Yavar Internship Selection Assessment – May 2025

Assessment Problem Statement-2

Image Captioning from Contextual Metadata Using Vision-Language Models (VLMs)

Approach Overview

Developed an end-to-end image captioning system using a **fine-tuned Vision-Language Model (VLM)** — specifically, the **BLIP model (Salesforce/blip-image-captioning-base)**. The goal was to generate both a **concise** and a **detailed** caption for each image, grounded in both its **visual content** and **surrounding textual metadata**.

Each image is paired with a structured metadata file that contains fields such as `section_header`, `above_text`, `caption`, `below_text`, and `footnote`. Our system combines these textual fields into a meaningful context, which is used alongside the image during both training and inference.

The pipeline includes preprocessing, model fine-tuning, caption generation, confidence scoring, inconsistency detection, and annotated output generation.

Preprocessing

Image Preprocessing:

- All images are resized to **384×384 pixels** to match the BLIP model's expected input size.
- Images are normalized using ImageNet mean and standard deviation.
- Images are converted to RGB and passed as tensors to the model.

Metadata Preprocessing:

- Each image has a corresponding `.txt` file with fields:
    - `section_header`

    - `above_text`
    - `caption`
    - `below_text`
    - `footnote`
    - `concise_caption` (ground truth)
    - `detailed_caption` (ground truth)
- Missing values (marked as `null`) are replaced with empty strings.
- These fields are combined into a single context string used during training and inference.

🔹 Model Architecture

- Used the **BLIP (Bootstrapped Language-Image Pretraining)** model from Hugging Face.
- The model accepts both an image and text input to generate captions.
- During training, the model learns to map image + metadata context → target caption.

🔹 Training Details

- **Model**: `Salesforce/blip-image-captioning-base`
- **Training Data**: Images wnot given for training dataith paired metadata [ground-truth `concise_caption` and `detailed_caption` not given for training data]
- **Loss Function**: Cross-entropy loss on generated token sequence
- **Batch Size**: 4
- **Epochs**: 5 (can be increased for better results)

- **Learning Rate**: 5e-5
- **Fine-Tuning Modes**:
    - Trained separately on concise and detailed captions
    - Controlled by a config flag (`TRAINING_CAPTION_TYPE`)
- **Optimiser:**

  AdamW

🔹 Inference & Caption Generation

- For each image:
    - Metadata fields are combined into a rich context.
    - The model generates:
        - A **concise caption** (short summary, 30 tokens max)
        - A **detailed caption** (longer explanation, up to 100 tokens)
- Captions are saved in `captions.json` and overlaid on the image using OpenCV.

🔹 Evaluation & Verifiability

- Each caption is scored using :
    - **ROUGE-L**
- A **confidence score (0–1)** is assigned to each caption.

  Since the model not generated a meaningful caption. Metadata is reflected in the output.

- Captions are checked for consistency against metadata:
    - If the section header has no overlap with the caption → marked as inconsistent

- **Low-confidence or inconsistent captions** are:
    - Logged in a timestamped log file
    - Underlined and highlighted in yellow in the annotated output

