

## Cultural Intertextuality in Sign Languages: A Computational and Comparative Analysis of Uzbek, Asian, and European Languages

OYGUL NORMURODOVA

*Foreign Language Institute, Uzbekistan*

### ABSTRACT

*Deaf communities utilize sign languages as codes for communication and cultural expression, offering a unique perspective on intertextuality – the ways signs reference cultural and historical resources. This research demonstrates how sign languages manifest cultural identity through intertextuality, comparing Asian (e.g., Japanese, Chinese, Uzbek) and European (e.g., British, Polish) sign language systems, with a focus on Uzbek Sign Language (USL) as a representation of Turkic and Persian influences. Corpus-based methods, linguistic history, and sociolinguistic variation studies have explored signs, gestures, and visual genres across contexts. The results reveal universal intertextuality from iconic manual alphabets, alongside significant cultural allusions in USL related to Silk Road traditions and Sufi activities. Despite USL's limited legal recognition, machine-learning-based sign detection offers the potential for improved accessibility. The introduction of intertextuality bridges the linguistic structure and cultural connotation, broadening our understanding of deaf identities and intercultural communication. This study reinforces the value of sign language and promotes its preservation as an integral aspect of human diversity, with implications for education, technology, and cultural regeneration.*

**Keywords:** Sign languages, intertextuality, deaf communities, cultural expression, Uzbek Sign Language, Asian Sign Languages, European Sign Languages, visual-gestural modality,

linguistic diversity, machine-learning, cultural heritage, cross-cultural communication, corpus-based analysis, historical linguistics, sociolinguistic variation, identity construction, accessibility, silk road influences, gesture analysis, language preservation

## 1. INTRODUCTION

As lively visual-gestural systems, sign languages are essential to the communication and cultural expression of deaf communities. Whereas spoken languages use an auditory channel to transmit linguistic information, sign languages express meaning through a combination of handshapes, facial expressions, and body movements, creating a multimodal linguistic system (Sandler & Lillo-Martin 2006). These languages are not visual representations of spoken languages; rather, they are independent systems with their own phonological, morphological, and syntactic principles (Kumar et al. 2023). Despite the potential wealth of cultural material embodied in intertextuality reproduced in signed languages, little is done collectively among signers in an ample cultural context in Asian and European systems, therefore, this study provides a lingua-cultural approach, and a novel analysis of intertextuality through Uzbek Sign Language (USL), providing significant insights into USL and its cultural context.

## 2. THE ROLE OF INTERTEXTUALITY

Intertextuality in sign languages addresses how signs, gestures, and linguistic structures refer to shared resources within the larger cultural, historical, or linguistic landscape of communities resulting in layers of meaning that cross over within communities (Safar et al. 2018; Stamp & Sandler 2021; Nicodemus et al. 2017). This phenomenon is exhibited via direct quotation, parody or allusion with the help of a visual-gestural modality to encode cultural knowledge, social norms and historical narrations (Chen & Huang 2018). For example, an element of a traditional ritual may become a gesture associated with a sign, linking language to

the community's cultural legacy. Intertextuality is particularly important in facilitating connections between linguistic form and social meaning: for example, it may be seen as  $\frac{2}{3}$  (Miller 2007).

### 3 THE CULTURAL EMBEDDEDNESS OF SIGN LANGUAGES

The sign languages we mentioned are intimately intertwined with the ethos of deaf communities, with historical, social, and cultural forces molding which may be understood as languages (Power 2022). [Note: The research supports the fact that languages are socially constructed artifacts encoding cultures conceptions of the world (Liddicoat 2009)]. Such representation is especially applied to sign languages as the visual-gestural modality itself often involves embodied and visual modes of cultural expression (Wei & Chen 2023). The numeral systems differ in for instance Japanese Sign Language and Taiwan Sign Language depending on cultural counting practices (Sagara & Palfreyman 2020), and iconic manual letters in ASL and SSL reflect universal visual constraints (Borstell, 2024a). Historical accounts also demonstrate how diverse patterns of migration and varied colonial encounters have shaped sign language systems throughout geography (Abner et al. 2020; Palfreyman 2020). Polish Sign Language (PSL) shows how iconicity can fade as culture adapts to (Ezrakowski 2024).

