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# MMModal - Multi-Images Multi-Audio Multi-turn Multi-Modal

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## Abstract

Our contribution introduces a groundbreaking multimodal large language model designed to comprehend multi-images, multi-audio, and multi-images-multi-audio within a single multiturn session. Leveraging state-of-the-art models, we utilize the SigLIP encoder for visual inputs and the Whisper Encoder for audio inputs. Notably, this multimodal large language model is bilingual, proficient in understanding both English and Malay simultaneously. We proudly unveil three versions of this model: Qwen1.5 with 0.5B parameters, TinyLlama with 1.1B parameters, and Mistral with 7B parameters. With its ability to navigate diverse modalities and languages, our model represents a significant advancement for the Malaysian context and beyond. All models released at [HuggingFace Mesolitica Multimodal Malaysian LLM](#).

## 1 Introduction

Language models trained with instructions have demonstrated remarkable performance across various domains. However, their limitation in handling only text-based data hampers their applicability. Recent advancements in multimodal pre-training have shown the potential to integrate knowledge from diverse modalities into a unified representation [1–3].

The introduction of OpenAI’s GPT-4 [3], which incorporates LLM with visual understanding capability, marked a milestone in the industry’s progress, demonstrating significant advancements in addressing open-ended visual question-answering (VQA) tasks. Pioneering research initiatives such as LLaVA [2] and MiniGPT-4 [4] provide insightful directions in visual and text understanding capability. Their findings suggest that by incorporating visual encoders into existing LLMs and fine-tuning them using multi-modal instruction-tuning datasets, LLMs can be effectively transformed into multimodal LLMs. While Macaw-LLM [1] introduces the integration of LLM with four different modalities: text, audio, video, and images. They successfully process information from different inputs effectively, enabling seamless information retrieval across domains. Existing dataset for multi-modal instruction made available from [2] primarily supports instruction-following data involving visual content for conversation, detailed description and complex reasoning data.

Despite recent advancements, there remains a lack of current research on multimodal models capable of handling multiple images or audio inputs along with multi-turn dialogue. Moreover, there is a lack of existing multimodal datasets incorporating multi-turn interactions with multiple audio and image inputs, and little consideration has been given to the Malaysian context. To address these gaps, our proposal introduces MModal, a multimodal large language model fine-tuned for multi-modal instruction, integrating image, audio, and text modalities within a single model architecture. Additionally, we present a corpus and employ an adaptive synthetic data generation method tailored to provide access to multi-image, multi-audio, multi-turn datasets with regards to languages in Malay and English.

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- **Synthetic Audio Instruction Dataset:** To construct Synthetic Audio Instruction Dataset, our approach involves gathering extracted audio content from YouTube videos. We employed the Whisper Large V3 model for pseudolabeling to transcribe the audio contents from scraped Youtube videos, followed by a post-filtering process based on score thresholds to ensure high-quality datasets. We then utilized the Mixtral-8x7B-Instruct-v0.1 Model to generate multiturn dialogue instruction-following data involving the audio context.
- **Synthetic Visual Malaysian Context Dataset:** We collected images from Malaysian websites along with their descriptions. Through data processing, we converted this information into conversational examples to better incorporate Malaysian context into our model.
- **Synthetic Multi-Images Multi-Audio relationship Dataset:** Our method involved randomly combining images, audios or pairing them together to create a dataset illustrating relationships of different images and audios. We utilized Mistral to generate multiturn dialogues, prompting the model to respond based on the images, audio captions, and descriptions. This enabled us to collect a corpus tailored for focusing on relationships within multi-modal content, encompassing both images and audio.
- **Pretraining Feature Alignment:** Our approach adopts a two-step training procedure to integrate multimodal and multiturn capabilities into our model. The initial step entails pretraining the feature alignment module. Through this process, we align the image and audio features with the pre-trained word embeddings of the Large Language Model (LLM). Specifically, this step involves training the projection layer to ensure alignment between the multi-modal features and textual representations. This alignment facilitates seamless integration of diverse modalities within the model architecture.
- **Finetuned Multi-Images Multi-Audio Multi-turn Model:** After pre-training for feature alignment, the projector module becomes familiar with the visual and embedding space. However, it still lacks the capability to discern the finer details of images and audios, or to respond to human questions and instructions effectively. In the second stage, we utilize generated synthetic Multimodal data to enhance performance and further align the embeddings with the Large Language Model (LLM). This step improves the LLM's ability to produce more natural and reliable language outputs for multimodal instructions.

