MultiMUC: Multilingual Template Filling on MUC-4

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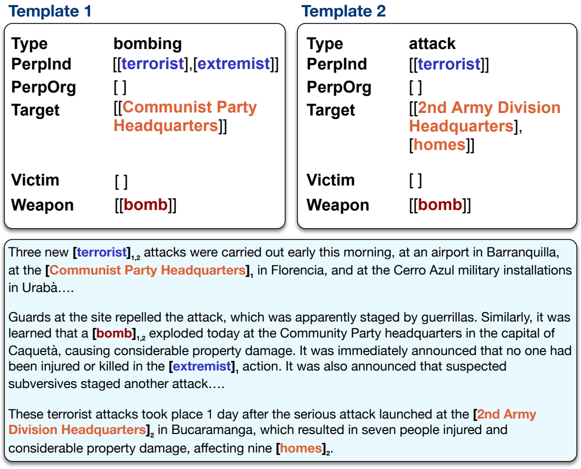
Abstract

We introduce MultiMUC, the first multilingual parallel corpus for template filling, comprising translations of the classic MUC-4 template filling benchmark into five languages: Arabic, Chinese, Farsi, Korean, and Russian. We obtain automatic translations from a strong multilingual machine translation system and manually project the original English annotations into each target language. For all languages, we also provide human translations for sentences in the dev and test splits that contain annotated template arguments. Finally, we present baselines on MultiMUC both with state-of-the-art template filling models and with ChatGPT.

1 Introduction

The Message Understanding Conferences (MUCs) were a series of U.S. government-sponsored competitions that ran from the late 1980s through the late 1990s whose aim was to promote the development of systems for extracting complex relations from text, and which have been credited with inaugurating the field of information extraction (IE; Grishman and Sundheim, 1996; Grishman, 2019). The third MUC (MUC-3) introduced the now classic task of *template filling*, in which systems must identify events, represented by predefined schemas or *templates*, in a document, and populate roles or *slots* in those templates with relevant information extracted or inferred from the text (muc, 1991). MUC-3 focused on identifying various forms of terrorism (e.g. bombings, kidnappings) in news reports from numerous countries in Latin America. Systems were required to extract one template per incident, containing details about the perpetrators, their victims, the weapons used, and damaged physical infrastructure. The data, task specification, and evaluation methodology of MUC-3 were then refined and updated in MUC-4 (muc, 1992).



Template 1

Type	**bombing**
PerpInd	[[terrorist],[extremist]]
PerpOrg	[ ]
Target	[[Communist Party Headquarters]]
Victim	[ ]
Weapon	[[bomb]]

Template 2

Type	**attack**
PerpInd	[[terrorist]]
PerpOrg	[ ]
Target	[[2nd Army Division Headquarters], [homes]]
Victim	[ ]
Weapon	[[bomb]]

Three new **[terrorist]**$_{1,2}$ attacks were carried out early this morning, at an airport in Barranquilla, at the **[Communist Party Headquarters]**$_{1}$ in Florencia, and at the Cerro Azul military installations in Urabà….

Guards at the site repelled the attack, which was apparently staged by guerrillas. Similarly, it was learned that a **[bomb]**$_{1,2}$ exploded today at the Community Party headquarters in the capital of Caquetà, causing considerable property damage. It was immediately announced that no one had been injured or killed in the **[extremist]**$_{1}$ action. It was also announced that suspected subversives staged another attack….

These terrorist attacks took place 1 day after the serious attack launched at the **[2nd Army Division Headquarters]**$_{2}$ in Bucaramanga, which resulted in seven people injured and considerable property damage, affecting nine **[homes]**$_{2}$.

Figure 1: An excerpted document and its (simplified) gold templates from the MUC-4 dataset.

Since then, the MUC-4 corpus has been an enduring and productive driver of IE research—not only for template filling (Du et al., 2021b; Das et al., 2022; Chen et al., 2023c) and role-filler entity extraction (Patwardhan and Riloff, 2007, 2009; Huang et al., 2021; Du et al., 2021a), but also for template *induction* (Chambers and Jurafsky, 2011; Cheung et al., 2013). Despite its international focus, MUC-4 is English-only, and multilingual, document-level IE datasets remain scarce. This work bolsters those resources with **MultiMUC**, the first ever translations of the MUC-4 dataset, and to our knowledge the first multilingual *parallel* corpus for template filling. This work provides:

- High-quality, automatic translations of the MUC-4 dataset into five languages: Arabic, Chinese, Farsi, Korean, and Russian, along with (1) manual projections of the template annotations into each target language, and (2) human translations for sentences in the dev and test splits containing annotated arguments.

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- Strong monolingual and bilingual supervised baselines for all five languages, based on state-of-the-art template filling models.
- Baselines for few-shot template filling with ChatGPT[1]—to our knowledge, the first few-shot evaluations of this task in the literature.
- Discussion and analysis of the translations, annotations, and model errors.

We release MultiMUC and to help further research in multilingual, document-level IE.[2]

2 Task and Corpus

Task Formally, the template filling task takes the following inputs:

- A document D
- A template ontology $(\mathcal{T}, \mathcal{S})$, consisting of a set of template types $\mathcal{T} = \{T_1, ..., T_M\}$, each representing a distinct event type, as well as a set of N_t slots for each template type $t \in \mathcal{T}$, representing the roles for that event type: $\mathcal{S} = \{S_t = \{s_t^{(1)}, \ldots, s_t^{(N_t)}\} : t \in \mathcal{T}\}$

Given D, systems must then determine the number of events or *template instances* ($N_D \geq 0$) attested in D (**template identification**), and populate the slots in each instance based on the information contained in D about the event it represents (**slot filling**).[3] Note that N_D is not given as input and may be zero; thus, part of the task is determining the *relevancy* of a document given the ontology. Supposing template instance $i_j \in \{i_1, \ldots, i_{N_D}\}$ has type $t \in \mathcal{T}$, we can write $i_j = \{s_t^{(1)} : x^{(1)}, \ldots, s_t^{(N_t)} : x^{(N_t)}\}$, where $x^{(k)}$ is a (possibly null) filler of the appropriate type for slot $s_t^{(k)}$. In general, fillers may be of any type, though for MUC-4, they are constrained to two types in principle and just one in practice (see below).

Corpus The MUC-4 corpus consists of 1,700 documents that concern incidents of terrorism and political violence in Latin America and that are annotated against a template ontology with six template types: `arson`, `attack`, `bombing`, `kidnapping`, `robbery`, and `forced work stoppage`. Each template type is associated with the same set of 24 slots, which can be divided into **string-fill** slots—those that take (a set of) entities as fillers—and **set-fill** slots, which take a single filler from a fixed set of categorical values specific to each slot.[4] Table 1 shows dataset statistics and Appendix A lists all slots.

	Train	Dev	Test
Documents	1300	200	200
Sentences	18,317	2,989	2,702
Templates	1,114	191	209

Table 1: Statistics for the MUC-4 dataset. Sentence counts are based on our own sentence splits, as canonical sentence boundaries do not exist. Statistics are the same for all languages in MultiMUC.

Since the original MUC evaluations, it has become standard to evaluate systems on simplified templates that contain only string-fill slots (Chambers and Jurafsky, 2011; Du et al., 2021a,b; Chen et al., 2023c, *i.a.*), with the notable exception of the set-fill slot for template type. Additionally, while the gold data often lists multiple valid mentions for each entity filler, a system receives full credit for extracting just one of them. We follow both of these conventions in our work. The string-fill slots are `PerpInd` (individual perpetrators), `PerpOrg` (organizational perpetrators), `Target` (targeted infrastructure), `Weapon` (perpetrators' weapons), and `Victim` (victims of the event). Figure 1 shows a MUC-4 document and its simplified templates.

3 Data Collection

The selection of languages for MultiMUC was inspired by the five focal languages of the IARPA BETTER program[5], which introduced the Granular template filling task—a spiritual successor to MUC-4 (see §6; Soboroff, 2023). For each language, our data collection process comprised four steps:

1. **Preprocessing** of the MUC-4 documents, including identification of sentence boundaries and locations of slot-filling entity mentions.
2. **Machine Translation** of the documents into each of the five target languages.
3. **Automatic Alignment** of slot-filling entity mentions in English with corresponding mentions in the target languages, followed by *projection* of the template annotations.

