Multilingual Large Language Model: A Survey of Resources, Taxonomy and Frontiers

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Abstract

Multilingual Large Language Models are capable of using powerful Large Language Models to handle and respond to queries in multiple languages, which achieves remarkable success in multilingual natural language processing tasks. Despite these breakthroughs, there still remains a lack of a comprehensive survey to summarize existing approaches and recent developments in this field. To this end, in this paper, we present a thorough review and provide a unified perspective to summarize the recent progress as well as emerging trends in multilingual large language models (MLLMs) literature. The contributions of this paper can be summarized: (1) First survey: to our knowledge, we take the first step and present a thorough review in MLLMs research field according to multi-lingual alignment; (2) New taxonomy: we offer a new and unified perspective to summarize the current progress of MLLMs; (3) New frontiers: we highlight several emerging frontiers and discuss the corresponding challenges; (4) Abundant resources: we collect abundant open-source resources, including relevant papers, data corpora, and leaderboards. We hope our work can provide the community with quick access and spur breakthrough research in MLLMs.

1 Introduction

In recent years, remarkable progress has been witnessed in large language models (LLMs) (Brown et al., 2020; Touvron et al., 2023a; Bang et al., 2023; Zhao et al., 2023b), which have achieved excellent performance on various natural language processing tasks (Pan et al., 2023; Nguyen et al., 2023a; Trivedi et al., 2023). In addition, LLMs raise surprising emergent capabilities, including in-context learning (Min et al., 2022; Dong et al., 2022), chain-of-thought reasoning (Wei et al., 2022; Huang et al., 2023a; Qin et al., 2023a), and even planning (Driess et al., 2023; Hu et al., 2023b).

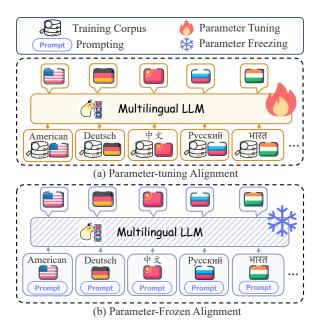


Figure 1: Parameter-Tuning Alignment (§4.1) v.s. Parameter-Frozen Alignment (§4.2). The former requires the model to fine-tune the MLLM parameters for cross-lingual alignment, while the latter directly uses prompts for alignment without parameter tuning.

Nevertheless, the majority of LLMs are English-centric, primarily focusing on English tasks (Held et al., 2023; Zhang et al., 2023i), which makes them somewhat weak for multilingual settings, especially in low-resource scenarios.

Actually, there are over 7,000 languages in the world. With the acceleration of globalization, the success of large language models should be considered to serve diverse countries and languages. To this end, multilingual large language models (MLLMs) possess the advantage of comprehensively handling multiple languages, gaining increasing attention. Specifically, the existing MLLMs can be broadly divided into two groups based on different stages. The first series of works (Xue et al., 2020; Workshop et al., 2022; Zhang et al., 2023g; Muennighoff et al., 2022) leverage multilingual

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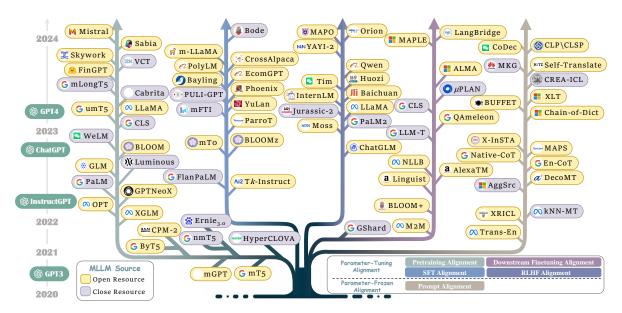


Figure 2: Evolution of selected MLLMs over the past five years, where colored branches indicate different alignment stages. For models with multiple alignment stages, the final stage is represented.

data to tuning the parameters to boost the overall multilingual performance. The second series of work (Shi et al., 2022a; Qin et al., 2023b; Huang et al., 2023a) also adapt the advanced prompting strategies to unlock deeper multilingual potential of MLLMs during parameter-frozen inference stage.

While remarkable success has been achieved in the MLLMs, there still remains a lack of a comprehensive review and analysis of recent efforts in the literature, which hinders the development of MLLMs. To bridge this gap, we make the first attempt to conduct a comprehensive and detailed analysis of MLLMs. Concretely, we first introduce the widely used data resource (§3). Furthermore, due to the key challenge of alignment across languages, we introduce a novel taxonomy according to alignment strategies (§4), aiming to provide a unified perspective in the literature, which includes: parameter-tuning alignment and parameter-frozen alignment (as shown in Figure 1). Specifically, parameter-tuning alignment requires the fine-tuning of model parameters to enhance alignment between English and target languages during pre-training, supervised fine-tuning, reinforcement learning from human feedback and downstream fine-tuning. parameter-frozen align*ment* refers to the alignment achieved by prompting across languages that can be achieved without the need for parameter tuning. Finally, we point out some potential frontier areas as well as the corresponding challenges for MLLMs, hoping to inspire the follow-up research ($\S 5$).

The contributions of this work can be summarized as follows: (1) First survey: To the best of our knowledge, we are the first to present a comprehensive survey in the MLLMs literature according to multi-lingual alignment; (2) New taxonomy: We introduce a novel taxonomy categorizing MLLMs into two alignment types: parameter-frozen and parameter-tuning, offering a unified view for understanding the MLLMs literature; (3) New frontiers: We discuss some emerging frontiers and highlight their challenges as well as opportunities, hoping to pave the way for future research developments; (4) Exhaustive resources: We make the first attempt to organize MLLMs resources including open-source software, diverse corpora, and a curated list of relevant publications, accessible at https://multilingual-llm.net.

We hope that this work can serve as a valuable resource for researchers and inspire more breakthroughs in future research¹.

2 Preliminary

In this section, we will formally describe the definitions of monolingual large language model ($\S 2.1$) and multilingual large language model ($\S 2.2$).