## 2 Synthetic Data Generation for Audio Instructions

We gathered the audio from youtube and use pseudolabeling approach to transcribe the audio from speech to text using OpenAI's Whisper Large V3.

We then generate synthetic audio instruction using [mistralai/Mixtral-8x7B-Instruct-v0.1](#) model. This model, specifically designed for instruction generation, integrates advanced natural language understanding capabilities to produce coherent and contextually relevant audio instructions from the transcribed text.

Below is the prompt to generate the synthetic dataset:

```
anda tahu keuntungan boleh lebih tinggi daripada keuntungan kewangan rumah maka
saya tidak akan mencari dalam akaun saya akan mencari ke dalam ethereum atau
beberapa crypto punks bergantung pada faktor risiko anda kerana rumah kajang
dihantar tidak mengganggu dsr saya sejauh ini jadi sekarang apa posisi saya
untuk mendapatkan kewangan ketiga jadi mungkin setelah melihat sekeliling saya
menemui seorang penjual yang dapat menutupi perhubungan tetapi bank hanya
menerima 70% dari itu saya boleh membayar perbezaan dengan menggunakan wang
ini kerana sekali lagi ia menyusahkan saya dan aset tetapi jika anda tidak
selesa dengan mencari
```

```
generate questions based on context above.
```

An example of generated dataset:

```
{'context': 'anda tahu keuntungan boleh lebih tinggi daripada keuntungan kewangan
rumah maka saya tidak akan mencari dalam akaun saya akan mencari ke dalam
ethereum atau beberapa crypto punks bergantung pada faktor risiko anda kerana
rumah kajang dihantar tidak mengganggu dsr saya sejauh ini jadi sekarang apa
```

