

Extending English Large Language Models to New Languages

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Outline

- Introduction to LLMs
- The Multilingual LLM Challenge
- Extending English LLMs
 - Vocabulary Expansion
 - Continued Pre-training
 - Instruction Tuning
- Summary

[BIBLIOGRAPHY](#) (*identify paper by PAPER_KEY on the slides*)

What are Large Language Models?

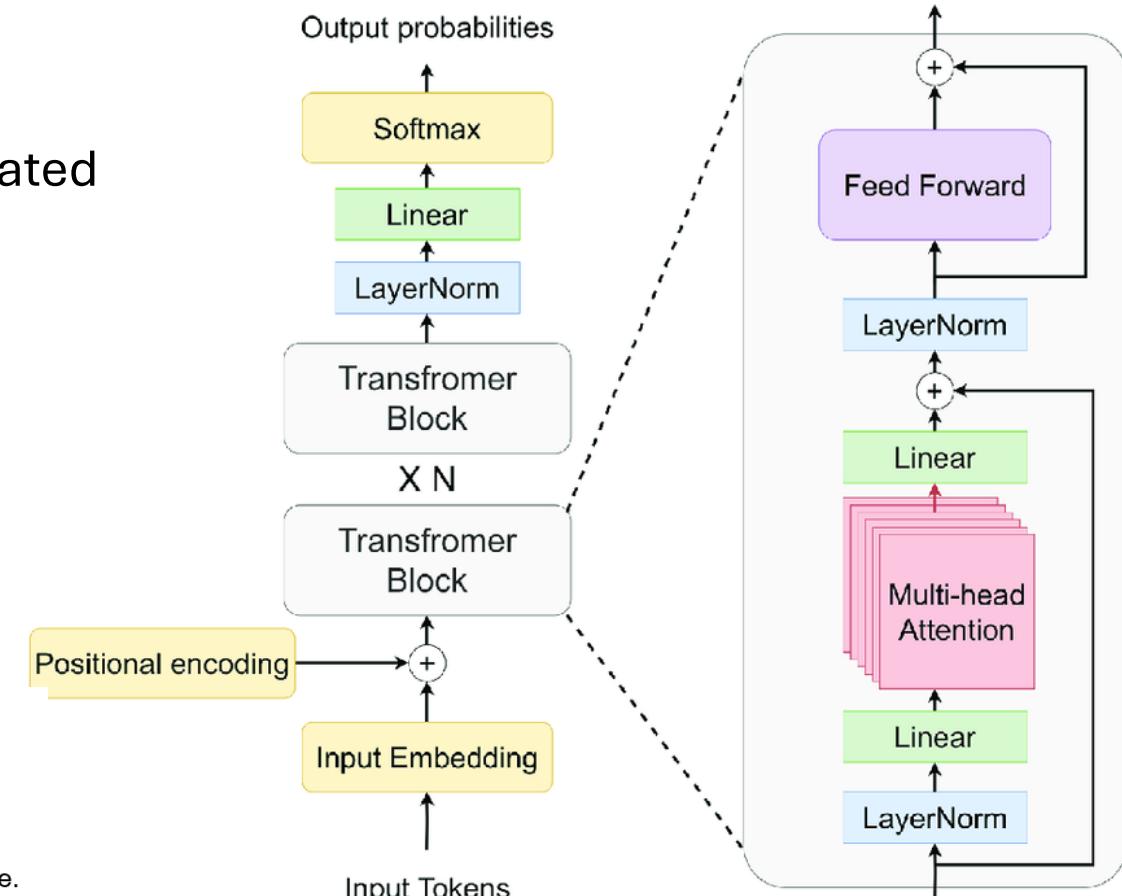
- Typically, transformer decoder models
- They generate text by looking at only previously generated text (*auto-regressive*)
- Trained on a **self-supervised** task
 - Next word prediction task
 - Large amount of text data
 - Large Models
- **In-context learning capability**

Instruction Tell me the sentiment of this review

Example The movie begins The plot is engaging, thoroughly enjoyable.
The movie is **great**

Oh, how can such a fine cast produce such a terrible performance..... A total waste of time.
The movie is **pathetic**

Prompt It is just a rehash of old movies
The movie is <MASK>



(GPT3)

- Finetuning on (relatively) small supervised and preference data to align instructions and values

(InstructGPT)

What makes LLMs exciting?

- Inherent knowledge
- Multi-task abilities and task-composition
- Little task-specific training required
- Help in writing , creativity, brainstorming, data generation, explanation, etc.

 Q&A Answer questions based on existing knowle...	 Summarize for a 2nd grader Translates difficult text into simpler concep...	 Text to command Translate text into programmatic commands.	 Natural language to Stripe API Create code to call the Stripe API using nat...	 SQL translate Translate natural language to SQL queries.
 Parse unstructured data Create tables from long form text	 Classification Classify items into categories via example.	 Python to natural language Explain a piece of Python code in human un...	 Movie to Emoji Convert movie titles into emoji.	 Calculate Time Complexity Find the time complexity of a function.
 Advanced tweet classifier Advanced sentiment detection for a piece o...	 Translate programming languages Translate from one programming language ...	 Explain code Explain a complicated piece of code.	 Grammar correction Corrects sentences into standard English.	 Natural language to OpenAI API Create code to call to the OpenAI API usin...
 English to other languages Translates English text into French, Spanish...	 SQL translate Translate natural language to SQL queries.	 Movie to Emoji Convert movie titles into emoji.	 Classification Classify items into categories via example.	 Advanced tweet classifier Advanced sentiment detection for a piece o...
 Explain code Explain a complicated piece of code.	 Grammar correction Corrects sentences into standard English.	 English to other languages Translates English text into French, Spanish...	 SQL translate Translate natural language to SQL queries.	 Natural language to OpenAI API Create code to call to the OpenAI API usin...

Plotting

Maths

Prompt: Can you write a proof that there are infinitely many primes, with every line that rhymes?

GPT-4:

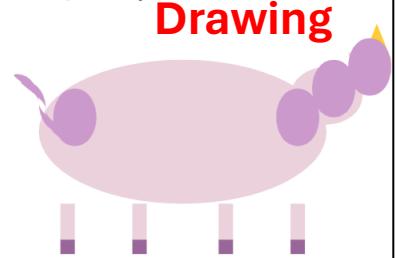
Yes, I think I can,
Though it might take a clever plan.
I'll start by noting Euclid's proof,
Which shows that primes aren't just aloof.
Assume we have a finite list,
Of primes, and that none have been missed.
Multiply them all together,
And add one, just to be clever.
The result will be a number,
That has no prime factors, oh wonder!
But every number has a prime,
That divides it, it's just a matter of time.
So we've found a contradiction,
And our finite list needs eviction.
There must be infinitely many primes,
And that's the end of my rhyming lines.s

Prompt: Can you generate a pyplot for the following data: $x = [1, 3, 5, 6, 8]$, $y1 = [2, 3, 5, 18, 1]$, $y2 = [3, 5, 6, 8, 1]$, $y3 = [5, 1, 2, 3, 4]$, $y4 = [9, 7, 2, 3, 1]$. I want $y1, y2$ to be in the same plot, but $y3$ is in another plot next to that plot, $y4$ is in below. I want the legend of $y1$ to be "bob", $y2$ to be "alice", $y3$ to be "bilbo", $y4$ to be "allie". I want the x -axis to be labeled with "time" and y axis to be labeled with "money". I want to add a 10 %-40% random error bar to each curve, through all times (including non-integers). I want smoothed curves to show the plot, and smoothed error bar. Do not use linear interpolation, use smooth interpolation! I want to also add some small zig-zag to the smoothed curve to make it look more real. I want to put a baseline as the mean of each line. I want to put a pie chart below indicating the fraction of the four people in each time step. I also want an animation to show how the fractions are changing in the pie chart in **continuous time**. Interpolate the missing fractions! I also want vertical line animation in other three plots to match the pie chart. I want the fanciest plot. Please add as many fancy things as possible.

Here is a possible code to generate a pyplot for the following data, with some comments to explain the steps:

Prompt: Draw a unicorn in TiKZ.

GPT-4: [Produces L^AT_EX compiling to following picture.]

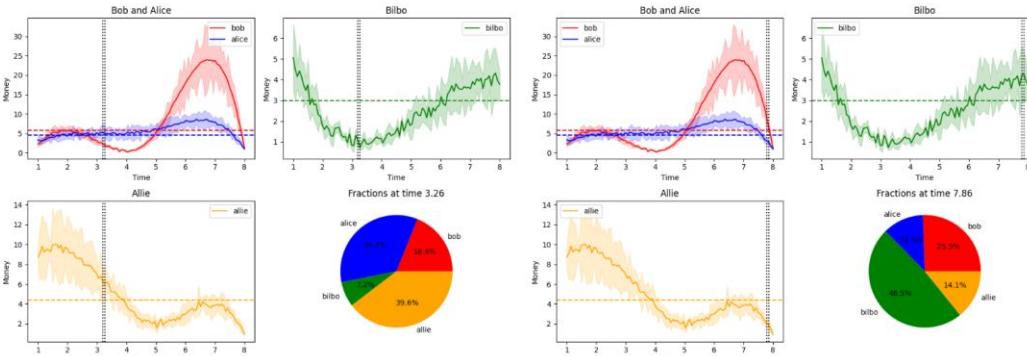


Drawing

Prompt: Can you generate a pyplot for the following data: $x = [1, 3, 5, 6, 8]$, $y1 = [2, 3, 5, 18, 1]$, $y2 = [3, 5, 6, 8, 1]$, $y3 = [5, 1, 2, 3, 4]$, $y4 = [9, 7, 2, 3, 1]$. I want $y1, y2$ to be in the same plot, but $y3$ is in another plot next to that plot, $y4$ is in below. I want the legend of $y1$ to be "bob", $y2$ to be "alice", $y3$ to be "bilbo", $y4$ to be "allie". I want the x -axis to be labeled with "time" and y axis to be labeled with "money". I want to add a 10 %-40% random error bar to each curve, through all times (including non-integers). I want smoothed curves to show the plot, and smoothed error bar. Do not use linear interpolation, use smooth interpolation! I want to also add some small zig-zag to the smoothed curve to make it look more real. I want to put a baseline as the mean of each line. I want to put a pie chart below indicating the fraction of the four people in each time step. I also want an animation to show how the fractions are changing in the pie chart in **continuous time**. Interpolate the missing fractions! I also want vertical line animation in other three plots to match the pie chart. I want the fanciest plot. Please add as many fancy things as possible.

Here is a possible code to generate a pyplot for the following data, with some comments to explain the steps:

GPT-4: [We give two snapshots from the animation resulting from the produced code]



GPT-4:

This is a conversation between a user and an artificial intelligence agent that follows instructions or answers questions. The AI always follows the instructions correctly.

User: Can you compose a short tune (say four to eight bars) using ABC notation?

AI: There are many possible ways to compose a short tune in abc notation, but here is one example:

X:1

T:Example Tune

M:4/4

L:1/8

K:C

:G2AB c2BA | G2AB c2c2 | edcB c2BA | G4-G2z2 :|

:c2de f2ed | c2de f2f2 | g2fe d2cB | c4-c2z2 :|

This tune has two four-bar phrases, each repeated once, forming an A part and a B part. The key is C major.

GPT-4:

User: After the first bar G2AB c2BA, you chose G to start the next bar. Give an example of a change to the notes in the first bar that would have caused you to pick D instead of G as the first note in the second bar.

AI: One possible change to the notes in the first bar that would have caused me to pick D instead of G as the first note in the second bar is:

:G2AB c2Bc | ...

This change creates a stronger cadence on the C note at the end of the first bar, which is the fifth degree of the scale. This suggests a modulation to the dominant key of G major, which has D as its fifth degree. Therefore, starting the second bar with D would create a smooth transition to the new key and imply a harmonic progression of V-I.

