Deep Learning for Computer Vision

Vision-Language Models: Introduction and History

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Computer Vision: Tasks and Limitations

Computer Vision Tasks

- Object Classification
- Object Detection
- Instance Segmentation
- Semantic Segmentation

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Limitations

Computer vision techniques output class labels, bounding boxes, masks, images, etc. However, humans communicate through language and text, which vision models lack.

Tying in Language into Computer Vision Tasks

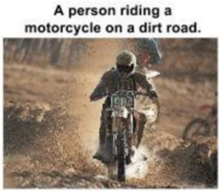
A person riding a motorcycle on a dirt road.

Figure 1: Image Captioning[a]

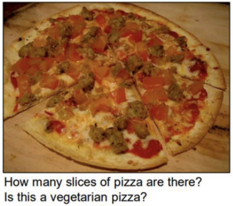
How many slices of pizza are there?
Is this a vegetarian pizza?

Figure 2: Visual Question Answering[a]

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[a] Vinyals et al. "Show and tell: A neural image caption generator", CVPR 2014

[a] Agrawal et al, "VQA: Visual Question Answering", IJCV 2015

Tying in Language into Computer Vision Tasks

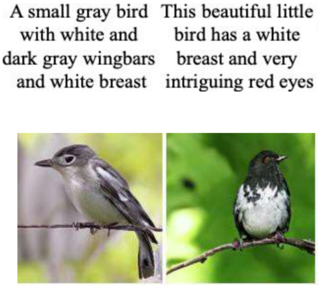
A small gray bird with white and dark gray wingbars and white breast
This beautiful little bird has a white breast and very intriguing red eyes

Figure 3: Text-to-image generation[a]

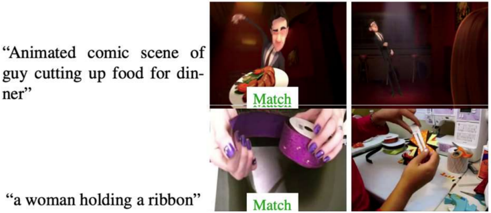
"Animated comic scene of guy cutting up food for dinner"
Match
"a woman holding a ribbon"
Match

Figure 4: Text-to-Video retrieval[a]

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[a] Gu et al, "Vector quantized diffusion model for text-to-image synthesis", CVPR 2022

[a] Sirnam et al, "Preserving Modality Structure Improves Multi-Modal Learning", ICCV 2023

Natural Language Processing (NLP): Tasks and Limitations

NLP Tasks

- Search engines
- Spam filtering
- Machine translation
- Sentiment analysis

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Limitations

Exhibit flair in analyzing and generating text; however, cannot process visual cues or verify interpretations against real-world visual references, especially when there are linguistic ambiguities

From Language Models to LLMs

Language Models

- Understand and generate text
- Based on Transformer architecture
- Learn from raw text

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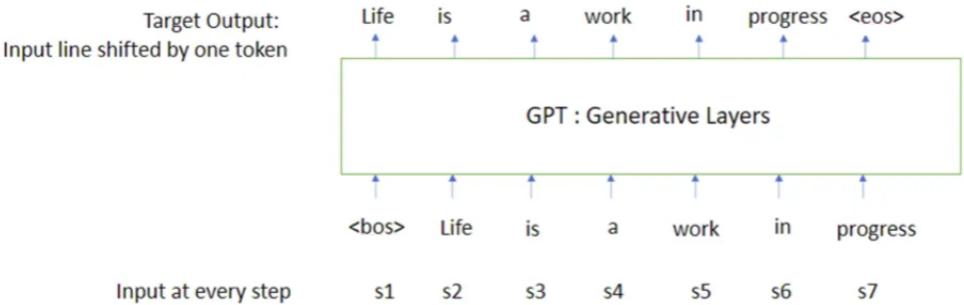
Large Language Models (LLMs)

- Pre-trained on large datasets
- Large number of parameters
- Datasets used to train are: Common Crawl (60%), WebText2 (22%), Books1 (8%), Books2 (8%), Wikipedia (3%)

LLMs: Generative Pretrained Transformer (GPT) [1]


Target Output:
Input line shifted by one token
Life is a work in progress <eos>
GPT : Generative Layers
<bos> Life is a work in progress
Input at every step
s1 s2 s3 s4 s5 s6 s7

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[1] *Source: Beginner's Guide to Large Language Models — by Digitate — Medium*

GPT Training[2]

Learning via Self-supervision

The model learns from raw sentences with a target sequence shifted by one token, enabling it to grasp word relationships for accurate output prediction.

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Auto-regressive

Words derive context from all preceding words. Each generated token is added to the input sequence, forming the input for the next step.

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Unidirectional

The GPT model learns context strictly from left to right (earlier models like BERT used a bidirectional approach, which considers context from both directions)

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[2] *Source: Beginner's Guide to Large Language Models — by Digitate — Medium*

Other LLMs[3]

- **LaMDA**: Developed by google, trained on 1.56 trillion words of public dialog data. It powered the BARD chatbot, and a lightversion of it led to the Gemini!

