The Decades Progress on Code-Switching Research in NLP: A Systematic Survey on Trends and Challenges

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Abstract

Code-Switching, a common phenomenon in written text and conversation, has been studied over decades by the natural language processing (NLP) research community. Initially, code-switching is intensively explored by leveraging linguistic theories and, currently, more machine-learning oriented approaches to develop models. We introduce a comprehensive systematic survey on code-switching research in natural language processing to understand the progress of the past decades and conceptualize the challenges and tasks on the code-switching topic. Finally, we summarize the trends and findings and conclude with a discussion for future direction and open questions for further investigation.

1 Introduction

Code-Switching is the linguistic phenomenon where multilingual speakers use more than one language in the same conversation (Poplack, 1978). The fragment of the worldwide population that can be considered multilingual, i.e., speaks more than one language, far outnumbers monolingual speakers (Tucker, 2001; Winata et al., 2021a). This alone makes a compelling argument for developing NLP technology that can successfully process code-switched (CSW) data. However, it was not until the last couple of years that CSW-related research became more popular (Sitaram et al., 2019; Jose et al., 2020; Doğruöz et al., 2021), and this increased interest has been motivated to a large extent by: 1) The need to process social media data. Before the proliferation of social media platforms, it was more common to observe code-switching in spoken language and not so much in written language. This is not the case anymore, as multilingual users tend to combine the languages they speak on social media; 2) The increasing release of voice-operated devices. Now that smart assistants are becoming more and more accessible, we have started to realize that assuming users will interact with NLP technology as monolingual speakers is very restrictive and does not fulfill the needs of real-world users. Multilingual speakers also prefer to interact with machines in a CSW manner (Bawa et al., 2020). We show quantitative evidence of the upward trend for CSW-related research in Figure 1.

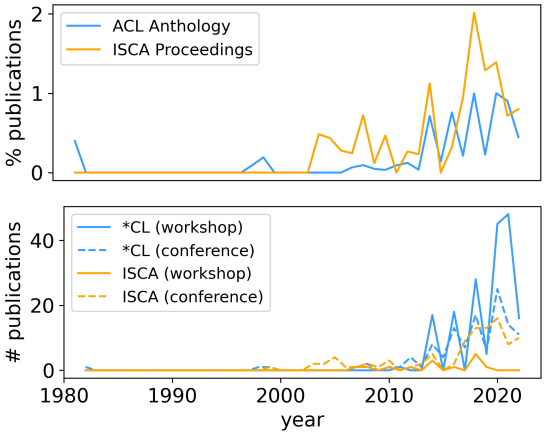

Figure 1: Number of publications over time in *CL and ISCA venues. We collect the papers on October 2022. **Top:** Relative to all *CL and ISCA papers. **Bottom:** absolute number, broken down into conferences vs workshops. It does not include papers published after. The graphs do not show the number of publications published in journals and symposiums.

In this paper, we present the first large-scale comprehensive survey on CSW NLP research in a structured manner by collecting more than 400 papers published on open repositories, such as the ACL Anthology and ISCA proceedings (see §2). We manually coded these papers to collect coarse- and fine-grained information (see §2.1) on CSW research in NLP that includes languages covered (see §3), NLP tasks that have been explored, and new and emerging trends (see §4). In addition, motivated by the fact that fields like linguistics, socio-linguistics, and related fields, have studied

* The work was done while at Bloomberg.

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Category	Options
Languages	Bilingual, Trilingual, 4+
Venues	Conference, Workshop, Symposium, Book
Papers	Theory / Linguistics, Empirical, Analysis, Position/Opinion/Survey, Metric, Corpus, Shared Task, Demo
Datasets	Social Media, Speech (Recording), Transcription, News, Dialogue, Books, Government Document, Treebank
Methods	Rule/Linguistic Constraint, Statistical Model, Neural Network, Pre-trained Model
Tasks	**Text:** Topic Modeling, Semantic Parsing, Dependency Parsing, Sentiment Analysis, Emotion Detection, Abusive Language Detection, Sarcasm Detection, Humor Detection, Humor Generation, Dialogue State Tracking, Text Generation, Natural Language Understanding, Named Entity Recognition, Part-of-Speech Tagging, Natural Language Entailment, Language Modeling, Regression, Language Identification, Machine Translation, Text Normalization, Micro-Dialect Identification, Question Answering, Summarization **Speech:** Acoustic Modeling, Speech Recognition, Text-to-Speech, Speech Synthesis

Table 1: Categories in the annotation scheme.

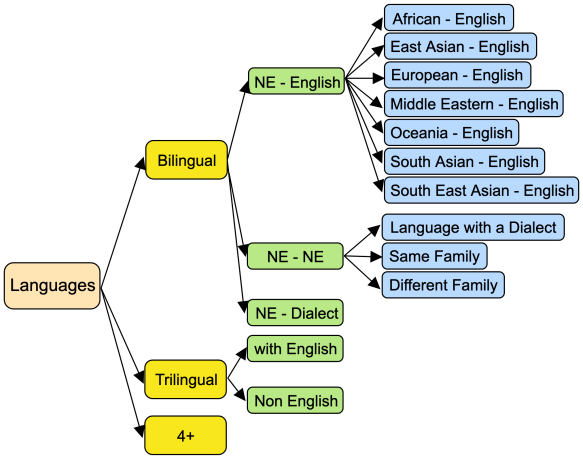


Figure 2: Language Categories. *NE denotes Non English. We show fine-grained categories in **green** and **blue**.

CSW since the early 1900s, we also investigate to what extent theoretical frameworks from these fields have influenced NLP approaches (see §5), and how the choice of methods has evolved over time (see §5.4). Finally, we discuss the most pressing research challenges and identify a path forward to continue advancing this exciting line of work (see §6).

The area of NLP for CSW data is thriving, covering an increasing number of language combinations and tasks, and it is clearly advancing from a niche field to a common research topic, thus making our comprehensive survey timely. We expect the survey to provide valuable information to researchers new to the field and motivate more research from researchers already engaging in NLP for CSW data.

2 Exploring Open Proceedings

To develop a holistic understanding of the trends and advances in CSW NLP research, we collect research papers on CSW from the ACL Anthology and ISCA proceedings. We focus on these two sources because they encompass the top venues for publishing in speech and language processing in our field. In addition, we also look into personal repositories from researchers in the community that contains a curated list of CSW-related papers. We discuss below the search process for each venue.

ACL Anthology We crawled the entire the ACL Anthology repository up to October 2022.[1] We then filtered papers by using the following keywords related to CSW: “codeswitch", “code switch", “code-switching", “code-switched", “code-switch", “code-mix", “code-mixed", “code-mixing", “code mix" “mixed-language", “mixed-lingua", “mixed language", “mixed lingua", and “mix language".

ISCA Proceedings We manually reviewed publicly available proceedings on the ISCA website[2] and searched for papers related to CSW using the same set of keywords as above.

Web Resources To extend the coverage of paper sources, we also gathered data from existing repositories.[3,4] We can find multiple linguistics papers studying about CSW.

2.1 Annotation Process

We have three human annotators to annotate all collected papers based on multiple categories shown in Table 1. All papers are coded by a least one

[1] https://github.com/acl-org/acl-anthology

[2] https://www.isca-speech.org

[3] https://github.com/gentaiscool/code-switching-papers

[4] https://genius1237.github.io/emnlp19_tut/

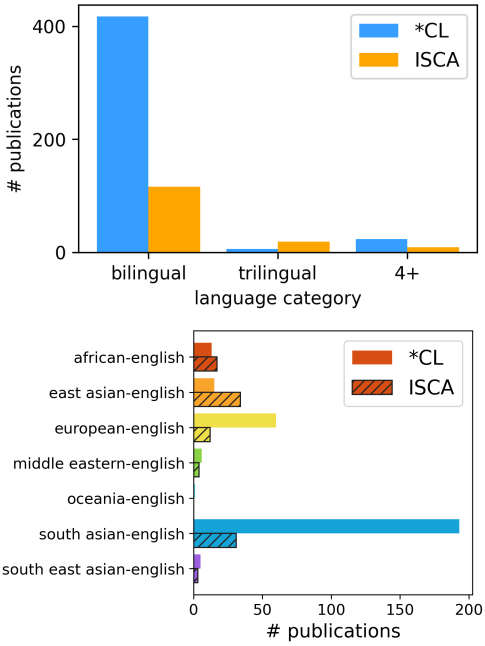


Figure 3: **(Top):** Number of publications across the type of language combination (bilingual, trilingual or 4+. **(Bottom):** Number of publications on fine-grained bilingual category with English as the L2 language.