Prompt:

```
struct mystruct_A { char a; int b; char c; } x;
struct mystruct_B { int b; char a; char c; } y;

#include <stdio.h>
int main(void) {
    printf("Size of x: %zu bytes\n", sizeof(x));
    printf("Size of y: %zu bytes\n", sizeof(y));
    return 0;
}
```

Possible Output:

GPT-4:

There are different ways to implement and align structures in memory, so the exact output may vary depending on the compiler, platform, and options used. However, one possible output is:

Size of x: 12 bytes
Size of y: 8 bytes

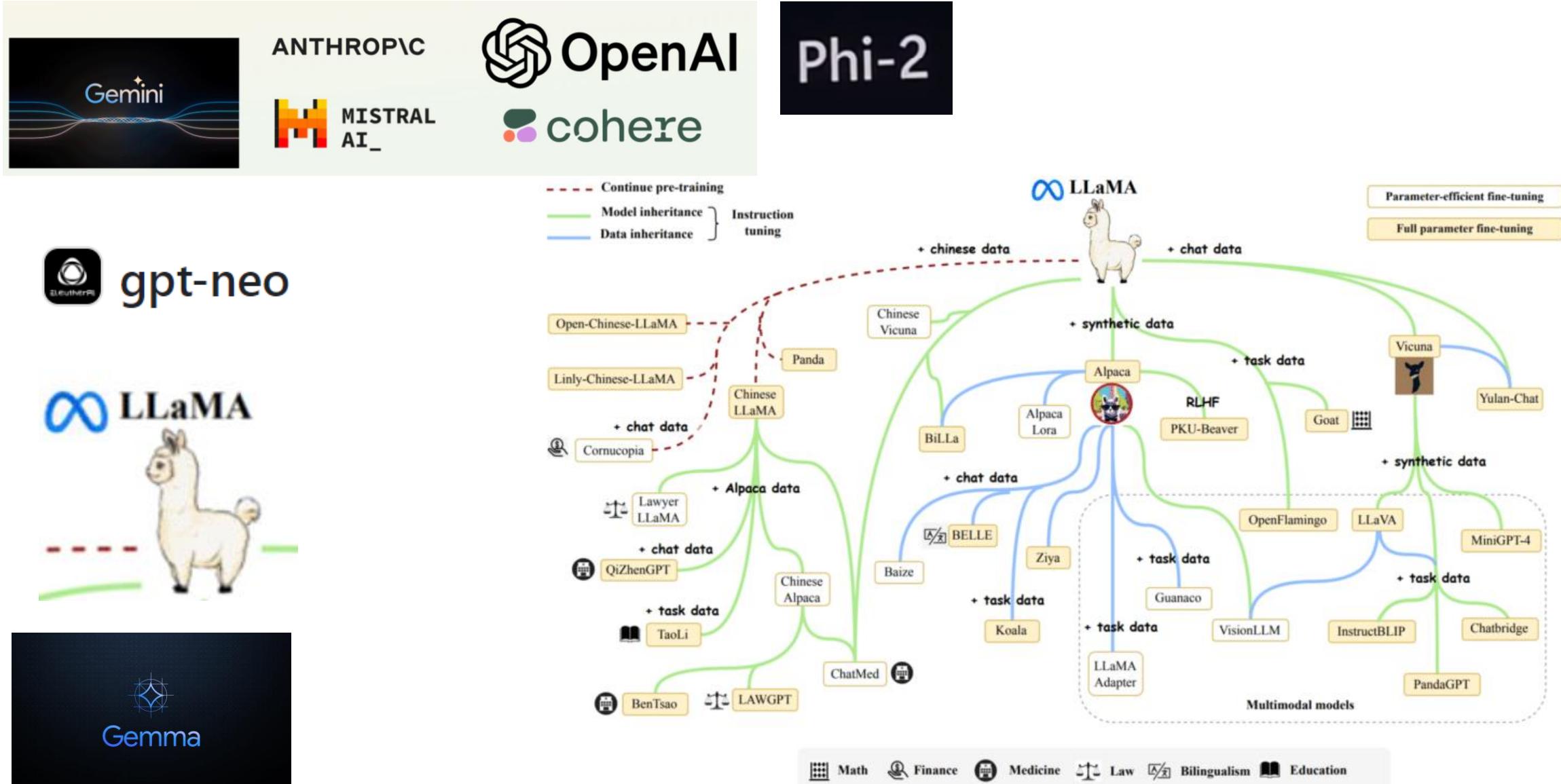
This output assumes that the compiler uses 4-byte alignment for structures, meaning that each structure member starts at an offset that is a multiple of 4 bytes from the beginning of the structure. This may result in some padding bytes being inserted between or after the members to maintain alignment. For example, in x, there may be 3 padding bytes after a and 3 padding bytes after c, while in y, there may be no padding at all. The size of a structure is the sum of the sizes of its members plus any padding bytes.

Understanding Programs

(SparksOfAGI)

Explanations

Explosion of LLMs ... but mostly limited to English



Benefits of LLMs are mostly limited to English

Language	Cat.	ChatGPT	
		(en)	(spc)
English	H	70.2	70.2
Russian	H	60.8	45.4
German	H	64.5	51.1
Chinese	H	58.2	35.5
French	H	64.8	42.2
Spanish	H	65.8	47.4
Vietnamese	H	55.4	44.8
Turkish	M	57.1	37.1
Arabic	M	55.3	22.3
Greek	M	55.9	54.5
Thai	M	44.7	11.5
Bulgarian	M	59.7	44.6
Hindi	M	48.8	5.6
Urdu	L	43.7	6.3
Swahili	X	50.3	40.8

Results on XNLI

Language	Cat.	ChatGPT(en)	
		EM	F1
English	H	56.0	74.9
Russian	H	30.2	49.1
German	H	45.9	65.8
Chinese	H	37.1	42.3
Spanish	H	41.8	65.8
Vietnamese	H	36.1	57.3
Turkish	M	34.5	56.4
Arabic	M	32.0	50.3
Greek	M	29.7	45.0
Thai	M	31.2	43.4
Hindi	M	17.5	37.8
Average		35.6	53.5

Results on QnA

	#langs.	avg. chrF	avg. BLEU
ChatGPT (0-shot)	203	32.3	16.7
ChatGPT (5-shot)	203	33.1	17.3
GPT-4	20	44.6	24.6
NLLB	201	45.3	27.1
Google	115	52.2	34.6

**Performance on translation
averaged across languages**

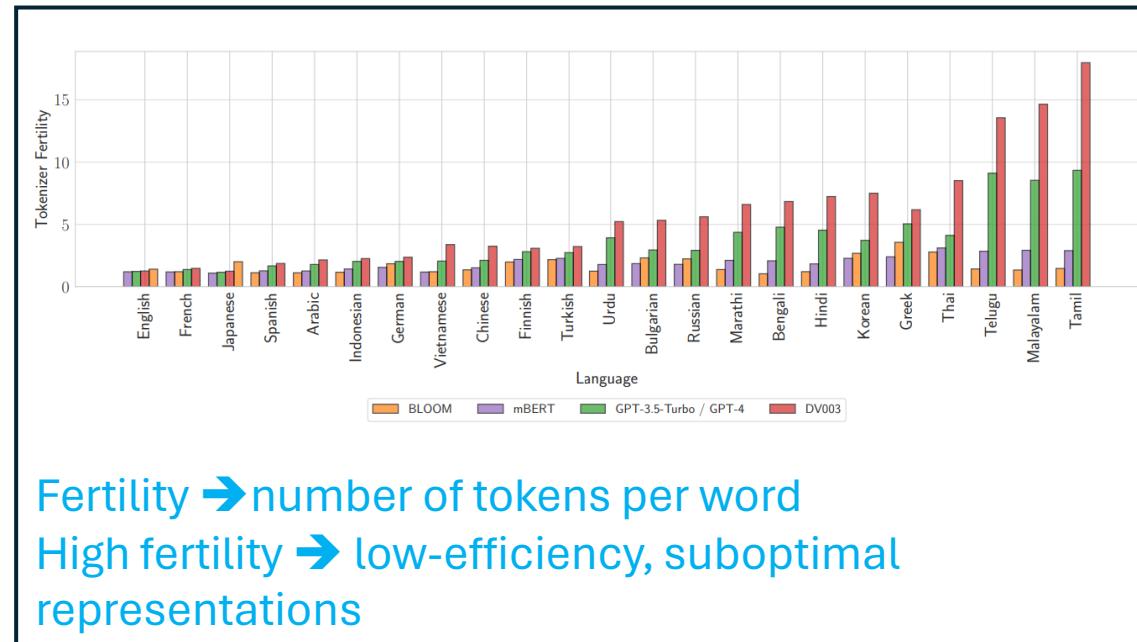
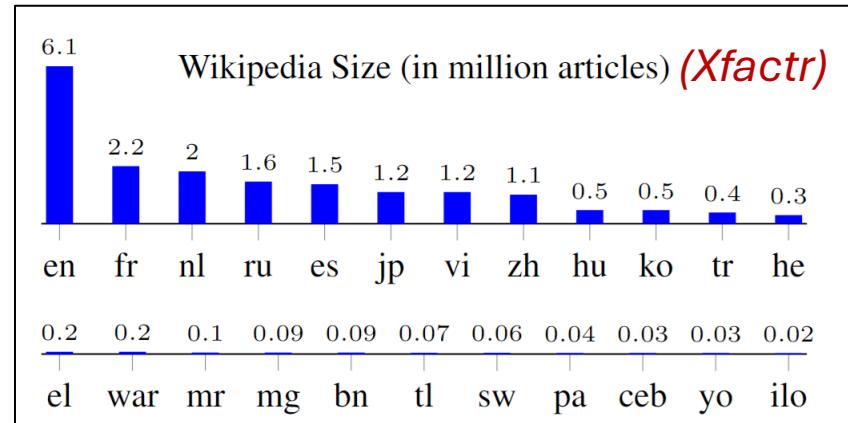
Lang.	ChatGPT		NLLB	
	BLEU	chrF	BLEU	chrF
srp_Cyrl	1.36	3.26	43.4	59.7
kon_Latn	0.94	8.50	18.9	45.3
tso_Latn	2.92	15.0	26.7	50.0
kac_Latn	0.04	2.95	14.3	37.5
nso_Latn	3.69	16.7	26.5	50.8
jpn_Jpan	28.4	32.9	20.1	27.9
nno_Latn	37.1	58.7	33.4	53.6
zho_Hans	36.3	31.0	26.6	22.8
zho_Hant	26.0	24.4	12.4	14.0
acm_Arab	28.2	44.7	11.8	31.9

**Performance on translation
High vs low resource**

- Significant gap between English and other languages on multiple tasks
- High-resource and Latin script languages can give good performance on GPT
- Poor performance on low-resource languages
- Translate-test is a strong baseline
- Open-source models lag behind GPT models → they are very English heavy

Why do LLMs lag behind for other languages?

- Lack of
 - Pre-training data
 - Token representation
 - Instruction tuning data
 - Human preference data
- Inability to transfer from English
- Limitations of Translate-Test



(BUFFET, MEGA, ChatGptMT)

Do English LLMs have some inherent multilingual capabilities?

Yes, to some extent ...

Why? – during training they might have been exposed to some non-English data

- Documents with multiple languages
- Incorrect LID

How good are the multilingual capabilities?

- Might be ok at language understanding e.g. *classification, sentiment analysis*
- Bad at generation
- Better on Latin script languages
- Languages with better pre-training representation perform better

How do English LLM achieve multilingual capabilities?

- Do LLMs think in English?
- Do LLM use English as a pivot for decision making?