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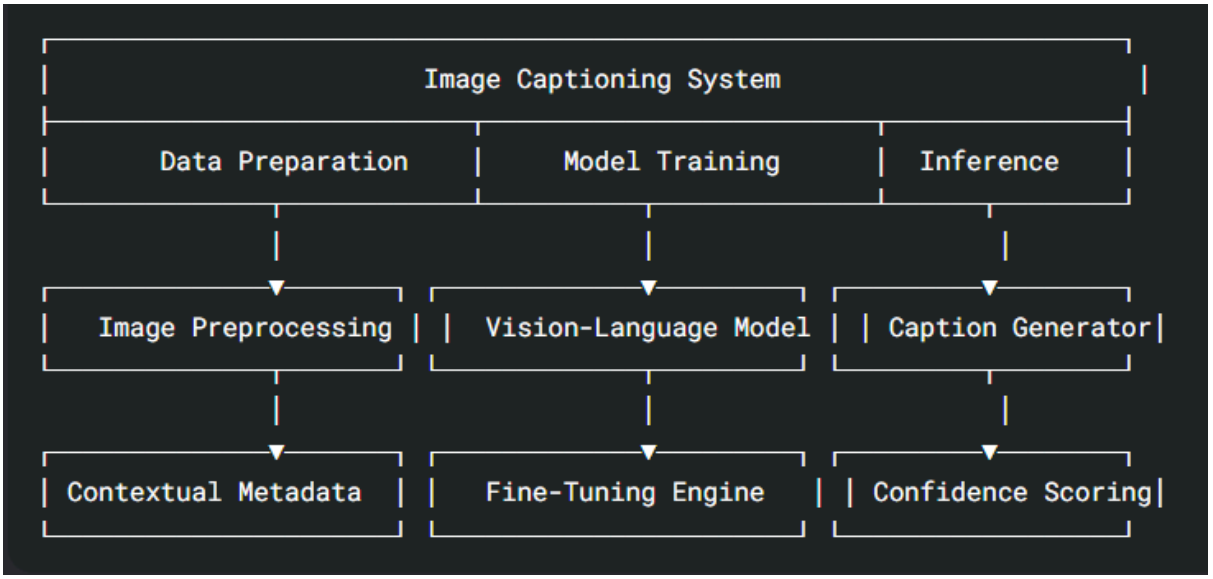
🔹 Output Structure

Outputs are saved in `output_folder/`:

- 📷 Annotated images with:
    - Blue text = Concise caption
    - underline = Low confidence or inconsistency
- 📄 `captions.json` file with:
    - Concise & detailed captions
    - Confidence scores
    - Context used
    - Inconsistency reports