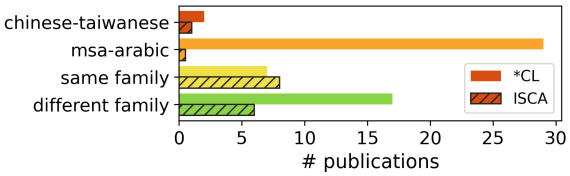


Figure 4: Number of publications of bilingual code-switched languages that do not contain English. *msa stands for Modern Standard Arabic. The first two are the combination of a language with its dialect.

annotator. To extract the specific information we are looking for from the paper, the annotator needs to read through the paper, as most of the information is not contained in the abstract. The full list of the annotations we collected is available in the Appendix (see §A).

To facilitate our analysis, we annotated the following aspects:

- **Languages:** CSW is not restricted to pairs of languages; thus, we divide papers by the number of languages that are covered into `bilingual`, `trilingual`, and `4+` (if there are at least four languages). For a more fine-grained classification of languages, we categorize them by geographical location (see Figure 2).

Languages	# Publications			
	*CL	ISCA	Total	Shared Task
Hindi-English	111	17	128	30
Spanish-English	78	8	86	40
Chinese-English‡	20	27	47	5
Tamil-English	37	2	39	17
Malayalam-English	23	2	25	13

Table 2: Most common code-switching languages in *CL and ISCA venues. ‡The count does not include the dialect or South East Asian Mandarin - English (Lyu et al., 2010a) since they contain more than two languages (i.e., it has words from the Chinese dialect).

- **Venues:** There are multiple venues for CSW-related publications. We considered the following type of venues: conference, workshop, symposium and book. As we will discuss later, the publication venue is a reasonable data point of the wider spread of CSW research in recent years.

- **Papers:** We classify the paper types based on their contribution and nature. We predict that we will have a high distribution of dataset/resource papers, as lack of resources has been a major bottleneck in the past.

- **Datasets:** If the paper uses a dataset for the research, we will identify the source and modality (i.e., written text or speech) of the dataset.

- **Methods:** We identify the type of methods presented in work.

- **Tasks:** We identify the downstream NLP tasks (including the speech processing-related tasks) presented in work.

3 Language Diversity

Here, we show the languages covered in the CSW resources. While focusing on the CSW phenomenon increases diversity of NLP technology, as we will see in this section, future efforts are needed to provide significant coverage of the most common CSW language combinations worldwide.

3.1 Variety of Mixed Languages

Figure 3 shows the distribution of languages represented in the NLP for CSW literature. Most of the papers use datasets with two language pairs. However, we did find a few papers that address CSW scenarios with more than two languages. We

Languages	# Publications		
	non-ST	ST	Total
Language Identification	46	17	63
Sentiment Analysis	31	30	61
NER	17	14	31
POS Tagging	29	1	30
Abusive/Offensive Lang. Detection	9	16	25
ASR	20	0	22
Language Modeling	19	1	20
Machine Translation	8	5	13

Table 3: Most common tasks in ACL venues. ST denotes shared task.

consider this a relevant future direction in CSW: scaling model abilities to cover n languages, with $n \geq 2$.

CSW in two languages We group the number of publications focusing on bilingual CSW based on world regions in Figure 3 (bottom). We can see that the majority of research in CSW has focused on South Asian-English, especially on Hindi-English, Tamil-English, and Malayalam-English, as shown in Table 2. The other common language pairs are Spanish-English and Chinese-English. That table also shows that many of the publications are shared task papers. This is probably reflecting efforts from a few research groups to motivate more research into CSW, such as that behind the CALCS workshop series.

Looking at the languages covered, we also find that there are many language pairs that come from different language families, such as Turkish-German (Çetinoğlu, 2016; Çetinoğlu and Çöltekin, 2019; Özateş and Çetinoğlu, 2021; Özateş et al., 2022), Turkish-Dutch (Gambäck and Das, 2016), French-Arabic (Sankoff, 1998; Lounnas et al., 2021), Russian-Tatar (Taguchi et al., 2021), Russian-Kazakh (Mussakhojayeva et al., 2022a), Hindi-Tamil (Thomas et al., 2018b), Arabic-North African (El-Haj et al., 2018), Basque-Spanish (Aguirre et al., 2022), and Wixarika-Spanish (Mager et al., 2019). There are only very few papers working on Middle Eastern - English language pairs, most of the time, the Middle Eastern languages are mixed with non-English and/or dialects of these languages (see Figure 4).

Trilingual The number of papers addressing CSW in more than two languages is still small (see 3 top), compared to the papers looking at pairs of languages. Not surprisingly, this smaller number of papers focus on world regions where either the official languages are more than two, or these languages are widely used in the region, for example, Arabic-English-French (Abdul-Mageed et al., 2020), Hindi-Bengali-English (Barman et al., 2016), Tulu-Kannada-English (Hegde et al., 2022), and Darija-English-French (Voss et al., 2014).

	# Publications		
	*CL	ISCA	Total
Public Dataset	38	4	42
Private Dataset	54	18	72

Table 4: Publications that introduce new corpus.

4+ When looking at the papers that focus on more than three languages, we found that many papers use South East Asian Mandarin-English (SEAME) dataset (Lyu et al., 2010a), which has Chinese dialects and Malay or Indonesian words. Most of the other datasets are machine-generated using rule-based or neural methods.

3.2 Language-Dialect Code-Switching

Based on Figure 4, we can find some papers with language-dialect CSW, such as Chinese-Taiwanese Dialect (Chu et al., 2007; Yu et al., 2012) and Modern Standard Arabic (MSA)-Arabic Dialect (Elfardy and Diab, 2012; Samih and Maier, 2016; El-Haj et al., 2018). The dialect, in this case, is the variation of the language with a different form that is very specific to the region where the CSW style is spoken.

4 Tasks and Datasets

In this section, we summarize our findings, focusing on the CSW tasks and datasets. Table 3 shows the distribution of CSW tasks for ACL papers with at least ten publications. The two most popular tasks are language identification and sentiment analysis. Researchers mostly use the shared tasks from 2014 (Solorio et al., 2014) and 2016 (Molina et al., 2016) for language identification, and the SemEval 2020 shared task (Patwa et al., 2020) for sentiment analysis. For ISCA, the most popular tasks are unsurprisingly ASR and TTS. This strong correlation between task and venue shows that the speech processing and *CL communities remain somehow fragmented and working in isolation from one another, from the most part.

Public vs. Private Datasets Public datasets availability also dictates what tasks are being

Source	*CL	ISCA	Total
Social Media	183	3	186
Speech (Recording)	29	102	141
Transcription	23	4	27
News	19	5	24
Dialogue	16	2	18
Books	7	1	8
Government Document	6	0	6
Treebank	5	0	5

Table 5: The source of the CSW dataset in the literature.

Type	*CL	ISCA	Total
Empirical	205	100	305
Shared Task	82	1	83
Corpus (Closed)	54	18	62
Corpus (Open)	38	4	42
Analysis	34	8	42
Demo	7	2	9
Theoretical/Linguistic	7	0	7
Position/Opinion/Survey	3	0	3
Metric	2	1	3

Table 6: Paper Type of the CSW papers.

explored in CSW research. Public datasets such as HinGE (Srivastava and Singh, 2021b), SEAME (Lyu et al., 2010a) and shared task datasets (Solorio et al., 2014; Molina et al., 2016; Aguilar et al., 2018; Patwa et al., 2020) have been widely used in many of the papers. Some work, however, used new datasets that are not publicly available, thus hindering adoption (see Table 4). There are two well-known benchmarks in CSW: LinCE (Aguilar et al., 2020) and GlueCOS (Khanuja et al., 2020b). These two benchmarks have a handful of tasks, and they are built to encourage transparency and reliability of evaluation since the test set labels are not publicly released. The evaluation is done automatically on their websites. However, their support languages are mostly limited to popular CSW language pairs, such as Spanish-English, Modern Standard Arabic-Egyptian, and Hindi-English, the exception being Nepali-English in LinCE.

Dataset Source Table 5 shows the statistics of dataset sources in the CSW literature. We found that most of the ACL papers were working on social media data. This is expected, considering that social media platforms are known to host informal interactions among users, making them reasonable places for users to code-switch. Naturally, most ISCA papers work on speech data, many of which are recordings of conversations and interviews. There are some datasets that come from speech transcription, news, dialogues, books, government documents, and treebanks.

Paper Category Table 6 presents the distribution of CSW papers. Most of the papers are empirical work focusing on the evaluation of downstream tasks. The second largest population is shared tasks. We also notice that many papers introduce new CSW corpus, but they are not released publicly. Some papers only release the URL or id to download the datasets, especially for datasets that come from social media (e.g., Twitter) since redistribution of the actual tweets is not allowed (Solorio et al., 2014; Molina et al., 2016) resulting in making reproducibility harder. Social media users can delete their posts at any point in time, resulting in considerable data attrition rates. There are very few papers working on the demos, theoretical work, position papers, and introducing evaluation metrics.