Bottom layers: Feature learning

Middle layers: Concept mapping to language tokens
(with English bias)

Top layers: Language generation in target language

There are language-specific neurons

The central question in building multilingual LLM is to bring representations of English and other languages closer to achieve good cross-lingual transfer

(LmLatent,PNLD,LSP)

Output	文	:	-"	花
31	文	:	-"	花
29	文	:	-"	花
27	文	:	_flower	花
25	文	:	_flowe...	_flowe...
23	文	:	-"	_flowe...
21	文	:	_flowe...	_flowe...
19	文	:	-"	_flowe...
17	eval	:	-"	<0xE5>
15	ji	:	-"	Ψ
13	ř	_vac	ols	_bore
11	eda	eda	_Als	abei
9	eda	ná	_Als	_hel
7	iser	arie	◀	arias
5	npa	orr	◀	arias
3	心	ures	_Bedeut	arda
1	_beskre	化	Portail	_Kontr...

Open-source Multilingual LLM Efforts



Trained from scratch: BLOOM, mGPT, PolyLM, EAGLE, mT0, XGLM

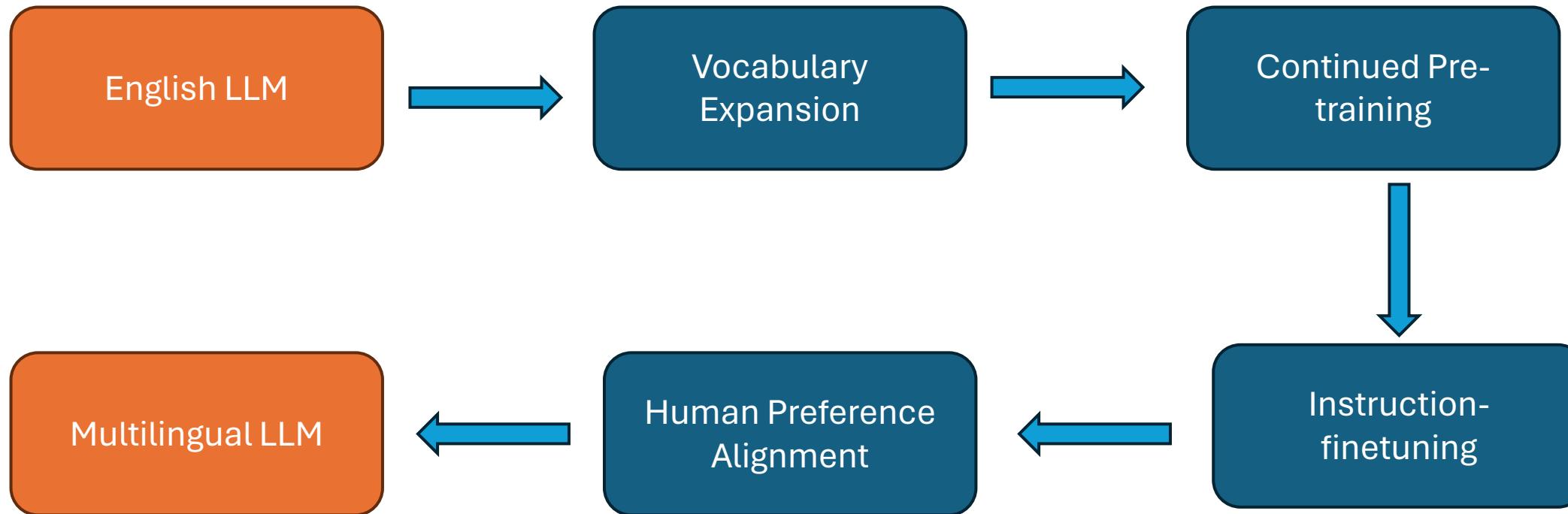
- English representation is lesser compared to models like Llama, Gemma, Mistral → limited English capabilities
- Cannot expect good non-English capabilities either
- Large-scale compute needed for training

Focus of this survey

Extending English LLMs: ChineseLLama, OpenHathi, SeaLLM, ALMA, RomanSetu

- Strong English capabilities of base LLMs
- Less compute-requirements

Extending English LLMs to Non-English Languages



*What properties do we
want to see in
multilingual corpora?*

Large-scale, Document-level Datasets

High Quality Documents

Wide coverage of topics

Representation of culture-specific data, native literature

Capture data in different modalities and genres

Data to Help Cross-lingual transfer with English

*Multilingual corpora like
mC4, CC-100, CulturaX
are good starting points*



Large-scale, Document-level Datasets



High Quality Documents



Wide coverage of topics



Representation of culture-specific data, native literature

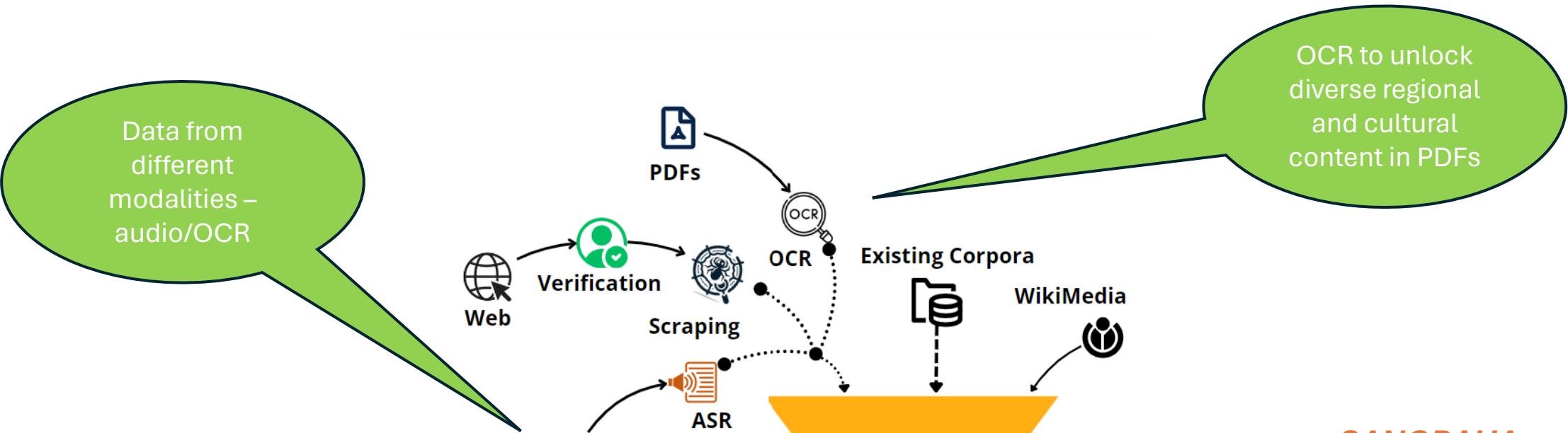


Capture data in different modalities and genres

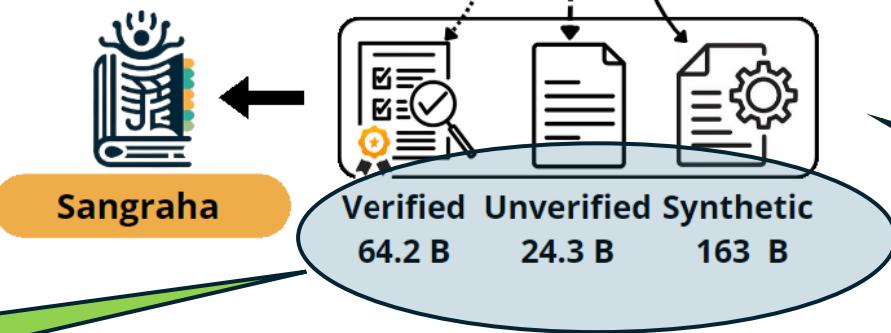


Data to Help Cross-lingual transfer with English

Build custom language (group) specific collections to address gaps



SANGRAHA
Creating high-quality pre-training data at scale

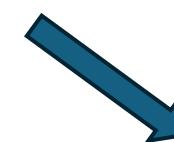
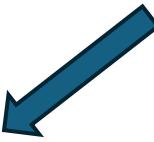


Translations and Transliterations to enable cross-lingual transfer

(IndicLLMSuite)

Data Sources at a Glance

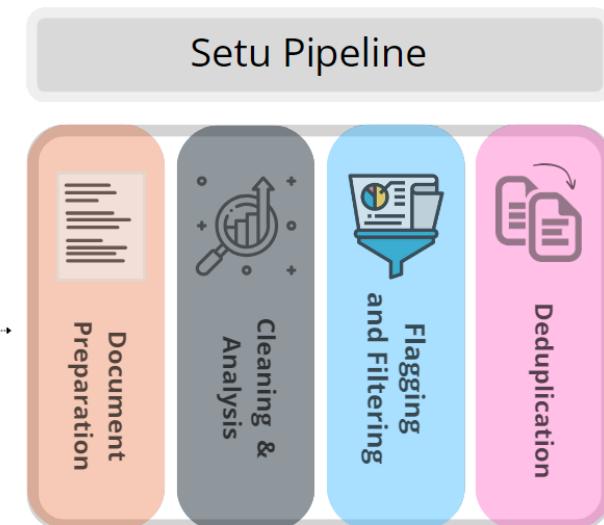
Sangraha Verified	Tokens (in billions)
Web	48.5
PDFs	14.6
Speech	1.2



PDF Sources	#PDFs	#Pages
Internet Archive	437,225	74M
eGyanKosh	5,133	88K
Indian Parliament	30,964	2.7M
AIR News	74,353	148K
Govt. Magazines	895	46K
School Books	4,315	359K
Miscellaneous	27,988	4.6M
Total	507,419	82M

Source	Number of Instances
YouTube - Hindi	276K videos
Open Subtitles	14K movies
NPTEL - Transcripts	1.4K courses
Mann Ki Baat	1.4K podcasts
Others	15K
Total	309K

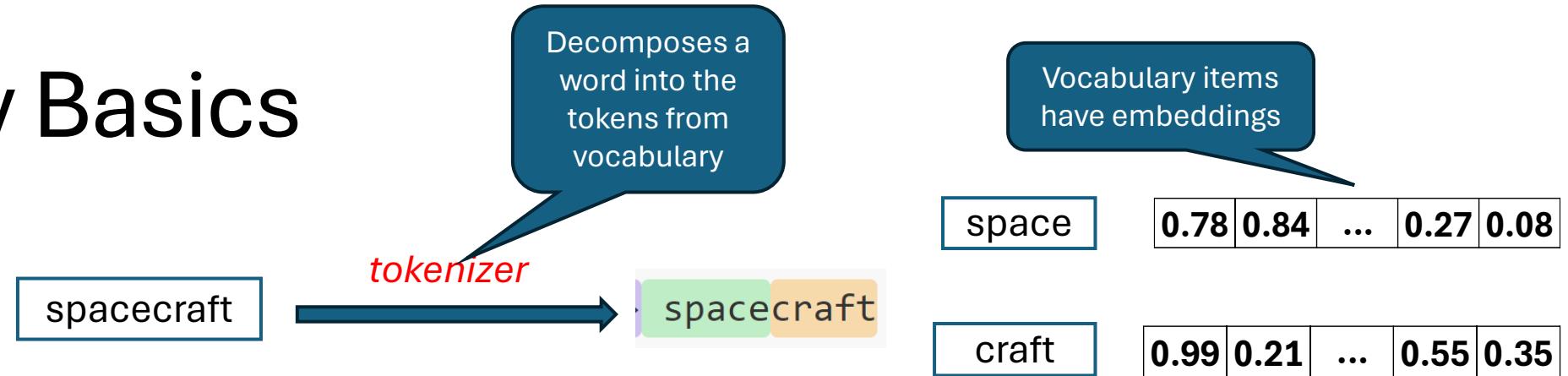
Data Processing Pipeline



Built on APACHE **Spark**™

Vocabulary Expansion

Vocabulary Basics



< s > Gaganyaan is an Indian crewed orbital spacecraft intended to be the formative spacecraft of the Indian Human Spaceflight Programme.