posisi saya untuk mendapatkan kewangan ketiga jadi mungkin setelah melihat sekeliling saya menemui seorang penjual yang dapat menutupi perhubungan tetapi bank hanya menerima 70% dari itu saya boleh membayar perbezaan dengan menggunakan wang ini kerana sekali lagi ia menyusahkan saya dan aset tetapi jika anda tidak selesa dengan mencari',

```
'chat': [{'role': 'user',
'content': 'Why might someone consider investing in cryptocurrencies like
Ethereum instead of traditional financial investments such as real estate?'},
'content_ms': 'Mengapakah seseorang mungkin mempertimbangkan untuk melabur dalam
mata wang kripto seperti Ethereum dan bukannya pelaburan kewangan tradisional
seperti hartanah?'}],
{'role': 'assistant',
'content': 'There are several reasons why someone might consider investing in
cryptocurrencies like Ethereum instead of traditional financial investments
such as real estate:\n\n1. Potential for higher returns: Cryptocurrencies
have the potential for much higher returns compared to traditional financial
investments. While the real estate market can be profitable, the potential
for exponential growth in the cryptocurrency market is significantly
higher.\n2. Diversification: Investing in cryptocurrencies can provide a
diversification benefit to an investment portfolio. By investing in a variety
of assets, including cryptocurrencies, investors can spread their risk and
potentially increase their overall returns.\n3. Liquidity: Cryptocurrencies
are generally more liquid than real estate investments. It is easier to buy
and sell cryptocurrencies, and they can be quickly converted into cash.\n4.
Accessibility: Investing in cryptocurrencies is generally more accessible
than investing in real estate. There are fewer barriers to entry, and it is
easier to get started with a smaller amount of money.\n5. Decentralization:
Cryptocurrencies are decentralized, meaning they are not controlled by any
government or financial institution. This can provide a level of independence
and autonomy that is not possible with traditional financial
investments.\n\nHowever, it is important to note that investing in
cryptocurrencies is also riskier than traditional financial investments. The
value of cryptocurrencies can be highly volatile, and there is a risk of
losing all or a significant portion of the investment. Therefore, it is
important to carefully consider your own risk tolerance and financial
situation before investing in cryptocurrencies.',
'content_ms': 'Terdapat beberapa sebab mengapa seseorang mungkin mempertimbangkan
untuk melabur dalam mata wang kripto seperti Ethereum dan bukannya pelaburan
kewangan tradisional seperti hartanah:\n\n1. Potensi untuk pulangan yang
lebih tinggi: Mata wang kripto mempunyai potensi untuk pulangan yang lebih
tinggi berbanding dengan pelaburan kewangan tradisional. Walaupun pasaran
hartanah boleh menguntungkan, potensi pertumbuhan eksponen dalam pasaran mata
wang kripto adalah jauh lebih tinggi.\n2. Kepelbagaian: Melabur dalam mata
wang kripto boleh memberikan manfaat kepelbagaian kepada portfolio pelaburan.
Dengan melabur dalam pelbagai aset, termasuk mata wang kripto, pelabur boleh
menyebarkan risiko mereka dan berpotensi meningkatkan pulangan keseluruhan
mereka.\n3. Kecairan: Mata wang kripto biasanya lebih cair daripada pelaburan
hartanah. Lebih mudah untuk membeli dan menjual mata wang kripto, dan ia
boleh ditukar dengan cepat kepada wang tunai.\n4. Kebolehcapaian: Melabur
dalam mata wang kripto secara umumnya lebih mudah diakses daripada melabur
dalam hartanah. Terdapat lebih sedikit halangan untuk masuk, dan lebih mudah
untuk bermula dengan jumlah wang yang lebih kecil.\n5. Desentralisasi: Mata
wang kripto adalah terdesentralisasi, bermakna ia tidak dikawal oleh
mana-mana kerajaan atau institusi kewangan. Ini boleh memberikan tahap
kebebasan dan autonomi yang tidak mungkin dilakukan dengan pelaburan kewangan
tradisional.\n\nWalau bagaimanapun, adalah penting untuk ambil perhatian
bahawa melabur dalam mata wang kripto juga lebih berisiko daripada pelaburan
kewangan tradisional. Nilai mata wang kripto boleh menjadi sangat tidak
menentu, dan terdapat risiko kehilangan semua atau sebahagian besar
pelaburan. Oleh itu, adalah penting untuk mempertimbangkan dengan teliti
toleransi risiko dan keadaan kewangan anda sendiri sebelum melabur dalam mata
wang kripto.'}],
{'role': 'user',
'content': 'mengapa orang menggunakan blockchain untuk mengurus siasia digital',
```

```

'content_ms': 'mengapa orang menggunakan blockchain untuk menguruskan sisa
digital'}},
{'role': 'assistant',
'content': 'There are several reasons why people use blockchain technology to
manage digital assets:\n\n1. Security: Blockchain technology provides a high
level of security for managing digital assets. The decentralized nature of
blockchain makes it difficult for hackers to manipulate or steal digital
assets.\n2. Transparency: Blockchain provides a transparent record of all
transactions related to a digital asset. This makes it easier to track
ownership and verify the authenticity of the asset.\n3. Accessibility:
Blockchain technology allows for the easy transfer and management of digital
assets, making them accessible to anyone with an internet connection.\n4.
Immutability: Once data is recorded on a blockchain, it cannot be altered or
deleted. This ensures that the record of ownership and transactions related
to a digital asset is permanent and cannot be tampered with.\n5.
Programmability: Blockchain technology allows for the creation of smart
contracts, which are self-executing contracts with the terms of the agreement
directly written into code. This enables automatic and secure transfer of
digital assets based on predefined conditions.\n6. Interoperability:
Blockchain technology enables the interoperability of different digital
assets and systems, allowing for seamless transfer and exchange of
value.\n\nOverall, the use of blockchain technology for managing digital
assets provides a secure, transparent, and decentralized system that is
accessible to anyone with an internet connection. This makes it an attractive
solution for managing various types of digital assets, including
cryptocurrencies, digital art, and other digital assets.',
'content_ms': 'Terdapat beberapa sebab mengapa orang menggunakan teknologi
blockchain untuk mengurus aset digital:\n\n1. Keselamatan: Teknologi
Blockchain menyediakan tahap keselamatan yang tinggi untuk mengurus aset
digital. Sifat blockchain yang tidak berpusat menyukarkan penggadam untuk
memanipulasi atau mencuri aset digital.\n2. Ketelusan: Blockchain menyediakan
rekod yang telus bagi semua transaksi yang berkaitan dengan aset digital. Ini
memudahkan untuk menjejak pemilikan dan mengesahkan ketulenan aset.\n3.
Kebolehcapaian: Teknologi Blockchain membolehkan pemindahan dan pengurusan
aset digital dengan mudah, menjadikannya boleh diakses oleh sesiapa sahaja
yang mempunyai sambungan internet.\n4. Ketidakbolehubahan: Setelah data
direkodkan pada rantaian blok, ia tidak boleh diubah atau dipadamkan. Ini
memastikan rekod pemilikan dan transaksi yang berkaitan dengan aset digital
adalah kekal dan tidak boleh diusik.\n5. Kebolehprograman: Teknologi
Blockchain membolehkan penciptaan kontrak pintar, yang merupakan kontrak yang
dilaksanakan sendiri dengan syarat perjanjian yang ditulis terus ke dalam
kod. Ini membolehkan pemindahan aset digital secara automatik dan selamat
berdasarkan syarat yang telah ditetapkan.\n6. Saling kendali: Teknologi
Blockchain membolehkan kesalingoperasian aset dan sistem digital yang
berbeza, membolehkan pemindahan dan pertukaran nilai yang lancar.\n\nSecara
keseluruhannya, penggunaan teknologi blockchain untuk mengurus aset digital
menyediakan sistem yang selamat, telus dan terpencar yang boleh diakses oleh
sesiapa sahaja yang mempunyai sambungan internet. Ini menjadikannya
penyelesaian yang menarik untuk mengurus pelbagai jenis aset digital,
termasuk mata wang kripto, seni digital dan aset digital lain.'}},
'filename': 'output-audio/1-0-0.mp3'}

