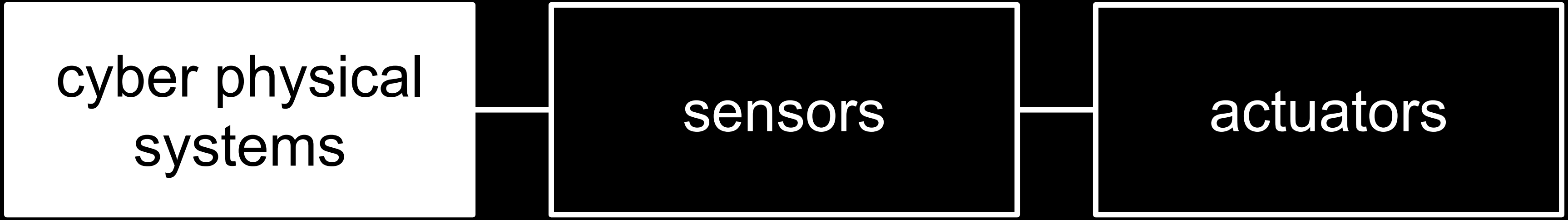
solution

output

cyber physical systems

artificial intelligence

software prototyping



cyber physical systems

sensors

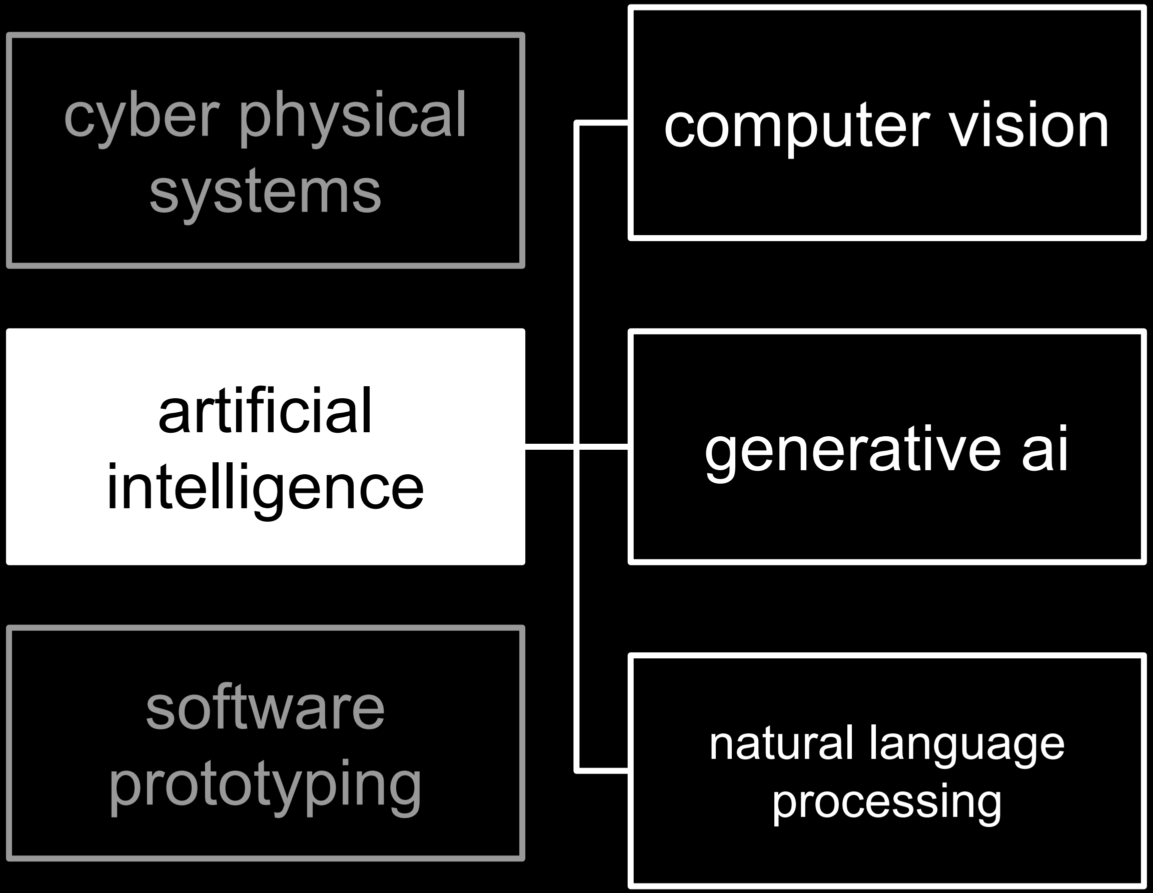
actuators

artificial intelligence

software prototyping

temperature
humidity
co2
uv light
ambient light
sound pressure
thermal image
camera
...

led
speaker
display
motor
…



cyber physical systems

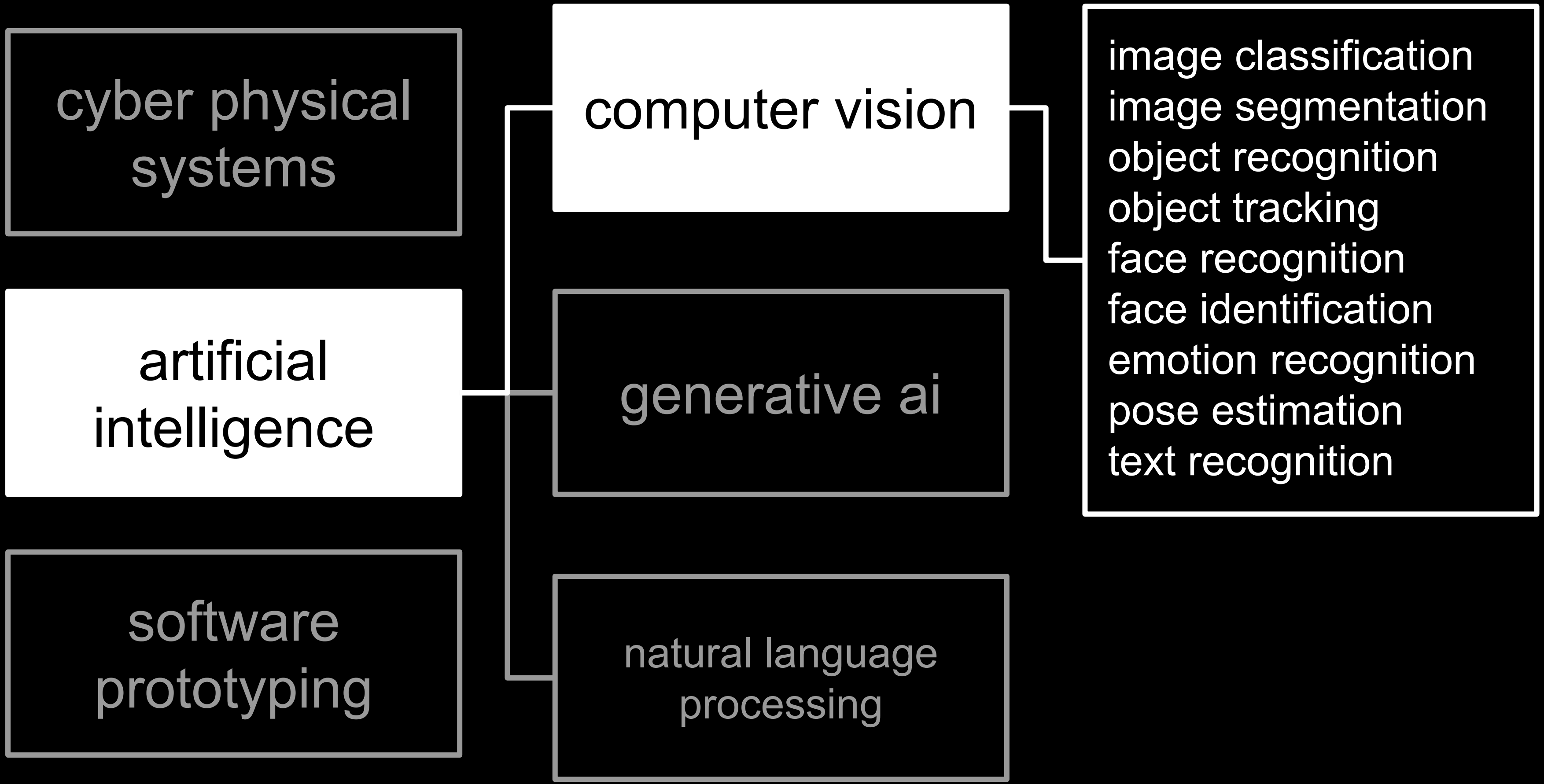
artificial intelligence

software prototyping

computer vision

generative ai

natural language processing



cyber physical systems

artificial intelligence

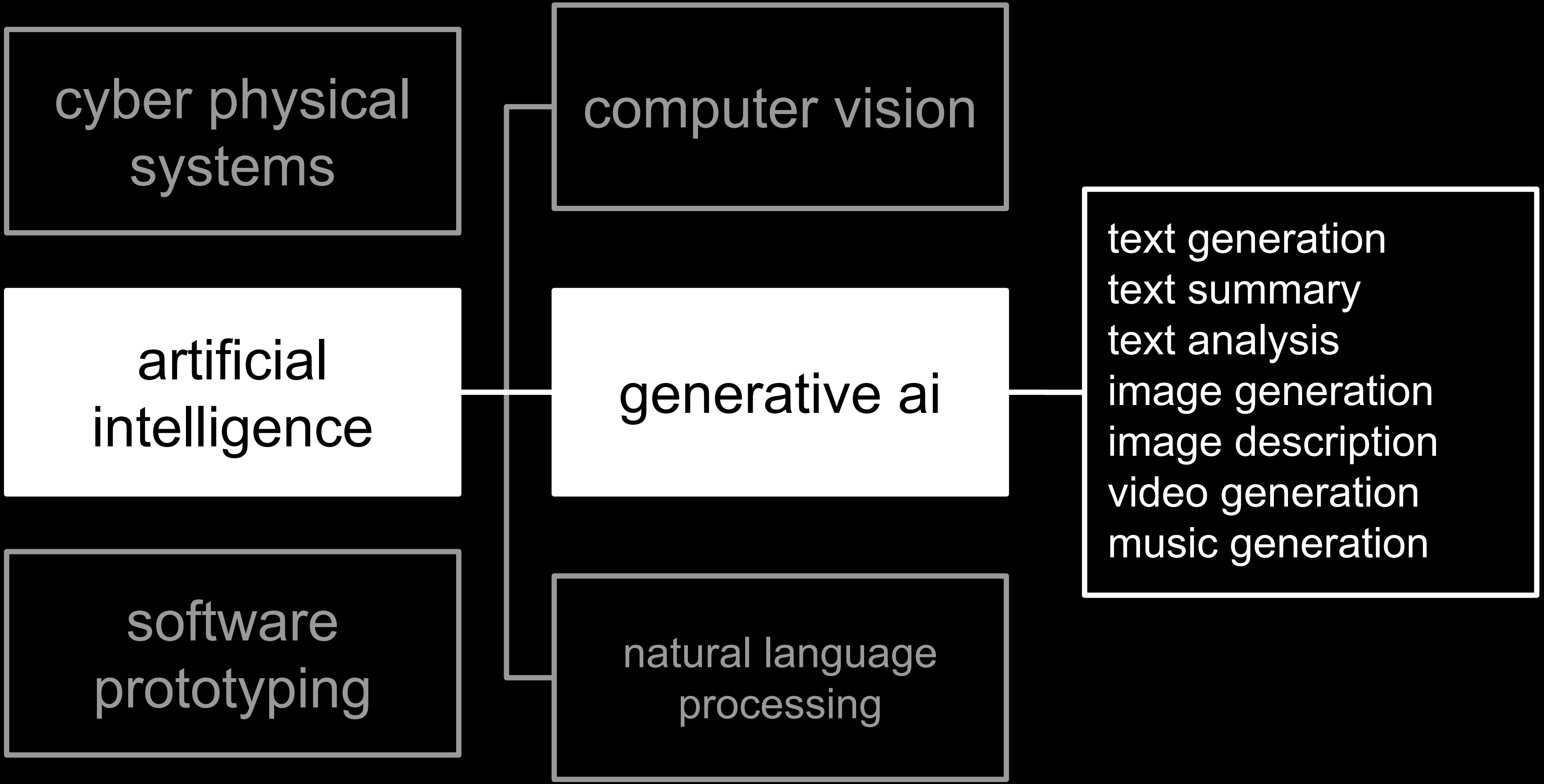
software prototyping

computer vision

generative ai

natural language processing

image classification
image segmentation
object recognition
object tracking
face recognition
face identification
emotion recognition
pose estimation
text recognition