[1] `https://openai.com/blog/chatgpt`

[2] `https://github.com/wgantt/multimuc`

[3] Following prior work (Du et al., 2021b; Chen et al., 2023c, *i.a.*), we will refer to template instances simply as *templates*.

[4] This is a minor simplification. See Appendix A.

[5] `https://www.iarpa.gov/index.php/research-programs/better`

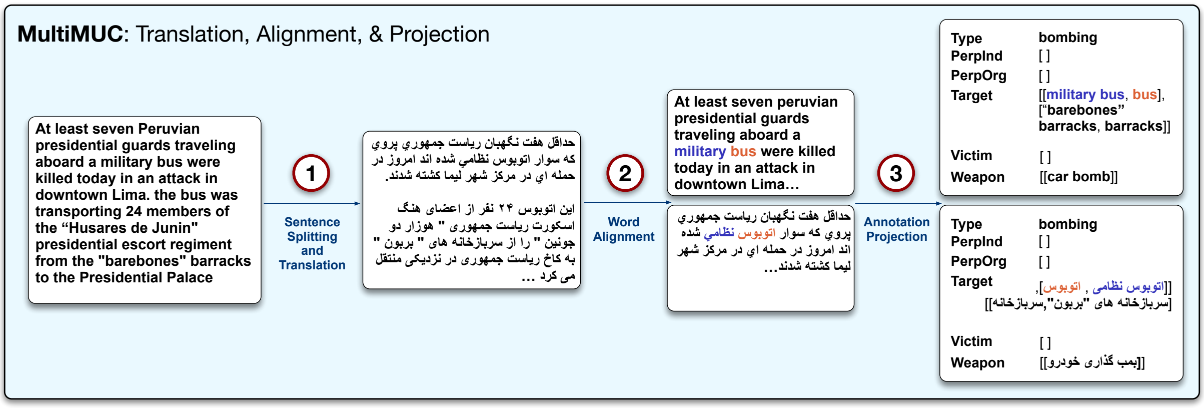
MultiMUC: Translation, Alignment, & Projection
At least seven Peruvian presidential guards traveling aboard a military bus were killed today in an attack in downtown Lima. the bus was transporting 24 members of the "Husares de Junin" presidential escort regiment from the "barebones" barracks to the Presidential Palace
1
Sentence Splitting and Translation
حداقل هفت نگهبان ریاست جمهوري پروي که سوار اتوبوس نظامي شده اند امروز در حمله اي در مرکز شهر لیما کشته شدند.
این اتوبوس ۲۴ نفر از اعضای هنگ اسکورت ریاست جمهوری " هوزار دو جونین " را از سربازخانه های " بربون " به کاخ ریاست جمهوری در نزدیکی منتقل می کرد ...
2
Word Alignment
At least seven peruvian presidential guards traveling aboard a military bus were killed today in an attack in downtown Lima…
حداقل هفت نگهبان ریاست جمهوري پروي که سوار اتوبوس نظامي شده اند امروز در حمله اي در مرکز شهر لیما کشته شدند…
3
Annotation Projection
Type bombing
PerpInd [ ]
PerpOrg [ ]
Target [[military bus, bus], ["barebones" barracks, barracks]]
Victim [ ]
Weapon [[car bomb]]
Type bombing
PerpInd [ ]
PerpOrg [ ]
Target [[اتوبوس نظامی , اتوبوس], [سربازخانه های "بربون",سربازخانه]]
Victim [ ]
Weapon [[بمب گذاری خودرو]]

Figure 2: Process for creating projected target language data for MULTIMUC from the gold MUC-4 data (§3).

4. **Manual Correction** of entity mention alignments for all data splits, as well as translation corrections for sentences in the dev and test splits containing entity mentions.

Each step is detailed separately below. Figure 2 illustrates steps (1)-(3) for Farsi.

3.1 Preprocessing

We use the preprocessed version of the MUC-4 dataset released by Du et al. (2021b).[6] Three quirks of the dataset deserve mention.

First, to our knowledge, the documents were never released with canonical sentence splits. As such, we used the NLTK Punkt sentence tokenizer (Bird et al., 2009), to obtain sentence splits.[7]

Second, the text is uncased. This caused the sentence tokenizer to erroneously split a small number of sentences containing initialisms and titles (e.g. "u.s." or "dr.") into two or more fragments. We manually corrected these cases by searching on a fixed set of problematic terms (identified via manual inspection) and combining identified fragments.[8]

Third, character offsets of entity mentions are not annotated. This may be because evaluation has historically used string-based, rather than offset-based, matching to score string-fill slots. We follow Du et al. (2021b) in annotating the *first* occurrence of each mention string in a document and leave annotation of later occurrences for future work.

3.2 Machine Translation

Given the preprocessed English text, we obtain automatic translations of all 1,700 MUC-4 documents for all five of the target languages. Our MT system has a Stratified Mixture of Experts (SMoE) architecture (Xu et al., 2023) for multilingual translation. Mixture-of-experts (MoE) (Shazeer et al., 2017; Lepikhin et al., 2021) significantly scales up the number of parameters of multilingual transformer-based MT models while maintaining low computational requirements per token. SMoE enhances MoE models by assigning dynamic model capacity to different tokens, thus enabling more efficient parameter use. SMoE has demonstrated improvements over state-of-the-art MoE baselines (Xu et al., 2023).

We use an SMoE model pretrained on the primary bitexts of six languages from NLLB (Costa-jussà et al., 2022), covering over 70 million parallel sentences and all MULTIMUC languages.

3.3 Automatic Alignment and Projection

Data projection involves automatically transferring span-level annotations from a source language to a target language based on word-to-word alignments. Given the translated documents, we first align each word in an English (source) sentence to the corresponding word(s) in the target sentence. Mentions in the target language are thus given by the sequence of target language tokens aligned to each token in an annotated source mention, and the corresponding slot and template in the source are thereby implicitly projected to the target.

We use Awesome-align (Dou and Neubig, 2021), an embedding-based word aligner that derives word alignments via comparison of word embeddings. Awesome-align fine-tunes a pretrained language model (in our case, XLM-R; Conneau et al., 2020) on parallel text or gold word alignments with training objectives designed to improve alignments.

We reuse the models and empirically chosen hy-

[6] https://github.com/xinyadu/gtt/

[7] https://www.nltk.org/_modules/nltk/tokenize/punkt.html. Punkt is based on the unsupervised, multilingual sentence tokenization algorithm of Kiss and Strunk (2006).

[8] The terms were *dr.*, *mr.*, *ms.*, *mrs.*, *gen.*, and *u.s.*

perparameters from prior work for a similar task (Zheng et al., 2023). These models are XLM-R encoders fine-tuned on around two million parallel target language-English sentences from the OSCAR corpus (Abadji et al., 2022). The encoders are further fine-tuned on gold alignments from GALE Chinese–English (Li et al., 2015), and the Farsi-English corpus by Tavakoli and Faili (2014), containing 2,800 Chinese–English and 1,200 Farsi-English sentence pairs with gold alignments. We further fine-tuned the Arabic model on the 2,300 GALE Arabic-English (Li et al., 2013) sentence pairs with gold alignments.

3.4 Translation and Alignment Correction

While we find our automatic alignments to be of good quality (Table 2), prior work has shown that for some IE tasks, models can benefit meaningfully from access to gold alignments (Stengel-Eskin et al., 2019; Behzad et al., 2023). Accordingly, we recruited annotators to inspect and (if necessary) correct the automatic alignments for all sentences containing the first occurrence of some entity mention. Additionally, for the dev and test splits, annotators corrected the *translations* of these sentences.

Annotation was performed using the TASA annotation tool.[9] Annotators included students from Johns Hopkins and professional linguists from the Human Language Technology Center of Excellence (HLTCOE). All are either native speakers of the language they annotated or have extensive training in that language. For practice, annotators completed 10 tasks that were not included in the final data. Given the annotators' level of competence as well as budgetary constraints, only a single annotator completed each main task. Between one and four annotators worked on each language, with tasks distributed based on availability. Three of the annotators are authors of this work and were not paid; others were paid at an average rate of $0.29 per task.[10] Task instructions, screenshots of the interface, and agreement statistics are in Appendix B.

Entity and mention statistics for the training split of each language are shown in Table 2. In general, only a small fraction of the automatic alignments required correction: Even for the two languages requiring the most correction (Chinese and Russian) fully 77.4% of target language mentions were unchanged from the automatic alignment. For the language requiring the least correction (Arabic), 86.5% of spans were unchanged. This is testament to the quality of the alignments, though alignment quality is necessarily constrained by translation quality, which we discuss in Appendix B.