```

The audio synthetic dataset and implementation published at [mesolitica/malaysian-youtube-audio-instructions](https://mesolitica.com/malaysian-youtube-audio-instructions/).

### 3 Synthetic Visual Malaysian Context Dataset

We gathered datasets that include images and captions, as detailed in the sources mentioned at [Multimodal Malaysian LLM dataset](#). We then generate synthetic instruction data based on image captions using a custom script as we parsed a JSON Lines file containing image captions.

Below are the script that we used to generate synthetic visual instructions:

```

chats = []
with open('motomalaysia-data.jsonl.translated') as fopen:
    for l in fopen:
        l = json.loads(l)
        overview = l['specs']['overview_translated']
        overview = [s for s in overview if s]
        overview = '\n'.join(overview)
        spec = '\n'.join(l['specs']['specs'])
        conversations = []
        conversations.extend([
            {"role": "user", "content": "<image>Ini model apa?"},
            {"role": "assistant", "content": l['specs']['model_name']},
        ])
        if len(overview):
            conversations.extend([
                {"role": "user", "content": "apa kelebihan moto tu?"},
                {"role": "assistant", "content": overview},
            ])
        conversations.extend([
            {"role": "user", "content": "apa spesifikasi moto tu?"},
            {"role": "assistant", "content": spec},
        ])
        chats.append({
            'image': l['local_image'],
            'image_url': l['img_url'],
            'conversations': conversations
        })