cyber physical systems

artificial intelligence

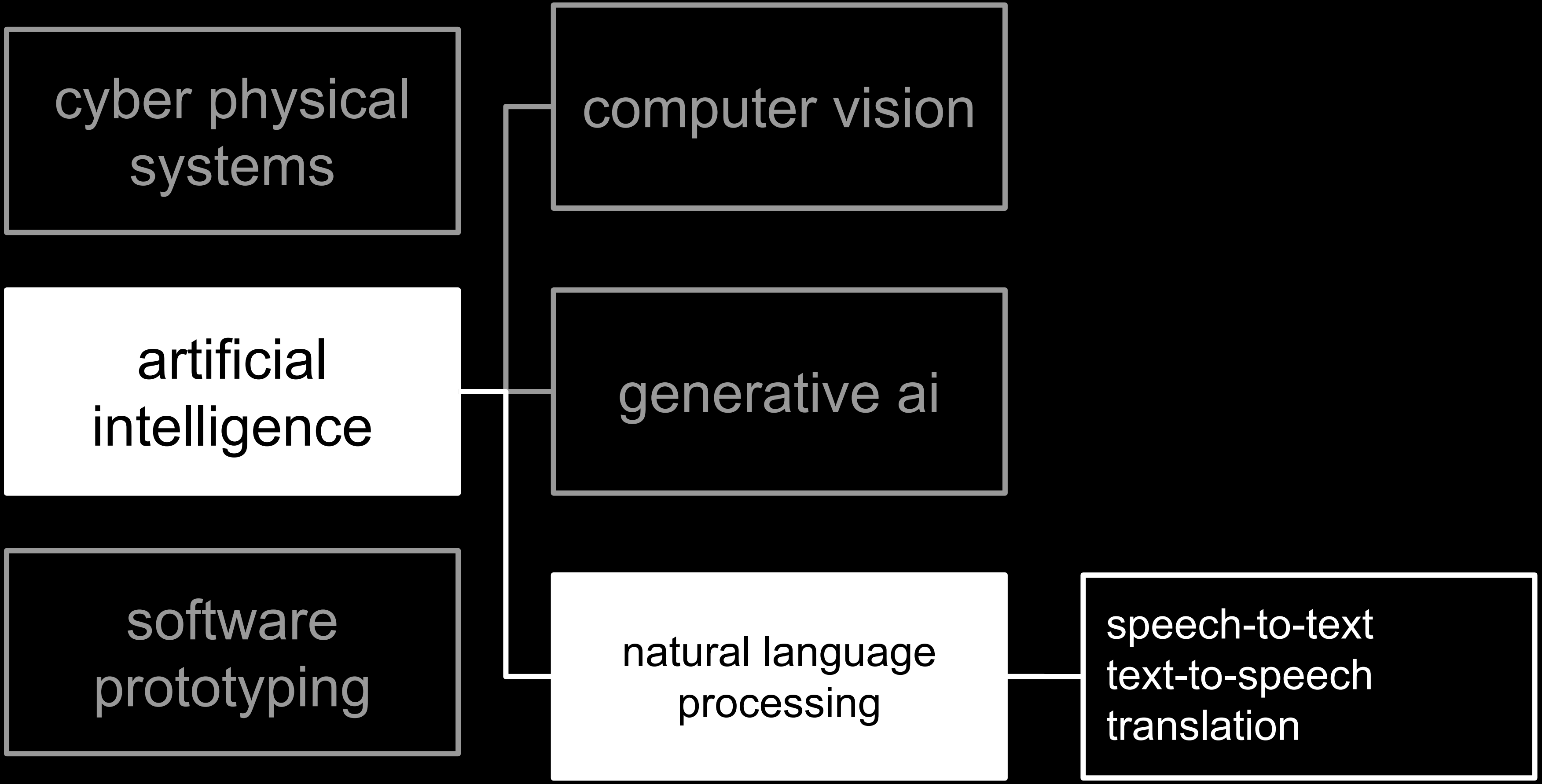
software prototyping

computer vision

generative ai

natural language processing

text generation
text summary
text analysis
image generation
image description
video generation
music generation



cyber physical systems

artificial intelligence

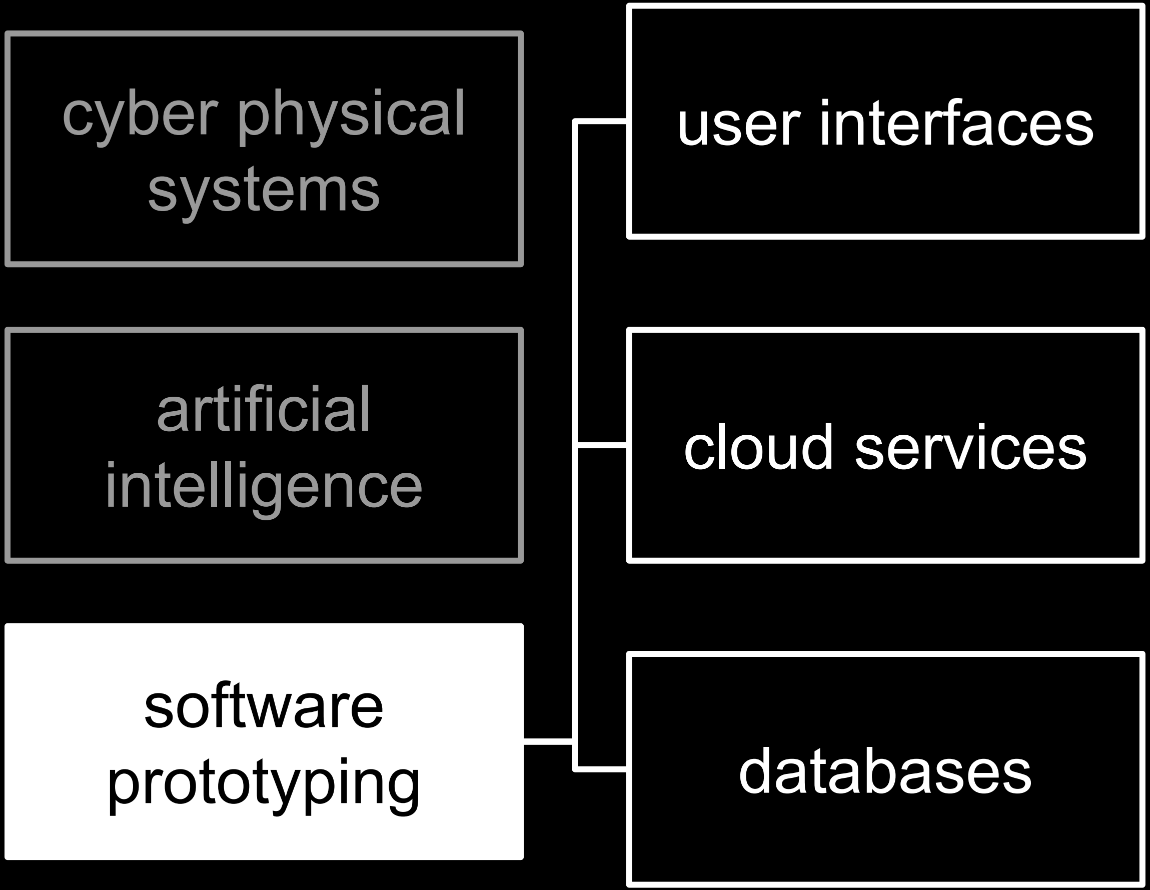
software prototyping

computer vision

generative ai

natural language processing

speech-to-text
text-to-speech
translation



cyber physical systems

artificial intelligence

software prototyping

user interfaces

cloud services

databases

introductory example

visual studio code
programs
python

LEDs

large language models

speech-to-text

user interface

SENSORS

temperature / humidity

rgb led button

camera

thermal imaging camera

microphone

keyboard

temperature / humidity

```
th = BrickletHumidityV2(UID, ipcon)…
```

```
th.get_humidity()

th.get_temperature()
th.register_callback(th.CALLBACK_HUMIDITY, cb_humidity)
th.register_callback(th.CALLBACK_TEMPERATURE, …)
th.set_humidity_callback_configuration(250, False, "x", 0, 0)
th.set_temperature_callback_configuration(...)
```

rgb led button

```
btn = BrickletRGBLEDButton(UID, ipcon)…
```

```
btn.set_color(255, 0, 0)
btn.get_button_state()
btn.register_callback(...)
```

camera

OpenCV

```
import cv2
```

```
# Get video capture device (webcam)
webcam = cv2.VideoCapture(0)
```

```
# Read a frame
success, frame = webcam.read()
```

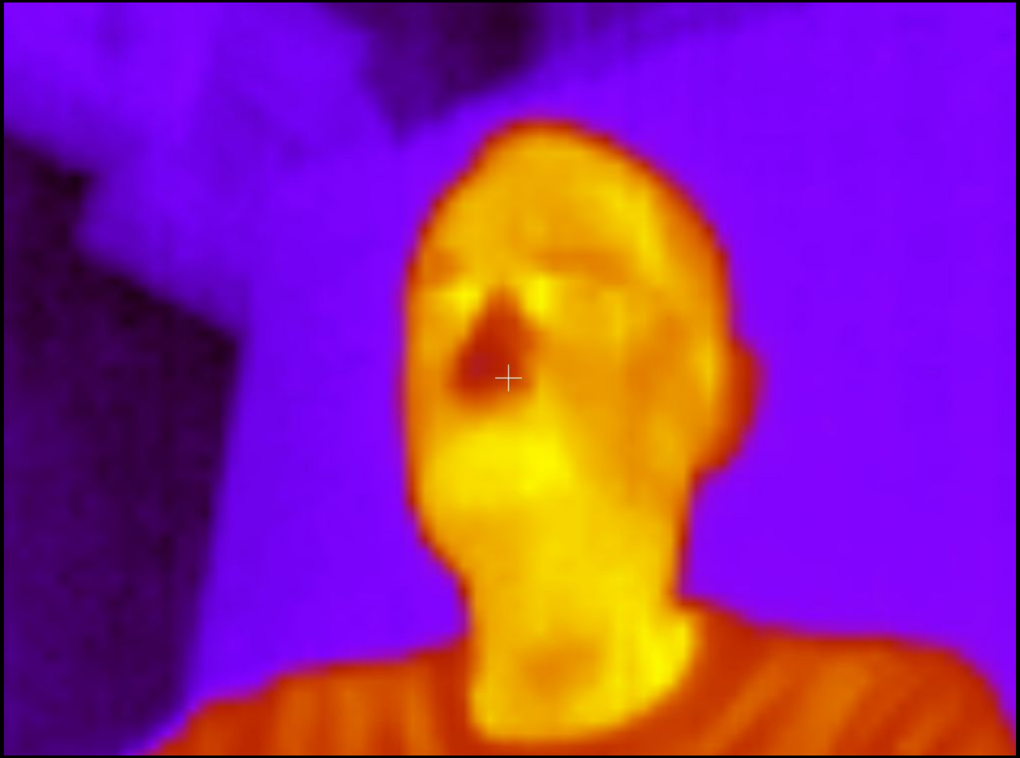
```
# Show the image from the frame
cv2.imshow("Webcam", frame)
```

```
# Save the frame as .png
cv2.imwrite("screenshot.png", frame)
```

thermal imaging camera

OpenCV

Tinkerforge



```
ti = BrickletThermalImaging(UID, ipcon)
ti.set_image_transfer_config(...)
img = ti.get_high_contrast_image()
```

```
ti.register_callback(...)
```

microphone

```python
import pyaudio
```

```python
# Define recording parameters
FORMAT = pyaudio.paInt16
CHANNELS = 1
RATE = 44100
CHUNK = 1024
```

```
# Get access to the microphone
audio = pyaudio.PyAudio()
```

```
# Start listening
stream = audio.open(...)
```

```
# Read a chunk of frames
stream.read(CHUNK)
```

```python
# Stop and close stream
stream.stop_stream()
stream.close()
```

```
# Terminate access to microphone
audio.terminate()
```

keyboard

```
import keyboard
```

```python
# Define a callback function for a key
def record_audio():
    print("Recording audio…")
```

```
# Add key listener
keyboard.add_hotkey("r", record_audio)
```

```python
# Wait until a specific key was pressed
keyboard.wait("esc")
```

ACTUATORS

rgb led

OLED display

speaker

rgb led

```
led = BrickletRGBLEDV2(UID, ipcon)

led.set_rgb_value(255, 0, 0)
```

OLED display

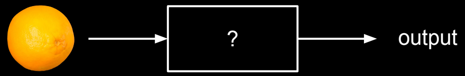
```
oled = BrickletOLED128x64V2(UID, ipcon)

oled.clear_display()

oled.write_line(0, 0, "Welcome!")
```

speaker

```
import simpleaudio as sa
```

```python
# Create a wave object from .wav-file and play it
wav = sa.WaveObject.from_wave_file("sound.wav")
wav.play().wait_done()
```