	Ar	Fa	Ko	Ru	Zh
Entities	2,421	2,432	2,417	2,394	2,071
Mentions$_{\text{man}}$	3,074	3,136	3,076	3,019	2,597
unchanged	86.5	84.0	79.7	77.4	77.4

Table 2: Entity and mention counts for the MULTIMUC training set. "Mentions$_{\text{man}}$" denotes *annotated* mentions. "Unchanged" denotes the percentage of Mentions$_{\text{man}}$ unchanged from the automatic alignment.

4 Experiments

We present three sets of experiments. All make use of the following three variations on training and dev data, designed to assess both the impact of alignment corrections and of parallel data:

1. **TGT$_{\text{AUTO}}$** uses only *target* language data, with mentions obtained via *automatic* alignments.

2. **TGT$_{\text{MAN}}$** uses only *target* language data, but with the *manually* corrected alignments for the training set and the corrected alignments *and translations* for the dev set.

3. **BI$_{\text{MAN}}$** is the same as TGT$_{\text{MAN}}$, but adds gold English training data (yielding *bilingual* data).

In all experiments, we report results on the *corrected* test set.

4.1 Span Extraction

Setup Prior work investigating the impact of alignment quality in IE has focused on span labeling tasks such as NER or SRL (Stengel-Eskin et al., 2019; Behzad et al., 2023), as these tasks arguably give the most direct view on the downstream impact of improved alignments. In our first set of experiments, we follow this line of work and assess span extraction and labeling performance on MULTIMUC using the neural span extractor of Xia et al. (2021), which has achieved state-of-the-art performance on FrameNet (Baker et al., 1998). We train the system to extract all slot-filling entity mentions and to label them with their slot.

Results Labeled and Unlabeled exact match F$_1$ scores for the three settings are shown in Table 3.

[9] https://github.com/hltcoe/tasa

[10] This figure is based on average pay for the student annotators. Linguists were paid by the HLTCOE at a rate that was not disclosed to the authors.

	Ar	Fa	Ko	Ru	Zh
TGT$_{\text{AUTO}}$	51.92	49.84	51.14	58.15	**54.46**
TGT$_{\text{MAN}}$	**56.25**	**55.62**	52.00	**59.34**	52.88
BI$_{\text{MAN}}$	54.89	53.34	**55.41**	57.40	53.44
TGT$_{\text{AUTO}}$	54.62	52.07	52.86	60.05	55.51
TGT$_{\text{MAN}}$	**58.88**	**56.82**	54.76	**62.54**	54.64
BI$_{\text{MAN}}$	56.60	55.10	**57.78**	59.66	**55.66**

Table 3: Labeled (top) and unlabeled (bottom) exact span match F$_1$ scores for all three data settings on the annotated test splits.

Across almost all languages, we observe improvements on both metrics when training on corrected (TGT$_{\text{MAN}}$) vs. uncorrected (TGT$_{\text{AUTO}}$) data. Given that a fairly small proportion of spans in the data were changed between these settings, some of the gains may also be explained by access to corrected dev data in the TGT$_{\text{MAN}}$ setting.

4.2 Template Filling with Fine-Tuned Models

Setup Our second set of experiments turns to template filling proper, focusing on the two models to have most recently achieved state-of-the-art on MUC-4. The first is GTT (Du et al., 2021b), which uses a single BERT-base model (Devlin et al., 2019) as both an encoder (to encode the document) and as a decoder, using causal masking and pointer decoding to generate linearized templates. As a minimal modification to support the MULTIMUC languages, we use *m*BERT-base (Devlin et al., 2019) in lieu of BERT-base, keeping all other aspects of the architecture unchanged.

The second model is ITERX (Chen et al., 2023c), which holds state-of-the-art on MUC-4. ITERX treats template filling as autoregressive span classification, assigning each of a set of candidate spans (extracted by an upstream system) either to a slot in the current template or else to a special "null" slot to indicate that the span fills *no* slot in that template. Embeddings for the candidate spans are updated at each iteration based on their use in previous templates, and are used to condition the span assignments for subsequent templates. Chen et al. obtain their best MUC-4 results with a T5 encoder (Raffel et al., 2020). As with GTT, we make a minimal modification to the English base model by substituting *m*T5-base (Xue et al., 2021) for the encoder, keeping all else unchanged.[11]

Evaluation Evaluating template filling systems requires aligning predicted (P) and reference (R) templates, subject to the constraints that each reference template is aligned to at most one predicted one and that their types match. This is treated as a maximum bipartite matching problem, in which one seeks the alignment that yields a maximum total score over template pairs (P, R) given some template similarity function ϕ_T:

$$A^* = \operatorname*{argmax}_A \sum_{(P,R)\in A} \phi_T(P, R) \qquad (1)$$

$\phi_T(P, R)$ measures similarity between two templates in terms of similarity of their slot fillers, and there are different ways to specify this. Du et al. (2021b) propose the CEAF-REE metric, which computes an optimal alignment between predicted and reference *entities* similar to the CEAF metric for coreference resolution (Luo, 2005), but where aligned entities must fill the same slot. CEAF-REE selects the template alignment that yields the highest micro-F$_1$ over all slot fills, *including template type*. However, Chen et al. (2023c) take issue with certain properties of CEAF-REE and propose a variant called CEAF-R*M*E. The key differences from CEAF-REE are (1) the template type is *excluded* from the F$_1$ calculation and (2) a different similarity function is used for entity alignments. We report both metrics and refer the reader to their paper or to Chen et al. (2023b) for details.[12]

Results Results for all languages are presented in the first six rows of Table 4. Several observations stand out. First, for nearly all languages, both models obtain their strongest performance when trained jointly on English and target language data (BI$_{\text{MAN}}$). This is consistent with past findings in IE establishing the value of English training data for lower-resource target languages (Subburathinam et al., 2019; Yarmohammadi et al., 2021; Fincke et al., 2022, *i.a.*). While the impact of the English data is valuable for both models, it is especially so for ITERX, for which it boosts performance relative to the next best setting by an average of about 8.3 CEAF-REE F$_1$ and an average of over 4.7 CEAF-RME F$_1$ (compared to 3.2 and 2.6 F$_1$ for GTT).[13]

[11] We stress that our interest here is to present the best results for each model type and to evaluate cross-lingual performance variation *within* type, not in cross-type comparisons. For a comparison on MUC-4 of ITERX and GTT under identical encoders, see Chen et al. (2023c). Additional details on architectures and hyperparameters are provided in Appendix D.

[12] In Chen et al.'s terminology, we report CEAF-REE$_{\text{impl}}$ and CEAF-RME$_{\phi_3}$.

[13] We additionally considered a fourth setting, ALL$_{\text{MAN}}$, in which models are jointly trained on the corrected data for all

Second, the benefits of training on the target language data with corrected alignments (TGT$_{\text{MAN}}$) are most evident for GTT, for which it shows consistent improvements relative to no corrections (TGT$_{\text{AUTO}}$) for CEAF-RME scores.[14] In contrast, performance does not substantially differ between the two settings for ITERX. This may be a consequence of ITERX's reliance on an upstream system for its candidate spans: to isolate the effect of ITERX *training*, these candidates were fixed across settings at inference time, but it's plausible that the added value of corrected alignments lies chiefly in the span extraction step, prior to IterX training.

Lastly, the best scores for both models in all five MULTIMUC langauges are low compared to the best reported results on English. There is clear room for improvement across all languages, and we are excited by the prospect of future models better tailored to specific languages.

4.3 Few-Shot Template Filling

With the staggering leaps in the capabilities of large language models of the past couple years, an immediate question for most tasks asks how competitive these models are in a zero- or few-shot setting compared to smaller, fine-tuned models (§4.2). We consider this question for MULTIMUC, investigating the capabilities of ChatGPT[15] on few-shot template filling. While ChatGPT's training corpus is predominantly English, some works have studied its abilities on MT (Jiao et al., 2023; Peng et al., 2023) and on IE tasks in other languages (Lai et al., 2023), and have found solid results. To our knowledge, this is the first work exploring few-shot template filling *at all*.