5 From Linguistics to NLP

Notably, papers are working on approaches that are inspired by linguistic theories to enhance the processing of CSW text. In this survey, we find three linguistic constraints that are used in the literature: equivalence constraint, matrix-embedded language Framework (MLF), and Functional Head Constraint. In this section, we will briefly introduce the constraints and list the papers that utilize the constraints.

5.1 Linguistic-Driven Approaches

Equivalence Constraint In a well-formed code-switched sentence, the switching takes place at those points where the grammatical constraints of both languages are satisfied (Poplack, 1980). Li and Fung (2012, 2013) incorporate this syntactic constraint to a statistical code-switch language model (LM) and evaluate the model on Chinese-English code-switched speech recognition. On the same line of work, Pratapa et al. (2018a); Pratapa and Choudhury (2021) implement the same constraint to Hindi-English CSW data by producing parse trees of parallel sentences and matching the surface order of child nodes in the trees. Winata et al. (2019c) apply the constraint to generate synthetic CSW text and find that combining the real

CSW data with synthetic CSW data can effectively improve the perplexity. They also treat parallel sentences as a linear structure and only allow switching on non-crossing alignments.

Matrix-Embedded Language Framework (MLF) Myers-Scotton (1997) proposed that in bilingual CSW, there exists an asymmetrical relationship between the dominant *matrix language* and the subordinate *embedded language*. Matrix language provides the frame of the sentence by governing all or most of the most of the grammatical morphemes as well as word order, whereas syntactic elements that bear no or only limited grammatical function can be provided by the embedded language (Johanson, 1999; Myers-Scotton, 2005). Lee et al. (2019a) use augmented parallel data by utilizing MLF to supplement the real code-switch data. Gupta et al. (2020) use MLF to automatically generate the code-mixed text from English to multiple languages without any parallel data.

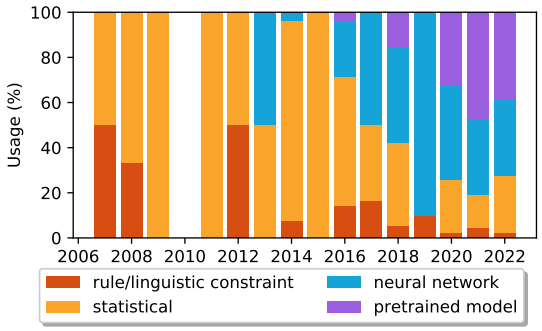
Functional Head Constraint Belazi et al. (1994) posit that it is impossible to switch languages between a functional head and its complement because of the strong relationship between the two constituents. Li and Fung (2014) use the constraint of the LM by first expanding the search network with a translation model and then using parsing to restrict paths to those permissible under the constraint.

5.2 Learning from Data Distribution

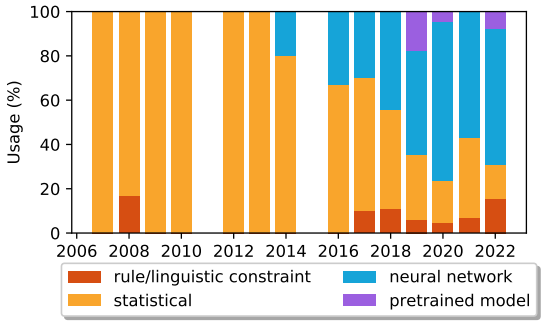
Linguistic constraint theories have been used for decades to generate synthetic CSW sentences to address the lack of data issue. However, the approach requires external word alignments or constituency parsers that create erroneous results instead of applying the linguistic constraints to generate new synthetic CSW data, building a pointer-generator model to learn the real distribution of code-switched data (Winata et al., 2019c). Chang et al. (2019) propose to generate CSW sentences from monolingual sentences using Generative Adversarial Network (GAN) (Goodfellow et al., 2020) and the generator learns to predict CSW points without any linguistic knowledge.

5.3 The Era of Statistical Methods

The research on CSW is also influenced by the progress and development of machine learning.



(a) *CL



(b) ISCA

Figure 5: Methods used for code-mixing NLP.

According to Figure 5, starting in 2006, statistical methods have been adapted to CSW research, while before that year, the approaches were mainly rule-based. There are common statistical methods for text classification used in the literature, such as Naive Bayes (Solorio and Liu, 2008a) and Support Vector Machine (SVM) (Solorio and Liu, 2008b). Conditional Random Field (CRF) (Sutton et al., 2012) is also widely seen in the literature for sequence labeling, such as Part-of-Speech (POS) tagging (Vyas et al., 2014), Named Entity Recognition (NER), and word-level language identification (Lin et al., 2014; Chittaranjan et al., 2014; Jain and Bhat, 2014). HMM-based models have been used in speech-related tasks, such as speech recognition (Weiner et al., 2012a; Li and Fung, 2013) and text synthesis (Qian et al., 2008; Shuang et al., 2010; He et al., 2012).

5.4 Utilizing Neural Networks

Following general NLP trends, we see the adoption of neural methods and pre-trained models growing in popularity over time. In contrast, the statistical and rule-based approaches are diminishing. Compared to ISCA, we see more adaptation of the pre-training model. This is because ACL work is more text-based focused, where pre-trained LMs

are more widely available.

Neural-Based Models Figure 5 shows that the trend of using neural-based models started in 2013, and the usage of rule/linguistic constraint and statistical methods diminished gradually through time, but they are still used even with a low percentage. RNN and LSTM architectures are commonly used in sequence modeling, such as language modeling (Adel et al., 2013; Vu and Schultz, 2014; Adel et al., 2014c; Winata et al., 2018a; Garg et al., 2018a; Winata et al., 2019c) and CSW identification (Samih et al., 2016a). DNN-based and hybrid HMM-DNN models are used in speech recognition models (Yilmaz et al., 2018; Yılmaz et al., 2018).

Pre-trained Embeddings Pre-trained embeddings are used to complement neural-based approaches by initializing the embedding layer. Common pre-trained embeddings used in the literature are monolingual subword-based embeddings, FastText (Joulin et al., 2016), and aligned-embeddings MUSE (Conneau et al., 2017). A standard method to utilize monolingual embeddings is to concatenate or sum two or more embeddings from different languages (Trivedi et al., 2018). A more recent approach is to apply an attention mechanism to merge embeddings and form meta-embeddings (Winata et al., 2019a,b). Character-based embeddings have also been explored in the literature to address the out-of-vocabulary issues on word-embeddings (Winata et al., 2018b; Attia et al., 2018; Aguilar et al., 2021). Another approach is to train bilingual embeddings using real and synthetic CSW data (Pratapa et al., 2018b). In the speech domain, Lovenia et al. (2022) utilize wav2vec 2.0 (Baevski et al., 2020) as a starting model before fine-tuning.

Language Models Many pre-trained model approaches utilize multilingual LMs, such as mBERT or XLM-R to deal with CSW data (Khanuja et al., 2020b; Aguilar and Solorio, 2020; Pant and Dadu, 2020; Patwa et al., 2020; Winata et al., 2021a). These models are often fine-tuned with the downstream task or with CSW text to better adapt to the languages. Some downstream fine-tuning approaches use synthetic CSW data due to a lack of available datasets. Aguilar et al. (2021) propose a character-based subword module (char2subword) of the mBERT that learns the subword embedding that is suitable for modeling the noisy CSW text. Winata et al. (2021a) compare the performance of the multilingual LM versus the language-specific LM for CSW context. While XLM-R provides the best result, it is also computationally heavy. There needed to be more exploration of larger models.

We see that pre-trained LMs provide better empirical results on current benchmark tasks and enables an end-to-end approach. Therefore, one can theoretically work on CSW tasks without any linguistic understanding of the language, assuming the dataset for model finetuning is available. However, the downside is that there is little understanding of how and when the LMs would fail, thus we encourage more interpretability work on these LMs in CSW setting.

6 Recent Challenges and Future Direction

6.1 More Diverse Exploration on Code-Switching Styles and Languages

A handful of languages, such as Spanish-English, Hindi-English, or Chinese-English, dominate research and resource CSW. However, there are still many countries and cultures rich in the use of CSW, which is still under-represented in NLP research (Joshi et al., 2020; Aji et al., 2022; Yong et al., 2023), especially on different CSW variations. CSW style can vary in different regions of the world, and it would be interesting to gather more datasets on unexplored and unknown styles, which can be useful for further research and investigation on linguistics and NLP. Therefore, one future direction is to broaden the language scope of CSW research.