Vocabulary: Set of tokens (basic I/O units)

LLM Vocabulary Properties

- Finite vocabulary size
- Subword units: basic units are smaller than words
- Open vocabulary: all words can be defined as concatenation of subwords

What if vocabulary is under-represented?

```
<s> गगनयान <0xE0><0xA4><0x8F>क भारतीय चालक दल कक्षीय अंतर्राष्ट्रीय यान है जिसका <0xE0><0xA4><0x89>देश्  
य भारतीय मानव अंतर्राष्ट्रीय <0xE0><0xA4><0x89>डान कार्यक्रम का प्रारंभिक अंतर्राष्ट्रीय यान होना है।
```

Fertility = Average number of tokens per word

Unknown characters (BPE-based vocab)	UNK vocab item
Fallback to known characters (BPE-based vocab)	High Fertility
Fallback to bytes (Byte BPE-based vocab)	Even Higher Fertility

High fertility →

More memory consumption

More decoding time

Limit on longest processable sequence

Addressing Vocabulary issues

Status-quo (use suboptimal vocab)

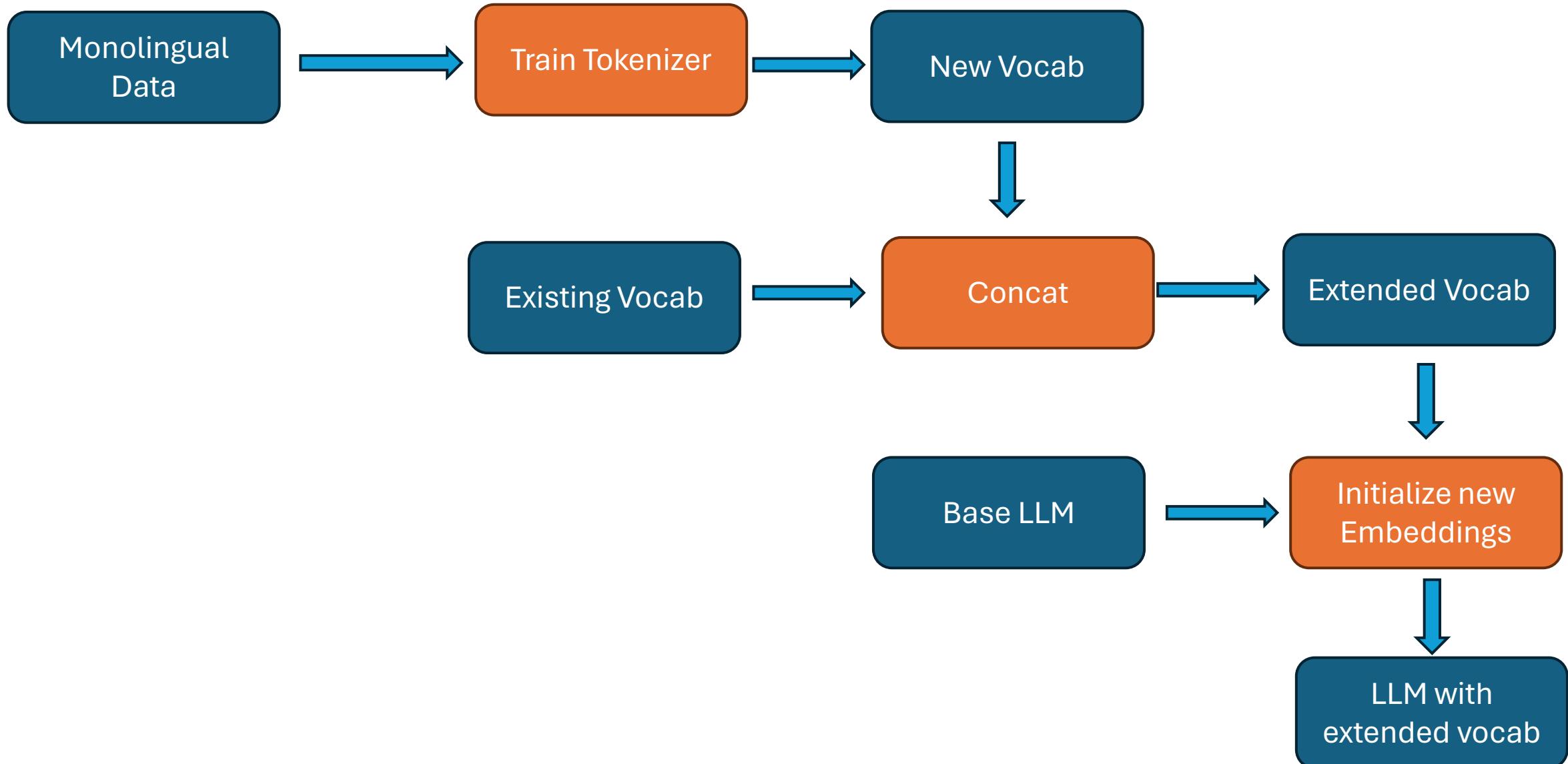
- ✗ • High fertility
- ✗ • Increased sequence length
 - Increased inference time
 - Limit on max sequence length
- ✗ • Inferior token representation
- ✓ • Lesser pre-training required

Extending Vocabulary

- ✓ • Low Fertility
- ✓ • Reasonable sequence length
 - Decreased inference time
 - Longer sequences possible
- ✗ • Increased softmax computation
- ✗ • More pre-training required

Some evidence seems to suggest that extending vocabulary needs a lot of pre-training to align languages (0.5B tokens vs 30B tokens) (LmaByndEng)

How to extend tokenizer vocabulary?



Initialization of New Embeddings

Sampling from Random (Normal) Distribution

Simple

*Changes existing vocab's probability distribution
Large convergence time*

Average of Existing Embeddings

*Limited change in existing vocab's distribution
Large convergence time [AveInit]*

Weighted Average of Existing Embeddings

*Limited change in existing vocab's distribution
Initializations like **WESCHEL, OFA, FOCUS, ZSTT***

WESCHEL uses similarities between vocab items across languages to decide weights; this improves convergence rates

Weighted Average Initialization

[WESCHEL]

- Target token embeddings as weighted average of source token embeddings
- Token weights based on source-target token similarities based on external static pre-trained word embeddings

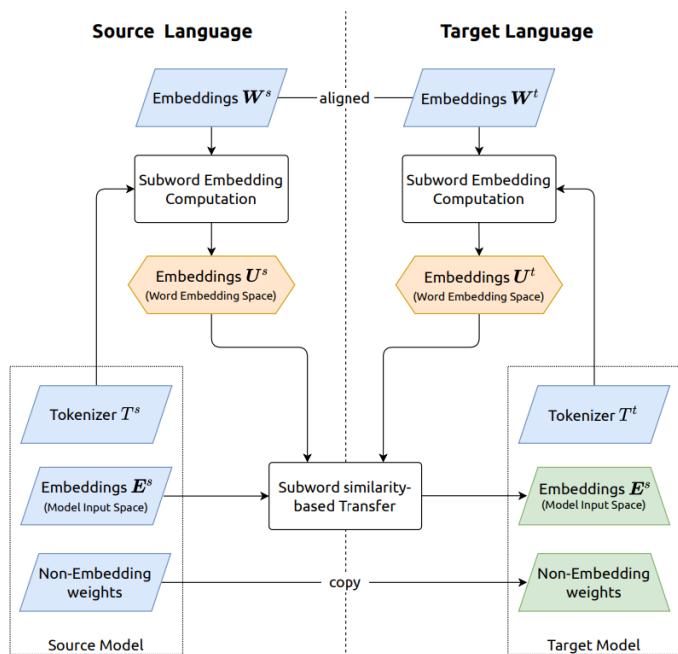
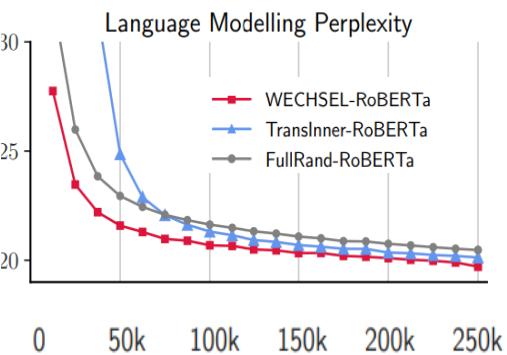


Figure 1: Summary of our **WECHSEL** method. We show inputs, intermediate results and outputs.



Model	Score@0			Score@25k			Score@250k		
	NLI	NER	Avg	NLI	NER	Avg	NLI	NER	Avg
WECHSEL-RoBERTa	78.25	86.93	82.59	81.63	90.26	85.95	82.43	90.88	86.65
TransInner-RoBERTa	60.86	69.57	65.21	65.49	83.82	74.66	81.75	90.34	86.04
FullRand-RoBERTa	55.71	70.79	63.25	69.02	84.24	76.63	75.28	89.30	82.29
XLM-R _{Base} (Final)	79.25	89.48	84.37						

Continued Pre-training

- Faster convergence vs. baselines for
- LM perplexity
 - Downstream performance

Results for small LMs → embeddings contribute a large % of parameters

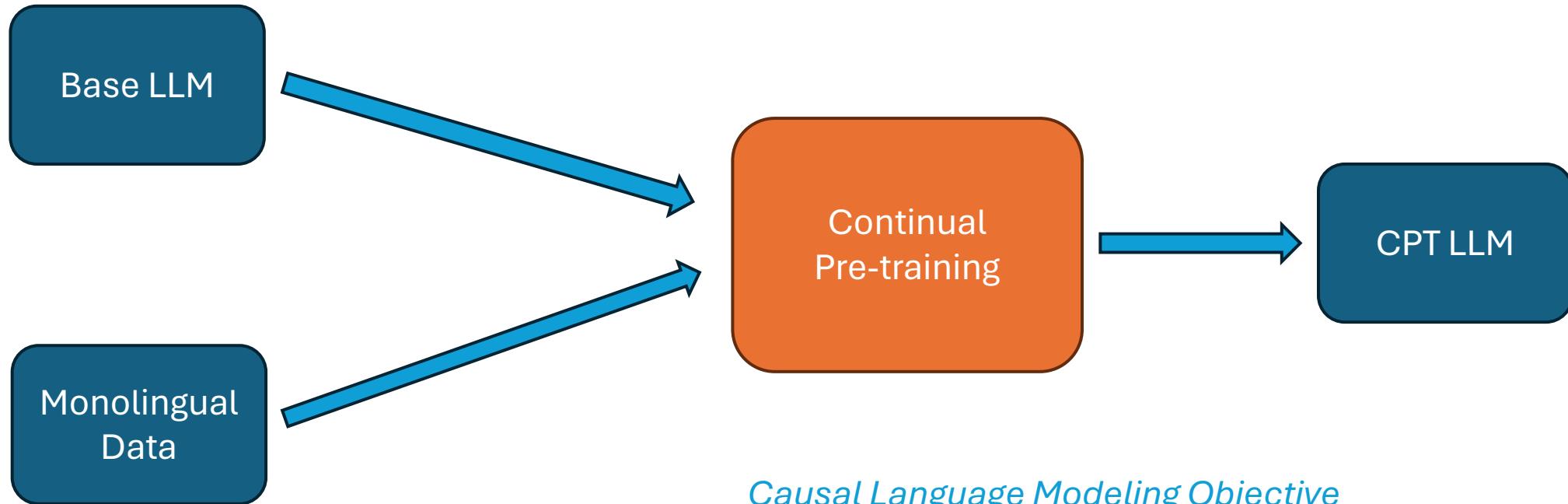
$$\mathbf{e}_x^t = \frac{\sum_{y \in \mathcal{J}_x} \exp(s_{x,y}/\tau) \cdot \mathbf{e}_y^s}{\sum_{y' \in \mathcal{J}_x} \exp(s_{x,y'}/\tau)}$$

Will we see such convergence improvements for Large LMs?

