Leveraging LLM For Synchronizing Information Across Multilingual Tables

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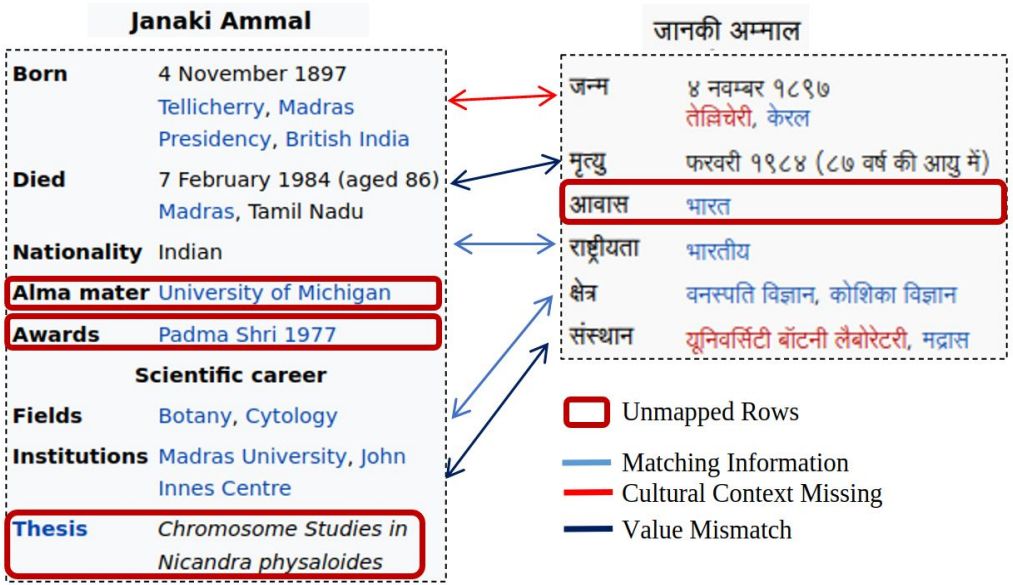
Problem :- Information Mismatch in Tables For Different Languages



English Table

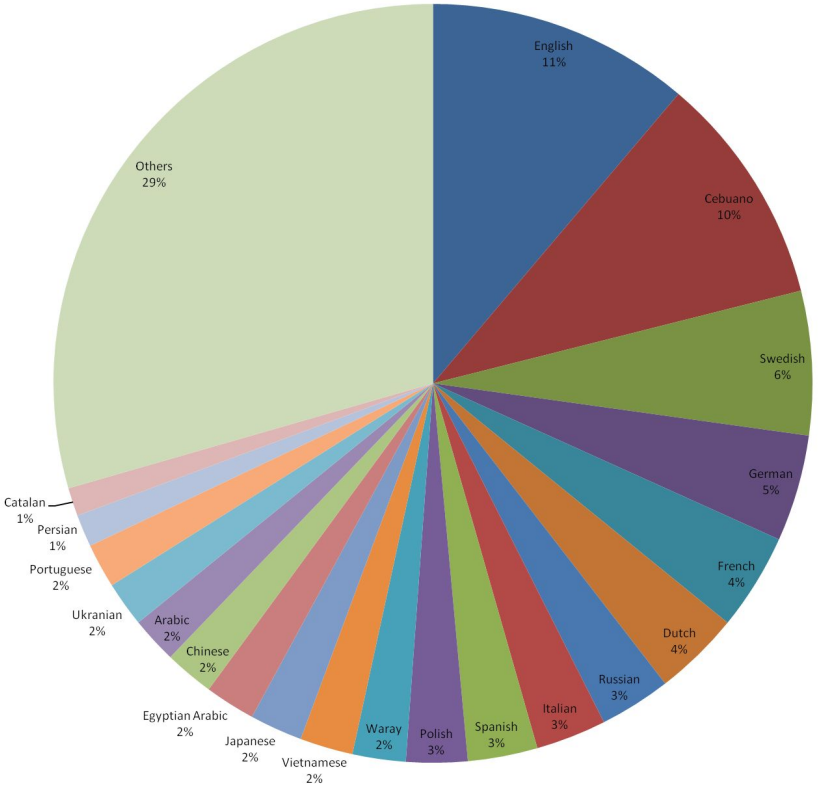
Hindi Table

Low Resource Language
- Outdated Table

Example from: Siddharth Khincha, Chelsi Jain, Vivek Gupta, Tushar Kataria, and Shuo Zhang. 2023. *InfoSync: Information Synchronization across Multilingual Semi-structured Tables*. In *Findings of the Association for Computational Linguistics: ACL 2023*, pages 2536–2559, Toronto, Canada. Association for Computational Linguistics.