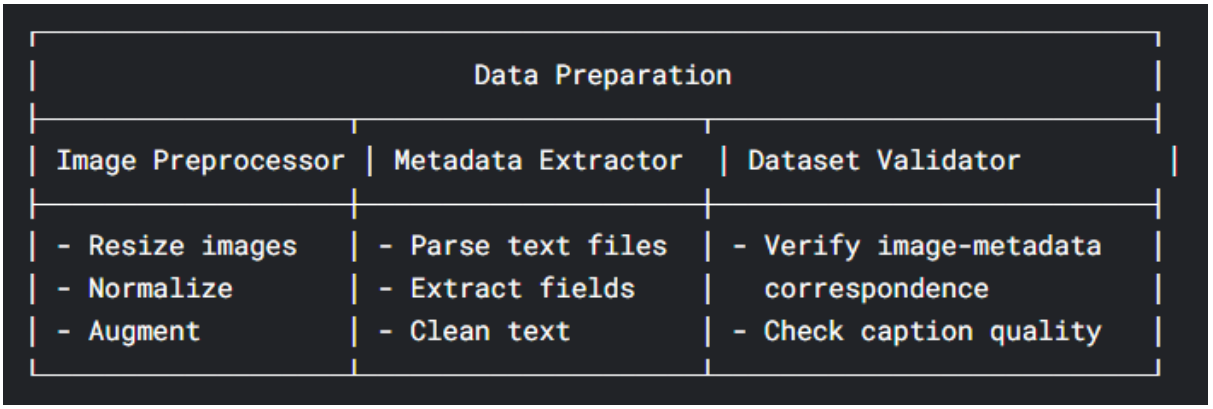
Related Images

1.Architecture overview

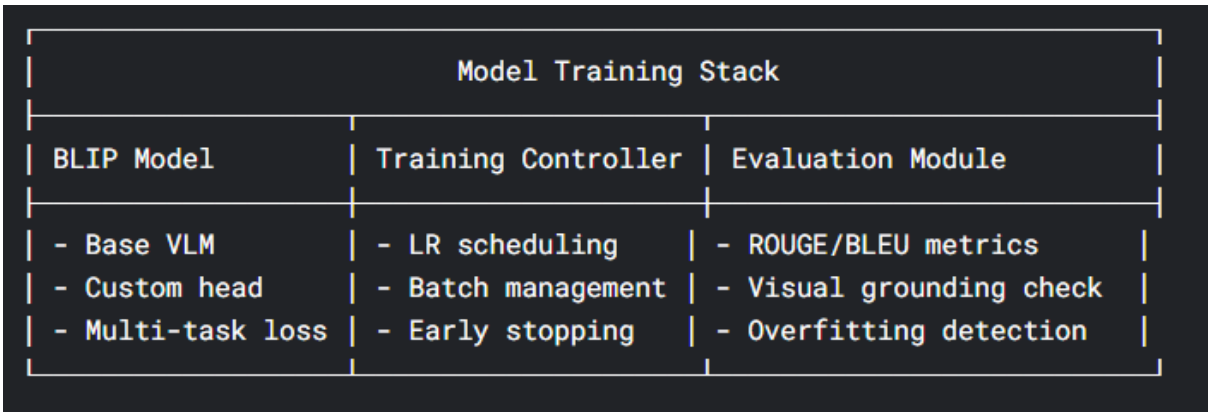


2. Component Breakdown

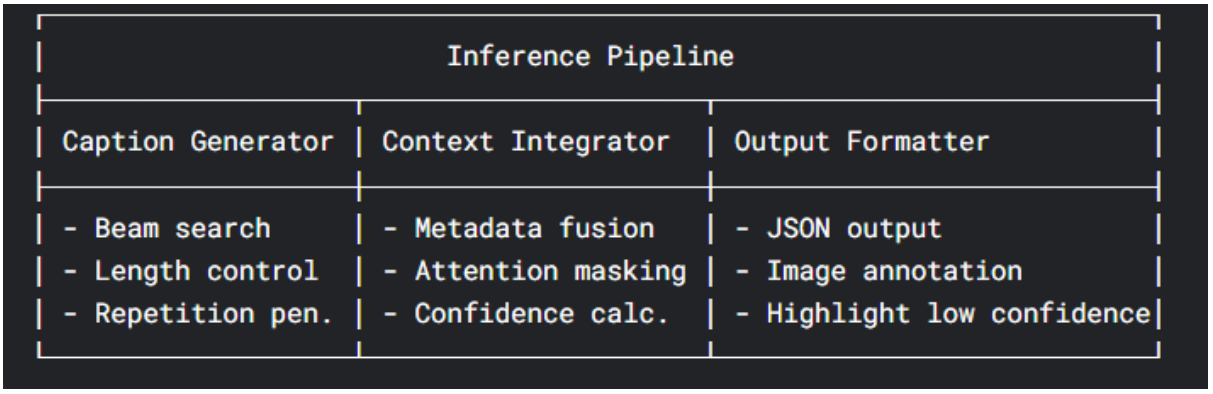
A. Data Preparation Layer



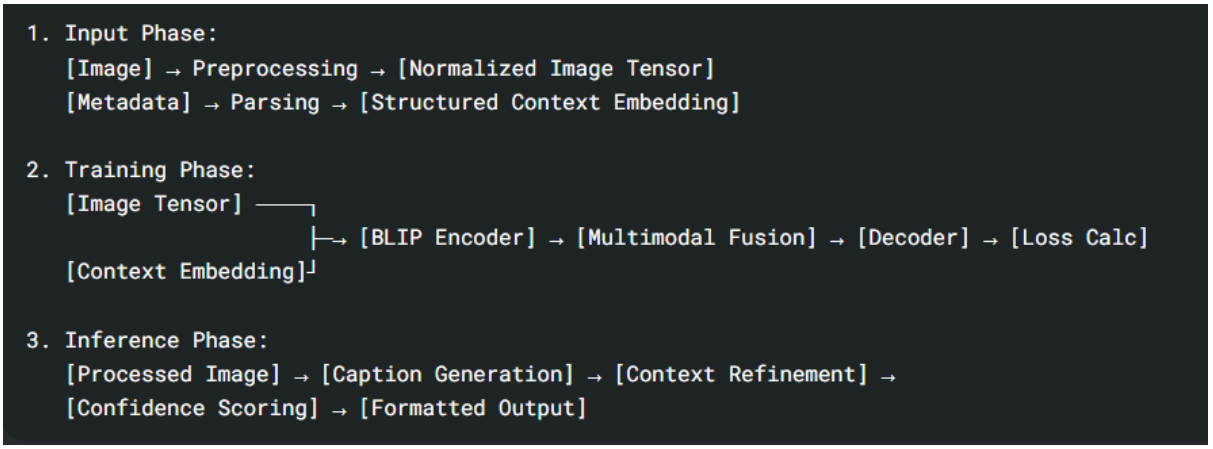