6.2 Datasets: Access and Sources

According to our findings, there are more than 60% of the datasets are private (see Table 4), and they are not released to the public. This eventually hampers the progress of CSW research, particularly in the results' reproducibility, credibility, and transparency. Moreover, many studies in the literature do not release the code to reproduce their work. Therefore, we encourage researchers who build a new corpus to release the datasets publicly. In addition, the fact that some researchers provide urls to download the data is also problematic due to the data attrition issue we raised earlier. Data attrition is bad for reproducibility, but it is also a waste of annotation efforts. Perhaps we should work on identifying alternative means to collect written CSW data in an ecologically valid manner.

6.3 Model Scaling

To the best of our knowledge, little work has been done on investigating how well the scaling law holds for code-mixed datasets. Winata et al. (2021a) demonstrate that the XLM-R-large model outperforms smaller pre-trained models on the NER and POS tasks in LinCE benchmark (Aguilar et al., 2020); however, the largest model in the study, which is the XLM-R-large model, only has 355 million parameters. Furthermore, they find that smaller models that combine word, subword, and character embeddings achieve comparable performance as mBERT while being faster in inference. Given the recent release of billion-sized large pre-trained multilingual models such as XGLM and BLOOM (Scao et al., 2022), we urge future research to study the scaling law and performance-compute trade-off in code-mixing tasks.

6.4 Zero-Shot and Few-Shot Exploration

The majority of pre-trained model approaches fine-tune their models to the downstream task. On the other hand, CSW data is considerably limited. With the rise of multilingual LMs, especially those that have been fine-tuned with prompt/instruction (Muennighoff et al., 2022; Ouyang et al., 2022; Winata et al., 2022), one direction is to see whether these LMs can handle CSW input in a zero-shot fashion. This work might also tie in with model scaling since larger models have shown better capability at zero-shot and few-shot settings (Winata et al., 2021b; Srivastava et al., 2022).

6.5 Robustness Evaluation

Since CSW is a widely common linguistic phenomenon, we argue that cross-lingual NLP benchmarks, such as XGLUE (Liang et al., 2020) and XTREME-R (Ruder et al., 2021), should incorporate linguistic CSW evaluation (Aguilar et al., 2020; Khanuja et al., 2020b). The reasons are that CSW is a cognitive ability that multilingual human speakers can perform with ease (Beatty-Martínez et al., 2020). CSW evaluation examines the robustness of multilingual LMs in learning cross-lingual alignment of representations (Conneau et al., 2020; Libovický et al., 2020; Pires et al., 2019; Adilazuarda et al., 2022). On the other hand, catastrophic forgetting is observed in pre-trained models (Shah et al., 2020), and human speakers (Hirvonen and Lauttamus, 2000; Du Bois, 2009, known as language attrition) in a CSW environment. We argue that finetuning LMs on code-mixed data is a form of *continual learning* to produce a more generalized multilingual LM. Thus, we encourage CSW research to report the performance of finetuned models on both CSW and monolingual texts.

6.6 Task Diversity

We encourage creating reasoning-based tasks for CSW texts for two reasons. First, code-mixed datasets for tasks such as NLI, coreference resolution, and question-answering are much fewer in comparison to tasks such as sentiment analysis, parts-of-speech tagging, and named-entity recognition. Second, comprehension tasks with the CSW text present more processing costs for human readers (Bosma and Pablos, 2020).

6.7 Conversational Agents

There has been a recent focus on developing conversational agents with LMs such as ChatGPT,[5] Whisper (Radford et al., 2022), SLAM (Bapna et al., 2021), mSLAM (Bapna et al., 2022). We recommend incorporating the capability of synthesizing code-mixed data in human-machine dialogue, as CS is a prevalent communication style among multilingual speakers (Ahn et al., 2020), and humans prefer chatbots with such capability (Bawa et al., 2020).

6.8 Automatic Evaluation for Generation

With the rise of pre-trained models, generative tasks gained more popularity. However, when generating CSW data, most work used human evaluation for measuring quality of the generated data. Alternative automatic methods for CS text based on word-frequency and temporal distribution are commonly used (Guzmán et al., 2017; Mave et al., 2018), but we believe there is still much room for improvement in this respect. One possible future direction is to align the evaluation metrics to human judgement of quality (Hamed et al., 2022) where we can assess separately the "faithfulness" of the resulting CSW data from other desired properties of language generation. Other nuances here are related to the intricacy of CSW patterns, where ideally the model would mimic the CSW style of the intended users.

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

7 Conclusion

We present a comprehensive systematic survey on code-switching research in natural language processing to explore the progress of the past decades and understand the existing challenges and tasks in the literature. We summarize the trends and findings and conclude with a discussion for future direction and open questions for further investigation. We hope this survey can encourage and lead NLP researchers in a better direction on code-switching research.

Limitations

The numbers in this survey are limited to papers published in the ACL Anthology and ISCA Proceedings. However, we also included papers as related work from other resources if they are publicly available and accessible. In addition, the category in the survey does not include the code-switching type (i.e., intra-sentential, inter-sentential, etc.) since some papers do not provide such information.

Ethics Statement

We use publicly available data in our survey with permissive licenses. No potential ethical issues in this work.

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A Annotation Catalog

We release the annotation of all papers we use in the survey.

A.1 *CL Anthology

Bilingual Table 7 shows the annotation for papers with African-English. Table 8 shows the annotation for papers with East Asian-English languages. Table 9 shows the annotation for papers with European-English languages. Table 10 shows the annotation for papers with Middle Eastern-English languages. Table 11 and Table 12 show the annotation for papers with South Asian-English languages. Table 13 shows the annotation for papers with South East Asian-English languages. Table 14 shows the annotation for papers with a combination of a language with a dialect. Table 15 shows the annotation for papers with languages in the same family. Table 16 shows the annotation for papers with languages in different families.

Trilingual Table 17 shows the annotation for papers with three languages.

4+ Table 18 shows the annotation for papers with four or more languages.

A.2 ISCA Proceeding

Bilingual Table 19 shows the annotation for papers with African-English. Table 20 shows the annotation for papers with East Asian-English languages. Table 21 shows the annotation for papers with European-English languages. Table 22 shows the annotation for papers with Middle Eastern-English languages. Table 23 shows the annotation for papers with South Asian-English languages. Table 24 shows the annotation for papers with South East Asian-English languages. Table 25 shows the annotation for papers with a combination of a language with a dialect. Table 26 shows the annotation for papers with languages in the same family. Table 27 shows the annotation for papers with languages in different families.

Trilingual Table 28 shows the annotation for papers with three languages.

4+ Table 29 shows the annotation for papers with four or more languages.

Paper	Proceeding	IsiZulu	Swahili	isiXhosa	Setswana	Sesotho
		5	1	3	3	3
(Joshi, 1982)	COLING	✓				
(Piergallini et al., 2016)	CALCS		✓			
(Niesler et al., 2018)	LREC	✓		✓	✓	✓
(Biswas et al., 2020)	CALCS	✓				
(Wilkinson et al., 2020)	SLTU and CCURL	✓		✓	✓	✓
(Biswas et al., 2020)	LREC	✓		✓	✓	✓

Table 7: *CL Catalog in African-English.

Paper	Proceeding	Chinese	Cantonese	Korean
		20	1	1
(Fung et al., 1999)	ACL	✓		
(Chan et al., 2009)	IJCLCLP		✓	
(Li et al., 2012)	LREC	✓		
(Peng et al., 2014)	ACL-IJCNLP	✓		
(Li and Fung, 2014)	EMNLP	✓		
(Solorio et al., 2014)	CALCS	✓		
(Chittaranjan et al., 2014)	CALCS	✓		
(Lin et al., 2014)	CALCS	✓		
(Jain and Bhat, 2014)	CALCS	✓		
(King et al., 2014)	CALCS	✓		
(Huang and Yates, 2014)	EACL	✓		
(Wang et al., 2015)	ACL-IJCNLP	✓		
(Gambäck and Das, 2016)	LREC	✓		
(Wang et al., 2016)	COLING	✓		
(Çetinoğlu et al., 2016)	CALCS	✓		
(Xia and Cheung, 2016)	CALCS	✓		
(Yang et al., 2020)	EMNLP	✓		
(Calvillo et al., 2020)	EMNLP	✓		
(Lin and Chen, 2020)	ROCLING	✓		
(Cho et al., 2020)	CALCS			✓
(Lin and Chen, 2021)	ROCLING	✓		
(Lovenia et al., 2021)	LREC	✓		

Table 8: *CL Catalog in East Asian-English.