Magnitude of the Problem

- Wikipedia
  - Articles in more than 300 languages.
  - English has the most significant Wikipedia covering 23% (11%) of total pages (articles).
  - Most users' edits (76%) are also done in English Wikipedia.
  - Except for the top 25 languages, the total number of active editors, pages, and edits is less than 1%



Our Prior Work (ACL 2023 Finding)

- Proposes a two step approach
  - Information Alignment Step
  - Information Updation Step
- Information Alignment Step
  - Novel dataset focusing on the Information Alignment
  - Propose a Multi-step Constraint Relaxation approach for the Alignment Step
    - Using pre-trained language models (RoBERT, Sentence Transformer etc)
- Information Updation Step
  - Rules based approach for coverage
  - Live Human Verification of Updates

Khincha et. al. 2023 ***did not focus on information updation*** *(no updations dataset), and* ***doesn't leverage SOTA Large Language Model's (LLMs)*** *for any of the above tasks.*

Siddharth Khincha, Chelsi Jain, Vivek Gupta, Tushar Kataria, and Shuo Zhang. 2023. *InfoSync: Information Synchronization across Multilingual Semi-structured Tables*. In *Findings of the Association for Computational Linguistics: ACL 2023*, pages 2536–2559, Toronto, Canada. Association for Computational Linguistics.

Can we do better?

- Can we leverage **LLMs** for **synchronization of multilingual entity-centric tables** across multilingual Wikipedia editions?

- How can LLMs be effectively utilized with **zero-shot prompts**, and how **can their performance be enhanced**?

- How **effective are LLMs** compared to the rule-based methods proposed in prior *Khincha et. al. 2023*?

Siddharth Khincha, Chelsi Jain, Vivek Gupta, Tushar Kataria, and Shuo Zhang. 2023. *InfoSync: Information Synchronization across Multilingual Semi-structured Tables*. In *Findings of the Association for Computational Linguistics: ACL 2023*, pages 2536–2559, Toronto, Canada. Association for Computational Linguistics.

Key Contributions of This Work

Information Alignment

- Use SOTA LLMs to enhance the InfoSync (Khincha et. al.) performance.

Information Updation

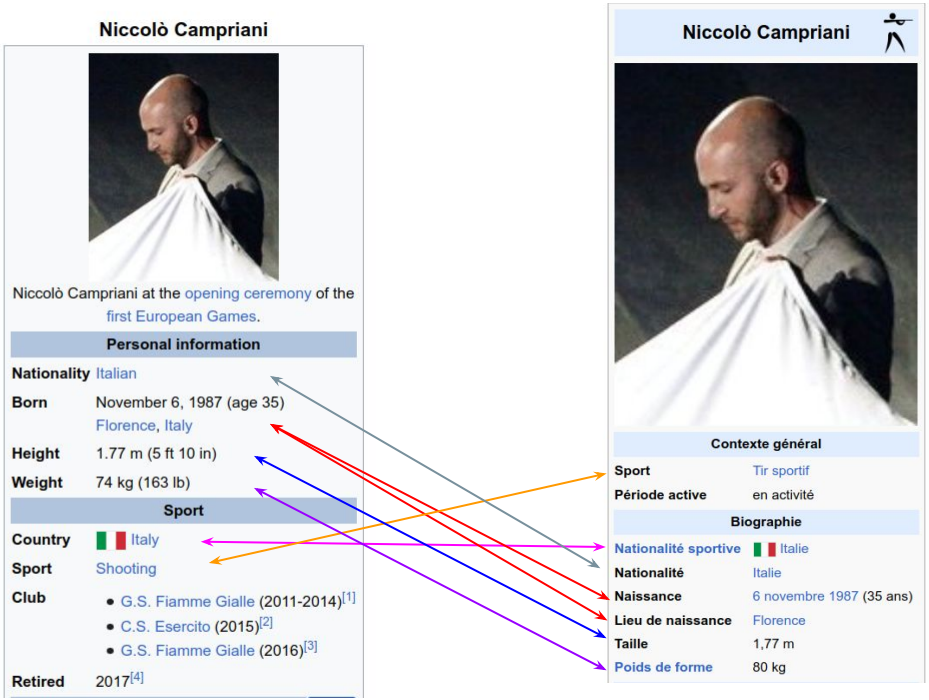
- **InfoUpdate** : First human annotated and verified **Information Updation benchmark**
- Propose a **multi-step decomposition based zero-shot LLM approach** that significantly **enhances the factuality and coherence** of the information updates.
- Developed **novel evaluation metrics** and conducted **detailed error analysis** to identify LLM limitations.

