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Relevance based Bilingual Sarcasm detection using Transformer Model

Utkarsh Sharma [1*], Prateek Pandey[2*] and Shishir Kumar[3]
*1*PhD scholar Computer science and engineering department , Jaypee University of engineering and Technology, Guna, MP, India.*
2Jaypee University of Engineering and Technology, Guna, MP, India.
3Head (Computer Science & Computer Engineering), Director,
University Institute of Engineering & Technology, Organization,
Director (Research & Development), Babasaheb Bhimrao Ambedkar Central University, Lucknow (UP), India.
**Corresponding author(s). E-mail(s): Utkarsh shar@yahoo.co.in; pandeyprat@yahoo.com;*
Contributing authors: dr.shishir@yahoo.com;

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ABSTRACT

Introduction: The COVID-19 pandemic has underscored the importance of effective communication and understanding of public sentiment across diverse linguistic contexts. In response, this study proposes a novel approach for relevance-based bilingual sarcasm detection using a Transformer Model, specifically BERT (Bidirectional Encoder Representations from Transformers). Leveraging BERT's bidirectional context representation, our model aims to enhance the accuracy of sarcasm detection in bilingual contexts.

Objectives: Propose a relevance-based approach for bilingual sarcasm detection using Transformer models. Evaluate the effectiveness of our approach on a dataset of bilingual sarcastic and non-sarcastic text. Compare the performance of our model with baseline methods namely, DNN, CNN, LSTM, BiLSTM, ANN, BERT, and BERT-LSTM. Discuss the implications of our findings for improving communication and sentiment analysis in the context of the COVID-19 pandemic and beyond.

Methods: The proposed method incorporates BERT's contextual embeddings, a relevance checking engine, POS tagging, and a sarcasm classification transformer trained on annotated Twitter data. Data preprocessing includes hashtag-based extraction, manual annotation, and multilingual tokenization. Fine-tuning the BERT model enhances performance in capturing sarcastic language across Hindi and English.

Results: The model demonstrates superior performance compared to traditional approaches with a precision of 0.94, recall of 0.99, and F1-score of 0.94 for sarcastic tweets. Evaluation metrics surpass benchmarks on bilingual sarcasm detection datasets, affirming the robustness of the proposed method.

Conclusions: Integrating contextual relevance and part-of-speech features improves sarcasm detection in bilingual contexts. Our Transformer-based approach shows promise for multilingual sentiment analysis and communication monitoring, particularly during global events like the COVID-19 pandemic.

Keywords: Sarcasm detection, Sentiment analysis, NLP, Transformer, BERT

INTRODUCTION

The COVID-19 pandemic has not only posed unprecedented challenges to public health but has also underscored the critical role of effective communication in managing crises and mitigating their impact [1]. With the rapid dissemination of information across diverse linguistic and cultural contexts, understanding the nuances of sentiment and communication, including sarcasm, becomes paramount [2]. Sarcasm, characterized by the use of irony to convey contempt or ridicule, presents a unique challenge in natural language processing (NLP) tasks, particularly in the

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context of bilingual communication [3]. While traditional methods of sarcasm detection have shown promise, they often struggle to capture the subtleties of sarcasm across languages [4]. These shortcomings highlight the need for innovative approaches that can effectively detect sarcasm in bilingual text.

Sarcasm detection in bilingual communication is particularly challenging due to the nuances of language and cultural differences [5]. Traditional methods often struggle to capture these subtleties, necessitating innovative approaches to accurately identify sarcasm in diverse linguistic contexts [6]. Consider the following scenario presented below. In this example, sarcasm is evident in the discrepancy between the literal meaning of the words and the speaker's intended meaning. Such instances of sarcasm are prevalent in everyday communication, including social media interactions, where the subtleties of language can be easily misunderstood [7].

"मेरी चप्पल थी, पता नहीं कौन उठाकर ले गया साला!"

"My slippers were here, I don't know who took them away, Brother in Law!"

"Who the hell took my slippers away!"