2.1 Monolingual Large Language Model

Monolingual large language models (LLM) can only process one language at a time. For example, as illustrated in Figure 3 (a), English and Chinese

¹Figure 2 illustrates the evolution of selected MLLMs over the past five years.

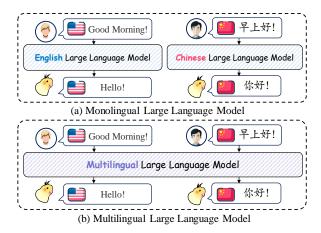


Figure 3: Monolingual Large Language Model v.s. Multilingual Large Language Model.

LLM can separately handle English and Chinese language, respectively. Formally, considering a set of languages $\mathcal{L} = \{\mathcal{L}_i\}_{i=0}^{|\mathcal{L}|}$, given input utterance $\mathcal{X}_i \in \mathcal{L}_i$ in languages \mathcal{L}_i , the process of monolingual LLM ($\mathcal{M}_{\texttt{mono}}$) generating the output \mathcal{Y}_i can be defined as:

$$\mathcal{Y}_i = egin{cases} \mathcal{M}_{ exttt{mono}}(\mathcal{X}_i, \mathcal{L}_i), & exttt{mono} = \mathcal{L}_i; \ exttt{Unexpect}, & exttt{mono}
eq \mathcal{L}_i, \end{cases}$$
 (1)

where Unexpect indicates that the LLM generates output in an unintended language; mono denotes the single language.

2.2 Multilingual Large Language Model

As shown in Figure 3 (b), unlike monolingual LLM, a multilingual LLM is capable of handling and producing content in various languages simultaneously, like English and Chinese. Formally, for MLLM $\mathcal{M}_{\text{multi}}$, where $\text{multi} \subseteq \mathcal{L}$ and $|\text{multi}| \geq 2$, the model's response is given by:

$$\mathcal{Y} = \mathcal{M}_{\text{multi}}(\mathcal{X}),$$
 (2)

where \mathcal{X} and \mathcal{Y} belong to multiple languages, multi.

3 Data Resource

In this section, we describe the widely used data resources in pre-training (§3.1), supervised fine-tuning (SFT) (§3.2) and reinforcement learning from human feedback (RLHF) (§3.3) stage (Zhao et al., 2023b) for multilingual large language model. Detailed statistics can be found in Table 1 and Table 2 in the Appendix.

3.1 Multilingual Pretraining Data

The widely used multilingual corpora for pretraining in MLLMs can be divided into 3 categories: (1) Manual Creation: obtains high-quality pretraining corpora through manual creation and proofreading, which consists of the Bible Corpus (Mayer and Cysouw, 2014) and MultiUN (Ziemski et al., 2016). (2) Web Crawling: involves crawling extensive multilingual data from the internet, which includes OSCAR (Suárez et al., 2019), CC-100 (Conneau et al., 2020), mC4 (Xue et al., 2021) and Redpajama-v2 (Computer, 2023). Another series of data are extracted from Wikipedia to enhance the knowledge of MLLMs. Common datasets include Wikipedia (Foundation), WikiMatrix (Schwenk et al., 2021) and WikiExpl (Han et al., 2023). (3) Benchmark Adaptation: means re-cleaning or integrating existing benchmarks to enhance data quality which includes OPUS-100 (Zhang et al., 2020), Culturax (Nguyen et al., 2023c), OPUS (Tiedemann, 2012), WMT (Kocmi et al., 2023) and ROOTS (Laurençon et al., 2022).

3.2 Multilingual SFT Data

Similarly, we categorize the existing multilingual SFT data into 4 classes: (1) Manual Creation: acquires SFT corpora through manual creation and proofreading, which includes Sup-NatInst (Wang et al., 2022b), OpenAssist (Köpf et al., 2023) and COIG-PClite (Team, 2023a). (2) *Machine Translation*: translates the existing monolingual datasets into multilingual instruction datasets, which comprises xP3-MT (Muennighoff et al., 2022), MGSM8K_{Instruct} (Chen et al., 2023b), CrossAlpaca (Ranaldi et al., 2023b; Cui et al., 2023), MultilingualSIFT (Chen et al., 2023i) and Bactrain-X (Li et al., 2023b). (3) Benchmark Adaptation: involves transformation from existing benchmarks to instruction format. Widely used datasets include xP3 (Muennighoff et al., 2022), PolyglotPrompt (Fu et al., 2022), and BUF-FET (Asai et al., 2023). (4) MLLMs Aided Generation: means that the data are automatically synthesized by the MLLMs, containing Vicuna (Chiang et al., 2023), OverMiss (Chen et al., 2023g), ShareGPT (ShareGPT, 2023), BELLE (Yunjie Ji, 2023), MultiAlpaca (Wei et al., 2023c), Guanaco (Dettmers et al., 2023) and Alpaca-4 (Peng et al., 2023).

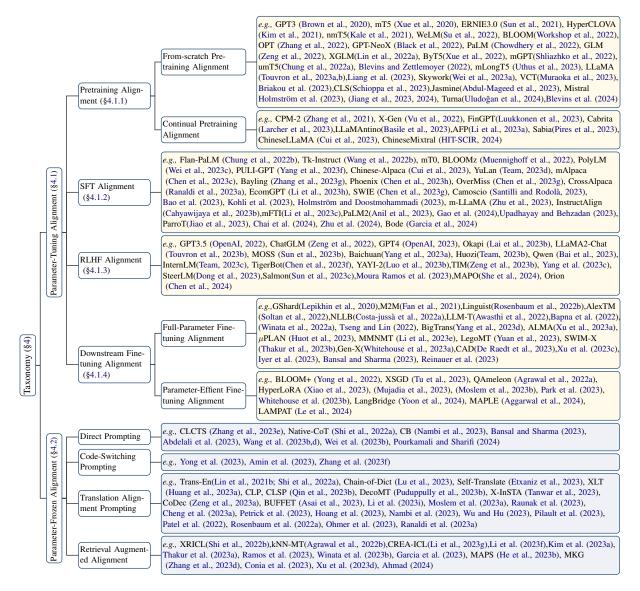


Figure 4: Taxonomy of MLLMs which includes *Parameter-Tuning Alignment Methodology* and *Parameter-Frozen Alignment Methodology*.