What is Information Alignment ?

A mapping of rows across two tables in different language

- which contain information about the same attribute
- This information is similar and comparable
- can be entailed or contradicted to each other

E.g. Nationality (En) ←→ Nationalite (Fr)

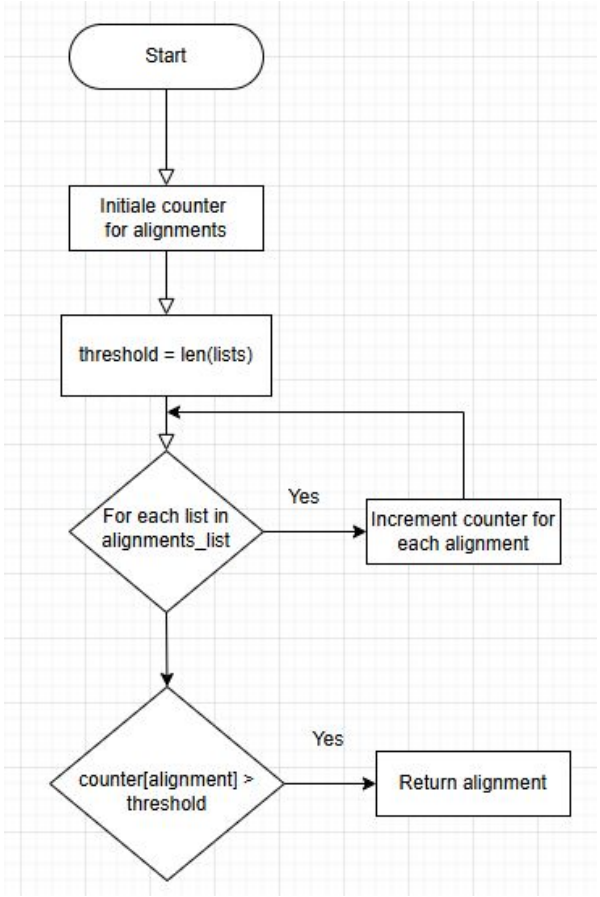


Information Alignment

Input: List of alignments from multiple models

- InfoSync - Khincha et. al. rule based
- **Multiple LLMs** (e.g. Gemini, GPT etc
- **Use multi-voting for final alignment**

Output: Final ensemble-selected alignments



Alignment Results

We manually annotate 400 **Input_Gold–Output_Gold** alignments.

Our Multi-Voting (3x) approach achieves higher scores.

Model	Type	Precision	Recall	F1
InfoSync	Input_Gold	96.62	88.64	91.26
	Output_Gold	89.37	82.07	84.42
	Overall Average	92.90	85.27	87.75
GPT3.5	Input_Gold	96.29	93.99	94.40
	Output_Gold	89.63	85.98	86.70
	Overall Average	92.88	89.88	90.46
GPT3.5 voting(3x)	Input_Gold	98.06	**94.10**	95.66
	Output_Gold	**94.57**	87.41	89.81
	Overall Average	96.27	90.67	92.66
Gemini voting(3x)	Input_Gold	96.88	92.05	93.63
	Output_Gold	92.52	83.95	86.46
	Overall Average	94.65	87.90	89.96
Multi voting(3x)	Input_Gold	**99.15**	93.88	**95.80**
	Output_Gold	94.18	**88.39**	**90.69**
	Overall Average	**96.60**	**91.07**	**93.18**