B. Model Training Layer



C. Inference Layer



3. Data Flow



Features
BLIP-based image captioning (Salesforce/blip-image-captioning-base)

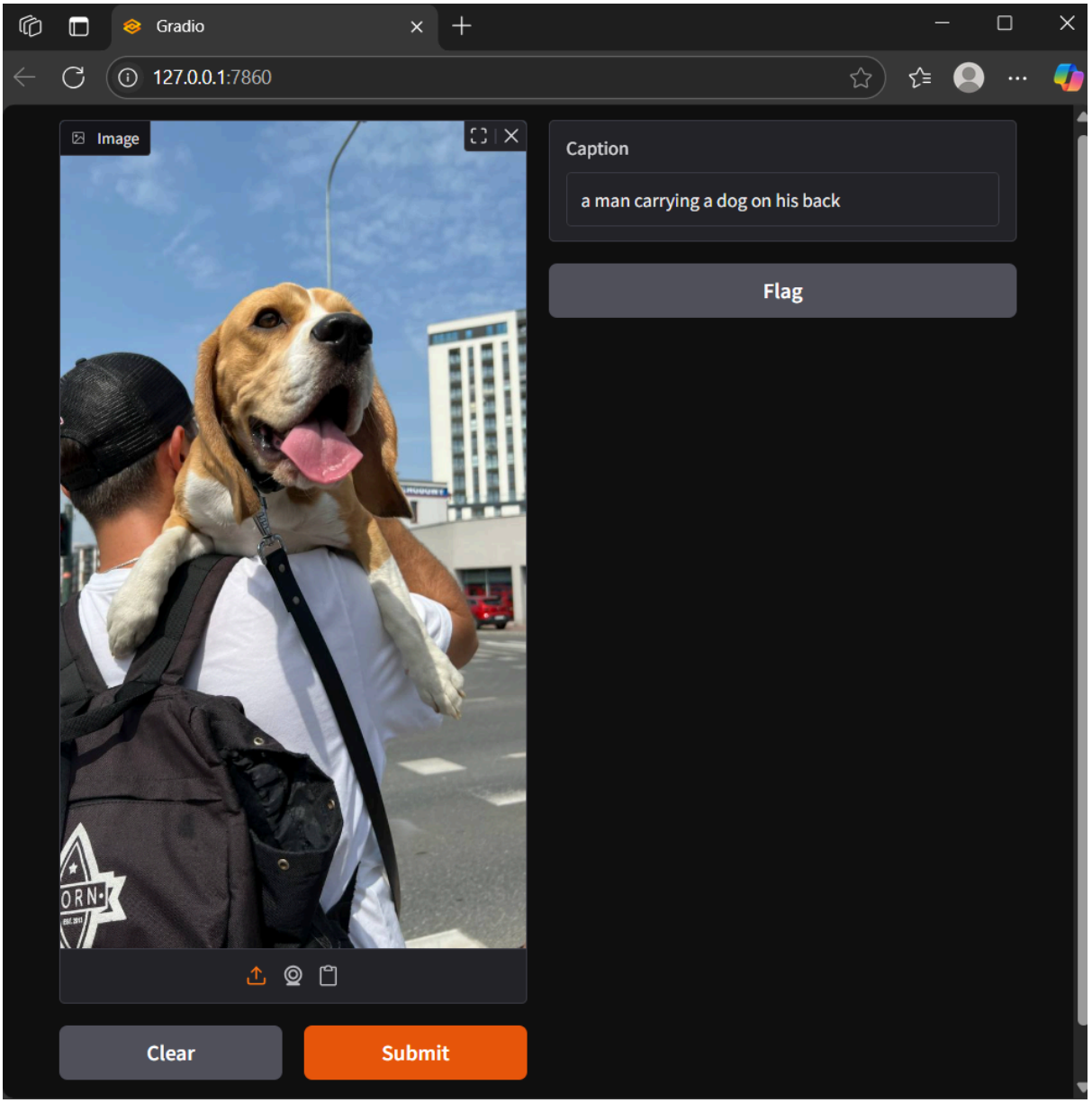
Custom dataset support with metadata (section headers, captions, etc.)