Setup We use the long-context version of ChatGPT (`gpt-3.5-turbo-16k-0613`) and evaluate in the TGT$_{\text{MAN}}$ and BI$_{\text{MAN}}$ settings. The system prompt instructs the model to adopt the persona of an expert in IE and to perform extraction on a target document. The user prompt provides more detailed instructions, including the desired output format for extracted templates, as well as three examples of other documents with their gold templates.[16] For the TGT$_{\text{MAN}}$ setting, example documents are chosen from the target language training set using a BM25 retrieval model and are sorted so that the most relevant example is last. For the BI$_{\text{MAN}}$ setting, we replace the most relevant target language example with the same example in English.

Results Results are shown in the bottom two rows of Table 4. Performance in both settings trails the performance of ITERX and GTT across languages—a finding in line with prior work showing that ChatGPT's few-shot capabilities on many tasks still fall short of those of the best supervised models (Lai et al., 2023; Gao et al., 2023), and an unsurprising result given its predominantly English training corpus. Furthermore, the clear gains from English training data for the supervised models do not clearly carry over here: Including a relevant English document in the prompt helps only in some cases and even then only modestly.

5 Discussion

Here we present some analysis of model errors (§5.1) and also discuss observations and challenges from annotation (§5.2).

5.1 Model Errors

We use the template filling error analysis tool of Das et al. (2022) to understand the distribution of error types in the predictions from GTT.[17] Das et al. define a set of transformations by which a set of predicted templates may be converted into the gold ones, given an optimized template alignment (see §4). These include insertion and deletion transformations for templates and role fillers, as well as edit transformations for mentions and their role assignments. Error types are then defined in terms of *sequences* of these transformations.

Figure 3 shows a breakdown of errors by type for all languages and all three data settings for GTT. Consistent with Das et al.'s observations for MUC-4, we find that, across languages and settings, missing role fillers account for a majority of the errors.[18] This is unsurprising when considering both that GTT's extractions heavily favor precision

MULTIMUC languages, though this did not show clear gains over the BI$_{\text{MAN}}$ setting. See Appendix C.

[14] CEAF-*REE* scores are expected to show a noisier relationship with alignment correction due to the inclusion of the template type slot in the F_1 calculation, as accuracy is usually much higher for this slot than for others.

[15] https://openai.com/blog/chatgpt

[16] Some effort was invested in identifying effective prompts for this task, but our aim here is merely a reasonable few-shot baseline—*not* an extensive prompt engineering project. Prompt examples and hyperparameters are in Appendix D.

[17] https://github.com/IceJinx33/auto-err-template-fill/

[18] This includes both "Missing Role Filler" errors (i.e. role fillers missing from a predicted template) and "Missing Template Role Filler" errors (i.e. role fillers missing due to the associated template not being predicted in the first place).

		CEAF-REE						CEAF-RME					
		En	Ar	Fa	Ko	Ru	Zh	En	Ar	Fa	Ko	Ru	Zh
GTT	TGT$_{\text{AUTO}}$	50.23	24.26	31.46	34.17	35.38	36.74	32.30	11.27	16.24	18.24	20.23	18.90
	TGT$_{\text{MAN}}$		28.81	36.01	33.79	38.05	36.35		15.05	21.27	18.71	**22.44**	19.11
	BI$_{\text{MAN}}$		36.76	**37.91**	36.52	36.97	**41.48**		**21.98**	**22.44**	**20.71**	21.26	**23.26**
IterX	TGT$_{\text{AUTO}}$	53.00	25.55	27.15	25.99	29.61	27.54	35.20	15.96	17.78	16.52	19.58	17.60
	TGT$_{\text{MAN}}$		25.70	25.36	27.24	30.08	27.32		15.73	16.41	17.11	19.30	17.06
	BI$_{\text{MAN}}$		**34.73**	**33.15**	**37.02**	**36.95**	**36.02**		**21.46**	**20.66**	**23.91**	**23.77**	**21.93**
ChatGPT	TGT$_{\text{MAN}}$	29.11	23.77	21.02	**17.14**	**25.40**	23.36	22.41	14.67	12.91	6.73	**16.38**	**15.02**
	BI$_{\text{MAN}}$		**24.62**	**22.06**	16.85	24.90	**24.46**		**14.79**	**13.42**	**7.12**	15.36	13.99

Table 4: CEAF-REE and CEAF-RME F_1 scores on English and the five MultiMUC languages for GTT (Du et al., 2021b), IterX (Chen et al., 2023c), and ChatGPT under the data settings described in §4. English results are the best ones reported by Chen et al., except for ChatGPT, and do not correspond to any of the three data settings. **Bolded** results are best results within model type. See §4.2 for caveats about cross-type comparisons.

(Du et al., 2021b) and that models tend to struggle significantly with template recall, perhaps due to difficulty in *individuating* events (Gantt et al., 2023). Spurious templates and role fillers represent a smaller but non-trivial fraction of all errors.

5.2 Annotation Observations

We now discuss observations and challenges from the annotation process. While there are obviously many language-specific considerations for both translation and alignment, we highlight several that were common to two or more languages.

5.2.1 Proper Nouns

MUC-4 annotations contain a significant number of proper nouns with a single canonical form, and these were sometimes translated into multiple forms in the target language, including both acceptable variants (e.g. the Farsi “هتل شراتن” [hoh-tel she-raa-tohn] or “هتل شرایتن” [hoh-tel she-reye-tohn] for *Sheraton Hotel*) and orthographic errors (레이 [ɭe.i], 릴리 [ɭiɭ.ɭi], or 릴 [ɭiɭ] for the name *Leigh*). In Chinese, each syllable in a proper noun may be translated into one of several characters that approximate the pronunciation. E.g. the first syllable of *Guatemala* may phonetically correspond to 危 [wēi] or 瓜 [guā], and the noun as a whole can be translated as either 危地拉 or 瓜地拉. These forms were canonicalized as much as possible in the dev and test annotations, but this could not be done for the training set, for which only span alignments were corrected.

5.2.2 Word Order

In general, Farsi has subject-object-verb (SOV) word order and Arabic has verb-subject-object (VSO) order. However, in both languages, the order can sometimes change due to context, certain case endings, and adverbs. In a number of instances, annotators noted that the automatic translations use the standard word order even when changing it would result in a more natural phrasing. As an example, for the sentence “the rebels who (...) attacked the building”, the automatic Arabic translation was “هاجم المتمردون الذين (...) المبنى”, where “هاجم” is the verb, “المتمردون” is the subject and “المبنى” is the object. But a more natural translation would be “المتمردون الذين (...) هاجموا المبنى”. Such cases were corrected in dev and test.

5.2.3 Numeral classifiers

Chinese and Korean mark nouns with classifiers (CL) when naming and counting them. In both languages, a CL always follows a numeral when an explicit number is present, and in Korean, when the combination of a numeral and a CL follows its associated noun, aligning the classifier to the noun is less desirable, as this yields discontiguous target language spans. As such, annotators aligned numerals in English to both the numeral and CL in the target languages, as illustrated in Example (1). Relatedly, for Chinese translation correction, annotators combined a (numeral, CL) pair into one token when they were translated as separate tokens.

(1)	경찰	세	명	(Korean)
	gyeongchal	***se***	**myeong**	
	policeman	**three**	**CL**	
	‘**three** policemen’			

6 Related Work

Template Filling Template filling has a long history. Participants in the MUCs, starting with MUC-3 (muc, 1991) and MUC-4 (muc, 1992), largely developed pipelined, rule-based systems with individual modules designed to solve problems that

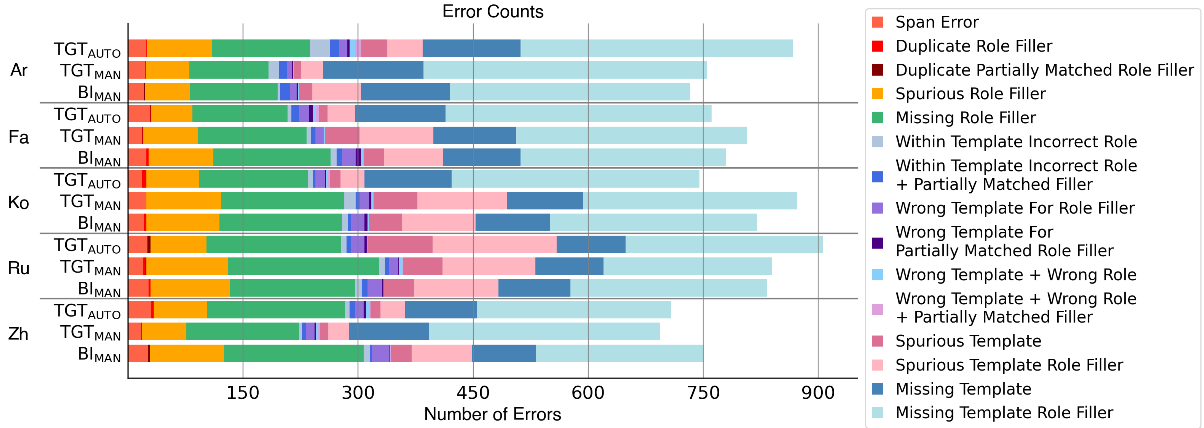

Figure 3: Automated error analysis results based on the tool provided by Das et al. (2022) for GTT test set predictions for all MultiMUC languages and all data settings (see §4). Missing role filler errors predominate.

are now major NLP tasks in their own right, such as coreference resolution and semantic role labeling (Hobbs, 1993; Grishman, 2019). MUC-5 introduced a considerably more complicated template ontology that represented entities *themselves* as templates, yielding nested template structures (muc, 1993). MUC-6 (muc, 1995) and MUC-7 (muc, 1998) also had nested templates, but the entity templates were pared down to fewer slots and their ontologies had only a single event type.