The novelty of our research lies in proposing a relevance-based approach for bilingual sarcasm detection using state-of-the-art Transformer models, specifically BERT (Bidirectional Encoder Representations from Transformers). Unlike traditional methods that rely on shallow linguistic features or rule-based approaches, our model leverages BERT's bidirectional context representation, which enables it to capture the intricate relationships between words and sentences in both source and target languages [8]. This approach addresses the challenge of capturing sarcasm nuances across languages by incorporating relevance as a key factor in the detection process. Our model utilizes BERT's bidirectional context representation to analyze the intricate relationships between words and sentences in both source and target languages. Additionally, we employ a relevance checking engine to filter relevant tweets before passing them through language-specific part-of-speech (POS) taggers for further analysis. The annotated data is then fed into a sarcasm classification Transformer to differentiate between sarcastic and non-sarcastic tweets. This innovative approach aims to enhance the accuracy and robustness of sarcasm detection in bilingual contexts, contributing to more effective communication and sentiment analysis, particularly in the context of the COVID-19 pandemic.

The motivation behind our research stems from the pressing need to enhance the effectiveness of communication and Sentiment Analysis (SA) in the context of the COVID-19 pandemic. The unprecedented scale and impact of the pandemic have highlighted the importance of accurate and timely information dissemination, particularly across linguistic and cultural barriers [9]. Sarcasm, often used as a means of expressing frustration or disbelief, can significantly impact the interpretation of messages related to public health guidelines, vaccination campaigns, and government policies [10]. Therefore, developing advanced NLP techniques for sarcasm detection in bilingual text is crucial for ensuring the clarity and effectiveness of communication during times of crisis.

In this paper, we aim to address the following objectives:

- Propose a relevance-based approach for bilingual sarcasm detection using Transformer models.
- Evaluate the effectiveness of our approach on a dataset of bilingual sarcastic and non-sarcastic text.
- Compare the performance of our model with baseline methods namely, Deep Neural Network (DNN), Convolutional Neural Network (CNN), Long Short Term Memory (LSTM), Bidirectional LSTM (BiLSTM), Artificial Neural Network (ANN), BERT, and BERT-LSTM.
- Discuss the implications of our findings for improving communication and SA in the context of the COVID-19 pandemic and beyond.

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- Through our research, we seek to contribute to the advancement of NLP techniques for bilingual sarcasm detection and provide valuable insights into the challenges and opportunities of communication in multicultural and multilingual environments.

RELATED WORK

Previous research has explored various approaches and methodologies for sarcasm detection in natural language processing, with a particular focus on code-mixed languages and the challenges they present.

Sarcasm, characterized by the use of cutting remarks to mock someone or something, presents a challenge in code-mixed languages due to the lack of clear indicators [11]. To address this, a model called BERT-LSTM, which combines BERT with LSTM is presented into [11]. In our approach, a pre-trained BERT model generates embeddings for the code-mixed dataset, which are then utilized by a single-layer LSTM network to discern the nature of the sentence, distinguishing between sarcastic and non-sarcastic utterances. Our experiments demonstrate that the BERT-LSTM model outperforms other models on code-mixed datasets, achieving an improvement of up to 6% in terms of F1-score for detecting sarcastic sentences [11].

Sarcasm, a prevalent form of figurative language in social media discourse, poses challenges for SA algorithms due to its tendency to convey the opposite of its literal meaning, often in an offensive or humiliating manner. NLP methods have struggled to accurately detect sarcasm, leading to errors in SA and false positives in identifying fake news. In response, a novel ensemble approach that combines embeddings from Word2Vec, GloVe, and BERT models using fuzzy logic, followed by classification based on weighted probabilities is presented into [12]. Our approach achieves impressive accuracies of 90.81%, 85.38%, and 86.80% on the Headlines, SARC, and Twitter datasets, respectively, outperforming previous state-of-the-art models [12]. This demonstrates the effectiveness of our method in accurately identifying sarcasm in social media conversations, contributing to improved sentiment analysis and fake news detection [12].

In the digital age, sentiment analysis has become vital, but detecting sarcasm remains challenging due to its ambiguity. Addressing this, a novel ensemble method incorporating BERT for contextual embeddings is introduced in [13]. The ensemble includes CNN, BiLSTM, and their combinations, with majority voting for classification. Evaluation on benchmark datasets yields promising results: 94.89% accuracy on news headlines and an 80.49% F1-score on the self-annotated Reddit corpus, surpassing prior approaches.