Training and inference scripts

Caption verifiability checks (semantic similarity, consistency)

Annotated output images with generated captions and confidence scores

Salesforce/blip-image-captioning-base model without fine-tuning



Folder Structure

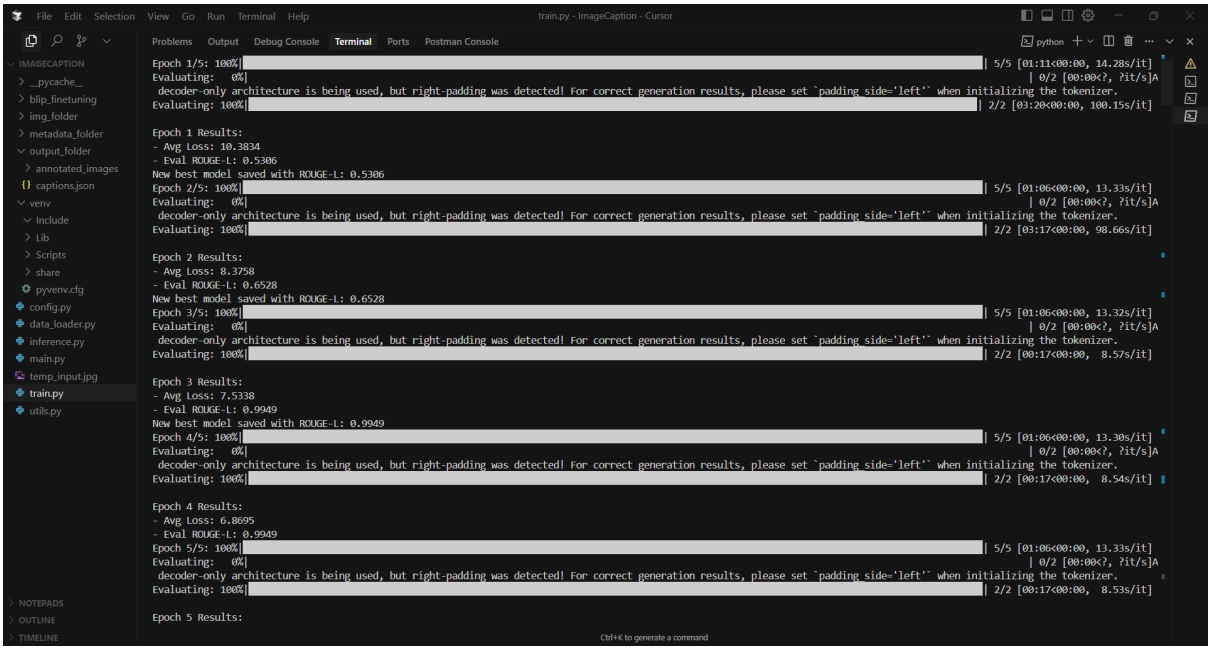
```
.
├── img_folder/           # Input images
├── metadata_folder/      # Metadata files (one per image, .txt format)
├── output_folder/        # Output images and results
├── config.py             # Configuration file
├── data_loader.py        # Custom dataset loader
├── train.py              # Training script
├── inference.py          # Inference and evaluation script
├── utils.py              # Utility functions
└── requirements.txt      # Python dependencies
```