Paper	Proceeding	Spanish	French	Portugese	Polish	German	Dutch	Finnish
		78	7	1	1	5	2	1
(Sankoff, 1998)	COLING							✓
(Solorio and Liu, 2008a)	EMNLP	✓						
(Solorio and Liu, 2008b)	EMNLP	✓						
(Peng et al., 2014)	ACL-IJCNLP	✓						
(Solorio et al., 2014)	CALCS	✓						
(Chittaranjan et al., 2014)	CALCS	✓						
(Lin et al., 2014)	CALCS	✓						
(Jain and Bhat, 2014)	CALCS	✓						
(King et al., 2014)	CALCS	✓						
(Carpuat, 2014)	CALCS		✓					
(Barman et al., 2014b)	CALCS	✓						
(Shrestha, 2014)	CALCS	✓						
(Bar and Dershowitz, 2014)	CALCS	✓						
(Gambäck and Das, 2016)	LREC	✓						
(Vilares et al., 2016)	LREC	✓						
(Çetinoğlu et al., 2016)	CALCS	✓						
(Guzman et al., 2016)	CALCS	✓						
(Molina et al., 2016)	CALCS	✓						
(Samih et al., 2016a)	CALCS	✓						
(Jaech et al., 2016)	CALCS	✓						
(AlGhamdi et al., 2016)	CALCS	✓						
(Al-Badrashiny and Diab, 2016)	CALCS	✓						
(Chanda et al., 2016a)	CALCS	✓						
(Shirvani et al., 2016)	CALCS	✓						
(Shrestha, 2016)	CALCS	✓						
(Sikdar and Gambäck, 2016)	CALCS	✓						
(Xia, 2016)	CALCS	✓						
(Duong et al., 2017)	CoNLL					✓		
(Rijhwani et al., 2017)	ACL	✓	✓	✓			✓	
(Choudhury et al., 2017)	ICON	✓						
(Núñez and Wisniewski, 2018)	TALN PFIA	✓						
(Pratapa et al., 2018b)	EMNLP	✓						
(Mendels et al., 2018)	LREC	✓						
(Soto and Hirschberg, 2018)	CALCS	✓						
(Mave et al., 2018)	CALCS	✓						
(Bullock et al., 2018a)	CALCS	✓						
(Rallabandi et al., 2018)	CALCS	✓						
(Bawa et al., 2018)	CALCS	✓						
(Jain et al., 2018)	CALCS	✓						
(Winata et al., 2018b)	CALCS	✓						
(Sikdar et al., 2018)	CALCS	✓						
(Janke et al., 2018)	CALCS	✓						
(Geetha et al., 2018)	CALCS	✓						
(Claeser et al., 2018)	CALCS	✓						
(Aguilar et al., 2018)	CALCS	✓						
(Trivedi et al., 2018)	CALCS	✓						
(Wang et al., 2018)	CALCS	✓						
(Gonen and Goldberg, 2019)	EMNLP	✓						
(Yang et al., 2020)	EMNLP		✓			✓		
(Khanuja et al., 2020b)	ACL	✓						
(Aguilar and Solorio, 2020)	ACL	✓						
(Cameron, 2020)	JEP		✓					
(Ahn et al., 2020)	SCiL	✓						
(Srinivasan et al., 2020)	CALCS	✓						
(Patwa et al., 2020)	SemEval	✓						
(De Leon et al., 2020)	SemEval	✓						
(Aparaschivei et al., 2020)	SemEval	✓						
(Kong et al., 2020)	SemEval	✓						
(Angel et al., 2020)	SemEval	✓						
(Palomino and Ochoa-Luna, 2020)	SemEval	✓						
(Ma et al., 2020)	SemEval	✓						
(Kumar et al., 2020)	SemEval	✓						
(Advani et al., 2020)	SemEval	✓						
(Javdan et al., 2020)	SemEval	✓						
(Wu et al., 2020)	SemEval	✓						
(Zaharia et al., 2020)	SemEval	✓						
(Sultan et al., 2020)	SemEval	✓						
(Zhu et al., 2020)	SemEval	✓						
(Parekh et al., 2020)	CoNLL	✓						
(Gupta et al., 2020)	Findings of EMNLP	✓	✓			✓		
(Aguilar et al., 2020)	LREC	✓						
(Iliescu et al., 2021)	CALCS	✓						
(Xu and Yvon, 2021)	CALCS	✓	✓					
(Gupta et al., 2021b)	CALCS	✓						
(Jayanthi et al., 2021)	CALCS	✓						
(Winata et al., 2021a)	CALCS	✓						
(Prasad et al., 2021)	MRL	✓						
(Chopra et al., 2021)	Findings of EMNLP	✓						
(Santy et al., 2021)	AdaptNLP	✓						
(Cheong et al., 2021)	W-NUT	✓						
(Pratapa and Choudhury, 2021)	W-NUT	✓	✓			✓	✓	
(Xia et al., 2022)	LREC				✓	✓		
(Mellado and Lignos, 2022)	LREC	✓						
(Ostapenko et al., 2022)	ACL	✓						

Table 9: *CL Catalog in European-English.

Paper	Proceeding	Egyptian Arabic	Arabic	Turkish
		3	1	2
(Rijhwani et al., 2017)	ACL			✓
(Hamed et al., 2018)	LREC	✓		
(Yirmibeşoğlu and Eryiğit, 2018)	W-NUT			✓
(Sabty et al., 2020)	WANLP		✓	
(Balabel et al., 2020)	LREC	✓		
(Hamed et al., 2020)	LREC	✓		

Table 10: *CL Catalog in Middle Eastern-English.

Paper	Proceeding	Hindi	Marathi	Konkani	Bengali	Bengali intra-word	Nepali	Telugu	Bangla	Gujarati	Punjabi	Tamil	Malayalam	Malayalam scripts	Kannada
		111	1	1	12	1	10	7	1	1	2	37	23	1	10
(Joshi, 1982)	COLING		✓												
(Sankoff, 1998)	COLING											✓			
(Bhattacharja, 2010)	PACLIC					✓									
(Diab and Kamboj, 2011)	ALR	✓													
(Dey and Fung, 2014)	LREC	✓													
(Das and Gambäck, 2014)	ICON	✓			✓										
(Vyas et al., 2014)	EMNLP	✓													
(Jhamtani et al., 2014)	PACLIC	✓													
(Barman et al., 2014a)	CALCS	✓			✓										
(Solorio et al., 2014)	CALCS						✓								
(Chittaranjan et al., 2014)	CALCS						✓								
(Lin et al., 2014)	CALCS						✓								
(Jain and Bhat, 2014)	CALCS						✓								
(King et al., 2014)	CALCS						✓								
(Bali et al., 2014)	CALCS	✓													
(Barman et al., 2014b)	CALCS						✓								
(Shrestha, 2014)	CALCS						✓								
(Jamatia et al., 2015)	RANLP	✓													
(Sequiera et al., 2015)	ICON	✓													
(Gupta et al., 2016)	ICON	✓													
(Asnani and Pawar, 2016)	ICON	✓													
(Begum et al., 2016)	LREC	✓													
(Gambäck and Das, 2016)	LREC	✓					✓								
(Sitaram and Black, 2016)	LREC	✓													
(Sharma et al., 2016)	HLT-NAACL	✓													
(Joshi et al., 2016)	COLING	✓													
(Çetinoğlu et al., 2016)	CALCS	✓													
(Chanda et al., 2016b)	CALCS				✓										
(Ghosh et al., 2016)	CALCS	✓			✓							✓			
(Pratapa and Choudhury, 2017)	ICON	✓													
(Phadte and Thakkar, 2017)	ICON			✓											
(Pandey et al., 2017)	ICON	✓													
(Bhat et al., 2017)	EACL	✓													
(Banerjee et al., 2018)	COLING	✓			✓					✓		✓			
(Gundapu and Mamidi, 2018)	PACLIC							✓							
(Ball and Garrette, 2018)	EMNLP	✓													
(Khandelwal et al., 2018)	LREC	✓													
(Kumar et al., 2018)	LREC	✓													
(Pandey et al., 2018)	LREC	✓													
(Hartmann et al., 2018)	LREC	✓													
(Gupta et al., 2018a)	LREC	✓										✓			
(Mandal and Nanmaran, 2018)	W-NUT				✓										
(Mandal and Singh, 2018)	W-NUT	✓			✓										
(Vijay et al., 2018)	SRW	✓													
(Gupta et al., 2018b)	CoNLL	✓													
(Singh et al., 2018)	SRW	✓													
(Chandu et al., 2019)	CALCS	✓						✓				✓			
(Sivasankaran et al., 2018)	CALCS	✓													
(Chandu et al., 2019)	CALCS	✓						✓				✓			
(Gupta et al., 2018c)	CALCS	✓													
(Mave et al., 2018)	CALCS	✓													
(Rallabandi et al., 2018)	CALCS	✓													
(Bawa et al., 2018)	CALCS	✓													
(Chandu et al., 2018)	CALCS	✓													
(Jain et al., 2018)	CALCS	✓													
(Mukherjee et al., 2019)	ICON	✓													
(Raha et al., 2019)	ICON				✓										
(Shah et al., 2019)	AnnoNLP	✓													
(Ghosh et al., 2019)	TLT, SyntaxFest	✓			✓										
(Srirangam et al., 2019)	SRW							✓							
(Lal et al., 2019)	SRW	✓													
(Chakravarthi, 2020)	PEOPLES											✓	✓		
(Singh and Lefever, 2020)	ICON										✓				
(Bansal et al., 2020a)	ICON										✓				
(Bansal et al., 2020c)	ACL	✓													
(Khanuja et al., 2020b)	ACL	✓													
(Aguilar and Solorio, 2020)	ACL	✓					✓								
(Rani et al., 2020)	TRAC	✓													
(Pant and Dadu, 2020)	SRW	✓													
(Khanuja et al., 2020a)	CALCS	✓													
(Singh and Lefever, 2020)	CALCS	✓													
(Srinivasan et al., 2020)	CALCS	✓													
(Patwa et al., 2020)	SemEval	✓													
(Liu et al., 2020)	SemEval	✓													
(Aparaschivei et al., 2020)	SemEval	✓													
(Kong et al., 2020)	SemEval	✓													
(Baruah et al., 2020)	SemEval	✓													
(Srinivasan, 2020)	SemEval	✓													
(Goswami et al., 2020)	SemEval	✓													
(Kumar et al., 2020)	SemEval	✓													
(Advani et al., 2020)	SemEval	✓													
(dos Santos Neto et al., 2020)	SemEval	✓													
(Gundapu and Mamidi, 2020)	SemEval	✓													
(Srivastava and Vardhan, 2020)	SemEval	✓													
(Srivastava and Singh, 2020a)	SemEval	✓													
(Parikh et al., 2020)	SemEval	✓													
(Javdan et al., 2020)	SemEval	✓													
(Garain et al., 2020)	SemEval	✓													
(Banerjee et al., 2020)	SemEval	✓													