Following the MUCs, many works revisiting these corpora focused on *role-filler entity extraction*, a simplified form of template filling in which the goal is to identify all entity fillers, but without collating them into distinct templates (Patwardhan and Riloff, 2007, 2009; Huang and Riloff, 2011, 2012; Du et al., 2021a; Huang et al., 2021). Template filling also differs from two other, closely related tasks. First, it differs from document-level *N-ary relation extraction* in being *event*-centric and in permitting null arguments. Second, it differs from *event extraction* (EE) in not requiring extraction of event triggers (indeed, MUC-4 does not annotate triggers).

Multilingual Template Filling Works cited in preceding sections (Du et al., 2021b; Chen et al., 2023c; Das et al., 2022) exhaust deep learning-era efforts on template filling with MUC-4. Even as early as the MUC-4 conference itself, though, there was interest in extending template filling systems to other languages. NYU's PROTEUS system, for instance, was extended to handle Spanish documents (Grishman et al., 1992), and the SOLOMON system from Systems Research and Applications (SRA) was enhanced to handle both Spanish and Japanese documents (Aone et al., 1992, 1993). This work presaged MUC-5, which had evaluations in both English and Japanese, but as best we know, no corpora were ever released for either language.

A number of multilingual resources exist for *sentence-level* event extraction, such as ACE (in Arabic, Chinese, and English; Doddington et al., 2004; Walker et al., 2006) and the Light and Rich ERE datasets from the DARPA DEFT program (Chinese, English, and Spanish; Song et al., 2015), though analogous resources at the document level are much more limited. The primary resource of note here is the Granular dataset from the IARPA BETTER program (Soboroff, 2023), featuring an ontology of six diverse template types (e.g. protests, epidemics, natural disasters), and covering news articles in English and five other languages. Granular is notable as the only multilingual template filling dataset that has both gold document texts and gold template annotations, though this is not parallel data and the corpus is much smaller than MUC-4, with only several hundred documents.

Cross-Lingual Alignment and Projection Cross-lingual projection is a method for transferring annotations from a source language to a target language, used primarily to create cross-lingual datasets for structured prediction tasks (Yarowsky and Ngai, 2001; Aminian et al., 2019; Fei et al., 2020; Daza and Frank, 2020; Ozaki et al., 2021; Yarmohammadi et al., 2021; Chen et al., 2023a, *i.a.*). The approach relies on two main steps: translation and source-to-target word alignment, and thus relies on high-quality translations and alignments between source and target texts. Studies have shown that access to gold entity alignments can improve downstream results (Stengel-Eskin et al., 2019; Behzad et al., 2023).

7 Conclusion

We have introduced MULTIMUC—the first multilingual *parallel* template filling dataset, featuring high-quality automatic translations of the MUC-4 corpus along with human translations of key portions of the dev and test splits, and human-annotated alignments for all fillers of string-fill slots. Moreover, we have established strong mono- and bilingual baselines using two recent, top-performing template filling models, as well as baselines for few-shot template filling—to our knowledge, the first few-shot evaluations for this task. Lastly, we have highlighted some observations and challenges involved in constructing this resource and presented a detailed breakdown of model errors. We hope that this work will facilitate further research on multilingual IE at the document level.

Limitations

Ideally, all datasets that include machine-generated outputs would have exhaustive human verification and correction of those outputs. This of course applies to MULTIMUC: while the dataset provides human translations of key portions of the dev and test splits (all sentences containing the first occurrence of each entity mention), the majority of sentences in the dataset are machine-translated, which results in a small number of data projection failures (see Appendix B). Obtaining gold translations and entity alignments for the entire corpus was simply infeasible with the personnel and budget available to us for the present work. Regardless, the automatic alignments and translations are of good quality (see §3 and Appendix B) and make MULTIMUC a valuable resource for developing document-level IE systems in multiple languages.

Ethics Statement

While the MUC-4 dataset has an established history in the NLP and IE communities, the documents it contains—and MULTIMUC, by extension—concern historical incidents of terrorism and use the names of real persons involved in those incidents. Caution is therefore warranted in using this data in the training, development, or deployment of models for template filling or for other tasks. Given the difficulty of template filling, even the best current systems trained to perform this task will hallucinate or misrepresent a non-trivial portion of the events they extract.

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A MUC-4 Template Slots

Below is the complete list of MUC-4 slots, which are the same for all template types, along with their definitions as provided in the conference appendices (nn-, 1992).[19] The names of the string-fill slots are **bolded** and their (more commonly used) alternative names are given in parentheses. The significant majority of others are set-fill, though some slots require a numerical answer (e.g. "PHYS TGT: NUMBER") and these are known as *text conversion* slots, as they require *converting* possibly implicit counts of entities in the text into explicit numerical values. We group these with set-fill slots in the main text as they have likewise traditionally been excluded from evaluation since the original conference. "MESSAGE: ID" and "MESSAGE: TEMPLATE" were never part of the evaluation, even in the original conference. Some of the slot names use one or more of the following abbreviations: PERP = perpetrator; PHYS = physical; TGT = target; HUM = human.

1. MESSAGE: ID — The first line of the message, e.g., DEV-MUC3-0001 (NOSC). This slot serves as an index and is not scored in its own right.
2. MESSAGE: TEMPLATE — A number that distinguishes the templates for a given message. In the answer key, the word OPTIONAL in parentheses after the template number indicates that there is significant doubt whether the incident belongs in the database.
3. INCIDENT: DATE — The date of incident (according to local time, not Greenwich Mean Time).
4. INCIDENT: LOCATION — The place where the incident occurred.
5. INCIDENT: TYPE — A terrorist act reported on in the message.
6. INCIDENT: STAGE OF EXECUTION — An indicator of whether the terrorist act was accomplished, attempted, or merely threatened.
7. **INCIDENT: INSTRUMENT ID** (`Weapon`) — A device used by the perpetrator(s) in carrying out the terrorist act.
8. INCIDENT: INSTRUMENT TYPE — The category that the instrument fits into.
9. PERP: INCIDENT CATEGORY — The subcategory of terrorism that the incident fits into, as determined by the nature of the perpetrators.
10. **PERP: INDIVIDUAL ID** (`PerpInd`) — A person responsible for the incident.
11. **PERP: ORGANIZATION ID** (`PerpOrg`) — An organization responsible for the incident.
12. PERP: ORGANIZATION CONFIDENCE — The way a perpetrator organization is viewed in the message.
13. **PHYS TGT: ID** (`Target`) — A thing (inanimate object) that was attacked.
14. PHYS TGT: TYPE — The category that the physical target fits into.
15. PHYS TGT: NUMBER — The number of physical targets with a particular ID and TYPE.
16. PHYS TGT: FOREIGN NATION — The nationality of a physical target, if the nationality is identified in the article and if it's different from country where incident occurred.
17. PHYS TGT: EFFECT OF INCIDENT — The impact of the incident on a physical target.
18. PHYS TGT: TOTAL NUMBER — The total number of physical targets.

[19] The original MUC-3 and MUC-4 data can be found at the following URL: `https://www-nlpir.nist.gov/related_projects/muc/muc_data/muc_data_index.html`. The licit set of values for each set-fill slot can also be found in (nn-, 1992). While the slots are the same across template types, the licit values of some set-fill slots are type-dependent.