3.3 Multilingual RLHF Data

Some work leveraged the multilingual RLHF data to improve alignment. Specifically, Lai et al. (2023b) leverages multilingual ranking data for training a reward model using RLHF. Zeng et al. (2023b) introduce the TIM dataset to train a more effective reward model in multilingual contexts.

4 Taxonomy

As shown in Figure 4, we introduce a novel taxonomy including *parameter-tuning alignment* (§4.1) and *parameter-frozen alignment* (§4.2), which aims to provide a unified view for researchers to understand the MLLMs literature. Specifically, parameter tuning alignment (PTA) comprises a series of progressively advanced training and alignment strategies, including Pretraining Alignment, Super-

vised Fine-Tuning (SFT) Alignment, Reinforcement Learning from Human Feedback (RLHF) Alignment, and, ultimately, Downstream Fine-Tuning Alignment. These stages collectively aim to refine model parameters to align the multilingual performance systematically. Conversely, the parameter frozen alignment (PFA) focuses on four prompting strategies based on PTA: Direct Prompting, Code-Switching Prompting, Translation Alignment Prompting, and Retrieval-Augmented Alignment. This method maintains the original model parameters to achieve desired outcomes.

4.1 Parameter-Tuning Alignment

Parameter-tuning alignment indicates that MLLMs should tune their parameters for better cross-lingual alignment (Wen-Yi and Mimno, 2023). As shown in Figure 5, we discuss the four categories of

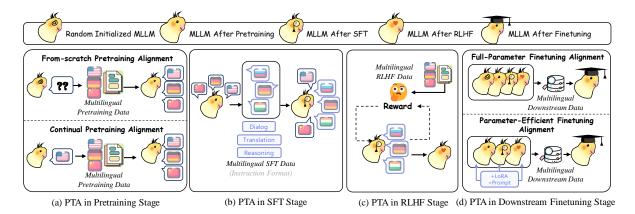


Figure 5: Overview of Parameter-Tuning Alignment (§ 4.1) Methods, which including *PTA in Pretraining Stage* (§ 4.1.1), *PTA in SFT stage* (§ 4.1.2), *PTA in RLHF stage* (§ 4.1.3) and *PTA in Downstream Finetuning stage* (§ 4.1.4).

parameter-tuning alignment (PTA), including PTA in pretraining stage ($\S4.1.1$), PTA in SFT stage ($\S4.1.2$), PTA in RLHF stage ($\S4.1.3$) and PTA in Finetuning stage ($\S4.1.4$).

4.1.1 PTA in Pretraining Stage

From-scratch Pretraining Alignment. A series of approaches have achieved to alignment across languages by tuning the initially random parameters of MLLMs during pretraining (see Figure 5 (a)). Specifically, Blevins and Zettlemoyer (2022); Briakou et al. (2023); Holmström et al. (2023) observed that adding a few multilingual data during the from-scratch pretraining alignment, even unintentionally, can significantly boost the multilingual performance. Inspired by this, Zeng et al. (2022); Su et al. (2022) used bilingual data in their fromscratch pretraining for alignment. mT5 (Xue et al., 2020), Ernie3.0 (Sun et al., 2021), ByT5 (Xue et al., 2022), BLOOM (Workshop et al., 2022), LLaMA (Touvron et al., 2023b,a), PaLM (Chowdhery et al., 2022), Mistral (Jiang et al., 2023), Mixtral (Jiang et al., 2024), PolyLM (Wei et al., 2023c), Kale et al. (2021); Kim et al. (2021); Shliazhko et al. (2022); Chai et al. (2022); Schioppa et al. (2023); Abdul-Mageed et al. (2023); Uthus et al. (2023); Wei et al. (2023a); Uludoğan et al. (2024) incorporated multilingual data in pretraining stage for better alignment. Blevins et al. (2024) utilizes Mixture-of-Experts (MoE) to independently train language models on subsets of multilingual corpora to alleviate the problem of multilingual parameter competition. Furthermore, to enhance the performance of low-resource languages, umT5 (Chung et al., 2022a) and XGLM (Lin et al., 2022a) adopted equitable data sampling methods during from-scratch pretraining. Muraoka et al. (2023) introduced VCT to leverage vision for indirect cross-lingual alignment in from-scratch pretraining.

Continual Pretraining Alignment. To address the high computational cost of from-scratch pretraining, continual pretraining alignment builds the pretraining process upon pretrained MLLMs (as shown in Figure 5 (a)). Specifically, CPM-2 (Zhang et al., 2021), Sabia (Pires et al., 2023), FinGPT (Luukkonen et al., 2023), X-Gen (Vu et al., 2022), AFP (Li et al., 2023a), Cabrita (Larcher et al., 2023), LLaMAntino (Basile et al., 2023) focused on adding more target language data during continual pretraining for general performance. Further, Cui et al. (2023); HIT-SCIR (2024) emphasized extending the MLLMs' vocabularies to adapt to new languages.

4.1.2 PTA in SFT Stage

As illustrated in Figure 5 (b), PTA in SFT stage means leveraging multiple multilingual task data with instruction format for tuning parameters (Fu et al., 2022; Yang et al., 2023f; Team, 2023d; Chen et al., 2023c,g; Ranaldi et al., 2023a; Li et al., 2023h; Chen et al., 2023g; Santilli and Rodolà, 2023; Bao et al., 2023; Kohli et al., 2023; Holmström and Doostmohammadi, 2023; Garcia et al., 2024). In particular, models like Flan-PaLM (Chung et al., 2022b), mT0, BLOOMz (Muennighoff et al., 2022), PolyLM (Wei et al., 2023c), Tk-Instruct (Wang et al., 2022b), Chinese-Alpaca (Cui et al., 2023), Bayling (Zhang et al., 2023g) and Phoenix (Chen et al., 2023h), directly incorporated multilingual data in the SFT stage to achieve implicit multilingual alignment across languages. Besides, to

solve the scarcity of multilingual SFT task data, PaLM2 (Anil et al., 2023), Zhu et al. (2023); Cahyawijaya et al. (2023b); Li et al. (2023c); Gao et al. (2024) added translation task during the SFT alignment stage to improve alignment. Further, Upadhayay and Behzadan (2023); Chai et al. (2024); Zhu et al. (2024) began to consider using a more effective SFT alignment strategy to optimize the reasoning process.