Summary

- **Can we do better than random initialization?**
 - Embeddings which initialize new tokens based on similarity with older embeddings do better
 - Faster convergence
 - Slightly better downstream performance
 - Results mostly for smaller LMs and encoder LMs
- **Is vocabulary expansion better than relying to initial sub-optimal vocab?**
 - Vocab expansion might require lot of pre-training for alignment
- **Will vocabulary extension lead to lower performance on English?**
 - If initialized embeddings are in convex hull, greedy decoding result does not change

Continual Pre-training



Train on document-level data

Finetuning on long, coherent sequences helps model learn and correlate different pieces of knowledge

Causal Language Modeling Objective

$$p(\mathbf{x}) = p(x_1, x_2, \dots, x_T) = \prod_{t=1}^T p(x_t | \mathbf{x}_{<t})$$

To avoid forgetting English competence and knowledge

- Include English in the pre-training data
- Finetune-only small number of adapter parameters
(ChineseLLama, OpenHathi)

Why do continual pre-training?

Language competence/fluency in target language

	L(0)	L(10k)	L(100k)	L(1M)
Chinese	10.151	8.697	6.634	5.249

*Perplexity reduces with increase in pre-training corpus size
(LmaByndEng)*

Improve alignment b/w English and target language

Language	Base LLM	After CPT
Gujarati	0.39	0.46
Hindi	0.40	0.44
Marathi	0.44	0.48

*Cosine similarities between English and target languages increases with CPT
(RomanSetu)*

Provide required knowledge in target language for better understanding

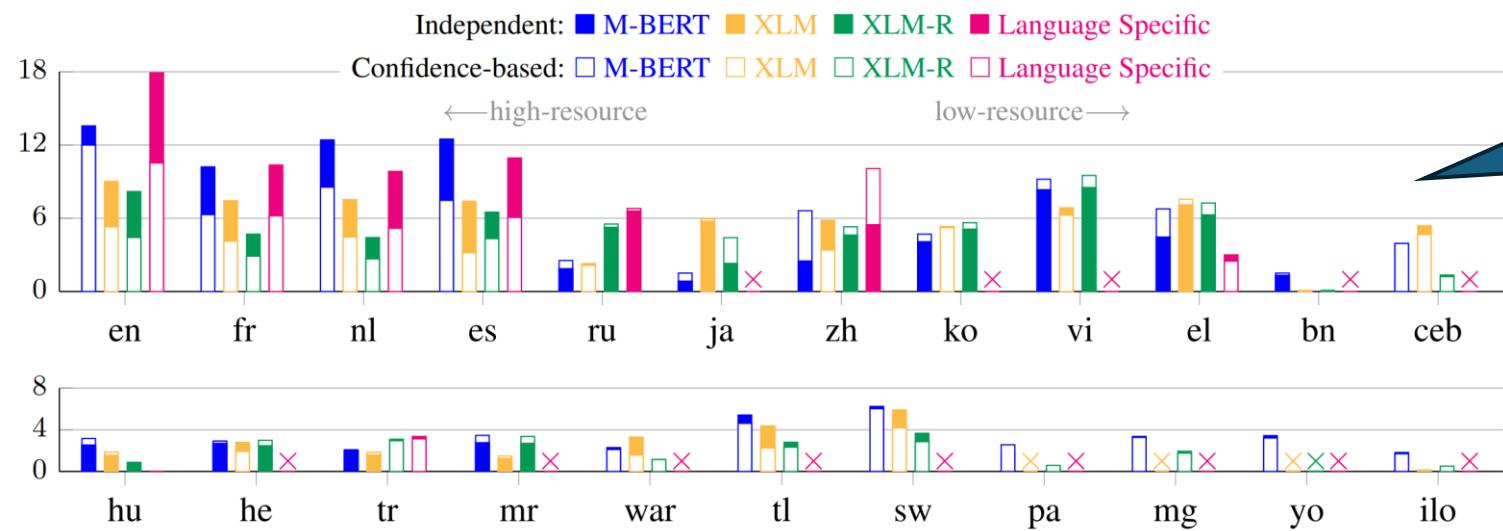
- LMs better at using in-language knowledge vs. cross-lingual transfer (**Xfactr, MLAMA**)
- Incorporate cultural-specific knowledge capture in native language corpora only

Most multilingual models can't transfer knowledge in English to other languages

Knowledge Probing Task → Predict missing tokens which capture model's knowledge

fact ⟨Bloomberg L.P., founded_in, New York⟩
en prompt [X] was founded in [Y].

es sentence	Bloomberg L.P. fue fundada en ⟨mask⟩ × 1 ~ 5.	#tokens	confidence
prediction			
2012	1	-1.90	
Nueva York	2	-0.61	
EE. UU	3	-1.82	
Chicago, Estados Unidos	4	-3.58	
2012 Bloomberg L.P	5	-3.06	



English accuracy for knowledge probing is much higher than other languages

Results on Knowledge Probing task shows that non-English languages don't have enough data

(Xfactr)

Improving Cross-lingual Transfer in Pre-training

- Using Parallel/Translated Data
- Using Romanized Representation

Why?

- Help improve cross-lingual alignment
- Make knowledge available in English in the target languages
- Help translation task

Using Parallel/Translated Data

Using parallel data

(*Tower, Palm2, PolyLM, OpenHathi, MTDataPretrain*)

- Train on document/paragraph pairs → very little availability
- Train on sentence pairs → modest availability depending on language pair
- MT Data modestly useful for NLU (results on encoder LMs) (*PrimerPMLM*)
 - More investigation needed

Using Machine Translated data

(*IndicMonoDoc*)

Use off-the-shelf MT data to generate target language data at scale → needs a decent MT model

- Model training includes translated documents
- Some evidence to show that translated documents can achieve performance close to pre-training with original documents

Need better to understand impact of translation quality

Romanized Representation

(*RomanSetu*)

*Challenges with non-Latin
script languages*

- High-fertility/data loss for under-represented vocab
- Poor representation quality
- Vocab extension requires lot of pre-training (*Lai et al . 2023*)

<s> चारों अंतरिक्ष यात्री बेंगलुरु में भारतीय अंतरिक्ष अनुसंधान संग<0xE0><0xA4><0xA0>न (<0xE0><0xA4><0x87>सरो) की अंतरिक्ष यात्री सुविधा में प्रशिक्षण ले रहे हैं।<0x0A>

(130 tokens)

<s> chaaron antariksh yaatree bengaluru mein bhaarateey antariksh anusandhaan sangathan (isaro) kee antariksh ya atree suvidha mein prashikshan le rahe hain.<0x0A>

(63 tokens)

Pre-train on romanized corpora

- Natural transliteration
- Fixed Romanization schemes

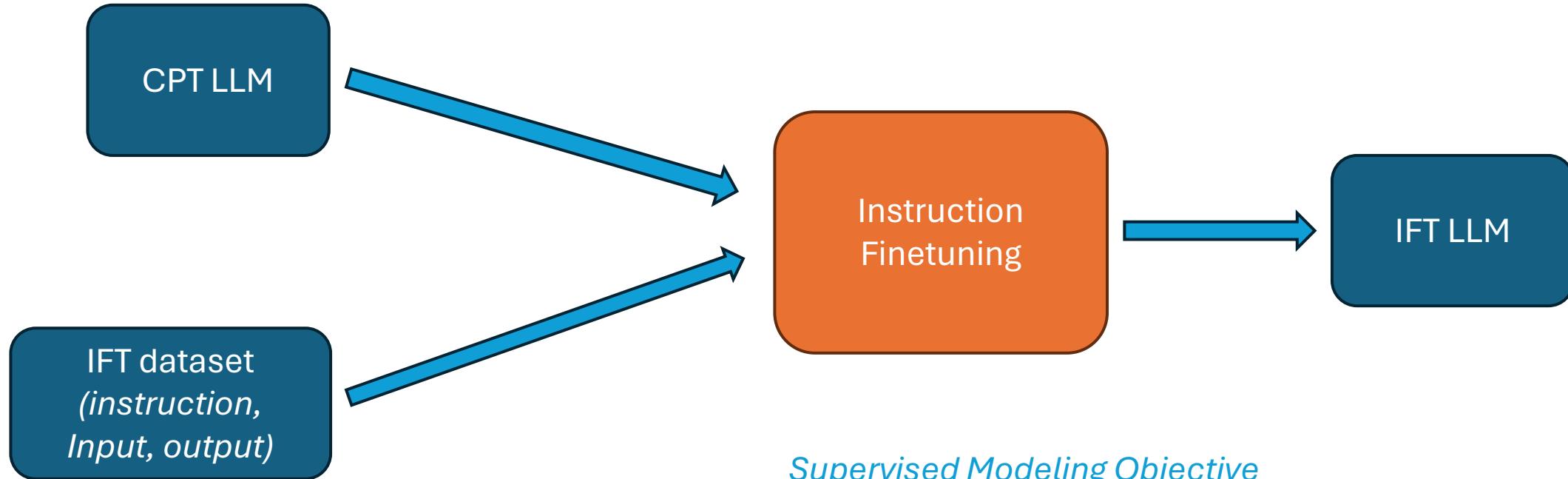
Language	N	R
Gujarati	18.44	3.39
Hindi	7.36	2.98
Malayalam	12.85	5.04
Marathi	8.91	3.64
Tamil	12.11	4.89

*Romanized fertility more
than 2x lower than native
script fertility*

Language	E - N	E - R
Gujarati	0.39	0.47
Hindi	0.40	0.50
Malayalam	0.40	0.46
Marathi	0.44	0.48
Tamil	0.44	0.43

*Romanized representations are
better aligned to English than
native script representations*

Instruction Tuning



Train on in-language IFT dataset

Sources of IFT dataset

Quality and diversity of IFT dataset

Supervised Modeling Objective

$$\ell_{\text{CE}}(\mathbf{y}, \hat{\mathbf{y}}) = - \sum_{j=1}^{|\mathcal{V}|} y_j \log(\hat{y}_j) \quad \mathcal{L}_{\text{SFT}} = \frac{1}{N} \sum_{i=1}^N \ell_{\text{CE}}(\mathbf{y}_i, \mathcal{M}_{\theta}(\mathbf{x}_i))$$

To retain English task performance

- Include English in the IFT training

Instruction Tuning Tasks

Variety of tasks/objectives to improve non-English performance

Generating IFT Data

- English Data IFT
- In-language IFT with Machine Translated Data
- Locally/Culturally relevant IFT data
- Parallel Data
- Monolingual Data
- Romanized IFT Data
- Cross-lingual Thought Data
- Cross-lingual IFT Data
- Code-switched IFT Data

Auxiliary Tasks

Transforming IFT
Datasets

Let's look at these tasks in detail

Using English IFT Dataset

- Instruction tune the model on English instruction dataset
- Evaluate on non-English data → Zero-shot cross-lingual evaluation
- Instruction tuning on English important to retain English capabilities

Using Machine Translated IFT Dataset

- Translate English instruction tuning datasets into the language
- Fine-tune model on translated dataset

Task	BeleBele QA	MKQA	XL-Sum
English IFT	Accuracy 45.58	F1 36.48	Rouge-L 8.42
Language IFT	48.28	37.95	15.87

Average performance across many languages; src: [SDRRL](#)