Information Updation - Dataset Creation

Language A

Input Table

Name	Elon Musk
Born	June 28, 1971

Gold Table

Name	Elon Musk
Born	June 28, 1971
Citizenship	South Africa, USA

Language B

Reference Table

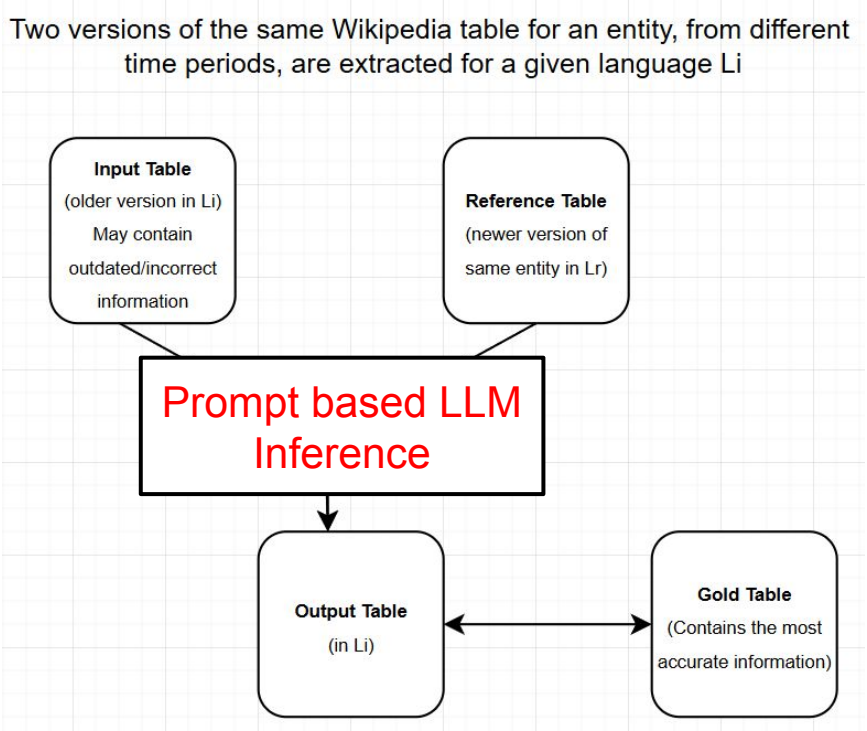
Nom	Elon Musk
Date de Naissance	28 juin 1971
Nationalité	Afrique du Sud, États-Unis

Task: Update Input Table (En) from Reference Tables (Fr), Ideal Table Gold Table (En)

Information Updation - Methodology

- **Simple Prompt -** Direct description of task with input/output and requirements specified
- **Task decomposition**
  Elementary with a Single Prompt - (1.) Alignment Step and (2.) Update Step
- **Our Approach**
  Hierarchical Task Decomposition Prompt

  Divide the task into **multiple prompts** with **sequential inference**.
  - Translation
  - Knowledge graphs conversion
  - Merge
  - Update
  - Back-Translation



What is Hierarchical Task Decomposition Prompt ?

Translation (X → En)

Knowledge graphs conversion

Merge

Update

Back-Translation (En → X)

Input Table (En)

Attribute	Value
Name	Elon Musk
Born	June 28, 1971
Citizenship	South Africa
Net Worth	$150 billion (2021)
Spouse(s)	Justine Musk
Children	5
Twitter Handle	@elonmusk

Reference Table (Fr)

Attribute	Value
Nom	Elon Musk
Date de Naissance	28 juin 1971
Nationalité	Afrique du Sud, États-Unis
Connu Pour	Tesla, SpaceX, Twitter
Fortune	220 milliards USD (2023)
Époux(se)	Justine Musk, Talulah Riley
Enfants	9
Entreprises	Tesla, SpaceX, Twitter

Hierarchical Task Decomposition Prompt

Translation (X → En)

Knowledge graphs conversion

Merge

Update

Back-Translation (En → X)

Input Table Translated (En)

Attribute	Value
Name	Elon Musk
Born	June 28, 1971
Citizenship	South Africa
Net Worth	$150 billion (2021)
Spouse(s)	Justine Musk
Children	5
Twitter Handle	@elonmusk