COMPUTER VISION



finding oranges in images

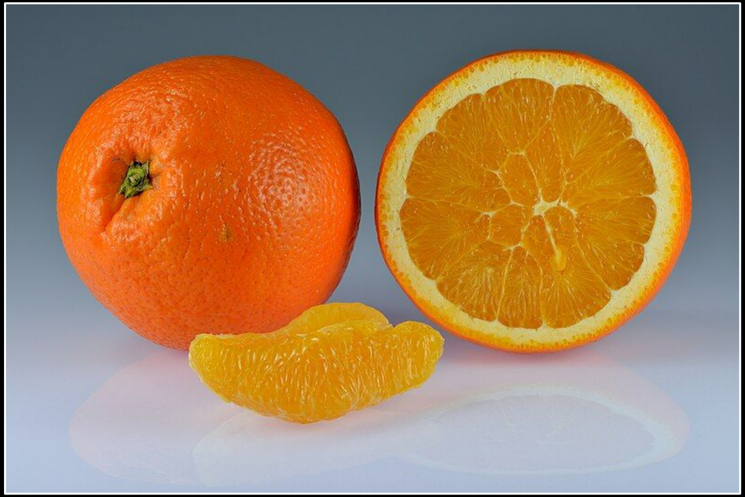


Image source: Wikimedia

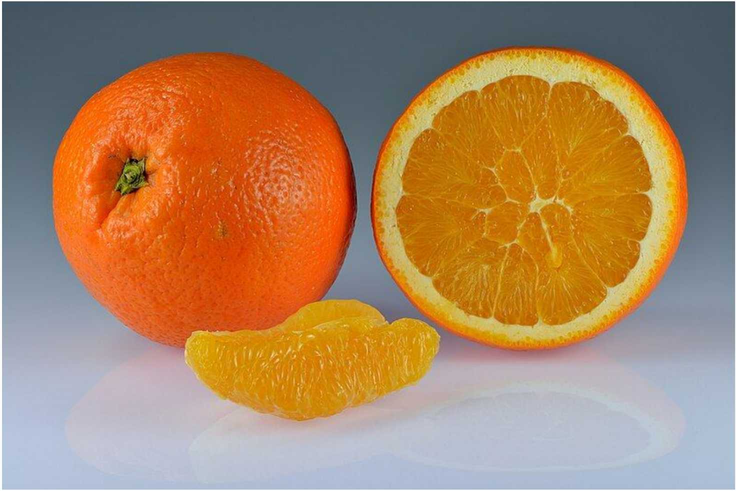


Image source: Wikimedia

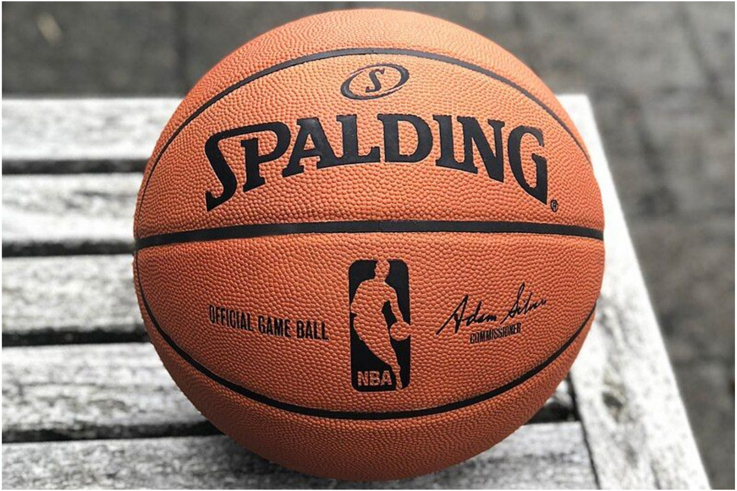
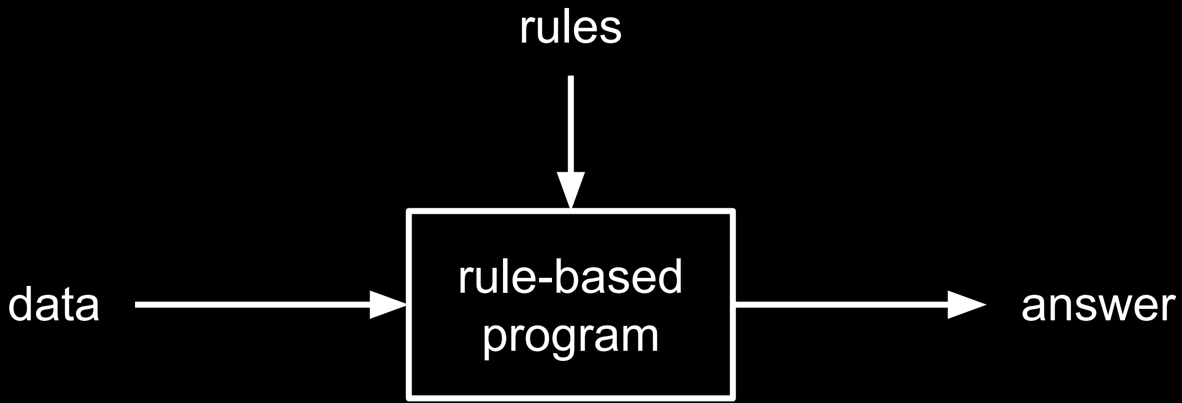


Image source: Wikimedia

what set of rules can solve this?