```

An example of generated dataset are as follow:

```

{
  "image": "pic/Yamaha NMAX (2016)_1.jpg",
  "image_url":
    "https://www.motomalaysia.com/wp-content/uploads/2017/10/yamaha-nmax-2.jpg",
  "conversations": [
    {
      "role": "user",
      "content": "<image>Ini model apa?"
    },
    {
      "role": "assistant",
      "content": "Yamaha NMAX (2016)"
    },
    {
      "role": "user",
      "content": "apa spesifikasi moto tu?"
    },
    {
      "role": "assistant",
      "content": "Manufacturer: Yamaha\nModel: 2016\nGeneration: Yamaha NMAX
        (2016)\n\nType: Scooter\nColour Available: Grey, Red\n\nDimension: 1,955
        x 740 x 1,115 mm\nWheelbase: 1,350 mm\nWeight: 136 kg\nSeat Height: 765
        mm\nGround Clearance: 135 mm\nMeter Display: Digital - Speedometer, Fuel
        Gauge\n\nEngine: 4-Stroke, SOHC\nDisplacement: 155 CC\nNo Of Cylinders:
        1-Cylinder\nCompression Ratio: 10.5 : 1\nBore x Stroke: 58mm x
        58.7mm\nMax Power: 11.1 kW @ 8,000 RPM\nMax Torque: 14.4 Nm @ 6,000
        RPM\nTransmission: Automatic, CVT\nClutch: Dry, centrifugal,
        Shoe\nIgnition System: Transistor Coil Ignition (TCI)\nStarting System:
        Electric Starter\nCooling System: Liquid Cooled\nFuel System: Fuel
        Injection\nFuel Capacity: 6.6 Liters\n\nFeatures:\nType: Underbone\nFront
        Suspension: Telescopic\nRear Suspension: Unit Swing\nFront Brake:
        Disc\nRear Brake: Disc\nFront Tire: 110/70-13\nRear Tire: 130/70-13"
    }
  ]
}

```

---

We designed a synthetic question-answering dialogues between assistant and a person about the photo. The answers are based on captions associated with the original data of the image.

The synthetic visual dataset and its implementation can be found on the HuggingFace Collections page under [Multimodal Malaysian LLM dataset](#).

## 4 Synthetic Multi-Images Multi-Audio relationship Dataset

### 4.1 Synthetic Multi-Images Instruction

### 4.2 Synthetic Multi-Audio Instruction

### 4.3 Synthetic Image-Audio Instruction

## 5 Synthetic Data Generation for Multi-Images, Multi-Audio Multi-turn Instructions

We have observed that most open-source multimodal models accept only single images in individual multi-turn dialogues. These limitations make it difficult for people to further enhance the models.

To bridge these gaps, we aim to generate a multiple images, audio and dialogue turns that offers fine-grained interactions between multiple images, audio and words, mimicking user-assistant conversations.

We build a script that parse visual and audio context datasets and perform an algorithm that combine each visual context row into another audio context or image context row based on probability which makes our combined data more varied.

Below are the script to combine synthetic visual and audio context dataset:

```
llava_index = set(range(len(llava_en)))
audio_index = set(range(len(audio_en)))
combine = []
llava = set()
audio = set()
for i in tqdm(range(50000)):
    try:
        filename = []
        conversations = []
        for _ in range(random.randint(2, 4)):
            if random.random() > 0.4:
                img_id = random.choice(list(llava_index - llava))
                llava.add(img_id)
                s = llava_en[img_id]
            else:
                audio_id = random.choice(list(audio_index - audio))
                audio.add(audio_id)
                s = audio_en[audio_id]
            filename.extend(s['filename'])
            conversations.extend(s['conversations'])
        combine.append({
            'filename': filename,
            'conversations': conversations
        })
    except Exception as e:
        print(e)
        break
```