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[3] *Source: Beginner's Guide to Large Language Models — by Digitate — Medium*

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- **Chinchilla**: Developed by DeepMind, considerably simplifies downstream utilization because it requires much less computer power for inference and fine-tuning

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LLMs: Applications and Limitations[4]

Applications

- Code generation
- Content generation tools
- Copywriting
- Conversational tools
- Educational tools

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LLMs: Applications and Limitations[4]

Applications

- Code generation
- Content generation tools
- Copywriting
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- Educational tools

Limitations

- LLMs are large, and compute-intensive to train
- LLMs can have bias
- LLMs can hallucinate

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Vision-Language Models[5]

- Vision systems are fundamental to understanding our world, however, lack the ability to communicate with humans naturally

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[5] Awais et al. "Foundational Models Defining a New Era in Vision: A Survey and Outlook", arXiv 2023

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- Complex relations between objects and their locations can be better described in human language (text)

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- Complex relations between objects and their locations can be better described in human language (text)
- Vision-Language models (VLMs) bridge the gap between vision and language, understanding both
- The output of a VLM can be modified through human-provided prompts, e.g:
  - segmenting a particular object by providing a bounding box
  - having interactive dialogues by asking questions about an image or video scene
  - manipulating the robot's behavior through language instructions

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[5] Awais et al. "Foundational Models Defining a New Era in Vision: A Survey and Outlook", arXiv 2023

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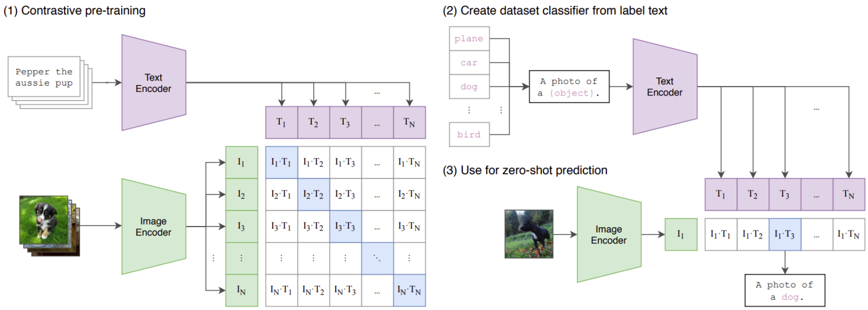
- Visual question answering, i.e., finding answers from an input image and a question in natural language
- Caption generation for a given image
- Detection of hate speech from social media content involving both images and text modalities

Glimpse of Topics in this Module

Contrastive Language Image Pre-training (CLIP) - the pivot![6]


(1) Contrastive pre-training
Pepper the aussie pup
Text Encoder
Image Encoder
T_1 T_2 T_3 ... T_N
I_1 I_2 I_3 ⋮ I_N
$I_1 \cdot T_1$ $I_1 \cdot T_2$ $I_1 \cdot T_3$ ... $I_1 \cdot T_N$
$I_2 \cdot T_1$ $I_2 \cdot T_2$ $I_2 \cdot T_3$ ... $I_2 \cdot T_N$
$I_3 \cdot T_1$ $I_3 \cdot T_2$ $I_3 \cdot T_3$ ... $I_3 \cdot T_N$
$I_N \cdot T_1$ $I_N \cdot T_2$ $I_N \cdot T_3$ ... $I_N \cdot T_N$
(2) Create dataset classifier from label text
plane
car
dog
bird
A photo of a {object}.
Text Encoder
(3) Use for zero-shot prediction
Image Encoder
I_1
T_1 T_2 T_3 ... T_N
$I_1 \cdot T_1$ $I_1 \cdot T_2$ $I_1 \cdot T_3$ ... $I_1 \cdot T_N$
A photo of a dog.

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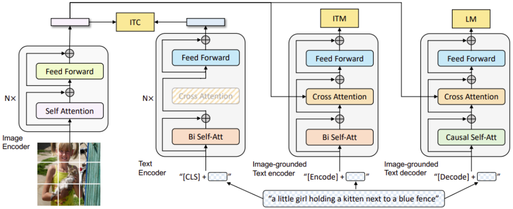
[6] Radford et al, "Learning Transferable Visual Models From Natural Language Supervision", ICML 2021

Glimpse of Topics in this Module

Bootstrapping Language-Image Pretraining (BLIP)[a]



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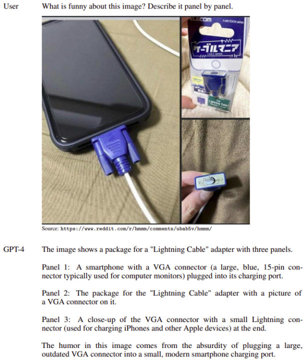
[a] Li "BLIP: Bootstrapping Language-Image Pre-training for Unified Vision-Language Understanding and Generation", ICML 2022

GPT-4[a]



User What is funny about this image? Describe it panel by panel.

Source: https://www.reddit.com/r/hmmm/comments/ubab5v/hmmm/

GPT-4 The image shows a package for a "Lightning Cable" adapter with three panels.

Panel 1: A smartphone with a VGA connector (a large, blue, 15-pin connector typically used for computer monitors) plugged into its charging port.

Panel 2: The package for the "Lightning Cable" adapter with a picture of a VGA connector on it.

Panel 3: A close-up of the VGA connector with a small Lightning connector (used for charging iPhones and other Apple devices) at the end.

The humor in this image comes from the absurdity of plugging a large, outdated VGA connector into a small, modern smartphone charging port.

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[a] Achiam et al, "GPT-4 Technical Report", OpenAI 2023