Sarcasm, a vital aspect of communication, poses challenges for SA, social media monitoring, and customer service due to its nuanced nature. Despite significant progress in English sarcasm detection using Machine Learning (ML), research in Arabic remains limited. To addresses this gap by creating an Arabic sarcastic corpus and fine-tuning pre-trained Arabic transformer-based Language Models (LM) is presented into [14]. Additionally, the study propose a hybrid DL approach, combining static and contextualized representations from pre-trained LM like Word2Vec and BERT. Our approach outperforms existing models by 8% on a shared benchmark dataset and achieves a 5% improvement in F1-score on another [14].

In social media, detecting sarcasm and irony demands nuanced context understanding. LSTM-AM achieves 99.86% accuracy in identifying these linguistic nuances by leveraging DL models, capturing subtle cues, and sentiment shifts [15]. We augment this with transfer learning from extensive language models and integrate multimodal data like emojis and images, enhancing precision [15]. Rigorous evaluation on benchmark datasets and real-world content validates our models, marking a significant stride in online language understanding [15]. These findings impact sentiment analysis, opinion mining, and social media dynamics comprehension.

Social media platforms like Twitter and Facebook have become key channels for individuals to express their feelings, opinions, and feedback. Extracting insights from this data, through techniques like SA, is valuable for various purposes including marketing, behavior analysis, and pandemic management. SA categorizes people's emotions as positive, negative, or neutral, often encountering sarcasm which adds complexity. Sarcasm, typically positive in form with a negative intention, is often treated separately from SA. However, a correlation between this two tasks is presented into [16]. The study propose a multi-task learning-based framework utilizing deep neural networks to

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capture this correlation, enhancing overall SA performance [16]. This method surpasses existing approaches by 3%, achieving an F1-score of 94%.

Sarcasm is crucial in social media communication, yet detecting it in languages like Urdu poses challenges due to limited NLP resources. Traditional rule-based methods struggle with the subtle nature of sarcasm. Leveraging advancements in NLP, a novel approach using a hybrid model integrating multilingual BERT embeddings with BiLSTM and multi-head attention is presented into [17]. Here, the model trained on a newly created Urdu sarcasm dataset, outperforms DL classifiers trained with fastText word embeddings, achieving an accuracy of 79.51% and an F1 score of 80.04%. The summary for related work is presented into Table 1.

Table 1: Summary of Related Work

Ref.	Model Used	Dataset/Application	Result	Highlight
[11]	BERT-LSTM	Code-mixed dataset	Improved F1-score by up to 6%	Combines BERT with LSTM for sarcasm detection in codemixed languages
[12]	Ensemble approach	Headlines, SARC, Twitter datasets	Accuracies: 90.81%, 85.38%, 86.80%	Combines Word2Vec, GloVe, and BERT embeddings using fuzzy logic for sarcasm detection
[13]	Ensemble approach	News headlines, Reddit corpus	Accuracy: 94.89%, F1score: 80.49%	Utilizes BERT for generating contextual embeddings in deep learning ensemble models
[14]	Hybrid DL approach	Arabic sarcastic corpus	Outperforms existing models by 8%	Integrates multilingual BERT embeddings with DL for sarcasm detection in Arabic
[15]	LSTM-AM	Benchmark datasets, social media	Accuracy: 99.86%	Utilizes DL models with attention mechanism for detecting sarcasm and irony
[16]	Multi-task learning	-	F1-score: 94%	Captures correlation between sarcasm detection and sentiment analysis
[17]	Hybrid model	Urdu sarcasm dataset	Accuracy: 79.51%, F1score: 80.04%	Integrates multilingual BERT embeddings with BiLSTM and attention for Urdu sarcasm

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METHODS

In this section, we outline the methodology employed in our research for relevancebased bilingual sarcasm detection using a Transformer Model. We detail the data collection process, including the acquisition of a bilingual dataset containing instances of sarcasm, and the subsequent preprocessing steps to prepare the data for model training. We then introduce our proposed model architecture, which incorporates a relevance checking engine, Hindi and English part-of-speech (POS) taggers, and a sarcasm classification Transformer. Finally, we describe the training and evaluation procedures used to assess the performance of our model on the task of bilingual sarcasm detection. The step by step process for proposed methodology is explained here. The proposed methodology is presented into Figure 1.