An example of combined synthetic visual and audio context datasets:

```
{'filename': ['/home/ubuntu/output-audio/0-3201-1.mp3',
```

```

'/home/ubuntu/filtered-llava-images/000000416018.jpg',
'/home/ubuntu/filtered-llava-images/000000128752.jpg',
'/home/ubuntu/filtered-llava-images/000000501015.jpg'],
'conversations': [{ 'role': 'user',
  'content': "<audio>What is Tasha's opinion on the spiciness of the first soup
served?"},
{ 'role': 'assistant',
  'content': 'Based on the conversation, Tasha felt that the first soup served was
too spicy.'},
{ 'role': 'user', 'content': 'Okay. Mengapa Tasha pandangan begini?'},
{ 'role': 'assistant',
  'content': 'The exact reason for Tasha\'s opinion is not mentioned in the
conversation, but she can be heard saying "Yup. Yes. Ni pedas gila." which
suggests that the first soup served was extremely spicy.'},
{ 'role': 'user',
  'content': 'Okay. Sekarang kita tanya Jane. Okay. Jane, how spicy is your
soup?'},
{ 'role': 'assistant',
  'content': 'Based on the conversation, Jane said "Second pedas" which means that
she found the spiciness of her soup to be less spicy compared to the first
soup.'},
{ 'role': 'user',
  'content': "What implications does the presence of the steering wheel controller
have for the type of game they're playing?\n<image>"},
{ 'role': 'assistant',
  'content': 'Given that one of the people in the image is holding a video game
controller shaped like a steering wheel, it is highly likely that they are
playing a racing or driving simulation game. The steering wheel controller
is specifically designed to provide a more immersive and realistic gaming
experience for games that involve controlling vehicles. This suggests that
the game they are engaging with is focused on car or vehicle navigation, and
the participants are actively controlling in-game actions by manipulating
the steering wheel controller.'},
{ 'role': 'user',
  'content': 'What factors could affect the flight of this aircraft?\n<image>'},
{ 'role': 'assistant',
  'content': "Several factors could affect the flight of the British Airways
jetliner observed in the image. These may include:\n\n1. Weather conditions:
The plane is flying through a foggy sky, which may impact visibility,
turbulence, and overall flight conditions. Adverse weather events, such as
storms or strong winds, could also significantly impact the flight.\n\n2.
Air traffic: The presence of other aircraft in the airspace could influence
the flight route, altitude, or speed. Air traffic controllers need to manage
multiple aircraft in the sky to maintain safety and avoid conflicts.\n\n3.
Technical issues: Aircraft systems and equipment must function properly to
ensure a safe and efficient flight. Any technical issues or malfunctions may
disrupt the flight and require prompt action from the crew.\n\n4. Human
factors: The skills, experience, and decision-making processes of pilots and
other crew members can significantly impact the safety, comfort, and
efficiency of the flight.\n\n5. Regulatory constraints: International
aviation regulations and guidelines from governing bodies can affect the
aircraft's flight trajectory, speed, altitude, and other operational
aspects.\n\nConsidering these factors, the British Airways jetliner needs to
navigate through the foggy sky efficiently while maintaining safety
protocols and adhering to aviation regulations."},
{ 'role': 'user',
  'content': '<image>\nHow would you describe the positioning of the bottles in
this image?'},
{ 'role': 'assistant',
  'content': "In the image, there are several bottles positioned in various
locations. Some bottles are inside the refrigerator, with one being held in
the person's hand, while others are placed outside of the fridge. The person
is posing near the open refrigerator, which appears to have quite a few
bottles arranged in it. The bottles inside the fridge are lined up
horizontally on different shelves at various heights, indicating that they

```

might be chilling until they are ready to be consumed. There are also a couple of bottles placed outside the fridge, possibly on a countertop or other surfaces within the image. The dining table and a laptop can also be seen in the background, but they are not directly related to the positioning of the bottles."}}}

By doing this approach, multimodal model would enhance its capabilities on understanding and reasoning across multiple images, audios and dialogue turns.

The implementation can be found on the Github repository page under <https://github.com/mesolitica/multimodal-LLM>.

## 6 Finetuning Procedure

MMModal aims to align visual and audio information from pretrained vision and audio encoders with an advanced large language model (LLM). We aim to bridge the gap between the visual and audio encoders and the LLM using a linear projection layer. To create an effective multimodal model, we followed a two-stage training approach exemplified by the works of [4–6] which have notably produced great results. In the initial stage, the model is pretrained on aligned image-text pairs and audio-text pairs to acquire knowledge of vision and audio language through the alignment projection layer. In the second stage, we fine-tune the pretrained model using a generated multiturn multiaudio images synthetic dataset, incorporating a designed conversational template to enable model comprehension on multi-images, multi-audio, and multi-images-multi-audio within a single multiturn session.