Table 11: *CL Catalog in South Asian-English (1).

(Wu et al., 2020)	SemEval	✓						
(Baroi et al., 2020)	SemEval	✓						
(Gopalan and Hopkins, 2020)	SemEval	✓						
(Malte et al., 2020)	SemEval	✓						
(Zaharia et al., 2020)	SemEval	✓						
(Zhu et al., 2020)	SemEval	✓						
(Parekh et al., 2020)	CoNLL	✓						
(Chakravarthi et al., 2020a)	SLTU & CCURL						✓	
(Chakravarthi et al., 2020b)	SLTU & CCURL					✓		
(Gupta et al., 2020)	Findings of EMNLP	✓	✓		✓	✓	✓	
(Makhija et al., 2020)	COLING	✓						
(Aguilar et al., 2020)	LREC	✓		✓				
(Chatterjere et al., 2020)	LREC	✓						
(Aggarwal et al., 2020)	W-NUT	✓						
(Srivastava and Singh, 2020b)	W-NUT	✓						
(Chakravarthy et al., 2020)	W-NUT	✓						
(Chinnappa, 2021)	LTEDI					✓	✓	
(Dave et al., 2021)	LTEDI					✓	✓	
(Hossain et al., 2021)	LTEDI					✓	✓	
(Balouchzahi et al., 2021)	LTEDI					✓	✓	
(Agarwal and Narula, 2021)	SRW	✓						
(Agarwal et al., 2021)	NLP4ConvAI	✓						
(Garg et al., 2021)	Eval4NLP	✓						
(Srivastava and Singh, 2021b)	Eval4NLP	✓						
(Tarunesh et al., 2021)	ACL	✓						
(Srivastava and Singh, 2021a)	CALCS	✓						
(Gautam et al., 2021a)	CALCS	✓						
(Dowlagar and Mamidi, 2021a)	CALCS	✓						
(Appicharla et al., 2021)	CALCS	✓						
(Jawahar et al., 2021)	CALCS	✓						
(Gautam et al., 2021b)	CALCS	✓						
(Gupta et al., 2021b)	CALCS	✓				✓	✓	
(Jayanthi et al., 2021)	CALCS	✓				✓		
(Parikh and Solorio, 2021)	CALCS	✓						
(Winata et al., 2021a)	CALCS	✓						
(Mehnaz et al., 2021)	EMNLP	✓						
(Prasad et al., 2021)	MRL	✓				✓	✓	
(Gupta et al., 2021a)	NAACL	✓						
(Ravikiran and Annamalai, 2021)	DravidianLangTech					✓		✓
(Mahata et al., 2021)	DravidianLangTech					✓		
(Saumya et al., 2021)	DravidianLangTech					✓	✓	✓
(Mandalam and Sharma, 2021)	DravidianLangTech					✓	✓	
(Dowlagar and Mamidi, 2021b)	DravidianLangTech					✓	✓	
(Gupta et al., 2021c)	DravidianLangTech					✓	✓	
(Balouchzahi and Shashirekha, 2021)	DravidianLangTech					✓	✓	
(Dowlagar and Mamidi, 2021c)	DravidianLangTech					✓	✓	✓
(Li, 2021)	DravidianLangTech					✓	✓	✓
(Andrew, 2021)	DravidianLangTech					✓	✓	✓
(Vasantharajan and Thayasivam, 2021)	DravidianLangTech					✓	✓	✓
(Huang and Bai, 2021)	DravidianLangTech					✓	✓	✓
(Sharif et al., 2021)	DravidianLangTech					✓	✓	✓
(Bharathi et al., 2021)	DravidianLangTech					✓	✓	✓
(Balouchzahi et al., 2021)	DravidianLangTech					✓	✓	✓
(Rajalakshmi et al., 2021)	DravidianLangTech					✓		
(Khan et al., 2021)	Findings of EMNLP	✓						
(Chopra et al., 2021)	Findings of EMNLP	✓	✓		✓			
(Srivastava and Singh, 2021c)	INLG	✓						
(Santy et al., 2021)	AdaptNLP	✓						
(Wadhawan and Aggarwal, 2021)	WASSA	✓						
(Priyanshu et al., 2021)	W-NUT	✓						
(Dutta, 2022)	DCLRL				✓			
(Biradar and Saumya, 2022)	DravidianLangTech					✓		
(Swaminathan et al., 2022)	DravidianLangTech					✓		
(SR et al., 2022)	DravidianLangTech					✓	✓	✓
(Ravikiran and Chakravarthi, 2022)	DravidianLangTech					✓		
(Ravikiran et al., 2022)	DravidianLangTech					✓		
(Nayak and Joshi, 2022)	WILDRE-6	✓						
(Gautam, 2022)	WILDRE-6	✓	✓		✓			
(Sonu et al., 2022)	WILDRE-6	✓						

Table 12: *CL Catalog in South Asian-English (2).

Paper	Proceeding	Vietnamese	Tagalog	Indonesian
		1	2	2
(Oco and Roxas, 2012)	PACLIC		✓	
(Stymne et al., 2020)	CALCS			✓
(Nguyen and Bryant, 2020)	LREC	✓		
(Arianto and Budi, 2020)	PACLIC			✓
(Herrera et al., 2022)	LREC			✓

Table 13: *CL Catalog in South East Asian-English.

Paper	Proceeding	Darija-MSA	MSA-Egyptian	MSA-Other Dialect	Chinese-Taiwanese	MSA-Levant Arabic	MSA-Gulf	Mixed-English
		1	15	10	2	2	1	1
(Chu et al., 2007)				✓				
(Yu et al., 2012)	CIPS-SIGHAN				✓			
(Elfardy and Diab, 2012)	COLING		✓			✓		
(Solorio et al., 2014)	CALCS			✓				
(Chittaranjan et al., 2014)	CALCS			✓				
(Lin et al., 2014)	CALCS			✓				
(Jain and Bhat, 2014)	CALCS			✓				
(Elfardy et al., 2014)	CALCS			✓				
(King et al., 2014)	CALCS			✓				
(Gambäck and Das, 2016)	LREC		✓					
(Samih and Maier, 2016)	LREC	✓						
(Diab et al., 2016)	LREC		✓					
(Molina et al., 2016)	CALCS		✓					
(Samih et al., 2016a)	CALCS		✓					
(Jaech et al., 2016)	CALCS			✓				
(Samih et al., 2016b)	CALCS			✓				
(AlGhamdi et al., 2016)	CALCS		✓					
(Al-Badrashiny and Diab, 2016)	CALCS			✓				
(Shrestha, 2016)	CALCS			✓				
(El-Haj et al., 2018)	LREC		✓			✓	✓	
(Shoemark et al., 2018)	W-NUT							✓
(Attia et al., 2018)	CALCS		✓					
(Janke et al., 2018)	CALCS		✓					
(Geetha et al., 2018)	CALCS		✓					
(Aguilar et al., 2018)	CALCS		✓					
(Wang et al., 2018)	CALCS		✓					
(Aguilar et al., 2020)	LREC		✓					
(Elmadany et al., 2021)	CALCS		✓					
(Winata et al., 2021a)	CALCS		✓					

Table 14: *CL Catalog in Dialect.