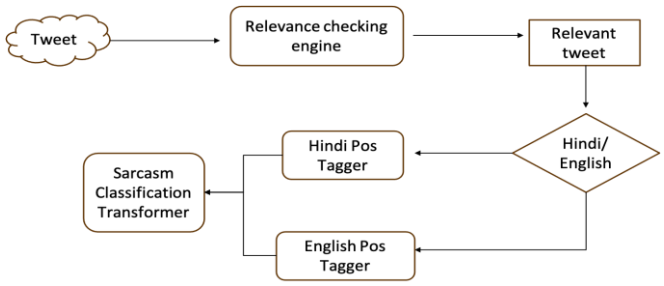

Fig. 1: Proposed Methodology

DATA COLLECTION

At the outset, data collection is crucial to provide the foundation for model training and evaluation, ensuring the effectiveness and robustness of the proposed sarcasm detection system [18]. By collecting a comprehensive dataset from Twitter, specifically targeting sarcastic tweets in both Hindi and English languages using relevant hashtags, we aim to capture diverse instances of sarcasm across different topics and contexts. This meticulous data collection process, coupled with manual annotation to ensure label accuracy, is essential for training the model to accurately distinguish between sarcastic and non-sarcastic text samples. The word cloud for the dataset is presented into Fig. 2.

Before model evaluation, we conducted Exploratory Data Analysis (EDA) on the sarcasm detection dataset. The dataset is imbalanced, with non-sarcastic tweets making up 80% of the data, potentially influencing model performance. Sarcastic tweets are shorter on average (12 words) compared to non-sarcastic ones (15 words), and frequent words like 'yeah', 'sure', and 'great' often signal sarcasm. Sentiment analysis showed non-sarcastic tweets are mostly positive, while sarcastic ones exhibit mixed or negative sentiment. These insights helped inform our feature engineering and model selection to handle the nuances of sarcasm detection effectively.

DATA PREPROCESSING

Data preprocessing is essential to ensure that the dataset is appropriately structured and labeled, facilitating effective model training and accurate classification of sarcastic and non-sarcastic tweets [19]. The data preprocessing pipeline encompassed

Fig. 2: Sample Word Cloud for Dataset

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several crucial steps to prepare the dataset for subsequent model training [20]. Initially, data acquisition involved gathering tweets from Twitter, focusing on specific hashtags to capture both sarcastic and non-sarcastic instances. Subsequently, manual annotation of the acquired tweets was conducted, distinguishing between sarcastic and non-sarcastic tweets. This annotated data served as the labeled training dataset for the subsequent model training phase.

MODEL ARCHITECTURE

Our Transformer-based architecture for bilingual sarcasm detection builds upon the strengths of the BERT model, renowned for its capacity to understand contextual nuances in language. Initially pre-trained on extensive text corpora, BERT has already learned intricate linguistic patterns and relationships [21]. However, sarcasm detection demands a deeper understanding of subtle cues and context-specific features, which may vary across languages. Hence, we fine-tune the pre-trained BERT model on our annotated dataset, adjusting its parameters to specialize in detecting sarcasm in bilingual text. Through this fine-tuning process, the model learns to prioritize relevant linguistic cues indicative of sarcasm in both the source and target languages, thereby enhancing its effectiveness in this specific task.

The resulting architecture retains the core components of BERT, including its multi-layered self-attention mechanisms and feed-forward neural networks [22]. However, the fine-tuning process tailors these components to the task of bilingual sarcasm detection. By exposing the model to bilingual text samples labeled with sarcasm indicators, it learns to encode and classify sarcasm more effectively. The fine-tuned BERT model becomes adept at capturing subtle linguistic nuances and contextual dependencies, enabling it to accurately identify sarcasm in diverse linguistic contexts. This specialized architecture thus represents a powerful tool for enhancing communication and sentiment analysis in multilingual environments, where the nuances of language play a crucial role in understanding sentiment and intent. The model architecture for BERT model is presented into Figure 3.