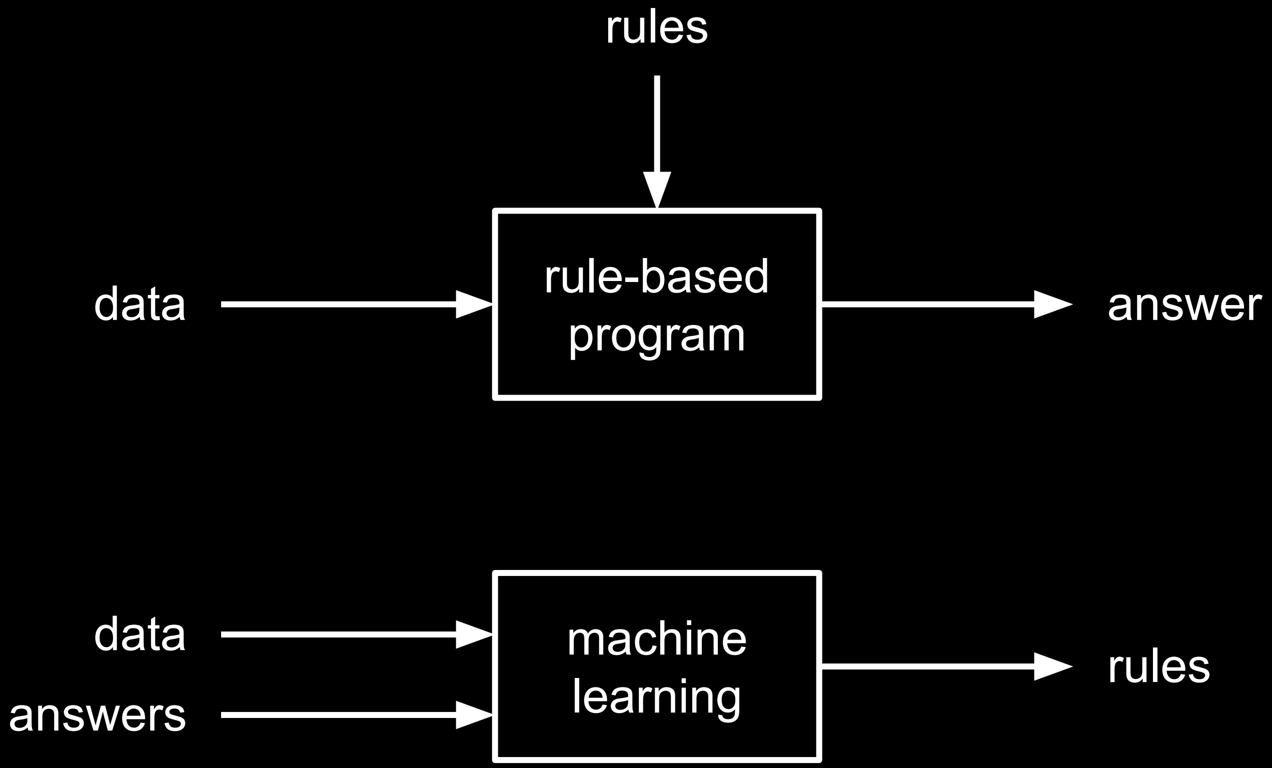
machine learning algorithms


rules

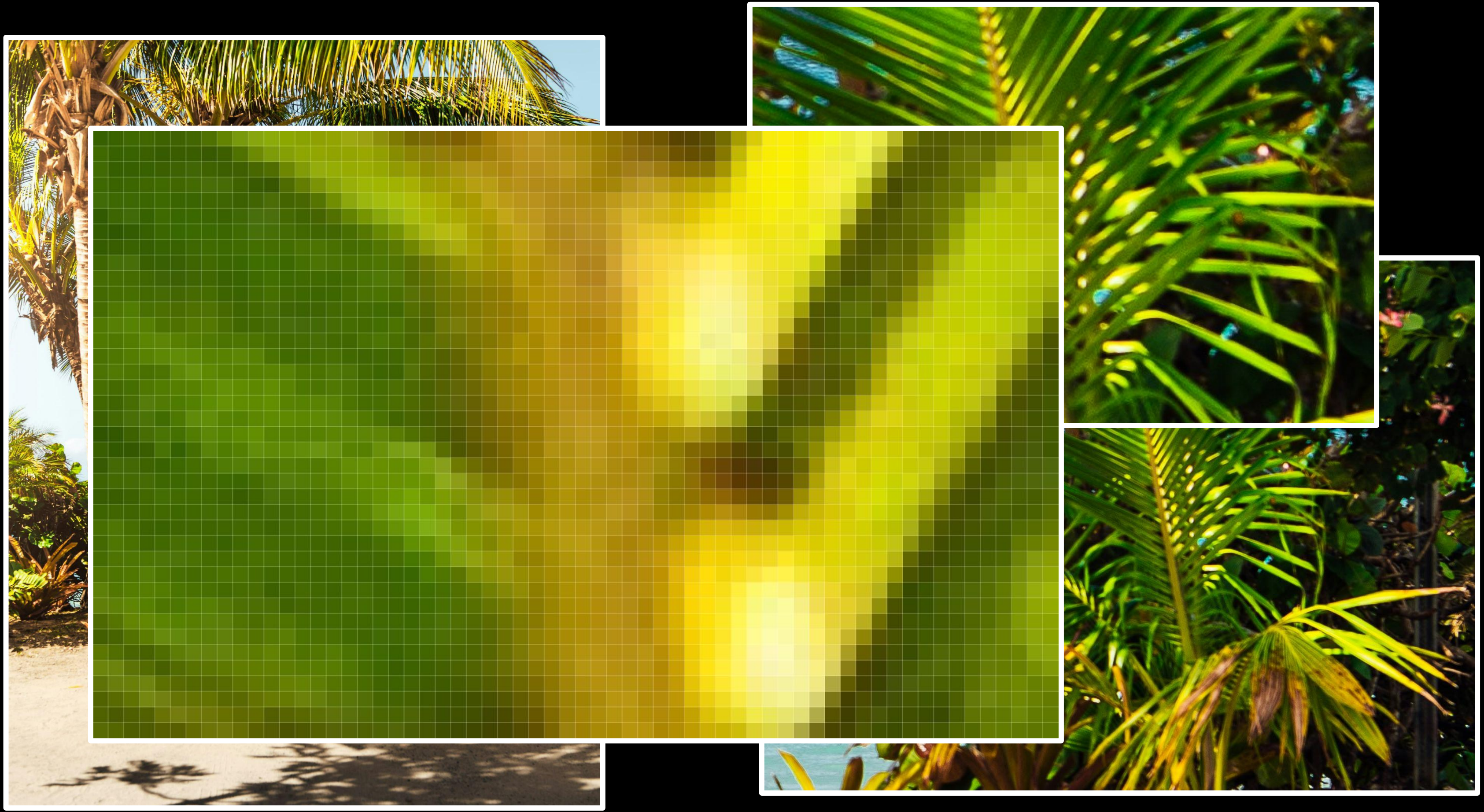
data

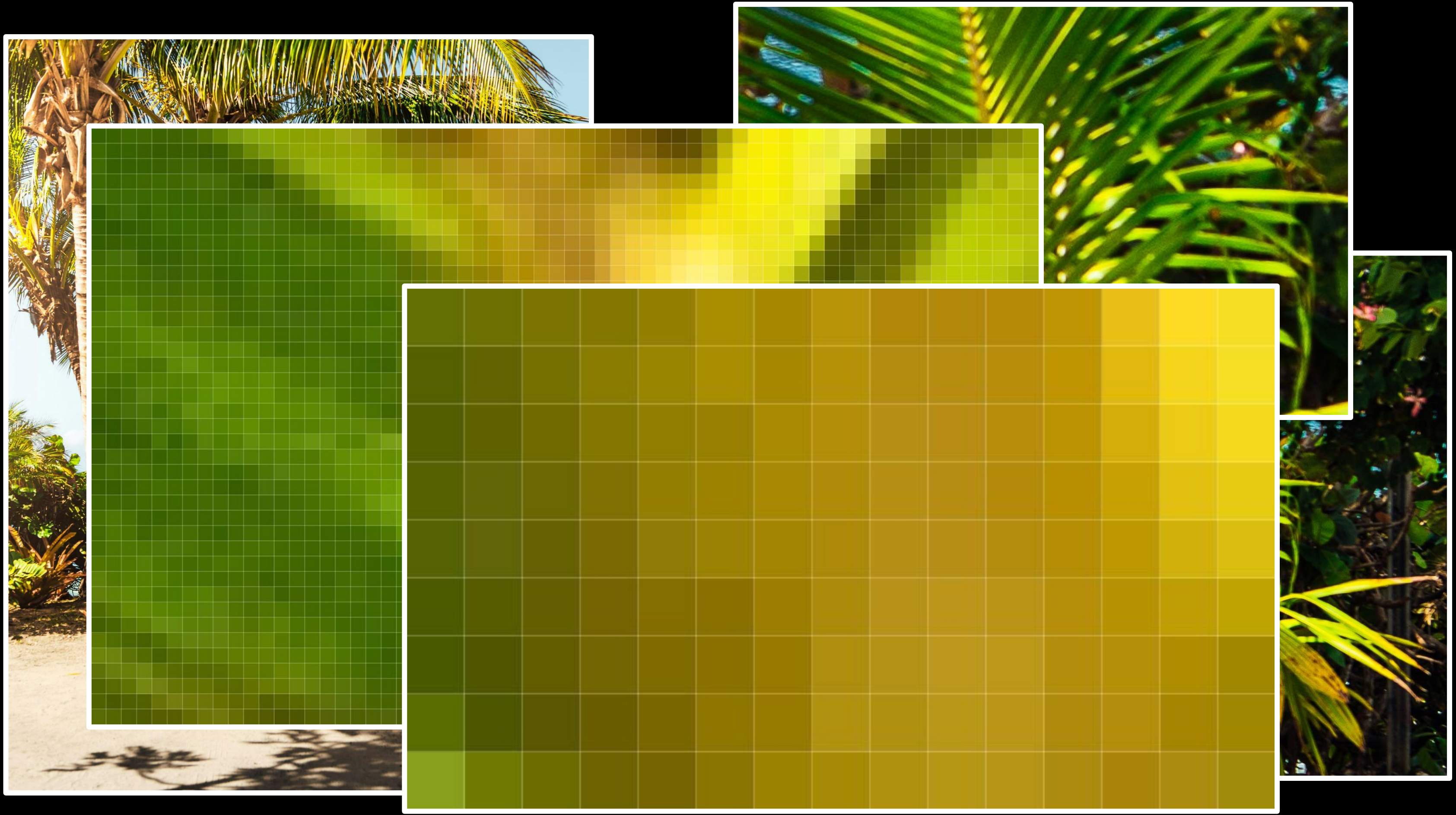
rule-based program

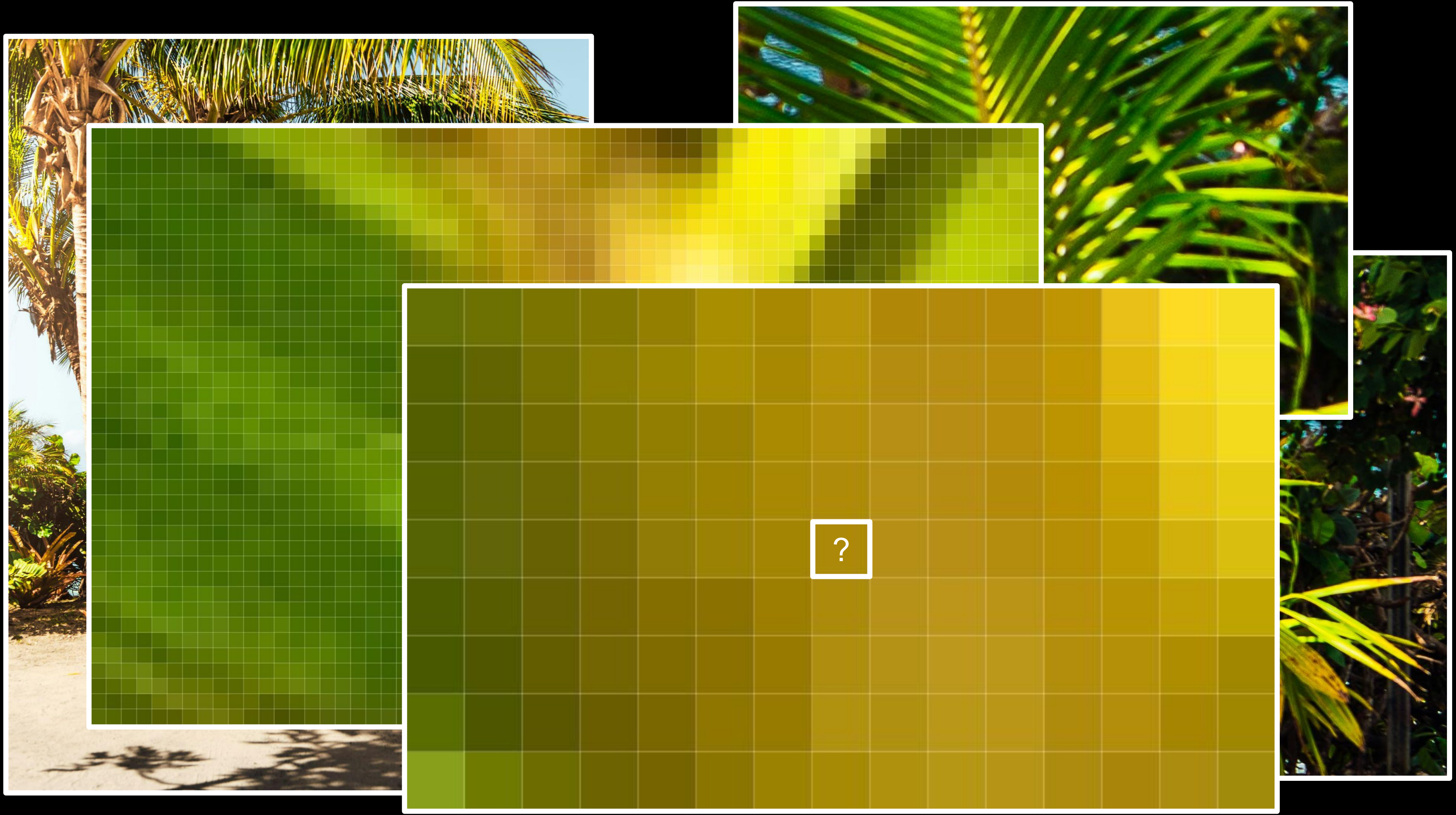
answer

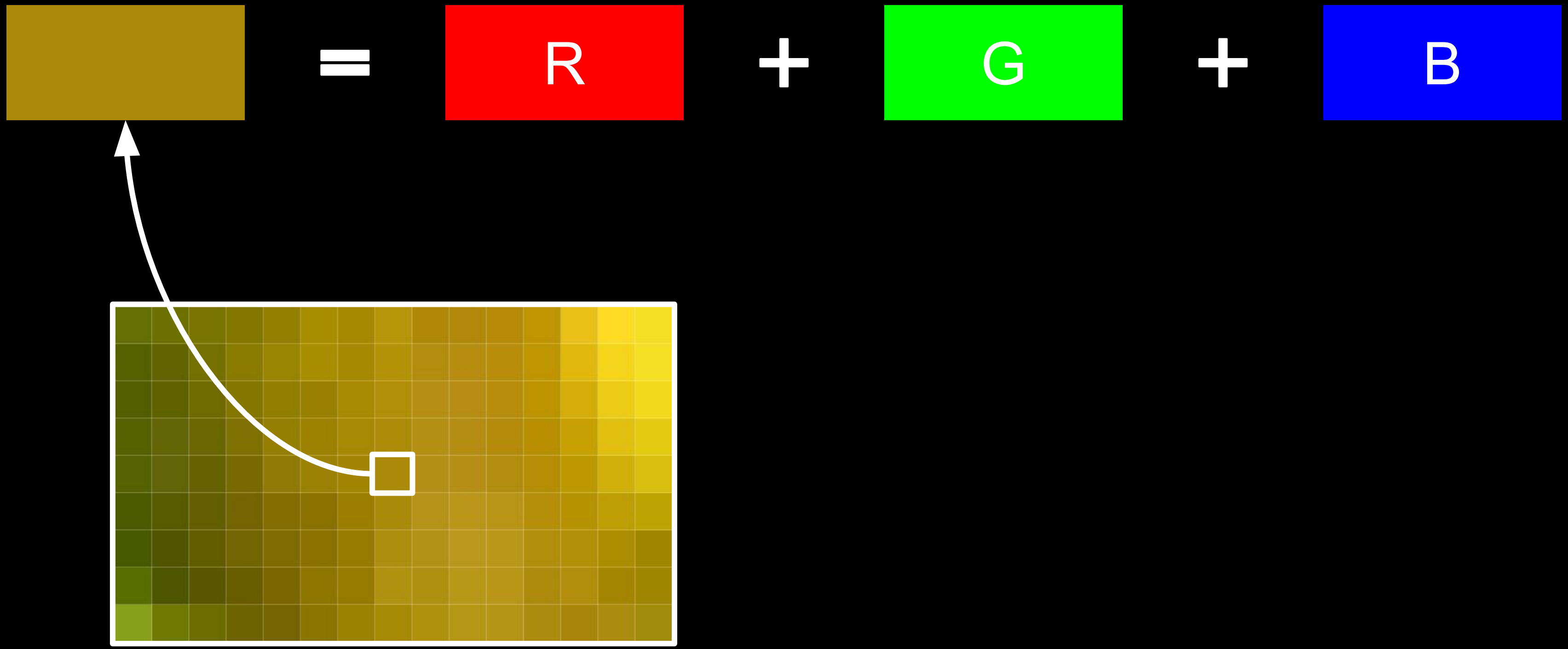

rules
data
rule-based program
answer
data
answers
machine learning
rules

images in a computer

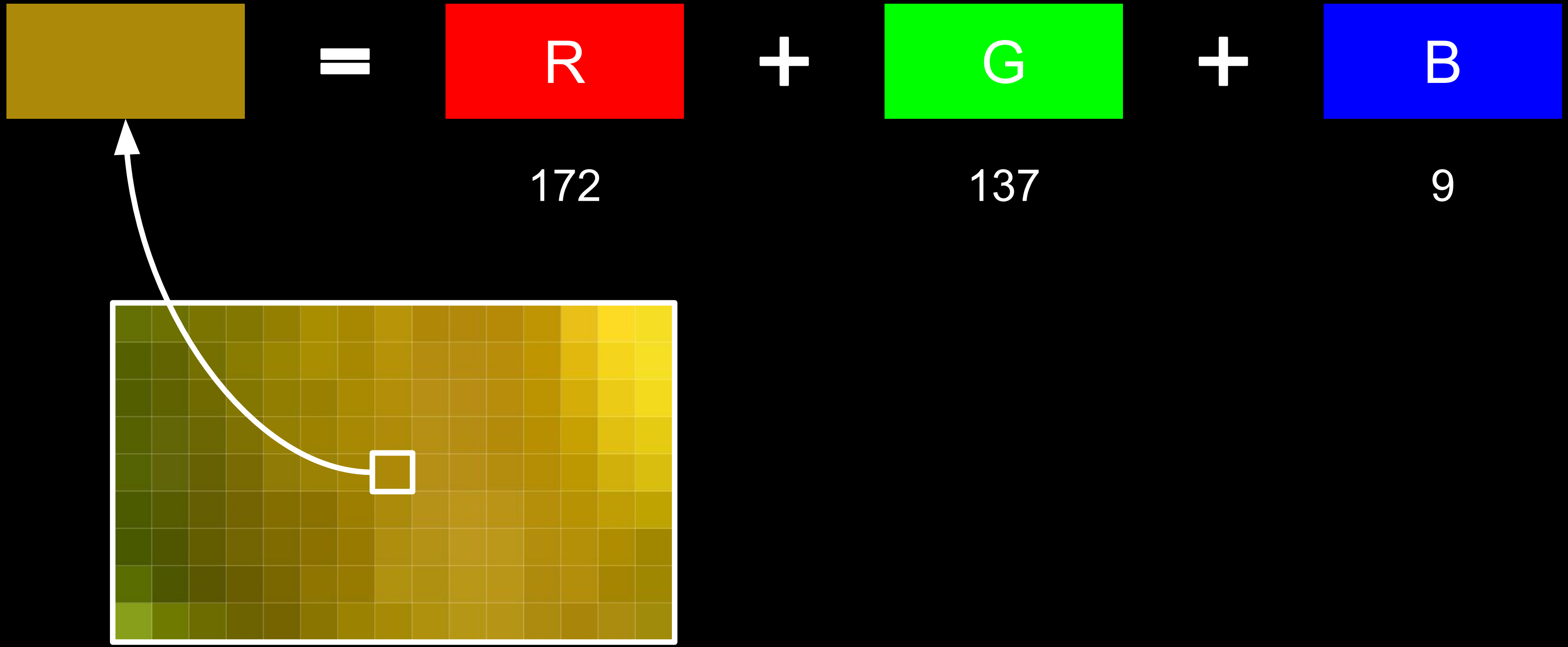








= R + G + B



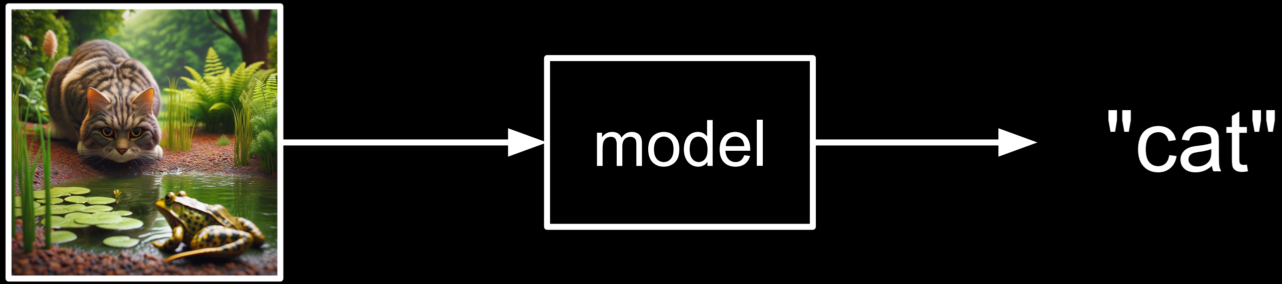
= R + G + B

172 137 9

image classification

Q: Does an image belong to one or the other class from a fixed set of classes?