4.1.3 PTA in RLHF Stage

As shown in Figure 5 (c), to achieve alignment in reinforcement learning from human feedback (RLHF) stage, Okapi (Lai et al., 2023b), LLaMA2-Chat (Touvron et al., 2023b), Chat-GLM (Zeng et al., 2022), MOSS (Sun et al., 2023b), Baichuan (Yang et al., 2023a), Huozi (Team, 2023b), Qwen (Bai et al., 2023), InternLM (Team, 2023c), ParroT (Jiao et al., 2023), TigerBot (Chen et al., 2023f), MOSS (Sun et al., 2023b), YAYI-2 (Luo et al., 2023b), Yang et al. (2023c); Moura Ramos et al. (2023) and Orion (Chen et al., 2024) directly integrated multilingual RLHF data for training multilingual reward models. Additionally, Zeng et al. (2023b); Dong et al. (2023); She et al. (2024) introduced a multilingual reward model to compare translation outputs across different granularity. Sun et al. (2023c) proposed a Salmon framework, to enhance multilingual RLHF by self-generating rewards for better alignment.

4.1.4 PTA in Downstream Finetuning Stage

Full-Parameter Finetuning Alignment Fullparameter finetuning in MLLMs means tuning all parameters in downstream tasks (see Figure 5 (d)). Specifically, GShard (Lepikhin et al., 2020), Linguist (Rosenbaum et al., 2022b), Fan et al. (2021); Bapna et al. (2022); Tseng and Lin (2022); Iyer et al. (2023), NLLB (Costa-jussà et al., 2022a) AlexTM (Soltan et al., 2022), and BigTrans (Yang et al., 2023d) focused on directly fine-tuning the full parameters across various downstream tasks (e.g., information extraction, machine translation). Xu et al. (2023c); Huot et al. (2023); Yuan et al. (2023); Li et al. (2023e) proposed multi-step or finegrained alignment strategies during full-parameter tuning. Furthermore, to enhance the efficiency, Awasthi et al. (2022); De Raedt et al. (2023); Thakur et al. (2023b); Whitehouse et al. (2023a); Bansal and Sharma (2023); Xu et al. (2023a); Reinauer et al. (2023) focused on knowledge distillation from larger to smaller MLLMs.

Parameter-Efficient Finetuning Alignment A series of studies employ Parameter-Efficient Finetuning (PEFT) alignment approaches for reducing full-parameter fine-tuning costs (Yong et al., 2022; Mujadia et al., 2023; Moslem et al., 2023b), which is shown in Figure 5 (d). Agrawal et al. (2022a); Tu et al. (2023); Park et al. (2023) proposed minimal soft prompt prefix fine-tuning for better alignment. Furthermore, Whitehouse et al. (2023b); Xiao et al. (2023); Aggarwal et al. (2024); Le et al. (2024) proposed methods based on Low-Rank Adaptation (LoRA) to achieve PEFT alignment. Further, Yoon et al. (2024) introduced a LangBridge model to bridge multilingual encoder to single-lingual LLM to effectively achieve promising performance.

Takeaways (1) PTA in pretraining stage brings the essential multilingual capabilities of the MLLMs. (2) The effectiveness of alignment in MLLMs is greatly influenced by previous alignment stage, (e.g. Pretraining will significantly influence SFT).

4.2 Parameter-Frozen Alignment

In contrast to the traditional parameter-tuning approaches (Zheng et al., 2022), parameter-frozen alignment methods aim to perform alignment without any parameter tuning. The most popular approaches employ prompting strategies to elicit the alignment potential of MLLMs. As shown in Figure 6, this section discusses four prompting strategies for alignment without parameter tuning, which include (1) *Direct Prompting*, (2) *Code-Switching Prompting*, (3) *Translation Alignment Prompting* and (4) *Retrieval Augmented Alignment*.

4.2.1 Direct Prompting

As shown in Figure 6 (a), *Direct Prompting* means directly outputting the request without any additional instruction for implicit alignment through MLLM itself (Abdelali et al., 2023; Zhang et al., 2023e; Wang et al., 2023b,d; Lin et al., 2022b; Bansal and Sharma, 2023; Wei et al., 2023b; Pourkamali and Sharifi, 2024).

4.2.2 Code-Switching Prompting

As shown in Figure 6 (b), it integrates multilingual words into a single-language utterance, which is a typical language phenomenon (Winata et al., 2022b; Doğruöz et al., 2023a,b) for effective language alignment (Qin et al., 2020, 2022). Specifically, Yong et al. (2023); Amin et al. (2023) showed the effectiveness of MLLMs in cross-

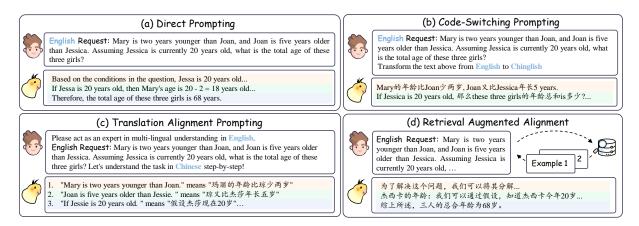


Figure 6: Overview of Parameter-Frozen Alignment (§ 4.2) methods, where prompts in sub-figures sourced from Qin et al. (2023b) and Zhang et al. (2023f).

lingual alignment through model-generated codeswitching texts. Furthermore, Zhang et al. (2023f) suggested the need for fairer and more detailed code-switching optimization for further research.