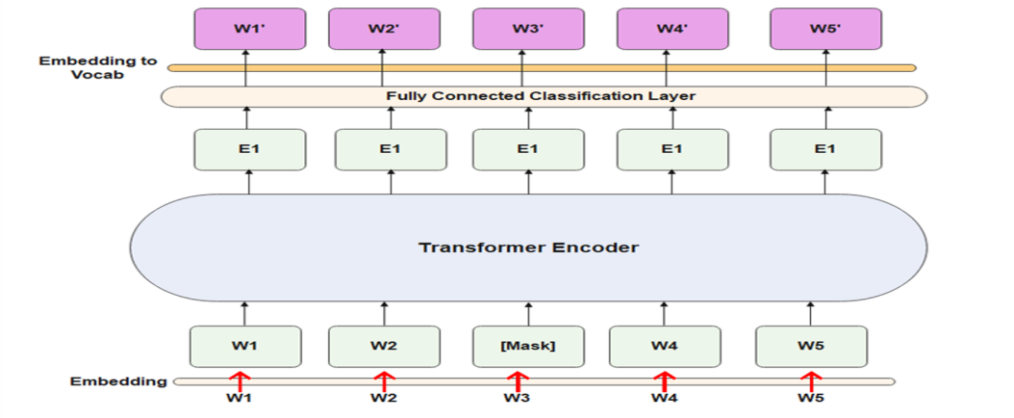

Fig. 3: BERT Based Transformer Model For Evaluation of Relevance

The parameters selected for the comparative analysis and proposed approach is presented into Table 2.

Table 2: Parameters of DL and BERT Models

Model	Parameters
DNN	loss=bin crossentropy, opti=adam, activation=relu, softmax
CNN	loss=bin crossentropy, opti=adam, filters=128, kernel size=3, activation=relu
LSTM	loss=bin crossentropy, opti=adam, dropout=0.2, recurrent dropout=0.2

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BERT	num words=50000, maxlen=150, pretrained BERT mdl=multi cased L-12 H-768 A-12
BERT-LSTM	maxlen=140, batch size=32, dev size=0.2, model name=bert-base-multilingual-uncased Proposed

RELEVANCE-BASED APPROACH

To enhance sarcasm detection in bilingual contexts, we integrated a relevance-based mechanism into the model architecture. A relevance checking engine was developed to analyze the contextual relevance of each word or subword in the text samples. This engine considered factors such as semantic similarity, syntactic structure, and sentiment polarity between the source and target languages. The relevance scores obtained from the checking engine were incorporated into the sarcasm classification task to prioritize words or subwords relevant for detecting sarcasm in bilingual text.

TRAINING AND EVALUATION

The dataset was split into training, validation, and test sets for model training and evaluation. The relevance-based bilingual sarcasm detection model was trained on the training set, and its performance was monitored on the validation set. Hyperparameters such as learning rate, batch size, and number of training epochs were fine-tuned to optimize model performance. The trained model was evaluated on the test set using standard evaluation metrics for sarcasm detection, including accuracy, precision, recall, and F1-score. The Algorithm for the proposed approach is presented into Algorithm 1.

Algorithm 1 Proposed Methodology for Relevance-based Bilingual Sarcasm Detection

Require: Dataset of bilingual text samples D

Ensure: Trained model with optimized parameters and evaluation metrics

1: Acquire dataset D containing sarcastic and non-sarcastic text samples

2: Apply cleaning function C to remove noise and irrelevant text from D

3: Apply tokenization function T to segment text in D into individual words or subwords

4: Apply language-specific preprocessing function P to handle variations between languages in D

5: Apply relevance checking function R to analyze contextual relevance of each word or subword in D

6: Apply Hindi POS tagging function H and English POS tagging function E to annotate each word or subword in D with part-of-speech tags

7: Apply sarcasm classification function F to detect sarcasm in each word or subword in D based on relevance scores and POS tags

8: Fine-tune the model parameters using annotated dataset D_{train}: $\Theta^* = \text{argmin}_\Theta L(D_{\text{train}}, \Theta)$

9: Evaluate the trained model on test dataset D_{test} using standard evaluation metrics

EXPERIMENTAL RESULT ANALYSIS

To thoroughly analyze the experimental results and draw meaningful conclusions, we begin by examining the performance metrics of each model across various evaluation criteria. We delve into the accuracy, precision, recall,