Paper	Proceeding	Komi-Zyrian - Russian	Arabizi-Arabic	Spanish-Catalan	Corsican-French	Frisian-Dutch
		1	1	1	1	3
(Eskander et al., 2014)	CALCS		✓			
(Yilmaz et al., 2016)	LREC					✓
(Braggaar and van der Goot, 2021)	AdaptNLP					✓
(Amin et al., 2022)	BioNLP			✓		
(Özateş et al., 2022)	Findings of NAACL	✓				✓
(Kevers, 2022)	SIGUL				✓	

Table 15: *CL Catalog in Two Languages in the same family.

Paper	Proceeding	Russian-Tatar	Russian-Tatar intra-word	Turkish-German	MSA-North African	French - Arabic Dialect	Dutch-Turkish	French-Algerian	Basque-Spanish	Spanish–Wixarika intra-word
		1	1	7	1	2	2	1	1	1
(Sankoff, 1998)	COLING					✓				
(Papalexakis et al., 2014)	CALCS						✓			
(Gambäck and Das, 2016)	LREC						✓			
(Çetinoğlu, 2016)	LREC			✓						
(Çetinoğlu et al., 2016)	CALCS			✓						
(Djegdjiga et al., 2018)	LREC							✓		
(El-Haj et al., 2018)	LREC				✓					
(Çetinoğlu and Çöltekin, 2019)	TLT, SyntaxFest 2019			✓						
(Mager et al., 2019)	NAACL			✓						✓
(Özateş and Çetinoğlu, 2021)	CALCS			✓						
(Taguchi et al., 2021)	CALCS	✓								
(Lounnas et al., 2021)	ICNLSP					✓				
(Aguirre et al., 2022)	LREC								✓	
(Özateş et al., 2022)	Findings of NAACL			✓						
(Taguchi et al., 2022)	EURALI		✓	✓						

Table 16: *CL Catalog in different family.

Paper	Proceeding	Tulu-Kannada-EN	Hindi-Bengali-EN	Greek-German-EN	Magahi-Hindi-EN	Arabic-EN-French	Darija-EN-French
		1	1	1	1	1	1
(Voss et al., 2014)	LREC						✓
(Çetinoğlu et al., 2016)	CALCS			✓			
(Barman et al., 2016)	CALCS		✓				
(Abdul-Mageed et al., 2020)	EMNLP					✓	
(Taguchi et al., 2021)	CALCS						
(Rani et al., 2022)	LREC				✓		
(Hegde et al., 2022)	ELRA	✓					

Table 17: *CL Catalog in Trilingual.

Paper	Proceeding	SEA Mandarin-English	Bangla-Chinese-Dutch-English-Farsi-German-Hindi-Korean-Russian-Spanish-Turkish	Early New High German, Latin, French, Greek, Italian, Hebrew	Telugu, Modern Standard Telugu, English, Hindi, Urdu,	MSA, Berber, French, local Algerian Arabic	Others (4+)	English, Swiss German Latin	Algerian, MSA, local Arabic varieties, Berber, French, and English	Mandarin-Hakka-Taiwanese-English
		10	4	1	1	2	3	1	1	1
(Wu et al., 2011)	ROCLING									✓
(Adel et al., 2013)	ACL	✓								
(Volk and Clematide, 2014)	CALCS							✓		
(Vu and Schultz, 2014)	CALCS	✓								
(Jurgens et al., 2014)	CALCS						✓			
(Garg et al., 2018a)	EMNLP	✓								
(Adouane et al., 2018)	CALCS						✓			
(Winata et al., 2018a)	CALCS	✓								
(Winata et al., 2019c)	CoNLL	✓								
(Lee and Li, 2020)	ACL	✓								
(Winata et al., 2020)	ACL	✓								
(Yu and Chen, 2020)	ROCLING	✓								
(Adouane and Bernardy, 2020)	CALCS					✓			✓	
(Adouane et al., 2020)	LREC					✓				
(Sravani et al., 2021)	CALCS				✓					
(Xu et al., 2021)	SCiL	✓								
(Zhang et al., 2021b)	EMNLP						✓			
(Cheong et al., 2021)	W-NUT	✓								
(Malmasi et al., 2022b)	SemEval		✓							
(Malmasi et al., 2022a)	COLING		✓							
(Volk et al., 2022)	LREC			✓						
(El Mekki et al., 2022)	SemEval		✓							
(Dowlagar and Mamidi, 2022)	SemEval		✓							

Table 18: *CL Catalog in 4+ languages.

Paper	Proceeding	isiZulu	isiXhosa	Setsawa	Sesotho	Sotho
		6	4	3	3	1
(Niesler and de Wet, 2008)	Odyssey	✓	✓			
(Mabokela et al., 2014)	SLTU					✓
(van der Westhuizen and Niesler, 2017)	Interspeech	✓				
(Yılmaz et al., 2018)	Interspeech	✓	✓	✓	✓	
(Biswas et al., 2018a)	Interspeech	✓				
(Biswas et al., 2018b)	SLTU	✓	✓	✓	✓	
(Biswas et al., 2019)	Interspeech	✓	✓	✓	✓	

Table 19: ISCA Catalog in African-English.

Paper	Proceeding	Chinese	Cantonese	Korean	Japanese
		27	5	1	1
(Fu and Shen, 2000)	ISCSLP	✓			
(Kojima and Tanaka, 2003)	Eurospeech				✓
(You et al., 2004)	ISCSLP	✓			
(Chan et al., 2004)	ISCSLP		✓		
(Chan et al., 2005)	Interspeech		✓		
(Ren et al., 2005)	Interspeech	✓			
(Chan et al., 2006)	Interspeech		✓		
(Liang et al., 2007)	SSW	✓			
(White et al., 2008)	Interspeech	✓			
(Qian et al., 2008)	ISCSLP	✓			
(Gu et al., 2008)	ISCSLP		✓		
(Zhang and Tao, 2008)	ISCSLP	✓			
(Cao et al., 2009)	Interspeech		✓		
(Shuang et al., 2010)	Interspeech	✓			
(He et al., 2012)	Interspeech	✓			
(Liang et al., 2013)	Interspeech	✓			
(Li and Fung, 2013)	Interspeech	✓			
(Xue et al., 2019)	Interspeech	✓			
(Gao et al., 2019)	Interspeech	✓			
(Zhang et al., 2019)	Interspeech	✓			
(Lu et al., 2020)	Interspeech	✓			
(Hu et al., 2020)	Interspeech	✓			
(Fu et al., 2020)	Interspeech	✓			
(Wang et al., 2020)	Interspeech			✓	
(Zhang et al., 2020)	Interspeech	✓			
(Chandu and Black, 2020)	Interspeech	✓			
(Zhao et al., 2020)	Interspeech	✓			
(Zhang et al., 2021a)	Interspeech	✓			
(Shen and Guo, 2022)	Interspeech	✓			
(Ye et al., 2022)	Interspeech	✓			
(Tian et al., 2022)	Interspeech	✓			
(Song et al., 2022)	Interspeech	✓			
(Zhang et al., 2022)	Interspeech	✓			
(Li et al., 2022)	Interspeech	✓			

Table 20: ISCA Catalog in East Asian-English.

Paper	Proceeding	Spanish	French	German	Maltese
(Pfister and Romsdorfer, 2003)	Eurospeech			✓	
(Romsdorfer and Pfister, 2005)	Interspeech		✓		
(Rosner and Farrugia, 2007)	Interspeech				✓
(Piccinini and Garellek, 2014)	SpeechProsody	✓			
(Sitaram et al., 2016)	SSW			✓	
(Soto and Hirschberg, 2017)	Interspeech	✓			
(Ramanarayanan and Suendermann-Oeft, 2017)	Interspeech	✓			
(Guzmán et al., 2017)	Interspeech	✓			
(Bullock et al., 2018b)	Interspeech	✓			
(Soto et al., 2018)	Interspeech	✓			
(Soto and Hirschberg, 2019)	Interspeech	✓			
(Chandu and Black, 2020)	Interspeech	✓			

Table 21: ISCA Catalog in European-English.