4.2.3 Translation Alignment Prompting

Translation alignment prompting approaches mean that translating the query into other languages for better alignment (see Figure 6 (c)), which can be divided into the following classes: (1) Key Information Translation: This approach focuses on extracting key information and executing translation for word-level cross-lingual alignment (Lu et al., 2023; Li et al., 2023i). (2) Direct Translation: the model directly translates the whole input, enhancing alignment performance (Etxaniz et al., 2023; Zhang et al., 2023a; Cheng et al., 2023a; Petrick et al., 2023; Hoang et al., 2023; Zeng et al., 2023a; Nambi et al., 2023; Lin et al., 2021b). (3) Stepby-step Translation: Instead of direct translation, this method prompts MLLMs to translate whole input step-by-step (Puduppully et al., 2023a; Moslem et al., 2023a; Raunak et al., 2023; Wu and Hu, 2023; Puduppully et al., 2023b; Pilault et al., 2023). (4) Restatement: Beyond preserving original semantics, some studies focus on prompting MLLM to restate multilingual inputs to enhance cross-lingual effectiveness (Shi et al., 2022a; Patel et al., 2022; Rosenbaum et al., 2022a; Asai et al., 2023; Qin et al., 2023b; Huang et al., 2023a; Tanwar et al., 2023). Further, considering the differences in multiple languages (Ohmer et al., 2023), Qin et al. (2023b); Ranaldi et al. (2023a) integrated knowledge and translation strategy across different languages by cross-lingual prompting.

4.2.4 Retrieval Augmented Alignment

Retrieval Augmented Alignment incorporates external retrieval during prompting to inject more knowledge in MLLMs (see Figure 6 (d)). Specifically, He et al. (2023b); Zhang et al. (2023d); Conia et al. (2023); Xu et al. (2023d); Ahmad (2024) focus on retrieving cultural or professional knowledge to enrich prompts. Another series of work focused on retrieval for high-quality alignment demonstrations, yielding significant improvements (Shi et al., 2022b; Agrawal et al., 2022b; Li et al., 2023g; Winata et al., 2023b; Garcia et al., 2023; Li et al., 2023f; Ramos et al., 2023; Kim et al., 2023a; Thakur et al., 2023a).

Takeaways (1) Translation alignment prompting is more effective for crosslingual alignment. (2) Retrieval augmented alignment mitigates knowledge gaps in LLM.

5 Future work and New Froniter

5.1 Hallucination in MLLMs

While remarkable progress has been achieved in MLLMs, the current approaches still face hallucination issues (Raunak et al., 2021). Specifically, Guerreiro et al. (2023a); Aharoni et al. (2023); Dale et al. (2023); Qiu et al. (2023) have previously pointed out the hallucination phenomenon on current MLLM. Further, a series of works provide corresponding solutions in the pre-training (Pfeiffer et al., 2023), SFT (Chen et al., 2023g) and decoding (Ahuja et al., 2022; Yang et al., 2023e; Sia et al., 2023; Zeng et al., 2023a) stages.

The key challenges in this direction include: (1) *Multilingual Hallucination Detection*: How to effectively detect the hallucination phenomenon of

MLLM across different languages is the primary problem to be solved in this field. (2) *Multilingual Hallucination Alleviation*: Current strategies for hallucination alleviation still focus on incorporating extensive factual data or utilizing external systems, which pose significant challenges for multiple languages, especially low-resource languages.

5.2 Knowledge Editing in MLLMs

The current MLLMs still face challenges with inaccurate, inconsistent, and outdated knowledge across different languages, which limits their performance. To solve this issue, Wu et al. (2023); Wang et al. (2023c) introduce a multilingual knowledge editing approach and propose a new benchmark for knowledge editing in MLLM. In addition, Qi et al. (2023) introduce the cross-lingual consistency metric to ensure factual consistency across languages. Additionally, Wang et al. (2023e) incorporate a multilingual knowledge base into MLLMs with retrieval methods to facilitate knowledge editing.

The key challenges of this research include: (1) *Continuous Knowledge Editing*: How to continuously integrate new knowledge while preserving the accuracy of existing knowledge is a core challenge to explore. (2) *Balancing Universal and Language-Specific Knowledge*: Current work often neglects language-specific details like culture and slang, impacting user experience and causing cultural conflicts (Held et al., 2023; Beniwal et al., 2024). How to balance universal knowledge, while preserving language-specific knowledge presents a fascinating question.

5.3 Safety in MLLMs

With the development and application of MLLMs, researchers have found that MLLMs often suffer some serious moral (Costa-jussà et al., 2022b; Sánchez et al., 2023) and privacy (Macko et al., 2023) risks, hindering the development of MLLMs (Wang et al., 2023f; Ye et al., 2023b; Hämmerl et al., 2022; Shen et al., 2024). Therefore, how to improve the safety of MLLMs is a promising research question.

The main challenges for safe MLLM are as follows: (1) *Lack of Safety Benchmark*: The lack of safe data in current literature hampers the relevant research. Consequently, acquiring a large-scale safety dataset to facilitate future research has become a hot topic. (2) *Removal of Unsafe Data*: The multilingual data generated by MLLMs poses

potential unsafe risks during training (Wang et al., 2023h). Therefore, identifying and filtering out unsafe multilingual content is a crucial issue (Bogoychev et al., 2023).

5.4 Fairness in MLLMs

Multilingual fairness refers to equal treatment and performance across languages and cultures (Yu et al., 2022; Shliazhko et al., 2022). But there is a significant performance gap between languages, especially on low-resource languages (Malkin et al., 2022; Sengupta et al., 2023; Ye et al., 2023a). Additionally, token consumption also varies by language in MLLMs, leading to unequal computational costs (Koishekenov et al., 2022; Hua et al., 2023; Nicosia and Piccinno, 2022; Xue et al., 2022; Sun et al., 2023a; Rust et al., 2022).

The main concerns regarding fairness in MLLM are as follows: (1) *Low-resource language performance improvement*: It is essential to improve the performance of low-resource languages with limited data (Lin et al., 2023; Ansell et al., 2023; Adeyemi et al., 2023). (2) *Multilingual Token Cost Improvement*: Current tokenizer exhibits biases in segmenting different languages, leading to varying token costs (Petrov et al., 2023; Ahia et al., 2023; Ali et al., 2023). Addressing this challenge is essential for ensuring fairer tokenization across languages.