19. **HUM TGT: NAME** (`Victim`) — The name of a person who was the obvious or apparent target of the attack or who became a victim of the attack.

20. **HUM TGT: DESCRIPTION** — The title or role of a named human target or a general description of an unnamed human target.

21. HUM TGT: TYPE — The category that the human target fits into.

22. HUM TGT: NUMBER – The number of human targets with a particular NAME, DESCRIPTION, and TYPE.

23. HUM TGT: FOREIGN NATION – The nationality of a human target, if the nationality is identified in the article and if it's different from country where incident occurred.

24. HUM TGT: EFFECT OF INCIDENT – The impact of the incident on a human target(s).

25. HUM TGT: TOTAL NUMBER – The total number of human targets.

B Data Collection

This appendix presents additional details about our data collection procedure, including the instructions that were provided to annotators (§B.1), screenshots of the annotation interface (§B.2), and some measures and discussion of data quality (§B.3).

All annotators were told about the broad goals of the project prior to starting the task and were told that their annotations would be used for this project. All linguists who provided annotations are employees of the HLTCOE who receive a regular salary for annotation work, though we (the authors) were not informed of the exact salary of each annotator. Some of the native speaker annotators were authors of the paper and were not paid, as mentioned in §3; others were undergraduate students at Johns Hopkins, recruited through an internal job posting. The $0.29 per-task pay rate given in the main text was computed by dividing the total pay for student annotators for each language ($720) by the total number of tasks for each language (2,450). All annotation has been approved by Johns Hopkins.

B.1 Task Instructions

Below are the task instructions that were presented to the annotators.

Overview

In each task, a pair of sentences, one in English ("source") and one in another ("target") language will be shown to the user. The English sentence will be shown on the top half of the screen and an automatic translation of the English sentence into the target language will be shown on the bottom half. Both sentences will be segmented into words ("tokenized"). The task is to verify and correct alignments between highlighted spans of English text (each consisting of one or more words) and their translations in the target language. In each English sentence, there will typically be more than one span to align. The user needs to annotate the English spans word by word. By clicking on each English word, a *suggested* span in the target language, based on an automatic ("default") alignment between words in the English and target language sentences, is highlighted as the default answer on the target side (bottom of the screen). In some cases, you may also have the option to correct the target language translation as well.

Instructions

The default alignment

- If you think the default alignment is correct (and the translation, if correcting the translation), simply press "submit."

- If you want to modify the default alignment, select the corresponding source span, modify the target span, and press "submit."

Aligning spans

- Only the source spans we are interested in are highlighted. All other words in the source sentence are greyed out.

- While ideally aligned spans in the target language will consist of contiguous sequences of words, it's OK to select non-contiguous target words if appropriate.

- It may sometimes be the case either that (1) a word in the English does not have any clear analogue in the target language, or (2) a word in the target language does not have any clear analogue in English. In these cases, you can do one of two things.
  - One possibility is to align the word without a clear analogue to a closely related word. For instance, "happiness" in English is translated in French as "le bonheur," where "le" is a definite article, which is not used in the English. Here, we would align "le" to "happiness," since it's part of a multi-word expression that denotes the same thing as "happiness" does. In general, this solution should be preferred.
  - Another possibility is to simply remove the word from the alignment. In general, this should be done only if the word is *not* part of a multi-word expression (unlike "le" in "le bonheur" above) or seems like a translation error (that you cannot correct; see **Retokenizing the target sentence**).

- As we are not experts in most of the languages we are annotating here, you will likely encounter other difficult alignment decisions we have not foreseen. When you first encounter such instances, try to formulate general rules that seem sensible to you and apply them consistently throughout the rest of your annotation.

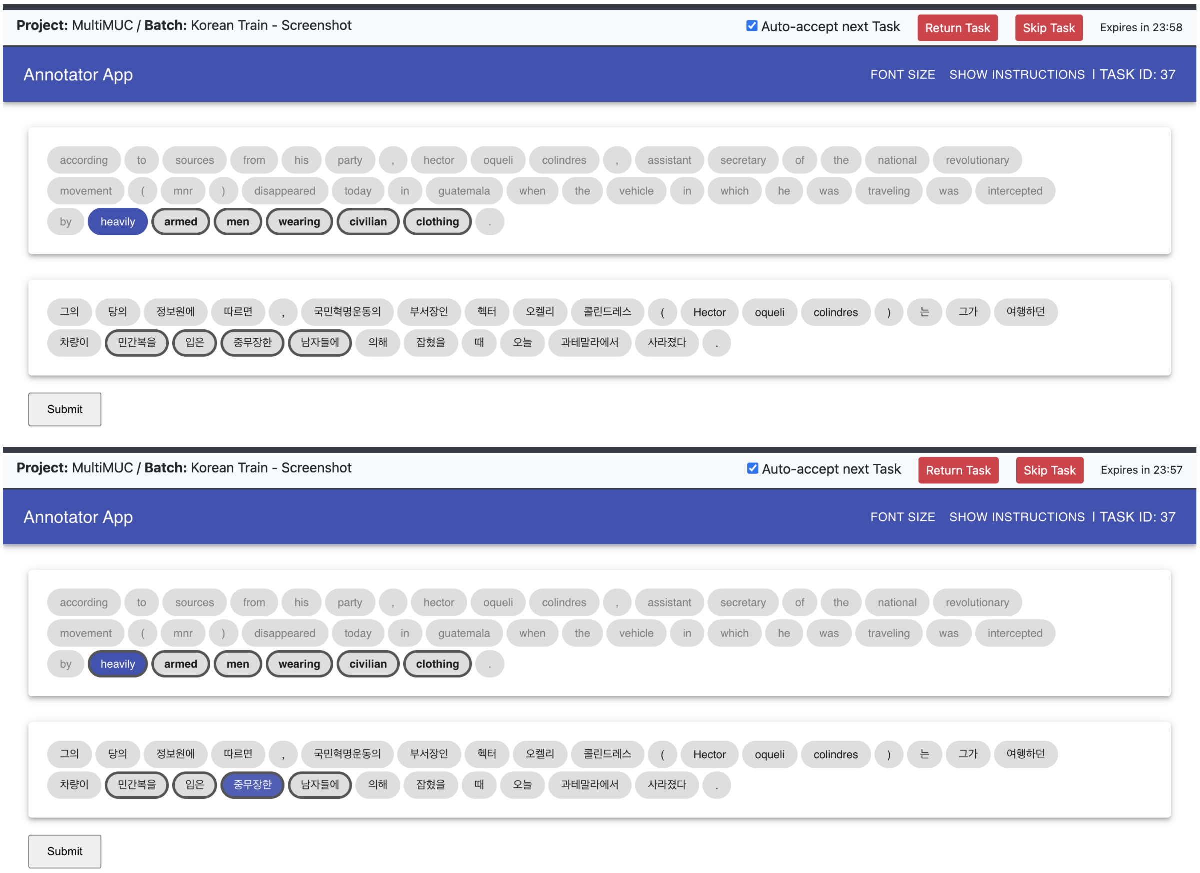
Retokenizing the target sentence

- If you see the "RE-TOKENIZE" button on the target side, you are allowed to edit the target side text to correct the potential mistakes in automatic translation or word segmentation. When correcting translations, you should correct ALL text in the sentence that needs it—not just the tokens highlighted by the default alignments. You are allowed to edit or remove existing tokens, add new words, or split or merge the existing words to correct word segmentation. When retokenizing, each word or punctuation mark should go on its own line.

- If you make changes using "RE-TOKENIZE," the suggested target spans will be automatically adjusted. In general, this adjustment should be correct: any words on the target side that you did not change should remain aligned to the correct word on the source side, even if you insert or delete other words. Of course, if you delete an aligned word on the target side, alignments to that word will be removed. Importantly, the same will be the case if you edit an aligned word, so you will have to realign any edited words. If you do make changes using "RE-TOKENIZE," you should always double-check that the alignments are correct before submitting.

Mistakes

- Finally, if you make a mistake during annotation or encounter a technical problem in the interface, please try to note down the ID of the task you are working on at the time and inform us of the mistake or problem. The Task ID can be found in the top right corner of the screen ("Task ID: ⟨#⟩"). **Please get in the habit of noting the task ID as soon as you accept it!**
  - **NOTE**: We have noticed that some workers accidentally click the submit button after re-tokenizing, when they mean to click the **save** button (to save their new tokenization). Please try to avoid doing this, but tell us if you do.