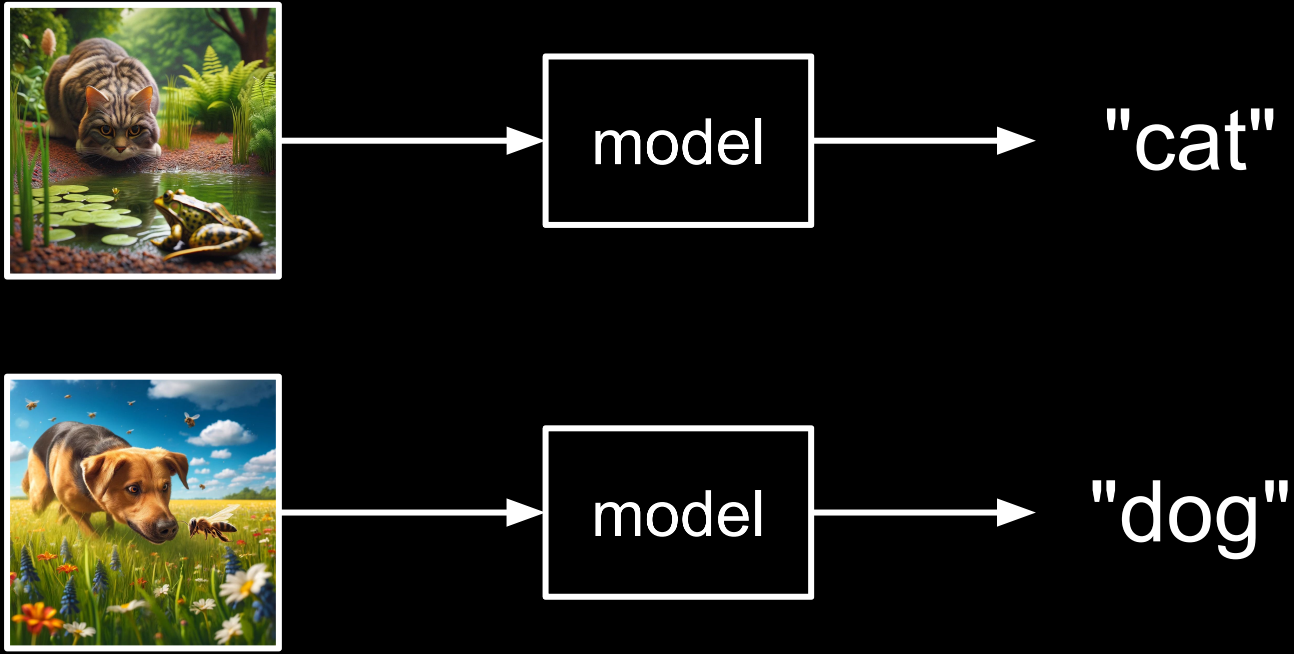
Cat or Dog?



model

"cat"

Cat or Dog?



model

"cat"

model

"dog"

Google's teachable machine

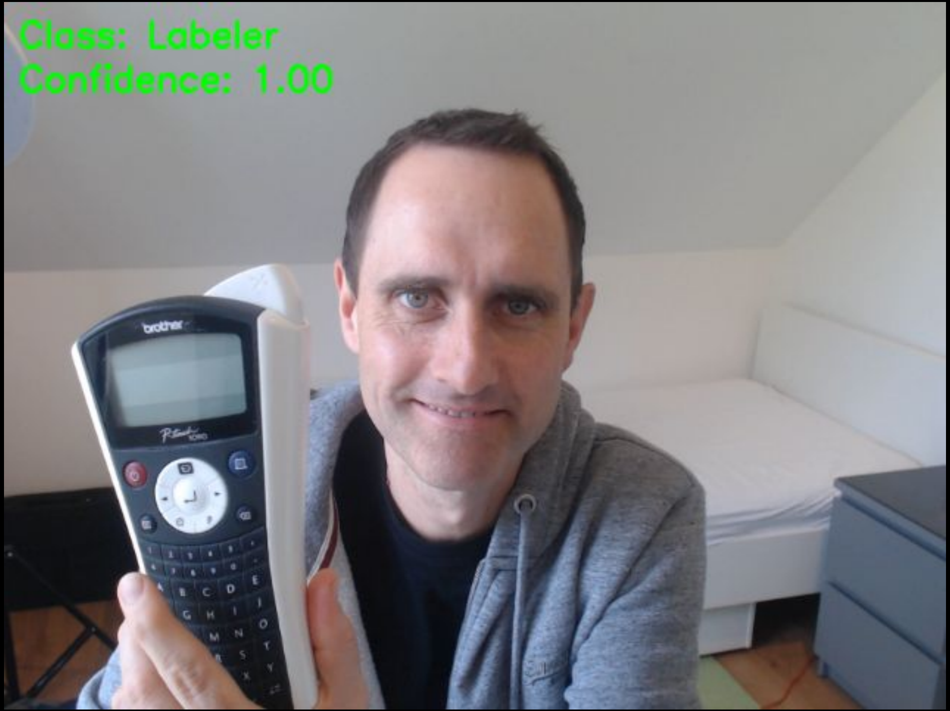
https://teachablemachine.withgoogle.com

```
pip install keras

pip install tensorflow==2.12.0
```

```
# Load the classifier and class names
model = load_model("my_model.h5")
class_names = open("labels.txt", "r").readlines()
```

```
# Convert the image t0 224 x 224
image = cv2.resize(image, (224, 224), interpolation=cv2.INTER_AREA)

# Turn into a list of pixels
image = np.asarray(image, dtype=np.float32).reshape(1, 224, 224, 3)

# Normalize each pixel's color value (-1/1)
image = (image / 127.5) - 1
```

```
# Make a prediction for the class
prediction = model.predict(image)

# Get the class with the highest confidence value
index = np.argmax(prediction)
class_name = class_names[index]

# Get the confidence score for the predicted class
confidence_score = prediction[0][index]
```



```
Class: Labeler
Confidence: 1.00
```

YOLO v8 Image Classification

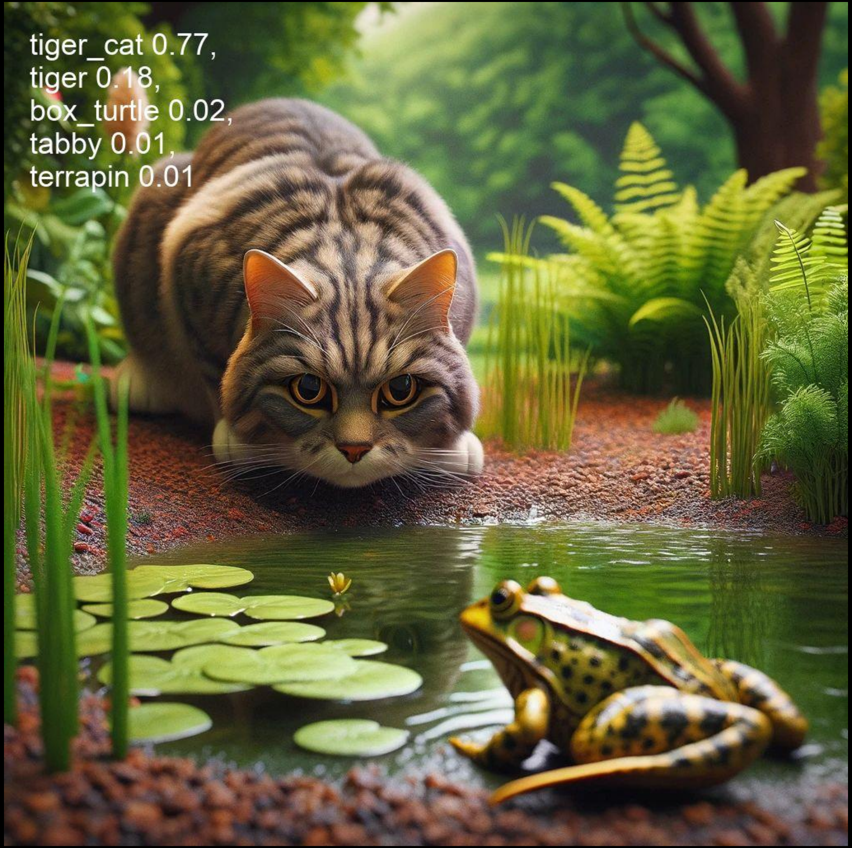
https://docs.ultralytics.com/

```
pip install ultralytics
```

```python
# Load the classifier
from ultralytics import YOLO
model = YOLO("yolov8n-cls.pt")
```

```
# Make a prediction
results = model('cat.jpg')
```

```
# Show result
results[0].show()
```



```
# Get the top result
top = results[0].probs.top1
class_name = results[0].names[top]
print(class_name)
```

zero-shot image classification

Q: Which classes do you train your model on?

GPT-4 Vision

```
pip install openai
```

```
# import openai API and set api key
from openai import OpenAI
os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()
```

```
# define a suitable prompt for the task
prompt = "Classify the image into 'dog' or 'cat'. Return
only the word for the class of the image."
```

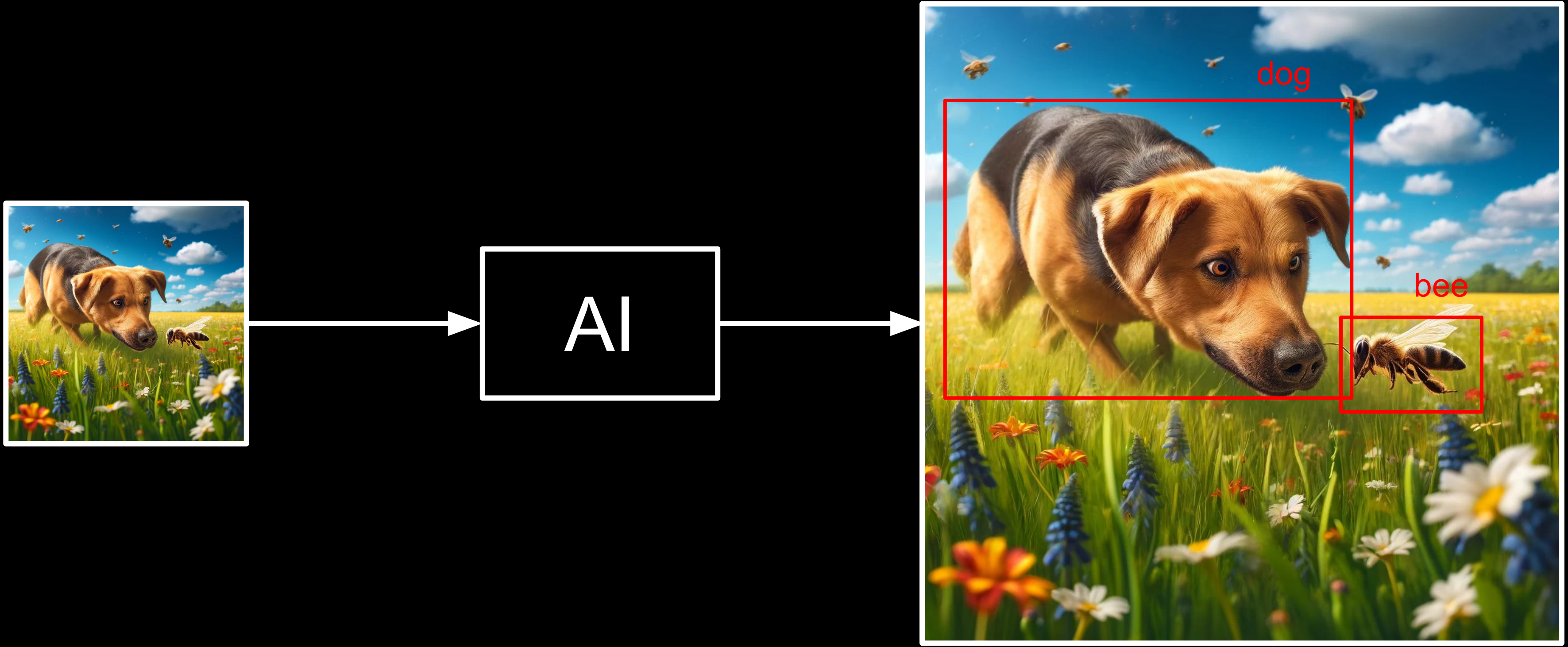
```
# This function is needed to encode an image to base64 for OpenAI's API
def encode_image(image_path):
  with open(image_path, "rb") as image_file:
    return base64.b64encode(image_file.read()).decode('utf-8')

image_path = "cat.webp"
image = encode_image(image_path)
```

```
response = client.chat.completions.create(
  model="gpt-4-turbo",
  messages = [
    { "role": "user", "content": [
        { "type": "text", "text": prompt },
        { "type": "image_url", "image_url": { "url": f"data:image/jpeg;base64,{image}" } }
      ]
    }
  ],
  max_tokens=300,
)
```