5.5 Language Extension in MLLMs

Due to the limited languages supported by current work, integrating new languages into existing MLLM is a promising direction to explore (Kew et al., 2023; Shaham et al., 2024). To this end, Cui et al. (2023); Yang et al. (2023d) suggest adding languages through two-stage pre-training. Yong et al. (2022) observe that adapter-based methods are more effective than continuous pre-training.

This challenge encompasses two main aspects: (1) *Multiple Languages Extension:* How to dynamically and effectively extend the languages for MLLMs is an interesting research question. (2) *Original Languages Preserving:* Since the expansion of the model in other languages will harm the original language performance, how to prevent the language extension in MLLM from forgetting the previously learned language is a major challenge.

5.6 Multi-Modality Extension in MLLMs

Since the improvement in the usability of MLLM, a large amount of work has begun to further extend

MLLM into visual modality (Geigle et al., 2023; Chen et al., 2022, 2023d,e; Ramos et al., 2023; Bai et al., 2023; Zhou et al., 2023; Hu et al., 2023a; Zhou, 2023; He et al., 2023a; Guo et al., 2023), speech modality (Huang et al., 2023b, 2024; Cheng et al., 2023b), video modality (Team et al., 2023) and even other modalities.

This field faces two main challenges: (1) *Complex Reasoning Exploration*: Current multi-modal MLLMs are limited to simple cross-modal crosslingual tasks, with a need for more exploration in complex reasoning. (2) *Comprehensive Benchmark*: The current literature lacks comprehensive benchmarks, which hinders progress and evaluation in this evolving field.

6 Conclusion

In this work, we present a comprehensive survey of the advancements in multilingual large language models (MLLMs). Specifically, we provide a new taxonomy for MLLMs from alignment perspectives, which can offer a unified view for researchers to understand the progress of MLLMs. In addition, we highlight some emerging trends and frontiers as well as their corresponding challenges in MLLMs. We hope this work can facilitate the research and inspire more breakthroughs in MLLMs literature.

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Appendix

A Multilingual Performance Evaluation

To facilitate the comparison of LLMs, extensive efforts have been invested in exploring enhanced evaluation methods for multilingual scenarios. This discussion will elaborate on MLLM evaluation, covering both (1) *Evaluation Metrics* and (2) *Evaluation Benchmarks*.

A.1 Evaluation Metrics

Traditional Automatic Metric means that we assess predicted output using probabilities or pretrained language model logits (Liu et al., 2023c; Zouhar and Bojar, 2024). Generally speaking, researchers use BLEU (Papineni et al., 2002), BLEURT (Sellam et al., 2020), chrF++ (Popović, 2017) and COMET (Rei et al., 2020) for translation evaluation, and use ROUGE (Lin, 2004) for summary evaluation. Further, Guerreiro et al. (2023b) proposed xCOMET for better translation evaluation through fine-grained error detection. In assessing the general quality of generated text, the commonly employed approach is the utilization of multi-lingual BERTScore (Zhang* et al., 2020) as an evaluation metric. Qin et al. (2023b) extended Roscoe (Golovneva et al., 2022) to multilanguage for quality assessment of multi-lingual CoT. Further, Hlavnova and Ruder (2023) developed a comprehensive and robust multi-lingual checklist system to thoroughly assess the MLLMs' performance.

MLLM-based Automatic Metric employs robust MLLMs to score or compare generated outputs for evaluation purposes (Li et al., 2023b; Zhang et al., 2023g; Vernikos and Popescu-Belis, 2024). Specifically, Zheng et al. (2023) introduced LLM-as-a-Judge, where GPT4 is prompted to assess the performance of other LLMs by comparing its output to the predicted one. However, this method discussed remains unreliable in multilingual settings (Hada et al., 2023). And caution should be exercised, particularly in languages where it is known that the MLLM has performed poorly. Furthermore, Kim et al. (2023b); Muller et al. (2023) conducted attribution evaluation to deeply evaluate the robustness of the model.

Human Evaluation involves manually assessing MLLMs through detailed evaluation (Zhang et al., 2023g; Li et al., 2023b; Khondaker et al., 2023; Zhang et al., 2023a). Lyu et al. (2023) initially

explored the multilingual challenges of ChatGPT through manually annotated cases. Furthermore, Hu et al. (2024) introduced a new platform for more convenient manual assessments.

A.2 Evaluation Benchmarks

Current MLLMs tend to pay more attention to the alignment effect of non-English languages. Based on the different angles of alignment, we divide it into two categories: (1) *Natural Language Understanding*; (2) *Natural Language Generation*.

A.2.1 Natural Language Understanding

Linguistics Analysis For multilingual models, the most basic thing is to understand the linguistic differences between different languages (Xu et al., 2023c). The most common multilingual linguistics assessment includes Part-of-Speech (POS) (Liang et al., 2020; Zeman et al., 2022), grammar analysis (Kwon et al., 2023b; Alhafni et al., 2023; Michaelov et al., 2023; Kwon et al., 2023a) and morphology (Weissweiler et al., 2023). Furthermore, Zhang et al. (2023l); Song et al. (2022) conducted a comprehensive evaluation the linguistic acceptability of MLLM across languages.

Semantic Understanding Researchers take more care of should be able to analyze and understand the specific semantics of multiple languages (Lai et al., 2023a; Schott et al., 2023; Panchendrarajan and Zubiaga, 2024). The most basic is to perform local semantic understanding, and the most typical one is the information extraction task (Wei et al., 2023b), including: masakhaNER (Adelani et al., 2021), MASSIVE (FitzGerald et al., 2022), Multi-CoNER (Malmasi et al., 2022; Fetahu et al., 2023), WikiAnn (Pan et al., 2019) and SMiLER (Seganti et al., 2021) The second is the semantic understanding of complete sentences, including: XNLI (Conneau et al., 2018), Paws-X (Yang et al., 2019b), MixATIS++ (Xu et al., 2020), MTOP (Li et al., 2020), MultiNLU (Schuster et al., 2018), and PRESTO (Goel et al., 2023). Finally, there is the semantic understanding of the paragraph, like question-answering tasks with context: MLQA (Lewis et al., 2019), XQuAD(Artetxe et al., 2020), TyDiQA (Clark et al., 2020) and X-PARADE (Rodriguez et al., 2023), X-CLAIM (Mittal et al., 2023), Readme++ (Naous et al., 2023a), XKaggle-DBQA (Shi et al., 2022b) and de Varda and Marelli (2023). Due to the