### 6.1 Overall Architecture

### 6.2 Pretraining for Visual Feature Alignment

During the initial pretraining stage, the primary objective is to equip the model with the ability to understand and generate language based on visual input. This is achieved through exposure to a diverse set of paired image-text data, where the model learns to associate visual information with corresponding textual descriptions. In our work, we utilize the pre-trained SigLip visual encoder to extract visual features for input into the projection layer. This projection layer facilitates the connection of image features into the text embedding space. The output of this projection layer then acts as the input to the Large Language Model, instructing it on how to generate appropriate textual responses based on the visual features provided. Only the linear projection layer is pretrained during the whole pretraining procedure; the pretrained vision encoder and the LLM stay frozen.

In our approach, we adopt the same projection layer as LLAVA, which consists of two hidden layers with GELU activation at the middle. However, we introduce two new tokens, `<image>` and `</image>`, to facilitate the incorporation of visual information. These tokens serve as markers to indicate the beginning and end of projected visual output, enabling seamless integration within the text embedding.

The visualization below illustrates the process of inserting projected visual output between the `<image>` and `</image>` tokens, enhancing the model’s ability to handle multimodal inputs effectively.

The hyperparameters involves in this pretraining stage are detailed below:

| Hyperparameter | Value          |
|----------------|----------------|
| DeepSpeed      | ZeRO-2 Offload |
| Batch Size     | 18             |
| Batch Size     | 1              |
| Learning Rate  | 1e-4           |
| Warmup Ratio   | 0.03           |
| Precision      | bfloat16       |

The implementation for visual feature alignment pretraining can be found [here](#)



### 6.3 Pretraining for Audio Feature Alignment

We also want to equip the model with the capability to comprehend and produce language from audio input. This is achieved by exposing the model to a diverse set of paired audio-text datasets, allowing it to learn the correspondence between audio features and corresponding textual descriptions. We utilize the pre-trained Whisper encoder to extract audio features for input into the projection layer. The injected projection layer plays a pivotal role in this process, serving as a bridge between the audio and text domains. The output of this projection layer serves as input to the Large Language Model, guiding it in generating appropriate textual responses based on the audio features provided. It is important to note that while the linear projection layer is trained throughout the entire pretraining procedure, the pretrained audio encoder and the Large Language Model remain static, or "frozen." This ensures that the model focuses specifically on learning the associations between auditory features and textual information without altering the underlying representations learned in the audio encoder or the language model.

Drawing inspiration from LLaVA, our projection layer diverges by employing a convolutional operation with a kernel size of 40 and a stride size of 3 for the first layer, followed by a linear layer for the second, with a GELU activation function applied at its midpoint. This design choice optimizes the model's ability to process audio inputs effectively. Additionally, we introduce two new tokens, `<audio>` and `</audio>`, serving as delimiters to demarcate the commencement and conclusion of projected audio output, thus facilitating its seamless integration within the text embedding.

The visualization below demonstrates the procedure of embedding projected audio output between the `<audio>` and `</audio>` tokens.

The hyperparameters involved in this pretraining stage are detailed below:

| Hyperparameter | Value          |
|----------------|----------------|
| DeepSpeed      | ZeRO-2 Offload |
| Batch Size     | 18             |
| Batch Size     | 1              |
| Learning Rate  | 1e-4           |
| Warmup Ratio   | 0.03           |
| Precision      | bfloat16       |

The implementation for audio feature alignment pretraining can be found [here](#)

### 6.4 Instruction Finetuning

Following the initial pre-training alignment phase, the projection layer will be able to generate image and audio features that are effectively aligned with the pretrained Large Language Model text embedding space. However the pretrained LLM may still struggle to provide effective responses to human inquiries and may be unable to comprehend instructions involving multiple images, multiple audio files, and combinations thereof. To address this, we implement a second stage, utilizing the generated synthetic data to enhance performance and refine the alignment between audio, visual embeddings, the LLM, and instructions.