Images (circuits,graphs,logos,charts)

Metadata File Format

```
section_header: "Section Title"
above_text: "Text above the image"
caption: "Ground-truth caption"
picture_id: "image_file_name"
footnote: "Footnote text"
below_text: "Text below the image"
concise: "Short summary"
detailed: "Detailed description"
```

Training



output

ID	NAME	CLASS	MARK	GENDER
1	John Deo	Four	75	female
2	Max Ruin	Three	85	male
3	Arnold	Three	55	male
4	Krish Star	Four	60	female
5	John Mike	Four	60	female
6	Alex John	Four	55	male
7	My John Rob	Five	78	male
8	Asruid	Five	85	male
9	Tes Qry	Six	78	male
10	Big John	Four	55	female

Setup

1.Clone the repository

```
git clone https://github.com/DharaniSowmiyan/YaavarHackathon-22PD11

cd your-repo
```

2.Install dependencies:

```
pip install -r requirements.txt
```

3.Prepare your data:

Place images in img_folder/

Place corresponding metadata .txt files in metadata_folder/

Resources:

Creating an image dataset:

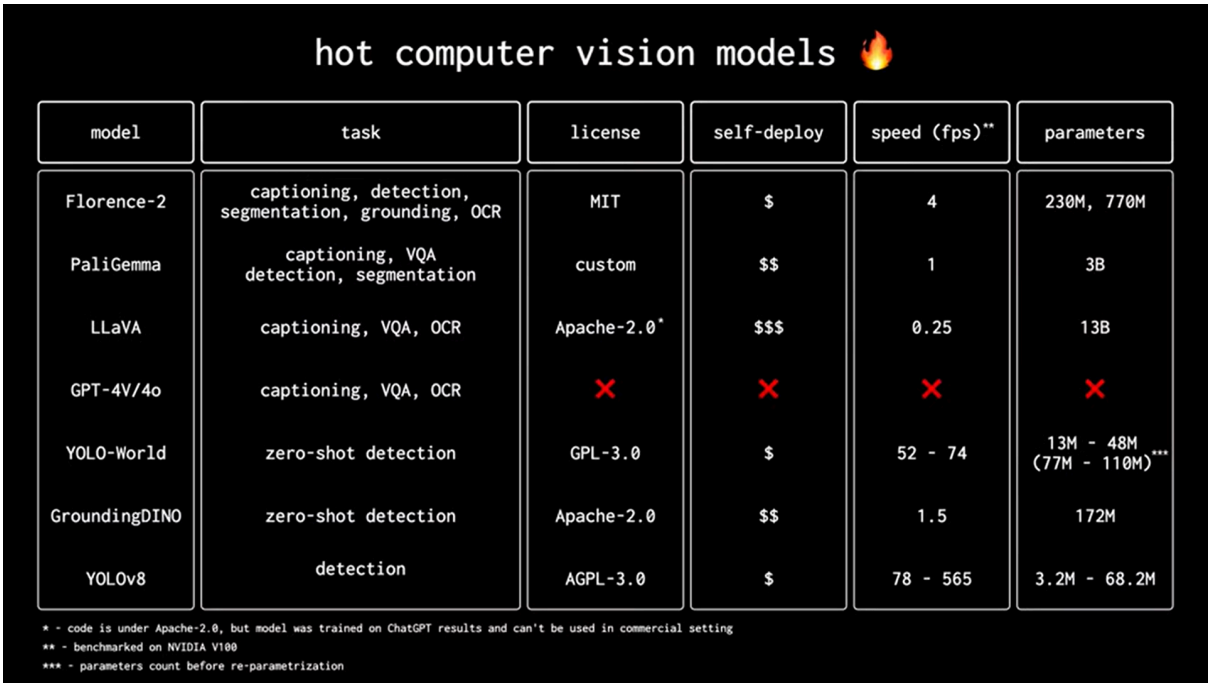
https://huggingface.co/docs/datasets/image_dataset