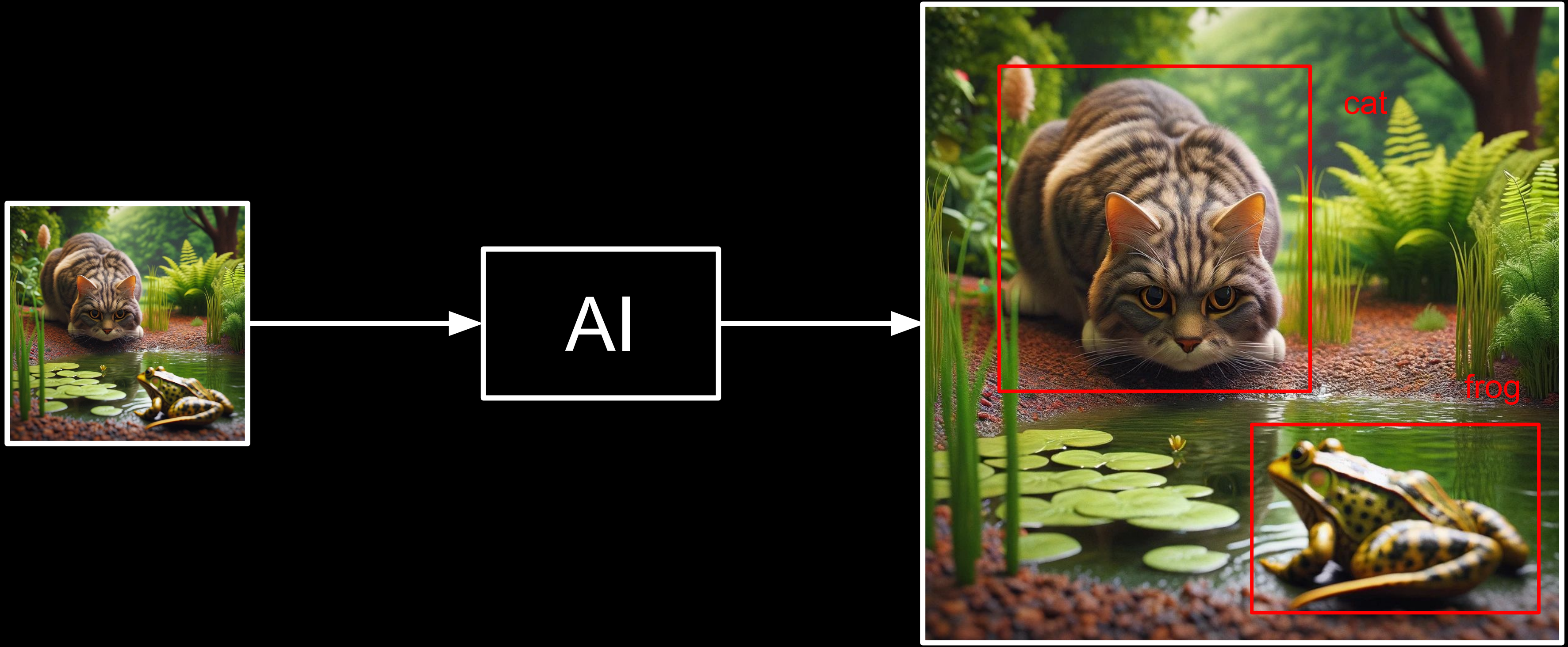
```
# Show the answer of the classification
print(response.choices[0].message.content)
```

object detection

Q: Which objects are in the image and where?



AI



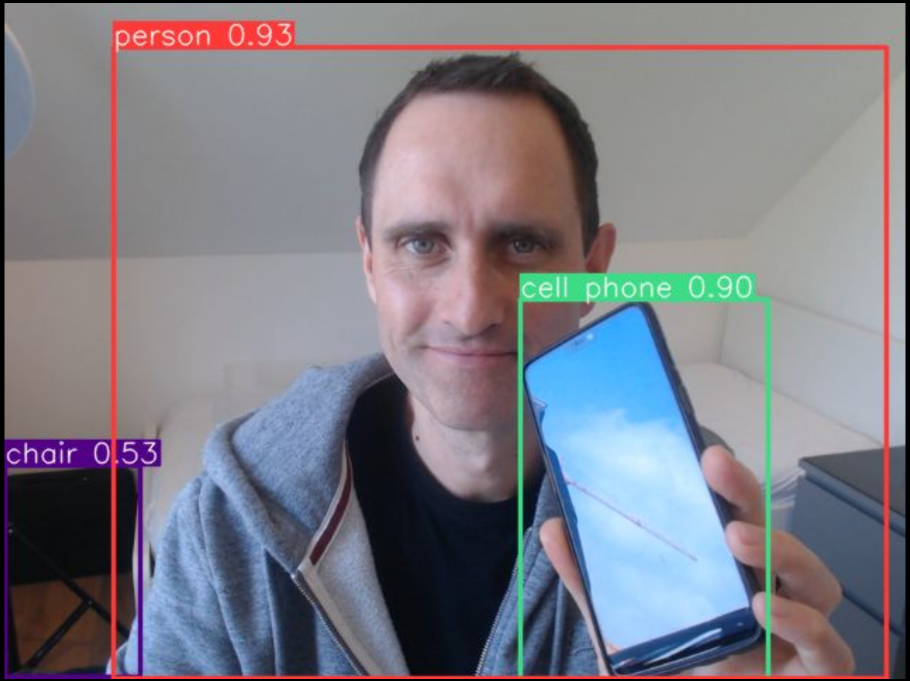
AI

YOLO v8 Object Detection

https://docs.ultralytics.com/

```
# Load the detector
from ultralytics import YOLO
model = YOLO("yolov8n.pt")
```

```
# Make a prediction one each frame
results = model(frame)

# Annotate frame
annotated_frame = results[0].plot()
```


person 0.93
cell phone 0.90
chair 0.53

Q: Which objects do you teach your model to recognize?

zero-shot object detection

"Simple Open-Vocabulary Object Detection with Vision Transformers"

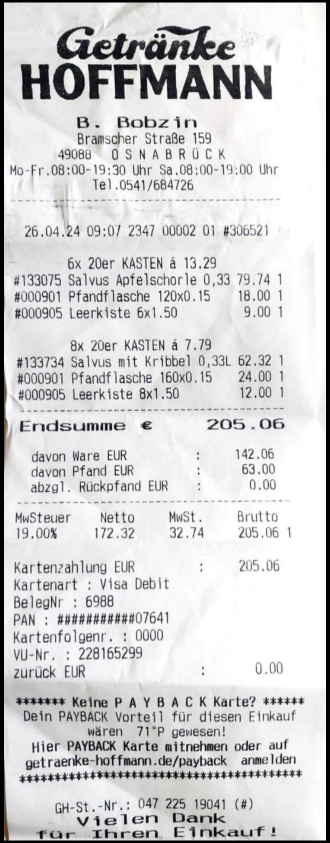
https://arxiv.org/abs/2205.06230

```python
# Load the open world detector
from ultralytics import YOLO
model = YOLO("yolov8s-world.pt")
```

```
# Define custom objects to look for
model.set_classes(["person with glasses"])
```

```
# Make a prediction one each frame
results = model(frame)

# Annotate frame
annotated_frame = results[0].plot()
```

optical character recognition (OCR)



```
        Getränke
        HOFFMANN

        B. Bobzin
   Bramscher Straße 159
   49088   O S N A B R Ü C K
Mo-Fr.08:00-19:30 Uhr Sa.08:00-19:00 Uhr
      Tel.0541/684726
----------------------------------------

 26.04.24 09:07 2347 00002 01 #306521

      6x 20er KASTEN á 13.29
#133075 Salvus Apfelschorle 0,33 79.74 1
#000901 Pfandflasche 120x0.15    18.00 1
#000905 Leerkiste 6x1.50          9.00 1

      8x 20er KASTEN á 7.79
#133734 Salvus mit Kribbel 0,33L 62.32 1
#000901 Pfandflasche 160x0.15    24.00 1
#000905 Leerkiste 8x1.50         12.00 1
----------------------------------------
Endsumme €                  205.06

  davon Ware EUR           :    142.06
  davon Pfand EUR          :     63.00
  abzgl. Rückpfand EUR     :      0.00
----------------------------------------
MwSteuer     Netto     MwSt.    Brutto
19.00%      172.32     32.74    205.06 1

Kartenzahlung EUR          :    205.06
Kartenart : Visa Debit
BelegNr : 6988
PAN : ##########07641
Kartenfolgenr. : 0000
VU-Nr. : 228165299
zurück EUR                 :      0.00

******* Keine P A Y B A C K Karte? ******
 Dein PAYBACK Vorteil für diesen Einkauf
        wären  71°P gewesen!
  Hier PAYBACK Karte mitnehmen oder auf
 getraenke-hoffmann.de/payback  anmelden
****************************************

     GH-St.-Nr.: 047 225 19041 (#)
          Vielen Dank
      für Ihren Einkauf!
```

`tesseract`

GPT-4 Vision

```
# define a suitable prompt for the task
prompt = "Extract all food and beverage items with their
quantity and price from this receipt into a JSON list. The
receipt is in German."
```

```
response = client.chat.completions.create(
  model="gpt-4o",
  response_format={ "type": "json_object" },
  messages = [
    { "role": "user", "content": [
        { "type": "text", "text": prompt },
        { "type": "image_url", "image_url": { "url": f"data:image/jpeg;base64,{image}" } }
      ]
    }
  ],
  max_tokens=300,
)
```

GENERATIVE AI

BACK

LARGE LANGUAGE MODELS

what has been said so far?
(*history* + *prompt*) → prediction of next token based on learnt probability distribution

what has been said so far?
(*history* + *prompt*)

➡

prediction of next token based on
learnt probability distribution

+

(randomness)

what has been said so far?
(*history* + *prompt*)

→

prediction of next token based on
learnt probability distribution

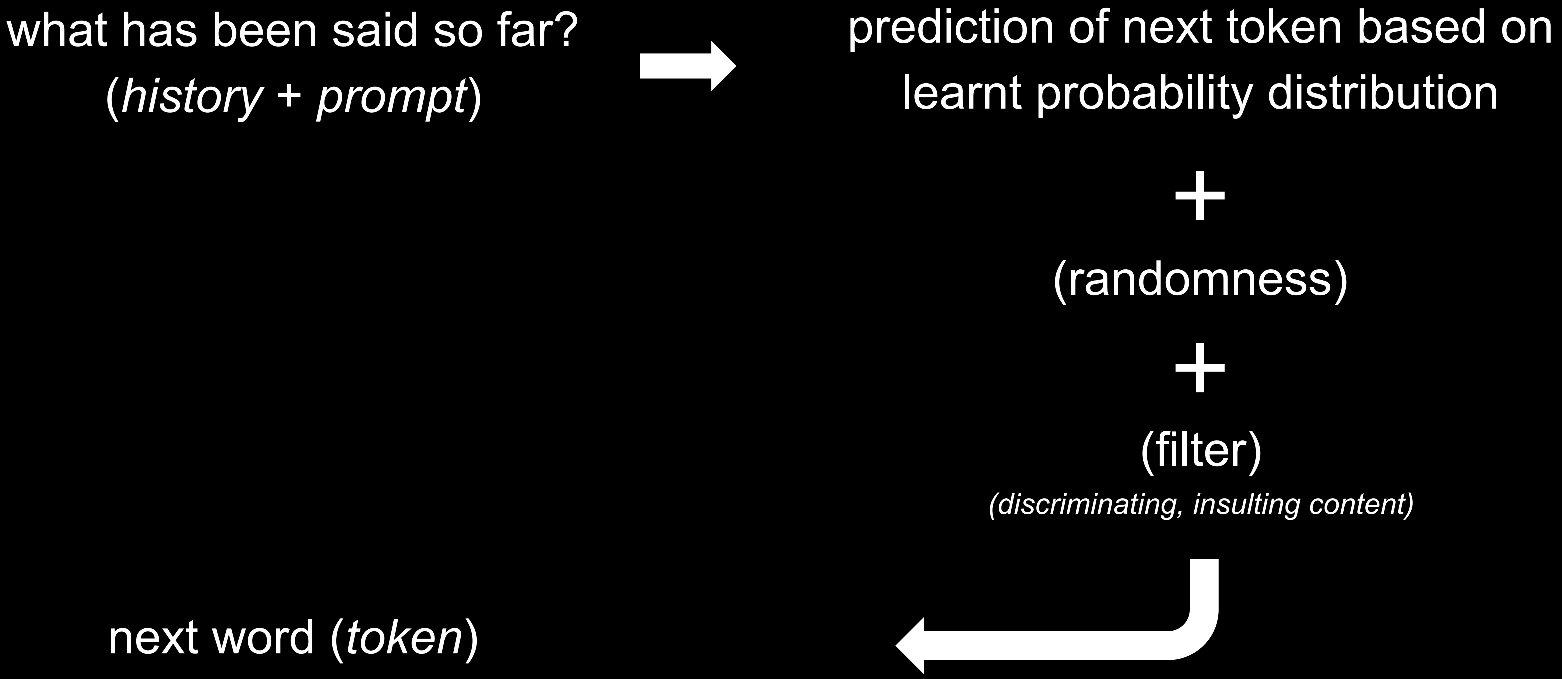
+

(randomness)