Reference Table Translated(En)

Attribute	Value
Name	Elon Musk
Date of Birth	28 juin 1971
Nationality	South Africa, USA
Known For	Tesla, SpaceX, Twitter
Net Worth	220 milliards USD (2023)
Spouses	Justine Musk, Talulah Riley
Children	9
Companies	Tesla, SpaceX, Twitter

Hierarchical Task Decomposition Prompt

Translation (X → En)

Knowledge graphs conversion

Merge

Update

Back-Translation (En → X)

```
Input_kg = {
    "name": "Elon Musk",
    "personal_information": {
        "born": "June 28, 1971",
        "citizenship": "South
Africa"
    },
    "financial_information": {
        "net_worth": "$150 billion
(2021)"
    },
    "family_information": {
        "spouse": "Justine Musk",
        "children": 5
    },
    "online_presence": {
        "twitter_handle":
"@elonmusk"
    }
}
```

```
Ref_kg =  {
    "name": "Elon Musk",
    "personal_information": {
        "date_of_birth": "June 28,
1971",
        "nationality": ["South
Africa", "USA"]
    },
    "professional_information": {
        "known_for": ["Tesla",
"SpaceX", "Twitter"],
        "companies": ["Tesla",
"SpaceX", "Twitter"]
    },
    "financial_information": {
        "net_worth": "220 billion USD
(2023)"
    },
    "family_information": {
        "spouses": ["Justine Musk",
"Talulah Riley"],
        "children": 9
    }
}
```

Hierarchical Task Decomposition Prompt

Translation (X → En)

Knowledge graphs conversion

Merge

Update

Back-Translation (En → X)

Input_kg

Ref_kg

```
Merged_kg = {
    "name": "Elon Musk",
    "personal_information": {
        "date_of_birth": "June 28, 1971",
        "citizenship": ["South Africa", "USA"]
    },
    "professional_information": {
        "known_for": ["Tesla", "SpaceX", "Twitter"],
        "companies": ["Tesla", "SpaceX", "Twitter"]
    },
    "financial_information": {
        "net_worth": "220 billion USD (2023)"
    },
    "family_information": {
        "spouses": ["Justine Musk", "Talulah Riley"],
        "children": 9
    },
    "online_presence": {
        "twitter_handle": "@elonmusk"
    }
}
```

- **Common information** in Reference and Input
- Information present **only in the Reference**

Hierarchical Task Decomposition Prompt

Translation
Knowledge graphs conversion
Merge
Update
Back-Translation

Attribute	Value
Name	Elon Musk
Born	June 28, 1971
Citizenship	South Africa
Net Worth	$150 billion (2021)
Spouse(s)	Justine Musk
Children	5
Twitter Handle	@elonmusk

merged_kg

Attribute	Value
Name	Elon Musk
Born	June 28, 1971
Citizenship	South Africa, U.S., Canada
Known For	Tesla, SpaceX, Twitter, Neuralink
Net Worth	$230 billion (2024)
Spouse(s)	Justine Musk, Talulah Riley (div.), Grimes (ex.)
Children	10
Companies	Tesla, SpaceX, Twitter, xAI, Neuralink
Twitter Handle	@elonmusk

Hierarchical Task Decomposition Prompt

Translation (X → En)

Knowledge graphs conversion

Merge

Update

Back-Translation : (En → X)

Not Required for this example

because input was in English.

Attribute	Value
Name	Elon Musk
Born	June 28, 1971
Citizenship	South Africa, U.S., Canada
Known For	Tesla, SpaceX, Twitter, Neuralink
Net Worth	$230 billion (2024)
Spouse(s)	Justine Musk, Talulah Riley (div.), Grimes (ex.)
Children	10
Companies	Tesla, SpaceX, Twitter, xAI, Neuralink
Twitter Handle	@elonmusk

Evaluation Metric

Given Source, Gold and Output Tables:

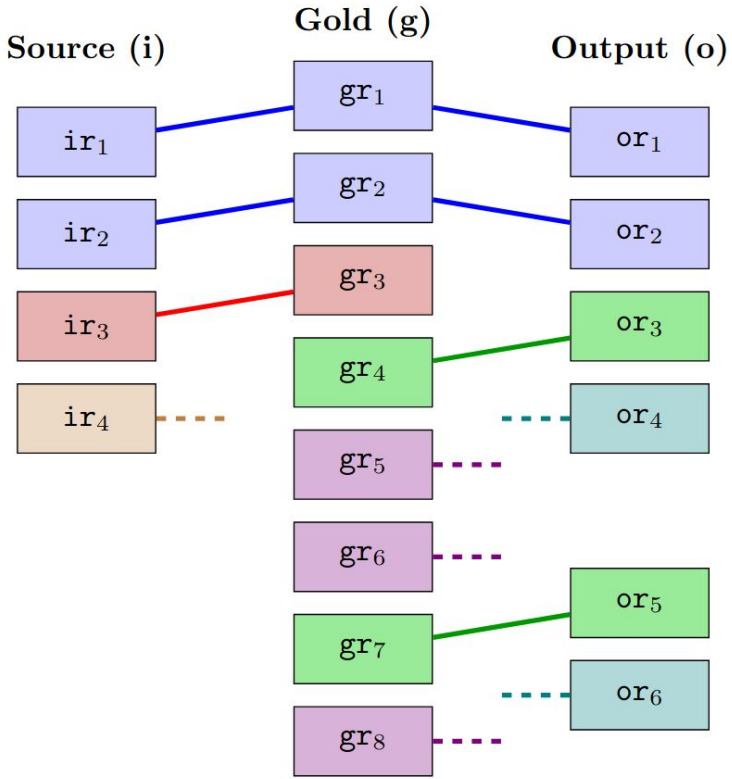
Compute <Source,Gold> and <Gold, Output> alignments

Categorised as follows:

Tri-align(tr) : Table keys common across the 3 tables

Bi-Align(bi) : Table keys common either between Source and Gold **or** Output and Gold

Un-aligned: Table keys remaining after removing tri-aligned and bi-aligned keys (Source , Gold, Output)



Evaluation Metric

Tri-Align (tr)

Information Updated:

$$\frac{\mathrm{tr}(o,g)-\mathrm{tr}(i,g)}{|g|} = \frac{2}{8}$$

Represents the net addition of relevant information to the Output.

Bi-Align (bi)

Information Added:

$$\frac{\mathrm{bi}(o,g)}{|g|} = \frac{2}{8}$$

Represents misaligned additions from the Output.

Information Deleted:

$$\frac{\mathrm{bi}(i,g)}{|g|} = \frac{1}{8}$$

Represents omissions from the Input that were relevant.

Evaluation Metric

Tri-Align (tr)

Information Updated:

$\frac{\text{tr}(o,g)-\text{tr}(i,g)}{|g|} = \frac{2}{8}$

Represents the net addition of relevant information to the Output.

Bi-Align (bi)

Information Added:

$\frac{\text{bi}(o,g)}{|g|} = \frac{2}{8}$

Represents misaligned additions from the Output.

Information Deleted:

$\frac{\text{bi}(i,g)}{|g|} = \frac{1}{8}$

Represents omissions from the Input that were relevant.

Un-Aligned (un)

Missing Information (Gold):

$\frac{\text{un}(g)}{|g|} = \frac{3}{8}$

Represents the proportion of relevant Gold elements left unaligned.

Un-Aligned (un)

Noisy Information Retain (Input):

$\frac{\text{un}(i)}{|i|} = \frac{1}{4}$

Indicates the proportion of irrelevant elements in Input.

Noisy Information (Output):

$\frac{\text{un}(o)}{|o|} = \frac{2}{6}$

Indicates the proportion of irrelevant elements in Output.

Results

	Trialign Rows (Tr)	Bialign Rows (Bi)		UnAlign Gold (UG)
Methods	Updated ↑	Added (%) ↑	Added (#Rows) ↑	Missed (G) ↓
InfoSync (Khincha et al., 2023)	1.28	12.18	2.99	4.67
Direct Prompt	0.63	11.55	3.63	4.40
Align-Update (Two Prompts)	-0.77	12.59	3.98	2.74
Align-Update (Joint Prompt)	0.51	13.58	3.48	3.24
Our Proposed Decomposition Approach				
Direct Decompose Prompt	0.90	12.06	2.98	4.65
Translation(+BackTrans)	0.62	16.88	4.09	3.71
+ Merge and Alignment	1.33	17.80	**4.99**	2.92
+ Knowledge Graph	**1.79**	**20.58**	4.88	**2.69**
Human (100 examples)	1.75	21.44	5.6	2.09