Instruction tuning on translated data outperforms English instruction-tuning

Creating Translated IFT Data

Choice of Translation Engine

- Off-the-shelf NMT systems ([Airavat](#)): higher quality, particularly for low-resource
- GPT ([Okapi](#)): can do translation taking the entire context of input/output

	#langs.	avg. chrF	avg. BLEU
ChatGPT (0-shot)	203	32.3	16.7
ChatGPT (5-shot)	203	33.1	17.3
GPT-4	20	44.6	24.6
NLLB	201	45.3	27.1
Google	115	52.2	34.6

Comparison of various translation engines
Sentence-level
([ChatGptMT](#))

Model	Human (General/Discourse)				
	News	Social	Fiction	Q&A	Ave.
Google	1.9/2.0	1.2/1.3	2.1/2.4	1.5/1.5	1.7/1.8
DeepL	2.2/2.2	1.3/1.1	2.4/2.6	1.6/1.5	1.9/1.9
Tencent	2.3/2.2	1.5/1.5	2.6/2.8	1.8/1.7	2.1/2.1
GPT-3.5	2.8/2.8	2.5/2.7	2.8/2.9	2.9/2.9	2.8/2.8
GPT-4	3.3/3.4	2.9/2.9	2.6/2.8	3.1/3.2	3.0/3.1

Comparison of various translation engines
Document-level
([ChatGptMT](#))

Creating Translated IFT Data (2)

What to Translate

- Instruction, Input, Output (Okapi, Airavat, xLLama, SDRRL)
- Input, Output (BLOOMZ)
 - English instruction is a common usecase
 - Models are good at English Instruction following

Quality Filtering

High quality examples are important for instruction tuning

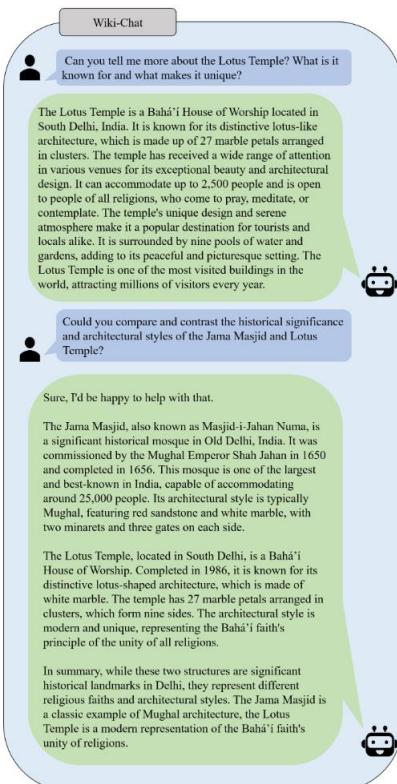
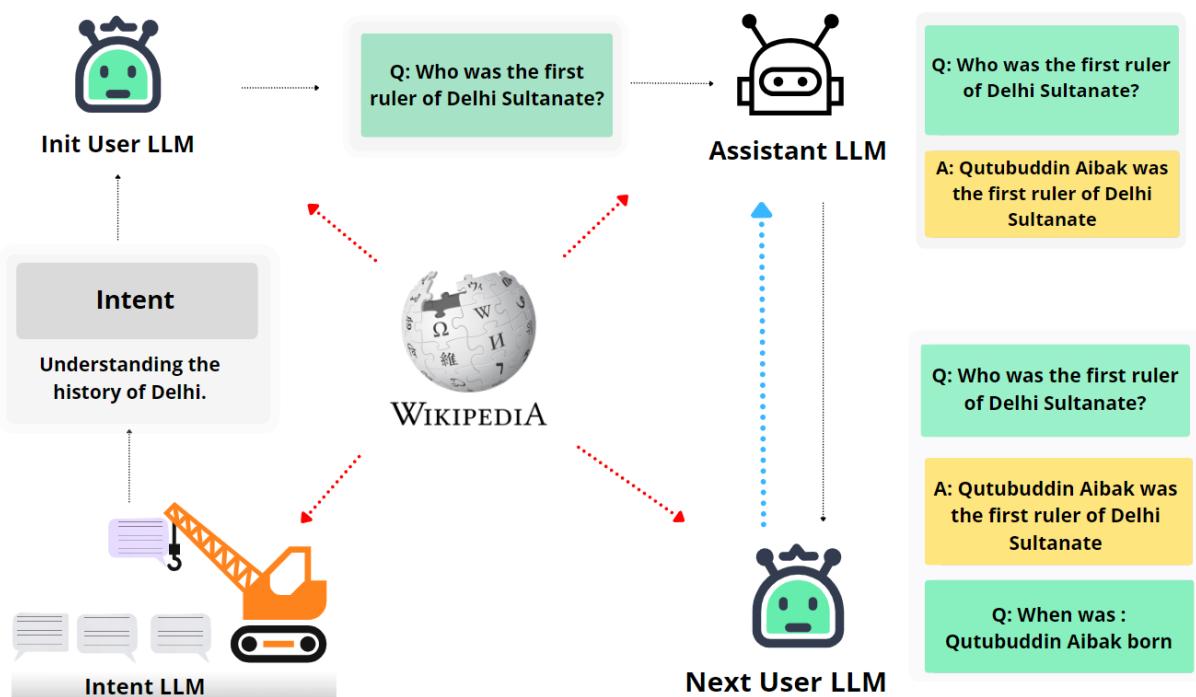
- Use an MT evaluation metric like COMET-QE to identify bad translations
- Rule-based filters to avoid code examples, etc. that are difficult to translate

*But we are just translating existing datasets – they might not be reflective
of topics relevant to the language users*

Creativity is the limit

Generating Culturally Relevant IFT Data

*Use multiple English LLMs along with Wikipedia context
to simulate conversations on topics of interest*



(a) English



(b) Telugu

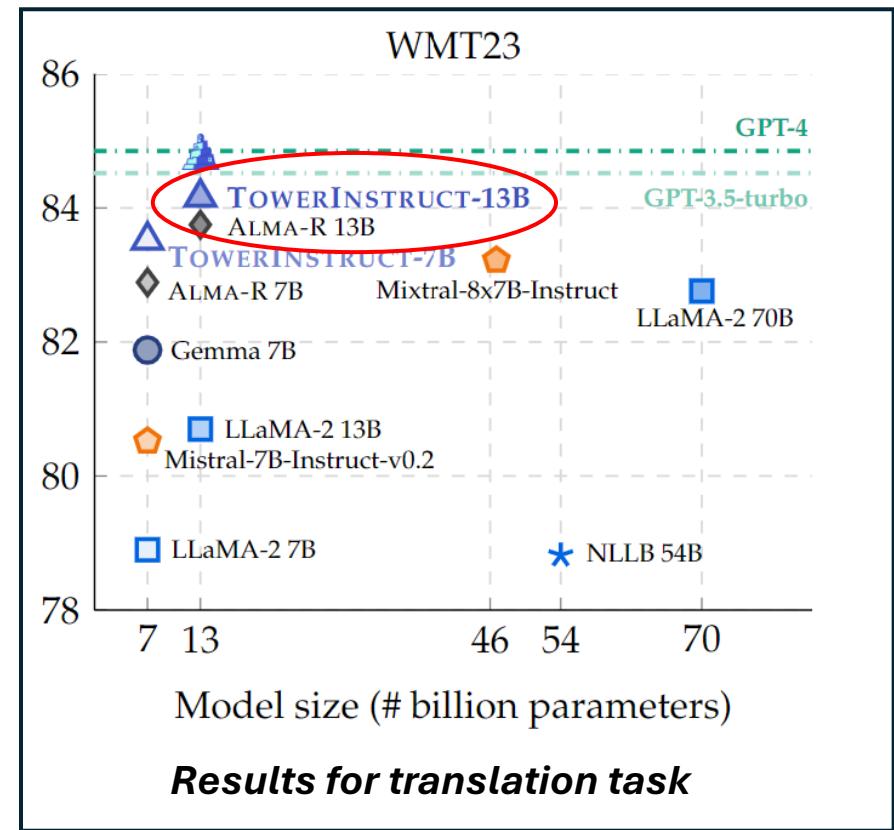
(IndicLLMSuite)

Translate the conversations into English

Using Parallel Data

Translation is a *special* task for multilingual IFT models

- Teaches the model to translate
- Aligns English and language representations better
- Improves performance on other downstream tasks
- Parallel data and translated IFT data both help



Instruction Data	XQUAD (exact match)	MLQA (exact match)	mLAMA (exact match)	XLSum (Rouge-1)
Alpaca-En	31.8	26.7	5.3	9.0
Alpaca-En+En-Zh	34.3	38.0	5.8	27.1
Alpaca-En+Alpaca-Zh	51.7	48.0	21.9	25.5
Alpaca-En+Alpaca-Zh+En-Zh	54.9	51.8	30.4	28.3

Results on Chinese for various Tasks

Instruction-tuning Data	Ar	Hi	Vi	Zh
Alpaca-En	16.1	13.7	34.1	26.7
Alpaca-En+En-Zh	33.6	35.1	42.2	38.0
Alpaca-En+Alpaca-Zh	33.1	35.1	50.1	48.0
Alpaca-En+Alpaca-Zh+En-Zh	37.0	42.3	50.8	51.8

Results for other languages on MLQA

Using Monolingual Data

- “Translationese IFT Data” → output language might not be fluent and high-quality
- Expose model to monolingual target language data during IFT
- Incorporate a task that helps model generate fluent output in target language

Task 1: Standard next-word prediction (CLM)

Switch between IFT and CLM objective in mini-batches

Task 2: Sentence Completion Task

Only IFT objective required

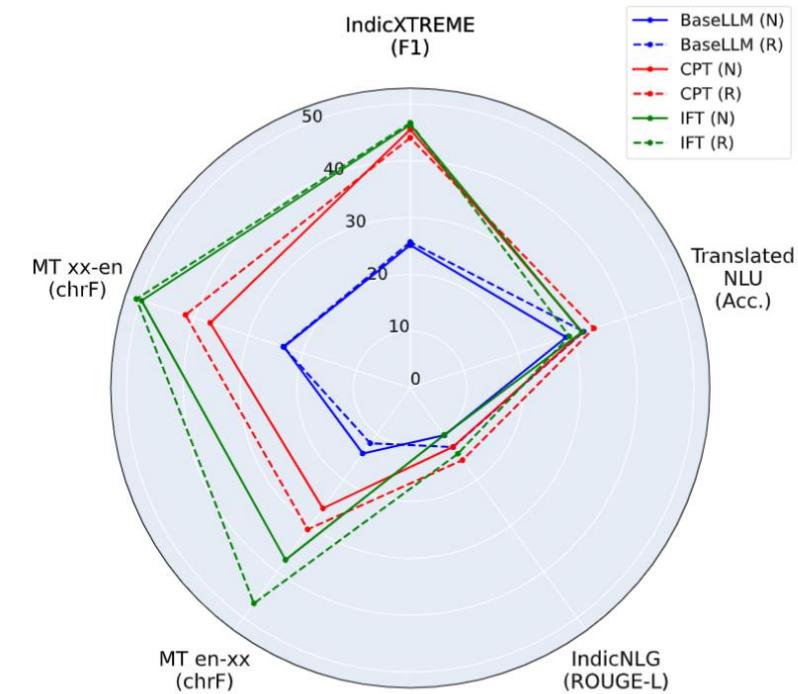
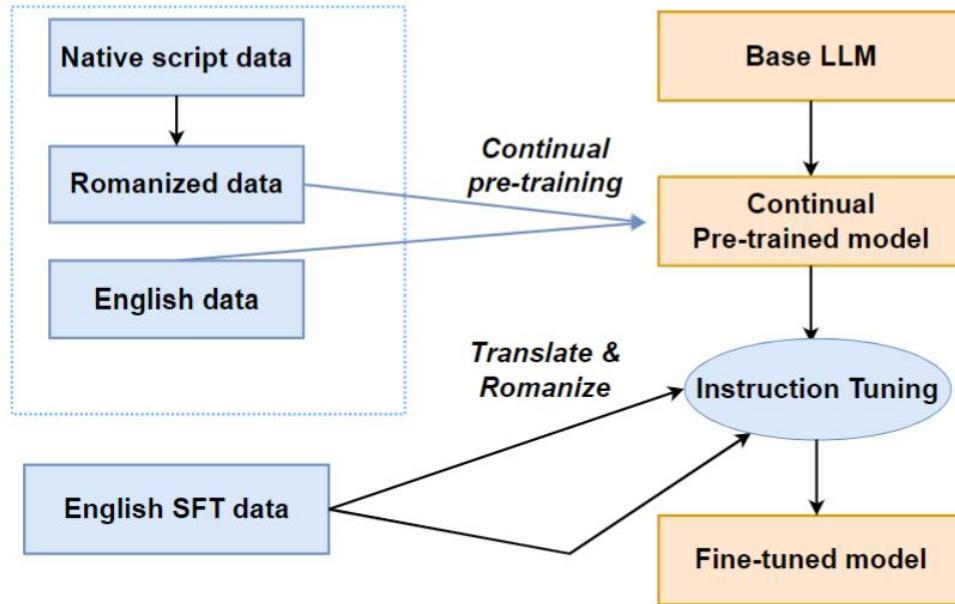
Question: Complete the following sentence in *Indonesian* according to its context.