Dataset	Storage Size	Token Size	Language Size	Source	Latest Update Time				
Manual									
Bible Corpus (Mayer and Cysouw, 2014)	5.2G	-	833	-	May-2014				
MultiUN (Ziemski et al., 2016)	-	0.3B	7	-	Dec-2014				
IIT Bombay (Kunchukuttan et al., 2018)	-	0.04B	2	-	Dec-2021				
Web Crawling									
CC-100 (Conneau et al., 2020)	-	208B	116	CommonCrawl	Oct-2022				
mC4 (Xue et al., 2021)	38.5T	6.3T	101	CommonCrawl	Oct-2022				
Redpajamav2 (Computer, 2023)	30.4T	-	5	CommonCrawl	Dec-2023				
OSCAR (Suárez et al., 2019)	6.3T	800B	166	CommonCrawl	Jan-2023				
Oromo (Ogueji et al., 2021)	0.939G	0.1B	11	CommonCrawl	Feb-2022				
Wu Dao 2.0	-	24B	2	CommonCrawl	Oct-2023				
Europarl (Koehn, 2005)	1.5G	0.6B	21	-	May-2012				
JW300 (Agic and Vulic, 2019)	-	1.5B	343	-	Jul-2019				
Glot500 (ImaniGooghari et al., 2023)	600G	-	511	-	May-2023				
Wikipedia (Foundation)	-	24B	300	Wikipedia	-				
WikiMatrix (Schwenk et al., 2021)	65G	-	85	Wikipedia	Apr-2021				
OPUS-100 (Zhang et al., 2020)	2.6G	-	100	OPUS	Jul-2020				
AfricanNews (Adelani et al., 2022)	12.3G	-	16	mC4	Sept-2023				
Taxi1500 (Ma et al., 2023)	-	-	1500	Bible Corpus	May-2023				
CulturaX (Nguyen et al., 2023c)	27T	6.3T	167	mC4, OSCAR	Jan-2024				
Benchmark Adaptation									
ROOTS (Laurençon et al., 2022)	1.6T	-	46	Huggingface	Jun-2022				
OPUS (Tiedemann, 2012)	-	40B	1304	-	Dec-2021				
CCMT (Yang et al., 2019a)	-	-	6	-	-				
WMT (Kocmi et al., 2023)	-	-	32	-	-				
IWSLT (Agarwal et al., 2023)	4.2G		10	-	-				

Table 1: Pre-training Data Resource, where * indicates different categories. The term "Source" refers to the origin datasets from which the pre-training data is derived.

emergence of a large number of multilingual benchmarks in recent years, a series of work has begun to combine the various existing semantic understanding tasks together for unified evaluation, including: XTREME (Hu et al., 2020), XTREME-R (Ruder et al., 2021), XGLUE (Liang et al., 2020), MEGA (Ahuja et al., 2023a), MEGA-Verse (Ahuja et al., 2023b), AGIEval (Zhong et al., 2023b), and Superlim (Berdičevskis et al., 2023). Further, Thapliyal et al. (2022); Changpinyo et al. (2022); Fujinuma et al. (2023); Kudugunta et al. (2023) extend the semantic understanding of multi-modal context. Since MLLMs have some biases (Costa-jussà et al., 2023; Lee et al., 2023) or vulnerabilities (Xu et al., 2023b; Puttaparthi et al., 2023; Shen et al., 2024), España-Bonet (2023); Cao et al. (2023); Jiang and Zubiaga (2024); Macko et al. (2024) has begun to consider the corresponding benchmark to evaluate MLLMs.

Cultural Understanding Limited by cultural differences, the understanding between different languages is not completely parallel (Li and Callison-Burch, 2023; Maity et al., 2023; Cahyawijaya et al.,

2023a), so researchers began to explore how to evaluate multi-cultural scenes (Naous et al., 2023b; Hershcovich et al., 2022). The most typical one is multi-cultural sentiment analysis. Sentiment Analysis (Davidson et al., 2017; Srinivasan and Choi, 2022; Li et al., 2023b; Muhammad et al., 2023; Winata et al., 2023a; Yadav et al., 2023). Furthermore, Zhang et al. (2023c) expands the multicultural scene to the entire Sociopragmatic Understanding level. In particular, Kabra et al. (2023); Wang et al. (2023g); Jiang and Joshi (2023); Fung et al. (2022); Li et al. (2023d); Son et al. (2023); Zhou and Zhang (2023) proposed new benchmarks, requiring the model to fully understand different cultures. Furthermore, due to the emergence of reasoning capabilities, Qin et al. (2023b); Liu et al. (2023a); Wang et al. (2023a) start to evaluate the reasoning ability of MLLMs with different cultural backgrounds.

Knowledge Understanding A large amount of work has been done to test the degree of knowledge transfer of MLLM between different languages through examination questions. Specif-

Dataset	Sample Size	Multi-lingual Instruction	Language Size	Task Size				
Manual								
Sup-NatInst (Wang et al., 2022b)	-	-	55	1616				
OpenAssist (Köpf et al., 2023)	-	-	35	-				
EcomInstruct (Li et al., 2023h)	2.5M	Yes	2	12				
COIG-PC-lite (Team, 2023a)	650k	No	2	3,250				
Benchmark Adaption								
xP3 (Muennighoff et al., 2022)	-	No	71	46				
BUFFET (Asai et al., 2023)	-	-	54	15				
PolyglotPrompt (Fu et al., 2022)	-	No	49	6				
Translation								
xP3-MT (Muennighoff et al., 2022)	-	Yes	46	71				
MultilingualSIFT (Chen et al., 2023i)	-	Yes	11	-				
Bactrian-X (Li et al., 2023b)	-	Yes	52	-				
MuIT (Zhu et al., 2023)	-	Yes	6	-				
CrossAlpaca (Ranaldi et al., 2023b)	-	-	6	-				
MGSM8KInstruct (Chen et al., 2023b)	73.6k	Yes	6	10				
XCoT (Chai et al., 2024)	7.4K	Yes	10	2				
MLLM Aided								
ShareGPT (ShareGPT, 2023)	-	-	-	-				
Vicuna (Chiang et al., 2023)	-	-	-	-				
OverMiss (Chen et al., 2023g)	54K	-	3	1 (Translation)				
MultiAlpaca (Wei et al., 2023c)	133K	-	11	-				
Guanaco (Dettmers et al., 2023)	535K	-	5	-				
Alpaca-4 (Peng et al., 2023)	52K	-	2	-				