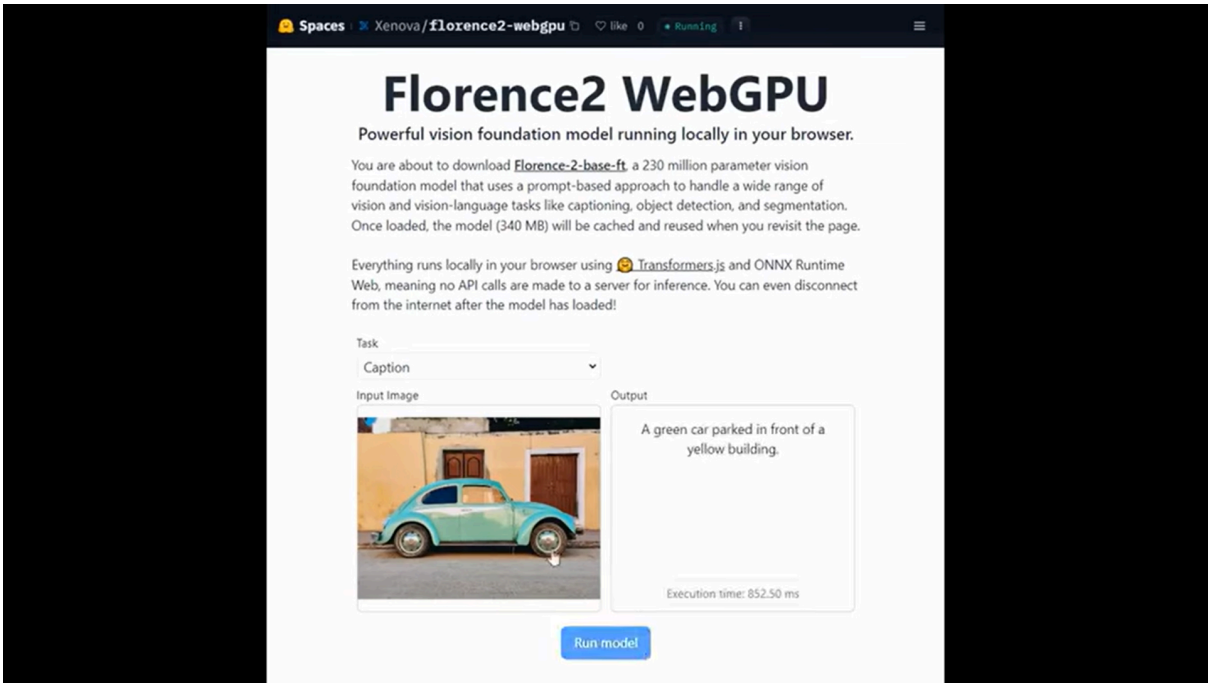
Fine-tune BLIP on an image captioning dataset:

https://colab.research.google.com/drive/1lbqiSiA0sDF7JDWPeS0tccrM85LloVha?usp=sharing#scrollTo=AFGnjCgDoLIJ

Various other models explored:

1.Florence-2
https://blog.roboflow.com/fine-tune-florence-2-object-detection/





Why it did not work:

Florence-2 requires `flash-attn`, which needs:

- GPUs like **A100**, **L4**, or **H100**.
- **CUDA 11.8+** and **PyTorch 2.1+**.

2.Salesforce/blip2-opt-2.7b
https://huggingface.co/Salesforce/blip2-opt-2.7b
3.Salesforce/blip2-flan-t5-xl
https://huggingface.co/Salesforce/blip2-flan-t5-x
(2,3)Why it did not work: while running the model-out of memory since my gpu VRAM is 4GB

4.huggingface.co/yifeihu/TF-ID-base
https://huggingface.co/yifeihu/TF-ID-base
Why it did not work: it detects tables/figures image captioning not supported.

Future work:

Making them(image+context and caption) better Relevance: How well the caption aligns with both the image and the provided context.