Our approach excels in correcting and adding missing information, reducing hallucination, thus consistently outperforming other strong baselines methods

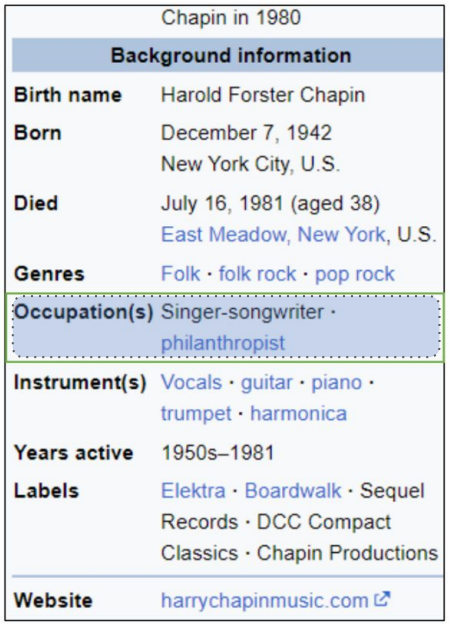
Error Analysis

Error Types.	In Refer.	+Tr. (En)	+ KG Cons.	+ Merge	+ Table Conv.	+ Tr. (BT-Orig)
Missing	145	145	**151 (+6)**	**198(+47)**	**202 (+4)**	202
Outdated (Full)	35	35	35	**51(+16)**	**59(+8)**	59
Outdated (Partial)	59	59	59	**68 (+9)**	**73 (+4)**	73
Redundant	0	0	**66 (+66)**	66	66	66
Total	239	239	**311 (+72)**	**383 (+72)**	**400 (+17)**	400

- Shows increasing errors per decomposition steps w.r.t to the Gold table (Human annotated data)
- Reference errors are the minimum baseline i.e. things missing in reference tables

Example Live Updates

Reference Infobox (en)



Chapin in 1980	
Background information	
Birth name	Harold Forster Chapin
Born	December 7, 1942 New York City, U.S.
Died	July 16, 1981 (aged 38) East Meadow, New York, U.S.
Genres	Folk · folk rock · pop rock
Occupation(s)	Singer-songwriter · philanthropist
Instrument(s)	Vocals · guitar · piano · trumpet · harmonica
Years active	1950s–1981
Labels	Elektra · Boardwalk · Sequel Records · DCC Compact Classics · Chapin Productions
Website	harrychapinmusic.com

Target Infobox(Ko)

해리 채핀 (1980년)	
기본 정보	
본명	해럴드 포스터 채핀 (Harold Forster Chapin)
출생	1942년 12월 7일 미국 뉴욕주 뉴욕
사망	1981년 7월 16일(38세) 미국 뉴욕주 이스트메도
국적	미국
직업	음악가
장르	포크, 포크 록, 팝 록
활동 시기	1966년 ~ 1981년
악기	보컬, 기타, 피아노, 트럼펫, 하모니카
레이블	엘렉트라, 브로드워크

Target Updated Infobox(Ko)

해리 채핀 (1980년)	
기본 정보	
본명	해럴드 포스터 채핀 (Harold Forster Chapin)
출생	1942년 12월 7일 미국 뉴욕주 뉴욕
사망	1981년 7월 16일(38세) 미국 뉴욕주 이스트메도
국적	미국
직업	음악가, 자선가
장르	포크, 포크 록, 팝 록
활동 시기	1966년 ~ 1981년
악기	보컬, 기타, 피아노, 트럼펫, 하모니카
레이블	엘렉트라, 브로드워크

The updated infobox is shown in column 3 where the 'job/occupation' key is updated. This is an example of "Value substitution".

TakeAways

- LLMs can **synchronize information in low-resource languages** by utilizing reference data from high-resource languages.

- Performance can be enhanced through **Hierarchical Task Decomposition**, such as **translating to English and converting to knowledge graphs**.

- Extending the dataset to include **more diverse languages and more complex structured information** structures to test LLM generalizability.