Sang rubah cokelat cepat

Answer: *Sang rubah cokelat cepat melompati angin malas.*

Romanized Representation

Just like pre-training, use romanized representation for IFT too



- Continual Pre-training with romanized data is crucial
- NLG task performance improves with romanized data
- NLU task performance is on par, though more efficient

Results: Machine Translation

Script		BaseLLM		CPT		IFT
		1-shot	3-shot	1-shot	3-shot	0-shot
XX-En translation	N	22.46	23.42	38.54	37.07	49.78
	R	22.52	23.52	42.53	41.64	50.75
En-XX translation	N	13.95	14.25	25.55	26.19	37.40
	R	14.20	12.02	29.55	30.77	46.87

Flores-200 devtest

Chrf scores on native script

Romanized outputs converted to native script with IndicXlit + unigram re-ranking

XE Translation

- Base model: roughly equivalent quality for both representations
- CPT and IFT improve both representations
- Romanized representation gains more with CPT

EX Translation

- Base model: bad quality for both representations
- **CPT and IFT improve quality for both representations**
- Romanized representation gains more with CPT
- **IFT also show significant improvements for romanized over native script representation**

Cross-Lingual Thought Prompting (XLT)

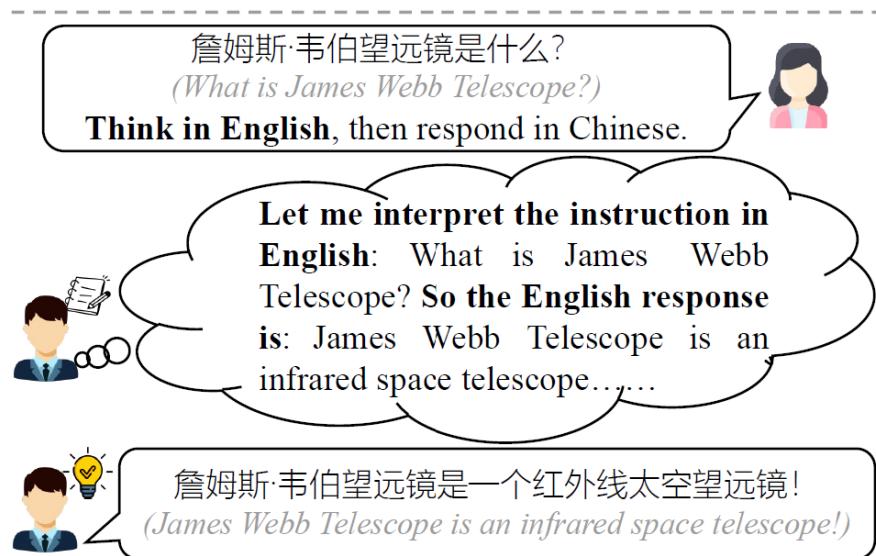
Ask the model to implicitly think in a different language

Monolingual QA



*Monolingual QA
with 'thinking in
English' aka*

*Cross-lingual
Thought
Prompting*



Model asked to generate intermediate English artifacts

No explicit translation call

The LLM itself is used as a translator **implicitly**

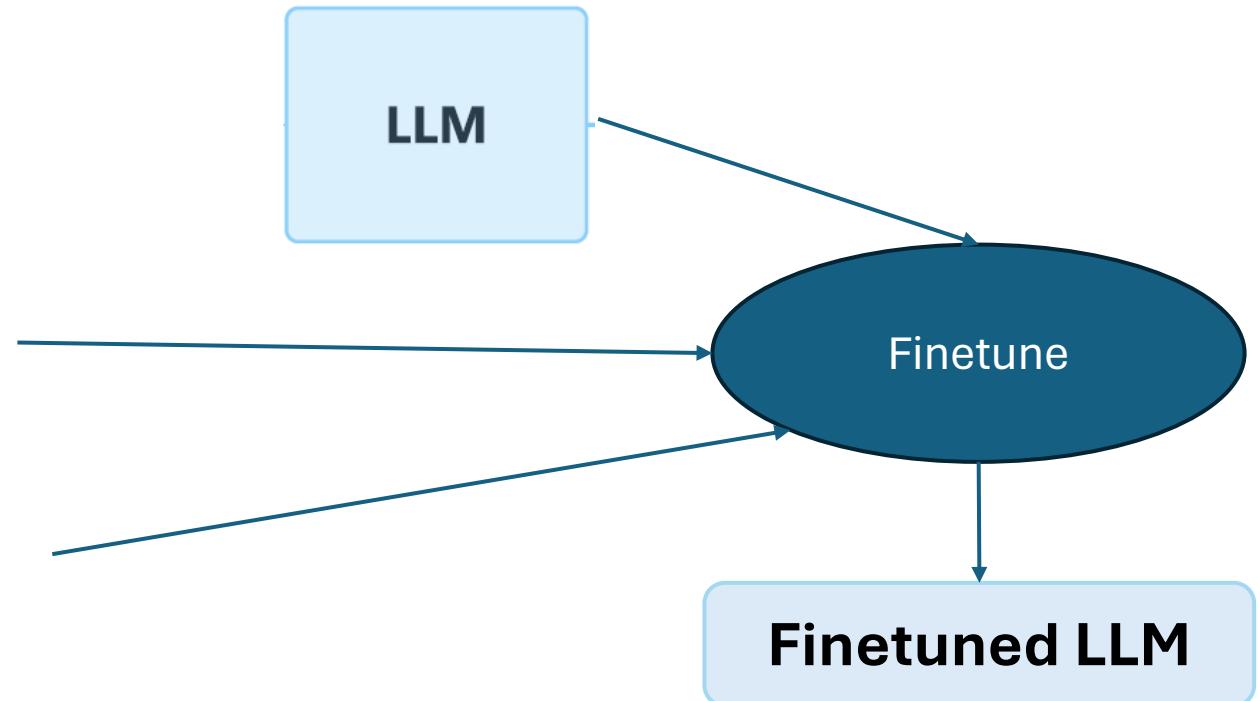
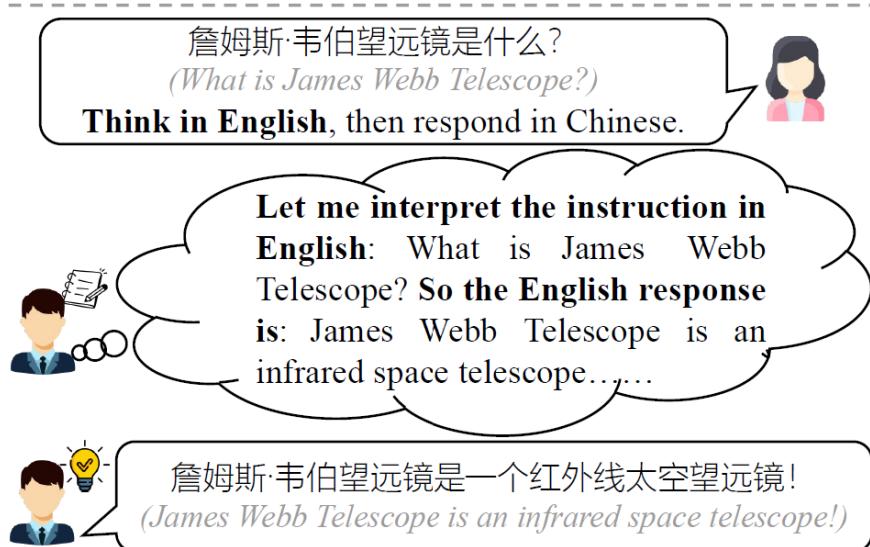
✓ **Multiple inferences are avoided**

✓ **Input in original language is available to LLM**

✗ **Increased token length for model, Reduces possible input token size**

(XLT, PLUG)

TaCo: Instruction tuning with Cross-Lingual Thought data



Limitations

- Reduced maximum sequence length
- Increased latency

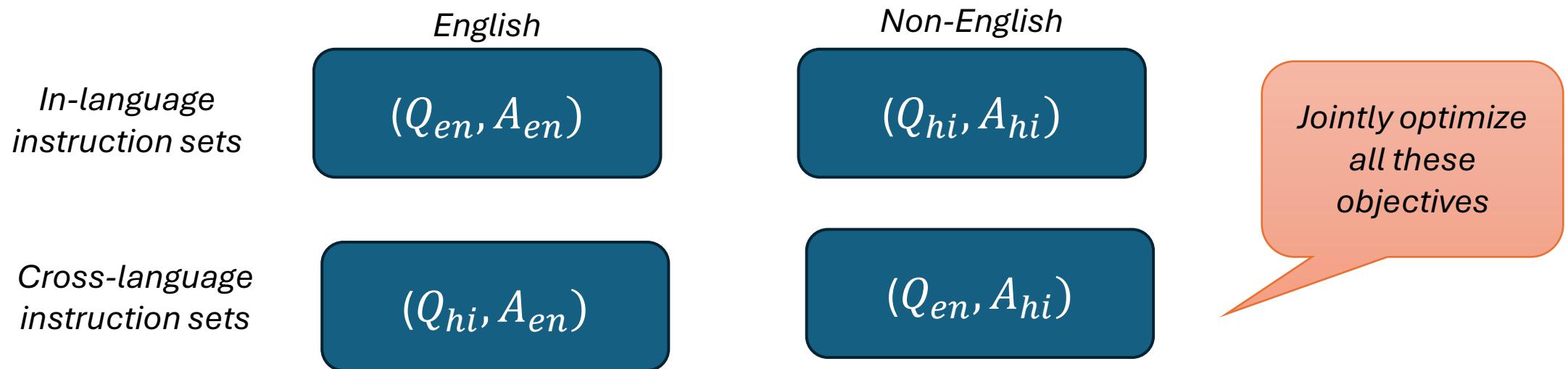
	Standard IFT	TaCo
Nepali	39.3	88.1
Persian	46.5	83.9

Evaluation on translated Vicuna Benchmark with GPT4

The PLUG paper also shows improvements (discussed later)

(TaCo, PLUG)

Cross-Lingual Instruction Tuning



Q_{hi} : मैं अपने समय प्रबंधन कौशल को कैसे सुधार सकता हूँ? मुझे 5 संक्षिप्त बिंदु दीजिये।

A_{en} :

1. Prioritize tasks based on importance and urgency.
2. Set specific goals with deadlines (SMART goals).
3. Use time management tools like calendars and apps.
4. Minimize distractions to maintain focus.
5. Regularly review and adjust your schedule for better efficiency.