This stage involves fine-tuning the projection layer and the LLM on our collection corpus of generated synthetic data encompassing multiturn, multi-images and multi-audios data. The objective is to enable our multimodal model to process multiple inputs from images or audios and engage in multiturn conversation seamlessly. A significant advancement in our multi-image input capability stems from this fine-tuning procedure.

Throughout fine-tuning, we maintain the visual and audio encoder weights frozen while updating both the pre-trained weights of the projection layer and the LLM. Notably, we also incorporate a mechanism to replace image and audio embeddings based on the position of the image and audio tokens in the text embeddings, ensuring the model's ability to comprehend audio, image and text information effectively.

The hyperparameters involved in this finetuning stage are detailed below:

Complete fine-tuning 8192 context length implementation at [here](#).

| Hyperparameter | Value          |
|----------------|----------------|
| DeepSpeed      | ZeRO-2 Offload |
| Batch Size     | 12             |
| Learning Rate  | constant 2e-5  |
| Precision      | bfloat16       |

## 7 Examples

This section presents examples that highlight the model’s capacity to comprehend and produce responses relating to visual and audio input, showcasing the efficacy and potential of our proposed MMModal. These examples clearly demonstrate how the model handles and combines various information modalities, including audio and pictures.

### Multi Images Input Example



|         |  |
|---------|--|
| User    | What is related between image 1 and image 2? |
| MMModal | Nothing?                                     |

### Multi Audio Input Example

Audio 1 Transcription: anda tahu keuntungan boleh lebih tinggi daripada keuntungan kewangan rumah maka saya tidak akan mencari dalam akaun saya akan mencari ke dalam ethereum atau beberapa crypto punks bergantung pada faktor risiko anda kerana rumah kajang dihantar tidak mengganggu dsr saya sejauh ini jadi sekarang apa posisi saya untuk sekali lagi ia menyusahkan saya dan aset tetapi jika anda tidak selesai dengan mencari

Audio 2 Transcription: anda tahu keuntungan boleh lebih tinggi daripada keuntungan kewangan rumah maka saya tidak akan mencari dalam akaun saya akan mencari ke dalam ethereum atau beberapa crypto punks bergantung pada faktor risiko anda kerana rumah kajang dihantar tidak mengganggu dsr say lagi ia menyusahkan saya dan aset tetapi jika anda tidak selesai dengan mencari

|         |  |
|---------|--|
| User    | What is related between audio 1 and audio 2? |
| MMModal | Nothing?                                     |

---

### Images Audio Input Example

---



Audio 1 Transcription: anda tahu keuntungan boleh lebih tinggi daripada keuntungan kewangan rumah maka saya tidak akan mencari dalam akaun saya akan mencari ke dalam ethereum atau beberapa crypto punks bergantung pri itu saya boleh membayar perbezaan dengan menggunakan wang ini kerana sekali lagi ia menyusahkan saya dan aset tetapi jika anda tidak selesai dengan mencari

User

What is related between audio 1 and image 2?

MMModal

Nothing?

---

## 8 Evaluation

## 9 Future Work

In our future endeavors, we aim to enhance our capabilities by focusing on several key areas. Firstly, we intend to refine our approach to generating synthetic datasets that incorporate multi-images and multi-audio inputs. This will involve expanding the dataset to include more complex relationships between inputs and facilitating comparisons involving more than two inputs. Additionally, we recognize the importance of incorporating a wider range of visual Malaysian context datasets into our model training pipeline. By diversifying our data sources, we can ensure that our model is equipped to handle a broader array of real-world scenarios and contexts, ultimately improving its performance and relevance in practical applications.

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## 11 Conclusion

In this paper, we introduce MModal, a multimodal instruction tuned Model (LLM) specifically designed to handle multiple modalities, including images, audio, and text in a multi-turn dialogue setting. Our novel approach focuses on aligning representations from various modality encoders into a unified space. Unlike existing methods, our model effectively able to process multi-turn dialogues and incorporate multiple images or audio inputs in its responses. We provide examples demonstrating the multi-modal understanding capabilities of MModal.

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