Paper	Proceeding	Modern Standard Arabic
(White et al., 2008)	Interspeech	✓
(Ali et al., 2021)	Interspeech	✓
(Chowdhury et al., 2021)	Interspeech	✓

Table 22: ISCA Catalog in Middle Eastern-English.

Paper	Proceeding	Hindi	Marathi	Bengali	Telugu	Gujarati	Tamil	Malayalam	Kannada
(Sitaram et al., 2016)	SSW	✓							
(Ramanarayanan and Suendermann-Oeft, 2017)	Interspeech	✓							
(Ganji and Sinha, 2018)	Interspeech	✓							
(Rao et al., 2018)	Interspeech	✓							
(Thomas et al., 2018a)	Interspeech	✓					✓		
(Srivastava and Sitaram, 2018)	Interspeech	✓							
(Rambabu and Gangashetty, 2018)	SLTU	✓							
(Taneja et al., 2019)	Interspeech	✓							
(Rallabandi and Black, 2019)	Interspeech	✓	✓		✓				
(Prakash et al., 2019)	SSW		✓						
(Sharma et al., 2020)	Interspeech	✓							
(Manghat et al., 2020)	Interspeech							✓	
(Bansal et al., 2020b)	Interspeech	✓							
(Chandu and Black, 2020)	Interspeech	✓							
(Kumar et al., 2021)	Interspeech	✓		✓					
(Liu et al., 2021)	Interspeech					✓	✓	✓	
(Diwan et al., 2021)	Interspeech	✓		✓					
(Klejch et al., 2021)	Interspeech	✓		✓					
(Wiesner et al., 2021)	Interspeech	✓		✓					
(Antony et al., 2022)	Interspeech	✓							
(Manghat et al., 2022)	Interspeech							✓	

Table 23: ISCA Catalog in South Asian-English.

Paper	Proceeding	Malay
(Yeong and Tan, 2010)	SLTU	✓
(Yeong and Tan, 2014)	Interspeech	✓
(Singh and Tan, 2018)	Interspeech	✓

Table 24: ISCA Catalog in South East Asian-English.

Paper	Proceeding	Chinese-Taiwanese
(Lyu and Lyu, 2008)	Interspeech	✓

Table 25: ISCA Catalog in Language with Dialects.

Paper	Proceeding	Frisian-Dutch	Russian-Ukrainan
(Lyudovyk and Pylypenko, 2014)	Interspeech		✓
(Yılmaz et al., 2016)	Interspeech	✓	
(Yılmaz et al., 2017b)	Interspeech	✓	
(Yılmaz et al., 2017a)	Interspeech	✓	
(Yılmaz et al., 2018)	Interspeech	✓	
(Yilmaz et al., 2018)	SLTU	✓	
(Wang et al., 2019)	Interspeech		✓
(Yılmaz et al., 2019)	Interspeech		✓

Table 26: ISCA Catalog in Two Languages in the same family.

Paper	Proceeding	Kazakh-Russian	Hindi-Tamil	French-Arabic
		1	1	4
(Amazouz et al., 2017)	Interspeech			✓
(Thomas et al., 2018a)	Interspeech		✓	
(Wottawa et al., 2018)	Interspeech			✓
(Chandu and Black, 2020)	Interspeech			✓
(Chowdhury et al., 2021)	Interspeech			✓
(Mussakhojayeva et al., 2022b)	Interspeech	✓		

Table 27: ISCA Catalog in Two Languages in different families.

Paper	Proceeding	Italian-German-English	Kiswahili-Shen-English
		1	1
(Knill et al., 2020)	Interspeech	✓	
(Otundo and Grice, 2022)	SpeechProsody		✓

Table 28: ISCA Catalog in Trilingual.

Paper	Proceeding	SEA Mandarin-English	African Languages-English	Indian Languages-English	Others
		17	1	1	7
(Badino et al., 2004)	Interspeech				✓
(Oria and Vetek, 2004)	Interspeech				✓
(Marcadet et al., 2005)	Interspeech				✓
(Romsdorfer and Pfister, 2006)	ML				✓
(Lyu et al., 2010b)	Interspeech	✓			
(Imseng et al., 2010)	Interspeech				✓
(Weiner et al., 2012b)	SLTU	✓			
(Adel et al., 2014c)	Interspeech	✓			
(Adel et al., 2014b)	Interspeech	✓			
(Giwa and Davel, 2014)	Interspeech		✓		
(Adel et al., 2014a)	SLTU	✓			
(Rallabandi and Black, 2017)	Interspeech			✓	
(Chandu et al., 2017)	Interspeech				✓
(Garg et al., 2018b)	Interspeech	✓			
(Xu et al., 2018)	Interspeech	✓			
(Guo et al., 2018)	Interspeech	✓			
(Chang et al., 2019)	Interspeech	✓			
(Khassanov et al., 2019)	Interspeech	✓			
(Lee et al., 2019b)	Interspeech	✓			
(Zeng et al., 2019)	Interspeech	✓			
(Hu et al., 2020)	Interspeech	✓			
(Li and Vu, 2020)	Interspeech	✓			
(Zhou et al., 2020)	Interspeech	✓			
(Nekvinda and Dušek, 2020)	Interspeech				✓
(Qiu et al., 2020)	Interspeech	✓			
(Liu et al., 2021)	Interspeech	✓			

Table 29: ISCA Catalog in 4+.

ACL 2023 Responsible NLP Checklist

A For every submission:

☑ A1. Did you describe the limitations of your work?
Limitations Section on page 9

☐ A2. Did you discuss any potential risks of your work?
Not applicable. This is a survey paper. There is no potential negative risk.

☑ A3. Do the abstract and introduction summarize the paper's main claims?
Abstract and Section 1 on page 1

☒ A4. Have you used AI writing assistants when working on this paper?
Left blank.

B ☒ Did you use or create scientific artifacts?

Left blank.

☐ B1. Did you cite the creators of artifacts you used?
No response.

☐ B2. Did you discuss the license or terms for use and / or distribution of any artifacts?
No response.

☐ B3. Did you discuss if your use of existing artifact(s) was consistent with their intended use, provided that it was specified? For the artifacts you create, do you specify intended use and whether that is compatible with the original access conditions (in particular, derivatives of data accessed for research purposes should not be used outside of research contexts)?
No response.

☐ B4. Did you discuss the steps taken to check whether the data that was collected / used contains any information that names or uniquely identifies individual people or offensive content, and the steps taken to protect / anonymize it?
No response.

☐ B5. Did you provide documentation of the artifacts, e.g., coverage of domains, languages, and linguistic phenomena, demographic groups represented, etc.?
No response.

☐ B6. Did you report relevant statistics like the number of examples, details of train / test / dev splits, etc. for the data that you used / created? Even for commonly-used benchmark datasets, include the number of examples in train / validation / test splits, as these provide necessary context for a reader to understand experimental results. For example, small differences in accuracy on large test sets may be significant, while on small test sets they may not be.
No response.

C ☒ Did you run computational experiments?

Left blank.

☐ C1. Did you report the number of parameters in the models used, the total computational budget (e.g., GPU hours), and computing infrastructure used?
No response.

The Responsible NLP Checklist used at ACL 2023 is adopted from NAACL 2022, with the addition of a question on AI writing assistance.

☐ C2. Did you discuss the experimental setup, including hyperparameter search and best-found hyperparameter values?
No response.

☐ C3. Did you report descriptive statistics about your results (e.g., error bars around results, summary statistics from sets of experiments), and is it transparent whether you are reporting the max, mean, etc. or just a single run?
No response.

☐ C4. If you used existing packages (e.g., for preprocessing, for normalization, or for evaluation), did you report the implementation, model, and parameter settings used (e.g., NLTK, Spacy, ROUGE, etc.)?
No response.

D ☒ Did you use human annotators (e.g., crowdworkers) or research with human participants?

Left blank.

☐ D1. Did you report the full text of instructions given to participants, including e.g., screenshots, disclaimers of any risks to participants or annotators, etc.?
No response.

☐ D2. Did you report information about how you recruited (e.g., crowdsourcing platform, students) and paid participants, and discuss if such payment is adequate given the participants' demographic (e.g., country of residence)?
No response.

☐ D3. Did you discuss whether and how consent was obtained from people whose data you're using/curating? For example, if you collected data via crowdsourcing, did your instructions to crowdworkers explain how the data would be used?
No response.

☐ D4. Was the data collection protocol approved (or determined exempt) by an ethics review board?
No response.

☐ D5. Did you report the basic demographic and geographic characteristics of the annotator population that is the source of the data?
No response.