+

(filter)

(discriminating, insulting content)



what has been said so far?
(*history* + *prompt*)

prediction of next token based on
learnt probability distribution

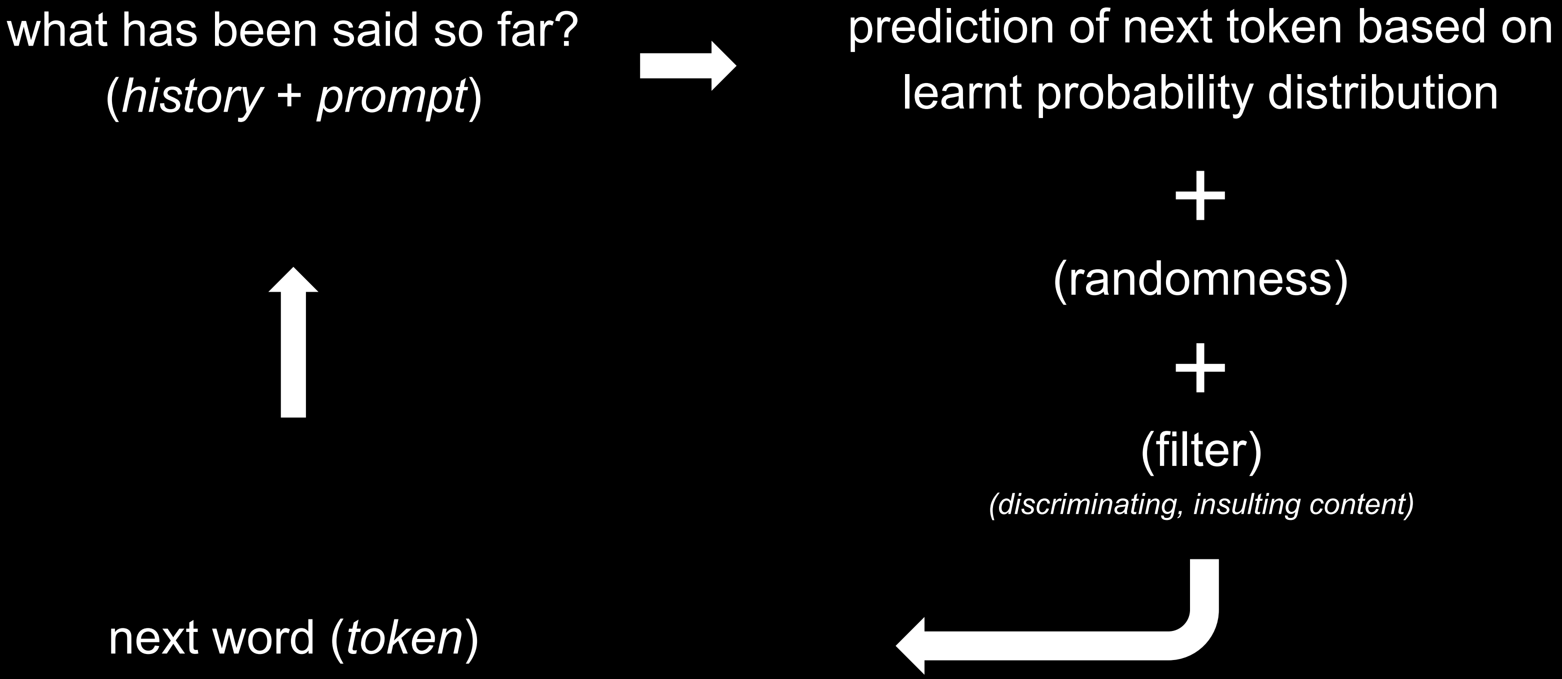
+

(randomness)

+

(filter)
(discriminating, insulting content)

next word (*token*)



what has been said so far?
(*history* + *prompt*)

prediction of next token based on learnt probability distribution

+

(randomness)

+

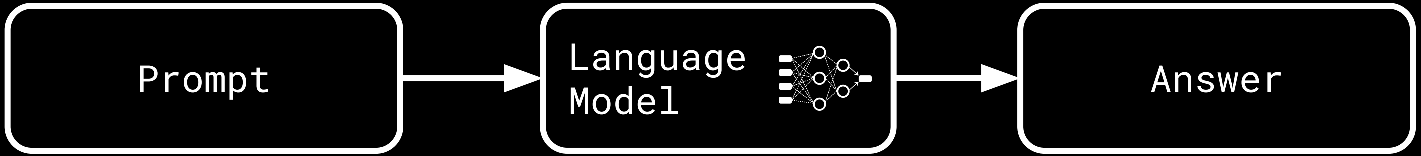
(filter)

(discriminating, insulting content)

next word (*token*)

PROMPTING

https://www.promptingguide.ai/



Prompt

Language Model

Answer

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Explain the binary number system.
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Explain the binary number system.
```

start simple

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
You are a friendly tutor and your
task is to explain complex
concepts as simple as possible.

Explain the binary number system.
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
You are a friendly tutor and your
task is to explain complex
concepts as simple as possible.

Your answers are never longer
than 10 sentence.

Explain the binary number system.
```

ZERO-SHOT PROMPTING

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Classify the text into neutral,
negative or positive.

Text: "What a great dinner!"

Sentiment:
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Classify the text into neutral,
negative or positive.

Text: "What a great dinner!"

Sentiment:
```

this will be replaced with data later…

FEW-SHOT PROMPTING

IN-CONTEXT LEARNING

examples in the context to learn from

```
Extract all references to countries and their continent in the following text
using the format from the examples below.

Example 1: "They played the team called 'Die Mannschaft' in the world cup final"
Correct answer: Germany, Europe

Example 2: "The Three Lions once again lost to Germany in a semi final"
Correct answer: England, Europe, Germany, Europe

Text: "The Selecao was destroyed 1:7 by the DFB selection in their home stadium."
Answer:
```

examples in the context to learn from

```
Extract all references to countries and their continent in the following text
using the format from the examples below.

Example 1: "They played the team called 'Die Mannschaft' in the world cup final"
Correct answer: Germany, Europe

Example 2: "The Three Lions once again lost to Germany in a semi final"
Correct answer: England, Europe, Germany, Europe

Text: "The Selecao was destroyed 1:7 by the DFB selection in their home stadium."
Answer:
```

more prompting strategies

chain-of-thought (CoT)
self-consistency
generate knowledge prompting
prompt chaining (subtasks)
tree-of-thoughts (ToT)
retrieval-augmented-generation (RAG)
…

OpenAI

```
pip install openai
```

```
from openai import OpenAI
import os

os.environ["OPENAI_API_KEY"] = "<YOUR_API_KEY>"
client = OpenAI()
```

```
# define a system message
system_message = """
    You are a world-famous 5-star chef. Based on ingredients the user has at home,
    you suggest easy-to-cook recipes. """
```

```
# define a prompt for the task
prompt = """
     Suggest a recipe for lunch.

     List of ingredients:
     - butter
     - eggs
     - flour
     - salt
     - milk

     Recipe: """
```

```
response = client.chat.completions.create(
  model="gpt-4o",
  messages = [
    {"role": "system", "content": system_message },
    {"role": "user", "content":  prompt },]
    }
  ],
  max_tokens=2000
)
```

USER INTERFACES

BACK

streamlit

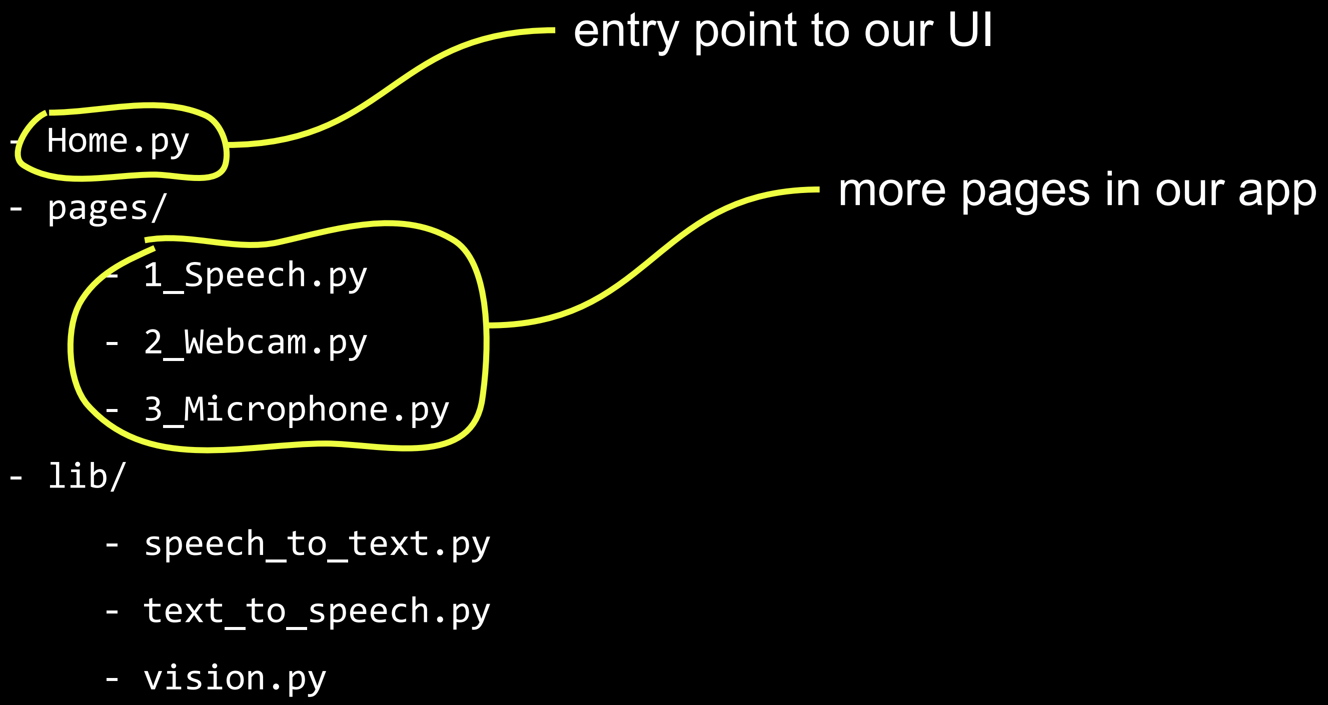
```
https://docs.streamlit.io/       # official documentation
https://streamlit.io/components  # third-party extensions
```