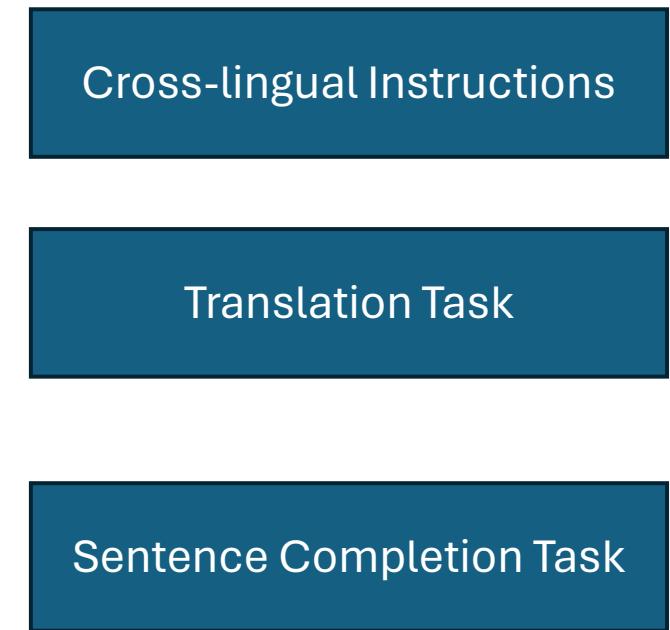
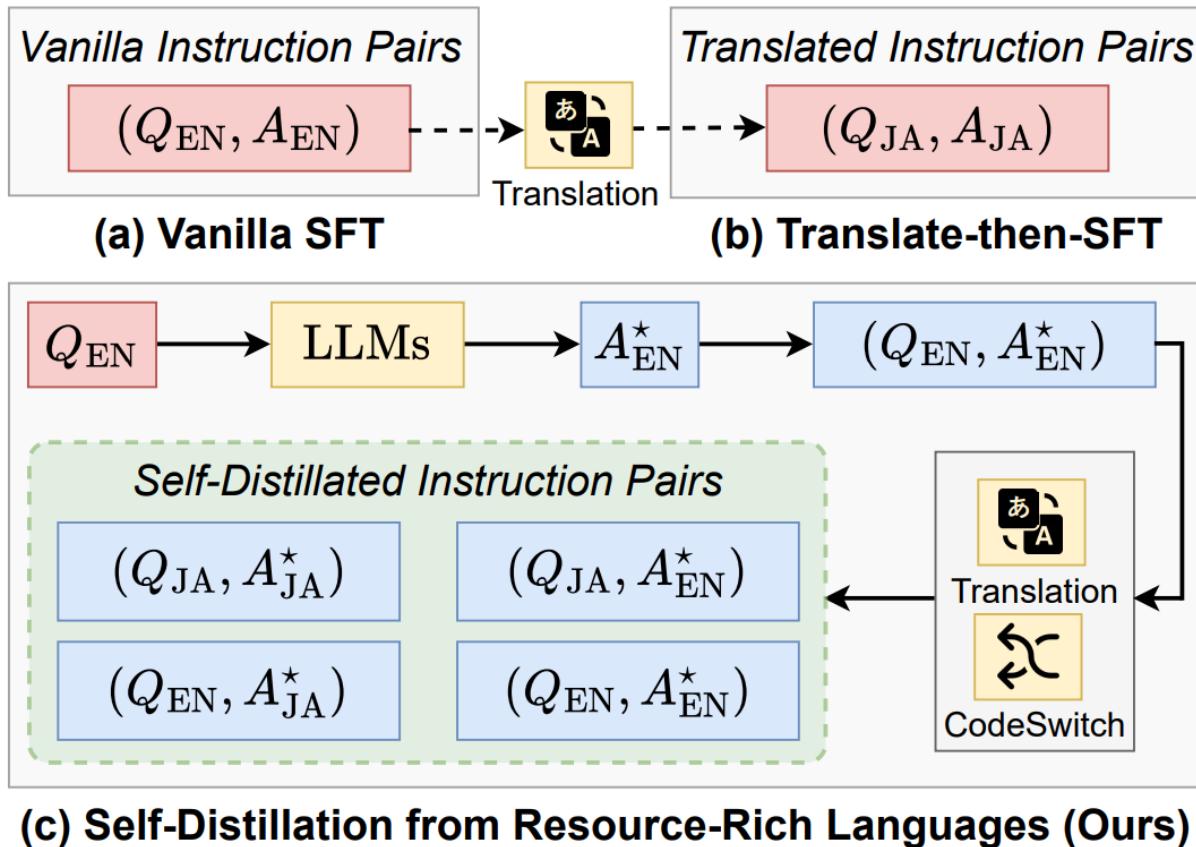
Cross-lingual instruction help the model to align languages and think in English

Avoids intermediate English generation of Cross-lingual Thought Prompting

(SDDRL,XCOT,CIT)

SDRRL: Putting it all together

(SDDRL)



(these tasks are added so model preserves native language competency)

Summary Results

(SDDRL)

	BELE.	XL-SUM	FLORES	MKQA	AVG.
<i>Performance on Target Language</i>					
SFT	42.24	<u>16.48</u>	18.45	38.86	29.01
T-SFT	<u>42.77</u>	15.32	16.59	43.40	29.52
CIT	42.53	15.75	<u>20.49</u>	<u>43.70</u>	<u>30.62</u>
XCOT	41.19	15.79	17.21	42.04	29.06
SDRRL	43.67	17.89	25.86	44.63	33.01
<i>Performance on English Language</i>					
SFT	<u>60.19</u>	15.25	<u>28.49</u>	<u>39.62</u>	<u>35.89</u>
T-SFT	<u>58.70</u>	<u>15.63</u>	23.72	37.43	33.87
CIT	58.66	15.42	18.31	36.67	32.27
XCOT	57.73	14.90	23.96	37.94	33.63
SDRRL	60.67	16.24	29.47	40.32	36.68

*(This summary is for the SeaLLM
backbone LLM, results in main paper are
for LLama)*

SFT: FT on English data

T-SFT: source and target translated

CIT: target translated

XCOT: source translated + source code-switching

Bringing together all these objectives and data augmentations:

- **Helps improve overall response quality across multiple tasks**
- **Retains English performance**

Ablation Studies (1)

(SDDRL)

	1	NLU Avg.		NLG Avg.	
		TAR.	ENG	TAR.	ENG
1	Full Method	50.58	66.29	28.24	31.69
2	- \mathcal{D}_{TL} and \mathcal{D}_{LT}	49.56	65.93	26.15	30.55
3	- $\mathcal{D}_{\text{synth}} + \mathcal{D}$	48.59	65.10	25.16	30.10
4	- \mathcal{D}_{mt} and $\mathcal{D}_{\text{comp}}$	<u>50.41</u>	<u>66.01</u>	26.61	30.19
5	- Code Switching	50.37	65.94	<u>27.13</u>	<u>30.69</u>
6	Only \mathcal{D}_{mt} and $\mathcal{D}_{\text{comp}}$	41.25	61.61	17.89	22.28

Table 6: Ablation study. Average scores of target language (TAR.) and English (ENG) on natural language understanding task (NLU, including BELEBELE) and natural language generation tasks (NLG, including FLORES, XL-SUM ROUGE-L, and MKQA) are reported.

- Using the LLMs own responses is a very useful method to improve cross-lingual transfer
- The MT and sentence completion tasks are very useful
- The cross-lingual instruction tuning tasks are also complementary
- Code-switching (on input side) has modest benefits

Ablation Studies (2)

(PLUG)

Training Method Comparison	Chinese			Korean			Italian			Spanish		
	Win%	Loss%	Δ%	Win%	Loss%	Δ%	Win%	Loss%	Δ%	Win%	Loss%	Δ%
<i>English-Centric Foundation LLM: LLaMA-2-13B</i>												
PLUG vs. Pivot-Only	70.9	19.1	+51.8	76.5	12.7	+63.9	67.6	17.8	+49.8	64.0	20.9	+43.1
PLUG vs. Mono. Response	58.0	25.2	+32.8	64.1	19.9	+44.2	50.3	25.8	+24.5	53.0	27.6	+25.5
PLUG vs. Mono.+ Translation	53.0	28.0	+25.1	62.7	20.1	+42.6	50.1	26.6	+23.5	51.3	25.6	+25.7
PLUG vs. Mono.+ Code-Switch	50.2	31.6	+18.6	55.2	25.6	+29.6	46.2	30.9	+15.3	48.4	29.9	+18.5

PLUG: Thinking in pivot language

Pivot-only: IFT On pivot language

Mono-Response: IFT on pivot and target language

Mono + Translation: add translation task to Mono-Response

Mono + Code-Switch: add cross-lingual instruction tuning to Mono-Response

Evaluation with GPT4

- Including Translation task is useful
- Training on cross-lingual thought data is most effective
- Cross-lingual instruction tuning is the best next, closes gap on cross-lingual thought data

Summary

- Rapid Advances in Multilingual LLMs
- Extending strong English LLMs to other languages is an effective and efficient direction
- Vocabulary expansion to support new languages and make LLMs efficient, but challenges in achieving convergence
- Continual pre-training important to improve language competence
- Lot of work on aligning languages in the instruction tuning stage

Future Directions

Modeling/Training

- Improving cross-lingual transfer
- Use of synthetic data
- Better “thinking” in English
- Composing Task and Language skills efficiently
- Small Multilingual models

Data/Resources

- Scalable evaluation methods for multilingual LLMs
- Creation of multilingual benchmarks
- Collection of large-scale culture-specific text corpora

Reading List

- Download HERE (*identify by PAPER_KEY on the slides*)

Reading List for *Making LLMs Multilingual*

1. [Airavata] Gala, Jay, Thanmay Jayakumar, Jaavid Aktar Husain, Mohammed Safi Ur Rahman Khan, Diptesh Kanojia, Ratish Puduppully, Mitesh M. Khapra, Raj Dabre, Rudra Murthy, and Anoop Kunchukuttan. "Airavata: Introducing Hindi Instruction-tuned LLM." *arXiv preprint arXiv:2401.15006* (2024).
2. [ALMA] Haoran Xu, Young Jin Kim, Amr Sharaf, Hany Hassan Awadalla. A Paradigm Shift in Machine Translation: Boosting Translation Performance of Large Language Models. ICLR (2024).
3. [ALMA-R] Xu, Haoran, Amr Sharaf, Yunmo Chen, Weiting Tan, Lingfeng Shen, Benjamin Van Durme, Kenton Murray, and Young Jin Kim. "Contrastive preference optimization: Pushing the boundaries of llm performance in machine translation." *arXiv preprint arXiv:2401.08417* (2024).

Multilingual Pre-training Corpora

- MADLAD-400
- CulturaX
- ROOTS
- mC4
- OSCAR
- CC100
- Glot500-c
- Sangraha
- SEA-LION-PILE

Notable Projects on Extending English LLMs

- BLOOM+1
- ChineseLLama
- Bactrian-X
- Okapi
- SeaLLM
- TOWER
- ALMA and ALMA-R
- AceGPT

Thanks

If you find this work useful, please cite it in your work

```
@online{kunchukuttan2024extendllm,  
author = {{Anoop Kunchukuttan}},  
title = {Extending English Large Language Models to New Languages: A Survey},  
url = {https://anoopkunchukuttan.gitlab.io/publications/presentations/extend\_en\_llms\_apr2024.pdf},  
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