Table 2: Supervised Fine-Tuning Data Resource, where * indicates different categories. The term "Multi-lingual Instruction" denotes the presence of instructions in multiple languages to form the specific data input.

ically, Hardalov et al. (2020); Xuan-Quy et al. (2023); Zhang et al. (2023j) proposed for the comprehensive knowledge test at the high school level in a multilingual scenario. Zhang et al. (2023i) design a complex translation strategy to translate existing benchmark for multilingual evaluation. On this basis, M3Exam (Zhang et al., 2023h) further expands comprehensive testing to multilanguage and multi-modal scenarios. Furthermore, Gekhman et al. (2023) tested the factual consistency of MLLM. And Choudhury et al. (2023); Joseph et al. (2023); Zhao et al. (2023a); Wei et al. (2023b); Goenaga et al. (2023); Datta et al. (2023); Thulke et al. (2024) proposed benchmarks to evaluate the multilingual scientific and applied professional domain knowledge for current MLLMs.

A.2.2 Natural Language Generation

Translation In the process of multi-lingual alignment, in addition to testing whether the multiple languages are aligned in terms of understanding capabilities, researchers often also need to consider whether the two can be aligned in terms of out-

put capabilities. The most typical task is machine translation (Dabre et al., 2020; Vilar et al., 2022), currently commonly used data sets are: FLORES-101 (Goyal et al., 2022), FLORES-200 (Costa-jussà et al., 2022a), WMT (Kocmi et al., 2023) and DiaBLa (Bawden et al., 2021). Recently, Lou et al. (2023) proposed CCEval for Chinese-centric translation for comprehensive evaluation on MLLMs. Furthermore, due to the large gap between languages (Zhang et al., 2023i; Choudhury et al., 2023; Mujadia et al., 2023; Fujii et al., 2023; Khatri et al., 2023; Etxaniz et al., 2023; Artetxe et al., 2023; Stefanovitch and Piskorski, 2023; Ramesh et al., 2023; Deng et al., 2022; Held et al., 2023; Bang et al., 2023; Lai et al., 2023a; Philippy et al., 2023; Ye et al., 2023a), Kuparinen et al. (2023); Wassie (2023); Liu et al. (2023b); Rakhimova et al. (2024) focused more on low-resource language translation. Additionally, Yang et al. (2023b); Gueuwou et al. (2023); Bellagente et al. (2023); Zhong et al. (2023a); Tuo et al. (2023) further extend the translation and restatement tasks into multi-modal settings

for practical scenario.

Reasoning Currently, the most commonly used reasoning ability assessments of MLLMs tend to focus on commonsense and mathematical reasoning (Huang et al., 2023a; Qin et al., 2023b). Specifically, commonsense reasoning includes XCOPA (Ponti et al., 2020), MARC (Keung et al., 2020), XWinograd (Tikhonov and Ryabinin, 2021), GEOMLAMA (Yin et al., 2022), X-CSQA (Lin et al., 2021a), XStoryCloze (Lin et al., 2022a), ASPEN (Razumovskaia et al., 2022) and Masakhanews (Adelani et al., 2023). Additionally, mathematical reasoning includes MGSM (Shi et al., 2022a) and WizardMath (Luo et al., 2023a). Due to the expensive annotations for multilingual reasoning, Zhang et al. (2023i) propose a complex translation and filter process to construct a multilingual reasoning benchmark.

Coding Generation Coding generation requires that MLLMs can generate structured, executable code programs. The common-used benchmarks include XSPIDER (Shi et al., 2022b), XSEM-PLR (Zhang et al., 2023k), ODEX (Wang et al., 2022d) and Mconala (Wang et al., 2022c).

Summarization To test the summarization ability of the model, the model is required to be able to summarize key information based on long texts. The simplest one, Ryan et al. (2023) proposed a multi-lingual text reduction benchmark for the evaluation of MLLM. Secondly, a lot of work focuses on cross-lingual summarization. Typical data sets include: XSUM (Narayan et al., 2018), and Cross-Sum (Bhattacharjee et al., 2021). On this basis, Wang et al. (2022a) introduced multilingual conversation summarization, and Zhang and Eickhoff (2023) proposed the concept of code-switch in the evaluation, making it more practical. Urlana et al. (2023) further proposed headline summarization for languages in India. SEAHORSE (Clark et al., 2023) further extended them to the multifaceted multilingual summarization. In addition Nguyen et al. (2023b); Verma et al. (2023) developed summarization benchmarks for multi-modal scenarios.

Dialogue The communication between models and humans is often interactive, so a lot of work pays attention to MLLMs' dialogue ability (Boughorbel and Hawasly, 2023). The current evaluation set includes xDial-Eval (Zhang et al., 2023b), Multi³WOZ (Hu et al., 2023c), DIA-LIGHT (Hu et al., 2024), HPD (Chen et al., 2023a)

and X-RiSAWOZ (Moradshahi et al., 2023). Since multiple rounds of dialogue are not controllable, traditional indicators cannot be used. Currently, we tend to use PLM for evaluation (Mendonça et al., 2023a). Furthermore, Mendonça et al. (2023b) proposed a new benchmark, which can achieve more robust evaluation by coordinating with pretrained language models. Ferron et al. (2023) proposed the MEEP benchmark to further evaluate the dialogue participation of MLLMs.