Project: MultiMUC / **Batch:** Korean Train - Screenshot ☑ Auto-accept next Task Return Task Skip Task Expires in 23:58

Annotator App FONT SIZE SHOW INSTRUCTIONS | TASK ID: 37

according to sources from his party , hector oqueli colindres , assistant secretary of the national revolutionary movement (mnr) disappeared today in guatemala when the vehicle in which he was traveling was intercepted by heavily armed men wearing civilian clothing .

그의 당의 정보원에 따르면 , 국민혁명운동의 부서장인 헥터 오켈리 콜린드레스 (Hector oqueli colindres) 는 그가 여행하던 차량이 민간복을 입은 중무장한 남자들에 의해 잡혔을 때 오늘 과테말라에서 사라졌다 .

Submit

Project: MultiMUC / **Batch:** Korean Train - Screenshot ☑ Auto-accept next Task Return Task Skip Task Expires in 23:57

Annotator App FONT SIZE SHOW INSTRUCTIONS | TASK ID: 37

according to sources from his party , hector oqueli colindres , assistant secretary of the national revolutionary movement (mnr) disappeared today in guatemala when the vehicle in which he was traveling was intercepted by heavily armed men wearing civilian clothing .

그의 당의 정보원에 따르면 , 국민혁명운동의 부서장인 헥터 오켈리 콜린드레스 (Hector oqueli colindres) 는 그가 여행하던 차량이 민간복을 입은 중무장한 남자들에 의해 잡혔을 때 오늘 과테말라에서 사라졌다 .

Submit

Figure 4: A Korean training split task before (top) and after (bottom) manual alignment correction.

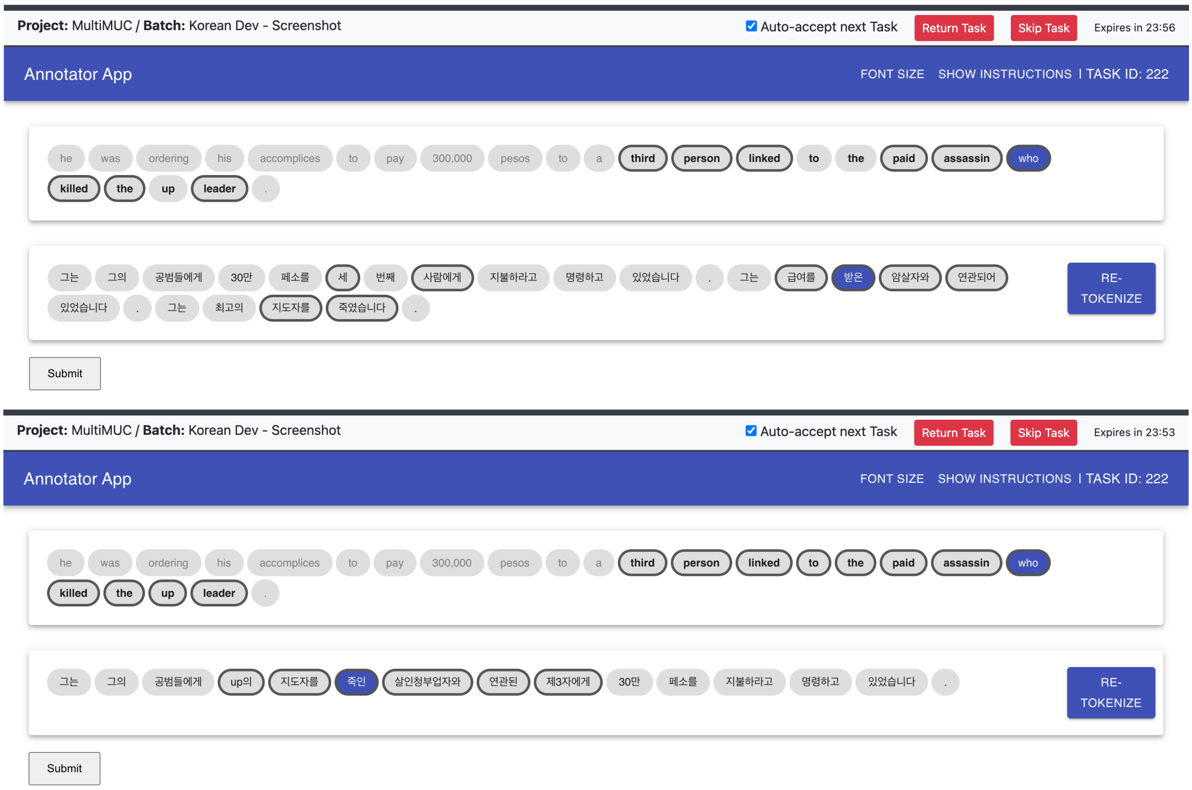
B.2 Task Interface

Recall from §3 that alignment corrections were collected for all three splits (train, dev, and test) and that translation corrections were collected only for the dev and test splits. The same interface was used for both types of annotation. Figure 4 and Figure 5 show examples of the interface for Korean annotation. Figure 4 shows the interface as it appears when doing alignment correction only (i.e. training set annotation), both before any alignment correction (top) and after (bottom). Figure 5 shows the interface as it appears when *also* doing translation correction (i.e. dev and test set annotation)—once again both before correction (top) and after (bottom). The only difference in the interface between the two figures is the presence of the "RE-TOKENIZE" button in Figure 5, which, when clicked, allows annotators to change (insert/edit/delete) target language tokens. In both cases, when a new task is loaded, the annotator sees a "default alignment," which is simply the automatic token alignment that is obtained using Awesome-align (Dou and Neubig, 2021) and that is in the TGT$_{\text{AUTO}}$ experiments. This is the alignment they must correct (if necessary).

B.3 Data and Annotation Quality

As discussed in §3, our annotators were all either native speakers of the language they annotated or else were linguists with significant formal training in that language. Given this, and given that effective alignment and translation correction require only linguistic competence, the quality of the annotations can be presumed to be very high.

Even so, we provide some limited quantitative measures of annotation quality. We first report inter-annotator agreement on alignment correction for Farsi and Chinese for a randomly selected 50 tasks from the training set. We report Cohen's κ at the token level: two alignments for a particular English token count as equivalent iff they align exactly the same target language token(s) to that English token. Two annotators completed these tasks for each language. For Farsi, we obtained a κ of 0.98. For Chinese, we



he was ordering his accomplices to pay 300,000 pesos to a third person linked to the paid assassin who killed the up leader .

그는 그의 공범들에게 30만 페소를 세 번째 사람에게 지불하라고 명령하고 있었습니다 . 그는 급여를 받은 암살자와 연관되어 있었습니다 . 그는 최고의 지도자를 죽였습니다 .

he was ordering his accomplices to pay 300,000 pesos to a third person linked to the paid assassin who killed the up leader .

그는 그의 공범들에게 up의 지도자를 죽인 살인청부업자와 연관된 제3자에게 30만 페소를 지불하라고 명령하고 있었습니다 .

Figure 5: A Korean dev split task before (top) and after (bottom) manual alignment *and* translation correction.

obtained a κ of 0.87. Both indicate "almost perfect" agreement.[20]

We additionally report sacreBLEU scores (Post, 2018) between the uncorrected and corrected dev and test data for all languages to give a more quantitative sense of how similar the translation corrections are to the original, machine-translated text. The BLEU scores on the combined dev and test sets for Arabic, Farsi, Korean, Russian, and Chinese are (respectively) 73.1, 83.6, 76.1, 89.3, and 65.2. BLEU scores higher than 60 are often considered "better than human"[21] and imply that the uncorrected and corrected translations can be considered as translations of the same source.

Finally, as we note in the limitations section, due to the lack of translation correction for the training set, translation errors resulted in alignment/projection failures for a small fraction of entity mentions. This included 4.6% of mentions (and 3.2% of entities) for Arabic, 3.0% of mentions (2.4% of entities) for Farsi, 4.4% of mentions (3.1% of entities) for Korean, 6.9% of mentions (4.1% of entities) for Russian, and 17.7% of mentions (15.6% of entities) for Chinese. We are in the process of correcting these cases and will be releasing a new version of the data with the corrections at `https://github.com/wgantt/multimuc`.