```
pip install streamlit
```

```
- Home.py
- pages/
    - 1_Speech.py
    - 2_Webcam.py
    - 3_Microphone.py
- lib/
    - speech_to_text.py
    - text_to_speech.py
    - vision.py
```

entry point to our UI

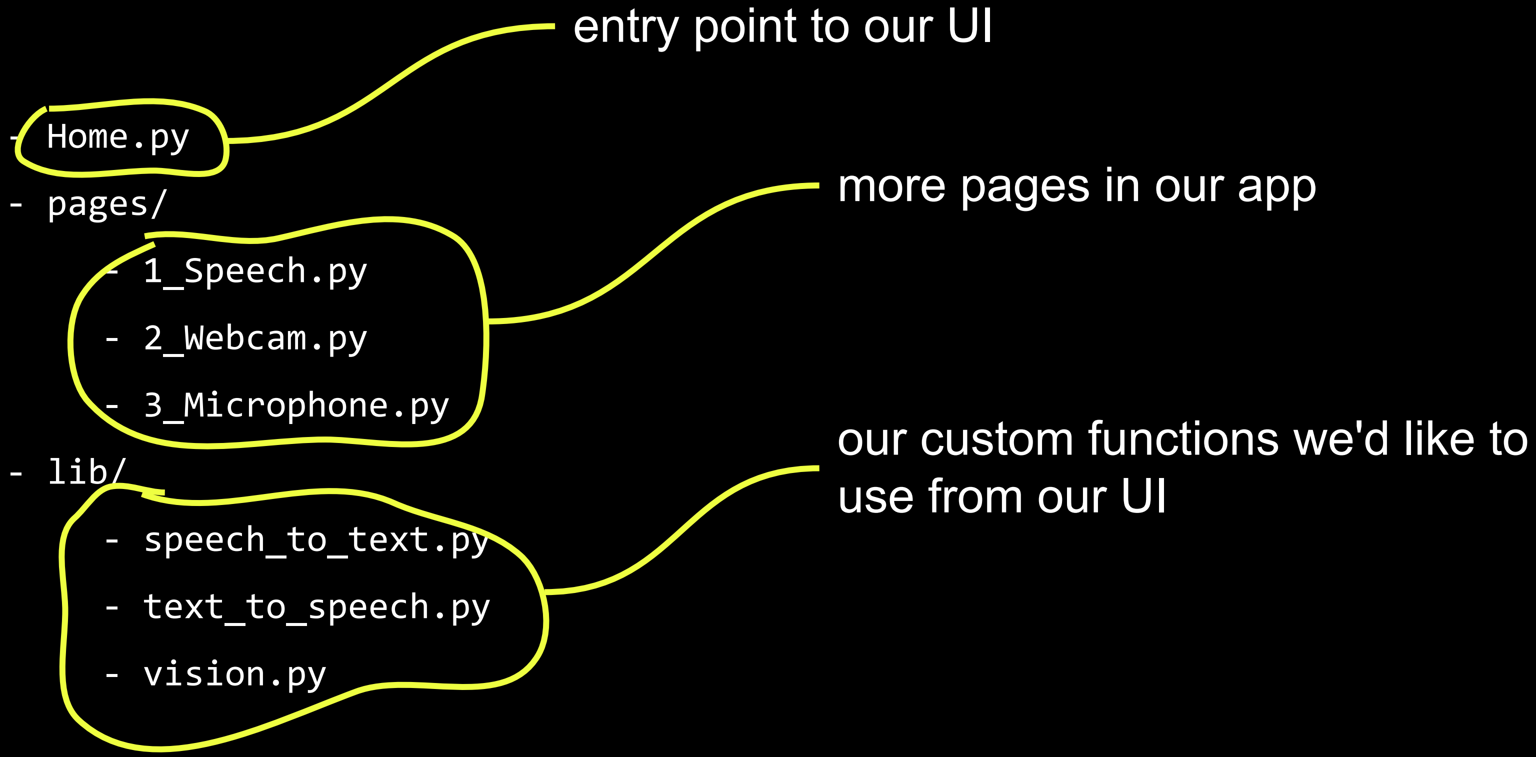
```
- Home.py
- pages/
    - 1_Speech.py
    - 2_Webcam.py
    - 3_Microphone.py
- lib/
    - speech_to_text.py
    - text_to_speech.py
    - vision.py
```



```
- Home.py
- pages/
    - 1_Speech.py
    - 2_Webcam.py
    - 3_Microphone.py
- lib/
    - speech_to_text.py
    - text_to_speech.py
    - vision.py
```

entry point to our UI

more pages in our app



```
- Home.py
- pages/
    - 1_Speech.py
    - 2_Webcam.py
    - 3_Microphone.py
- lib/
    - speech_to_text.py
    - text_to_speech.py
    - vision.py
```

entry point to our UI

more pages in our app

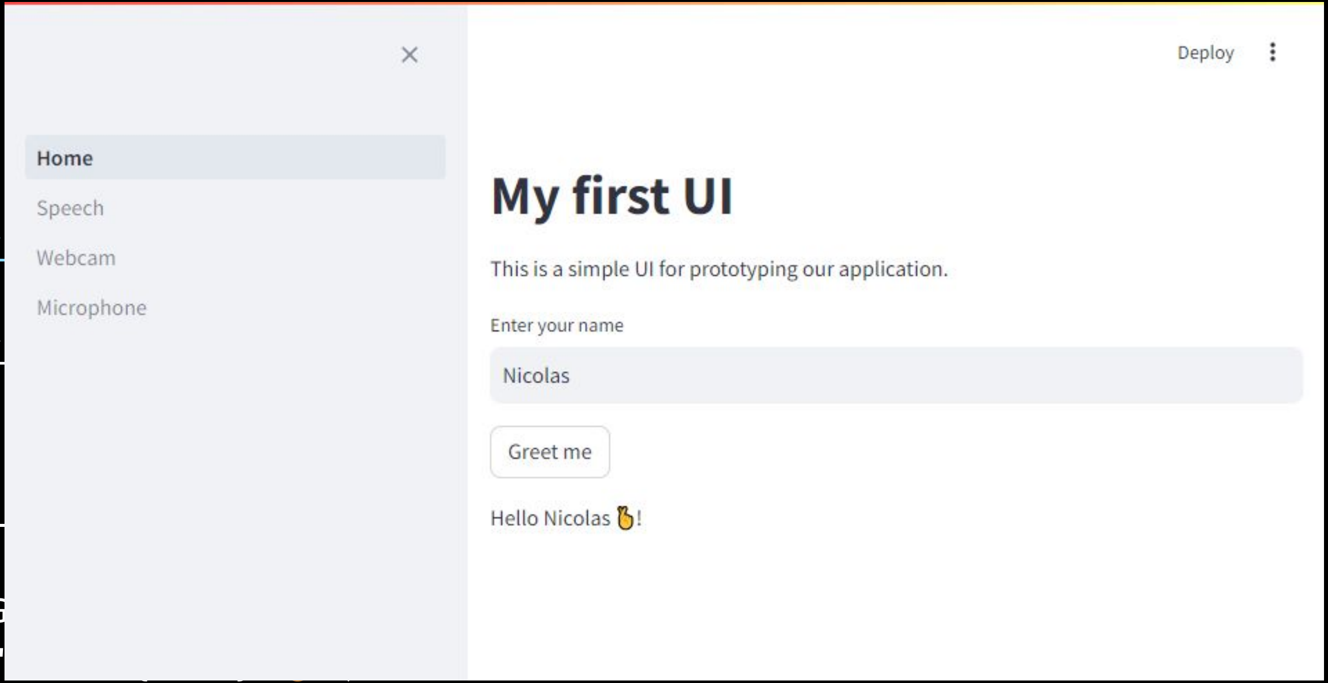
our custom functions we'd like to use from our UI

Home.py

```python
import streamlit as st

st.title("My first UI")
st.write("This is a simple UI for prototyping our application.")

name = st.text_input("Enter your name")

if st.button("Greet me"):
    st.write(f"Hello {name} 🤞")
```

Home.py

```
import streamli

st.title("My fi
st.write("This

name = st.text_

if st.button("G
    st.write(f"
```



My first UI

This is a simple UI for prototyping our application.

Enter your name

Nicolas

Hello Nicolas 🫰!

1_Speech.py

```python
import streamlit as st
from pages.lib.text_to_speech import text_to_speech

st.title("Speech demo")
st.write("Enter a text and it will be converted to speech.")

text = st.text_input("Enter some text")
voice = st.selectbox("Select a voice", ["alloy", … "shimmer"])

if st.button("Turn to speech"):
    audio_file = text_to_speech(text, voice=voice)
    st.audio(audio_file.as_posix(), format="audio/mpeg")
```

1_Speech.py

```python
import streamlit as st
from pages.lib.text_to_speech import text_to_speech

st.title("Speech demo")
st.write("Enter a text and it will be converted to speech.")

text = st.text_input("Enter some text")
voice = st.selectbox("Select a voice", ["alloy", … "shimmer"])

if st.button("Turn to speech"):
    audio_file = text_to_speech(text, voice=voice)
    st.audio(audio_file.as_posix(), format="audio/mpeg")
```

from lib/text_to_speech.py

lib/text_to_speech.py

```python
from openai import OpenAI
import os
os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()

def text_to_speech(text, voice="alloy"):
    speech_file_path = Path(__file__).parent / "speech.mp3"
    response = client.audio.speech.create(
        model="tts-1",
        voice=voice,
        input=text
    )

    response.write_to_file(speech_file_path)
    return speech_file_path
```

lib/text_to_speech.py

```python
from openai import OpenAI
import os
os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()

def text_to_speech(text, voice="alloy"):
    speech_file_path = Path(__file__).parent / "speech.mp3"
    response = client.audio.speech.create(
        model="tts-1",
        voice=voice,
        input=text
    )

    response.write_to_file(speech_file_path)
    return speech_file_path
```

setup OpenAI API

lib/text_to_speech.py

```python
from openai import OpenAI
import os
os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()
```

setup OpenAI API

```python
def text_to_speech(text, voice="alloy"):
    speech_file_path = Path(__file__).parent / "speech.mp3"
    response = client.audio.speech.create(
        model="tts-1",
        voice=voice,
        input=text
    )

    response.write_to_file(speech_file_path)
    return speech_file_path
```

define custom function

2_Webcam.py

```python
import streamlit as st
from pages.lib.vision import ask_gpt4o


st.title("Video camera test")

picture = st.camera_input("Take a picture")

if picture:
    st.image(picture)
    answer = ask_gpt4o("What is in this picture?", picture)
    st.write(answer)
```

2_Webcam.py

```
import streamlit as st
from pages.lib.vision import ask_gpt4o

st.title("Video camera test")

picture = st.camera_input("Take a picture")

if picture:
    st.image(picture)
    answer = ask_gpt4o("What is in this picture?", picture)
    st.write(answer)
```

from lib/vision.py

lib/vision.py

```python
from openai import OpenAI
import os
os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()

def encode_image(image_buffer):

def ask_gpt4o(prompt, image_buffer):
  image = encode_image(image_buffer)
  response = client.chat.completions.create(
    model="gpt-4o",
    messages=[
      {
        "role": "user", "content": [
          { "type": "text", "text": prompt },
          { "type": "image_url", "image_url": { "url": f"data:image/jpeg;base64,{image}" } }
        ],
      }
    ]
    )

  return response.choices[0].message.content
```

lib/vision.py

```
from openai import OpenAI
import os
os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()
```

setup OpenAI API

```
def encode_image(image_buffer):
```

```
def ask_gpt4o(prompt, image_buffer):
  image = encode_image(image_buffer)
  response = client.chat.completions.create(
    model="gpt-4o",
    messages=[
      {
        "role": "user", "content": [
          { "type": "text", "text": prompt },
          { "type": "image_url", "image_url": { "url": f"data:image/jpeg;base64,{image}" } }
        ],
      }
    ]
    )

  return response.choices[0].message.content
```

define custom function

3_Microphone.py

```
import streamlit as st
from streamlit_mic_recorder import mic_recorder
from pages.lib.text_to_speech import speech_to_text

st.title("Microphone test")

def callback():
    if st.session_state.my_recorder_output:
        audio = st.session_state.my_recorder_output
        text = text_to_speech(audio)
        st.success(text)

audio = mic_recorder(key='my_recorder', callback=callback)
```

3_Microphone.py

```
pip install streamlit-mic-recorder
```

```python
import streamlit as st
from streamlit_mic_recorder import mic_recorder
from pages.lib.text_to_speech import speech_to_text

st.title("Microphone test")

def callback():
    if st.session_state.my_recorder_output:
        audio = st.session_state.my_recorder_output
        text = text_to_speech(audio)
        st.success(text)

audio = mic_recorder(key='my_recorder', callback=callback)
```

3_Microphone.py

pip install streamlit-mic-recorder

```
import streamlit as st
from streamlit_mic_recorder import mic_recorder
from pages.lib.text_to_speech import speech_to_text

st.title("Microphone test")

def callback():
    if st.session_state.my_recorder_output:
        audio = st.session_state.my_recorder_output
        text = text_to_speech(audio)
        st.success(text)

audio = mic_recorder(key='my_recorder', callback=callback)
```

from lib/speech_to_text.py

lib/speech_to_text.py

```python
from openai import OpenAI
import os
import io

os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()

def speech_to_text(audio):
    audio_bio = io.BytesIO(audio['bytes'])
    audio_bio.name = 'audio.mp3'

    transcription = client.audio.transcriptions.create(
        model="whisper-1",
        file=audio_bio
    )
    return transcription.text
```

lib/speech_to_text.py

```
from openai import OpenAI
import os
import io

os.environ["OPENAI_API_KEY"] = "..."
client = OpenAI()
```

setup OpenAI API

```
def speech_to_text(audio):
    audio_bio = io.BytesIO(audio['bytes'])
    audio_bio.name = 'audio.mp3'

    transcription = client.audio.transcriptions.create(
        model="whisper-1",
        file=audio_bio
    )
    return transcription.text
```

define custom function