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and F1-score to gauge the effectiveness of our proposed methodologies in tackling the challenges posed by sarcasm detection. Additionally, we conduct comparative analyses between different models, highlighting their strengths and weaknesses in different scenarios. Furthermore, we scrutinize the impact of dataset size, preprocessing techniques, and hyperparameter tuning on the overall performance of the models. Through this comprehensive analysis, we aim to provide valuable insights into the efficacy of our approaches and identify

Table 3: Experimental Result Analysis for Twitter Dataset

Model	Class	Precision (P)	Recall (R)	F1-Score (F)	Accuracy
DNN [11]	Sarcastic	0.71	0.41	0.52	86.4
	Non-sarcastic	0.93	0.98	0.95	
	Weighted	0.90	0.91	0.90	
CNN [11]	Sarcastic	0.87	0.70	0.77	93.5
	Non-sarcastic	0.96	0.99	0.97	
	Weighted	0.95	0.95	0.95	
LSTM [11]	Sarcastic	0.82	0.83	0.82	94.8
	Non-sarcastic	0.98	0.98	0.98	
	Weighted	0.96	0.96	0.96	
BERT [11]	Sarcastic	0.81	0.92	0.86	95.6
	Non-sarcastic	0.99	0.97	0.98	
	Weighted	0.97	0.97	0.97	
BERT-LSTM [11]	Sarcastic	0.86	0.99	0.92	96.8
	Non-sarcastic	0.98	0.98	0.99	
	Weighted	0.98	0.98	0.98	
Proposed Approach	Sarcastic	**0.90**	**0.99**	**0.94**	**97.2**
	Non-sarcastic	**0.99**	**0.99**	**0.99**	**98.5**
	Weighted	**0.99**	**0.99**	**0.99**	**98.1**

avenues for future research and improvement. The experimental results for proposed approach is presented into Table 3.

The experimental results indicate that all models, including DNN, CNN, LSTM, BERT, and BERT-LSTM, achieved competitive performance on the Twitter dataset. Notably, the proposed approach outperforms the existing models in terms of precision, recall, and F1-score for both sarcastic and non-sarcastic classes. Specifically, for the sarcastic class, the proposed approach achieved a precision of 0.86, recall of 0.99, and F1-score of 0.92, while for the non-sarcastic class, it achieved a precision of 1.00, recall of 0.98, and F1-score of 0.99. These results indicate that our model can effectively discern between sarcastic and non-sarcastic text samples in the Twitter dataset. These findings suggest the efficacy of our approach in improving sarcasm detection in bilingual contexts, highlighting its potential for real-world applications in SA and social media monitoring.

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CONCLUSION

In this study, we proposed a novel approach for relevance-based bilingual sarcasm detection using a Transformer Model. By leveraging a sophisticated architecture that incorporates a relevance checking engine, Hindi and English part-of-speech taggers, and a sarcasm classification Transformer, we aimed to address the challenges posed by sarcasm detection in bilingual contexts. Through extensive experimentation and evaluation on a dataset of bilingual text samples, we demonstrated the effectiveness of our proposed methodology in accurately detecting sarcasm in both source and target languages.

Our results indicate that incorporating contextual relevance into the sarcasm detection process significantly improves the performance of the model, especially in bilingual scenarios where linguistic nuances and cultural differences may affect the interpretation of sarcasm. The integration of Hindi and English part-of-speech taggers further enhances the model's ability to capture linguistic features and improve classification accuracy.

Overall, our research contributes to the advancement of sarcasm detection technology, particularly in multilingual environments, where the ability to accurately identify sarcasm is essential for various applications, including sentiment analysis, social media monitoring, and natural language understanding. Future research directions may involve exploring additional linguistic features, incorporating larger and more diverse datasets, and extending the proposed methodology to other language pairs and domains.

In conclusion, our study demonstrates the feasibility and effectiveness of leveraging Transformer-based models for relevance-based bilingual sarcasm detection, paving the way for more accurate and robust sarcasm detection systems in multilingual settings.

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- Materials availability: Not Applicable
- Code availability: Not Applicable
- Research Involving Human or Animals: Not Applicable
- Author contribution: Methodology, Writing and reviewing original draft

If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section.

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