C Additional Results

As noted in §4, we also considered a fourth setting for our supervised template filling experiments, ALL$_{\text{MAN}}$, which is similar to BI$_{\text{MAN}}$ except that models are trained on the gold English data and the corrected training data for *all* MULTIMUC languages, using macro-average dev performance across languages for early stopping. Table 5 shows the results, with BI$_{\text{MAN}}$ numbers repeated from Table 4.

GTT shows gains in CEAF-REE scores under the ALL$_{\text{MAN}}$ setting for three languages (Arabic, Korean, Russian) and minor gains in CEAF-RME scores for Russian. In all other cases, however, GTT's performance is comparable to, or somewhat lower than, what we observe in the BI$_{\text{MAN}}$ setting. Given these results, we do not think the greater compute requirements of the ALL$_{\text{MAN}}$ setting are warranted.

The story is less ambiguous for ITERX, where we observe substantial performance degradations under

[20] `https://en.wikipedia.org/wiki/Cohen%27s_kappa#Interpreting_magnitude`

[21] `https://cloud.google.com/translate/automl/docs/evaluate#interpretation`

]

		CEAF-REE						CEAF-RME					
		En	Ar	Fa	Ko	Ru	Zh	En	Ar	Fa	Ko	Ru	Zh
GTT	Bi$_{\text{MAN}}$		36.76	**37.91**	36.52	36.97	**41.48**		**21.98**	**22.44**	**20.71**	21.26	**23.26**
	All$_{\text{MAN}}$		**37.77**	**37.91**	**37.31**	**38.63**	37.11		21.27	20.50	19.81	**21.83**	20.83
IterX	Bi$_{\text{MAN}}$		**34.73**	**33.15**	**37.02**	**36.95**	**36.02**		**21.46**	**20.66**	**23.91**	**23.77**	**21.93**
	All$_{\text{MAN}}$		20.98	28.92	21.53	27.64	28.94		6.16	6.38	6.39	7.37	11.49

Table 5: IterX and GTT results under the Bi$_{\text{MAN}}$ and All$_{\text{MAN}}$ settings (Bi$_{\text{MAN}}$ results are repeated from Table 4). While we observe modest improvements in GTT's CEAF-REE scores for some languages, most results suggest that bilingual training should be preferred (and for IterX, strongly preferred) over joint training on all languages.

the All$_{\text{MAN}}$ setting relative to Bi$_{\text{MAN}}$. A significant part of the benefit that Bi$_{\text{MAN}}$ confers on IterX's performance (relative to Tgt$_{\text{MAN}}$ and Tgt$_{\text{AUTO}}$) is likely a consequence of Bi$_{\text{MAN}}$ exposing the model to more English fillers, which occasionally appear untransliterated in the target language, as the additional English data in Bi$_{\text{MAN}}$ may help the model learn to recover such fillers more accurately. However, it's very unclear what further benefits non-English, non-target language data could provide—especially given the diversity of language families represented here—and for IterX, it seems only to confuse the model.

D Training and Hyperparameters

Our choices of hyperparameters for both GTT (§D.1) and IterX (§D.2) follow those associated with the best results in prior work (modulo a change in encoders) and are detailed below. While there is likely room for performance improvements from adopting language-specific encoders and hyperparameters, we leave these experiments for future work. The results for the models in the main text are based on single training runs, each of which was conducted on a single 24GB NVIDIA RTX 6000 GPU using the stopping criteria specified below. §D.3 gives details on API hyperparameters and prompts for ChatGPT.

D.1 GTT

We use the GTT code base, available here: `https://github.com/xinyadu/gtt`. We use the hyperparameter settings exactly as listed in Appendix B of Du et al. (2021b), with the following changes:

- We used the cased version of mBERT-base (Devlin et al., 2019) as the encoder in lieu of the original uncased BERT-base encoder.
- We train for 30 epochs in all experiments, as we found the default for MUC-4 (18) to be insufficient for convergence in most cases. We use the checkpoint associated with best token-level accuracy on the dev set (this is the default behavior of GTT).

Since the MUC-4 data is uncased, we also experimented with *uncased* mBERT, though we found it yielded consistently worse performance. Devlin et al. (2019) in fact expressly recommend using the cased model, on the grounds that it corrects various issues with the uncased version.[22]

D.2 IterX

We use the IterX code base, available here: `https://github.com/wanmok/iterx`. We use the same hyperparameters for IterX as are listed in the "best" column of Table 7 in Chen et al. (2023c), with the following changes:

- We trained on *gold* spans (rather than those predicted by an upstream system), as we empirically found this yielded superior results for MultiMUC.
- We used mT5-base as the encoder to accommodate all MultiMUC languages, as discussed in §4.

[22] See here: `https://github.com/google-research/bert/blob/master/multilingual.md`.

Chen et al. report only average training time for MUC-4 in their work, but we use the default maximum epochs (150) and patience (30) provided for the MUC-4 training configuration in their repository. We limit total training time to 24 hours.

To ensure fair comparison across settings for inference (including for validation), we fix the candidate spans for all settings to those predicted for the relevant language by the span extraction system of Xia et al. (2021) that we trained for that language in the BI_{MAN} setting (see §4.1).

D.3 ChatGPT

The few-shot experiments described in §4.3 were run using `gpt-3.5-turbo-16k-0613` with a maximum context length of 8,192, a maximum of 1,024 new tokens to be generated, a temperature of 0.5, and a top p of 1.0, with no presence penalty, frequency penalty, or logit biases. A single completion was generated per prompt. We recognize the potential for non-trivial performance variation that may result from even relatively minor changes to a prompt. Given the length of our prompts, cost prohibited us from running multiple variations for the main experiments, so results should be interpreted with caution.

The system prompt for all experiments was as follows:

> You are an expert in information extraction, where you are given a few exemplars to help you understand the task. You have to perform textual analysis on a new document thereafter. Your analysis should be based on the ontology (inferred) and the exemplars.

The structure of the remainder of the prompt is shown below, with prompt-specific components (i.e. the exemplars) described in italicized purple *// comments*. Each "[DOCUMENT TEXT]:" together with the full text document that followed constituted a single **user** message (provided as input in the `messages` API parameter). Likewise, each "[TEMPLATES]:" together with the annotated templates that followed constituted a single **assistant** message. The final instructions ("Please follow...") and target document made up the last user message. All templates in the exemplars are formatted in the same way as the one given in the initial instructions below.

> You are given a few exemplars to learn how to perform the template extraction task. You have to learn to do the same extraction to a new document. There are only 5 roles to use: PerpInd, PerpOrg, Target, Victim, Weapon. Valid incident types are: ATTACK, ARSON, ROBBERY, BOMBING, KIDNAPPING, FORCED_WORK_STOPPAGE, BOMBING_OR_ATTACK, ATTACK_OR_BOMBING. A target structures looks like this: Template(incident_type="bombing", PerpInd=[Entity(mentions=[Mention("guerilla column")])], PerpOrg=[Entity(mentions=[Mention("army of national liberation"), Mention("eln")])], Target=[Entity(mentions=[Mention("4-wheel drive vehicle"), Mention("vehicle")])], Victim=[Entity(mentions=[Mention("carlos julio torrado")]), Entity(mentions=[Mention("torrado's son, william"), Mention("william")]), Entity(mentions=[Mention("gustavo jacome quintero")]), Entity(mentions=[Mention("jairo ortega")])], Weapon=[Entity(mentions=[Mention("four explosive charges"), Mention("explosive charges")])])
>
> [EXEMPLARS]:
>
> [DOCUMENT TEXT]:
>
> *// full text of example document 1 (least relevant; always in target language)*
>
> [TEMPLATES]:
>
> *// gold templates for example document 1 (always in target language)*
>
> [DOCUMENT TEXT]:
>
> *// full text of example document 2 (second most relevant; always in target language)*
>
> [TEMPLATES]:
>
> *// gold templates for example document 2 (always in target language)*
>
> [DOCUMENT TEXT]:

// full text of example document 3 (most relevant; in target language except in BI$_{\text{MAN}}$ *setting)*

[TEMPLATES]:

// gold templates for example document 3 (in target language except in BI$_{\text{MAN}}$ *setting)*

Please follow the previous exemplars to process the new document. You have to use the same domain specific language to describe your extraction results. Do not add additional explanations except for the DSL generated. Make sure that you stick to the exact DSL as shown in the exemplars.

[DOCUMENT TEXT]:

// full text of target (test set) document (always in target language)