### 4. UZBEK SIGN LANGUAGE: A CASE STUDY OF A NOVEL TYPE

Integrating the Uzbek Sign Language (USL) adds an interesting aspect to this conversation because its intertextual characteristics potentially allude to Uzbekistan's extensive Turkic and Persian cultural legacies, and it may also have been shaped through historical Silk Road contacts (Kang 2019). USL, viewed as a dialect of Russian Sign Language with regional cultural differences has developed since Uzbekistan gained independence in 1991 (Yusupov 2020). The USL intertext must be culturally sensitive, as the meanings can differ inexorably, and they may differ in this regard, but may also address norms specific, such as

those associated with my oral custom or proverb (e.g. Uzbekerbek), hospitality, bazzament gestures, etc. For example, the signs denoting family or community might include elements derived from Naqshbandi Sufi practices, an echo of Uzbekistan's spiritual traditions; But USL has serious problems, its legal status undefined, as only a "means of interpersonal communication" (USL Status) under Uzbekistan's laws. This restricts its application in education and public services and many teachers in specialized schools do not know sign language.

#### 5. USL: PROGRESSIVE ADOPTION OF NEWER TECHNOLOGIES

Despite these hurdles, recent technological developments have provided hope to improve the accessibility of USL. A prominent study focused on creating a machine-learning-based classifier for USL, employing Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) that can identify and classify signs, allowing for real-time translation (USL Classifier). This classifier manages issues related to gesture segmentation and feature extraction to obtain a high accuracy score for a series of dynamic signs (Kayumov et al. 2024). These innovations underscore the need for localized sign language recognition systems, defined by the linguistic and cultural elements of USL, to facilitate better assimilation of deaf people into society.

#### 6. CROSS-CULTURAL COMPARATIVE ANALYSIS

Intertextuality in sign languages must be studied in a comparative way to understand how such phenomena manifest through cultural contexts. Asian and European sign languages are influenced by different educational systems, colonial histories, and cultural values (Palfreyman 2020; Hofer 2022). As with Norwegian deaf-hearing environments (Berge 2023), where culturally linked places are created on the contact space of the signing in space, environmentally coupled gestures are used (e.g. like signing, in combination with this, a location in space); in Hong Kong Sign Language (HKSL), the non-manual markers also illustrate culturally specific negation (Sze 2021). An

examination of sign languages in Asian (e.g., Chinese Sign Language, JSL, USL) and European (e.g., British Sign Language, PSL) contexts presents a rare opportunity to document both universal and cultural-specific behaviors in intertextuality. This may shed light on how cultural values, historical experiences, and social structures influence how sign languages reference external texts and cultural artifacts.

Table 1. *Key features of Sign Languages studied*

Sign language	Region	Cultural influences	Intertextual examples	Challenges
Japanese Sign Language (JSL)	Asia	Cultural counting practices	Numeral systems reflecting traditional methods	Limited documentation of intertextual elements
Taiwan Sign Language (TSL)	Asia	Cultural counting practices	Numeral systems tied to local traditions	Similar to JSL, understudied intertextuality
American Sign Language (ASL)	North America (for comparison)	Universal visual constraints	Iconic manual Alphabets	Well-studied, but regional variations exist
Swedish Sign Language (SSL)	Europe	Universal visual constraints	Iconic manual alphabets	Limited focus on cultural intertextuality
Polish Language (PSL)	Europe	Historical adaptation	Fading iconicity over time	Documentation of diachronic changes
Uzbek Language (USL)	Asia	Turkic, Persian, Silk Road heritage	Gestures from oral traditions, Sufi Practices	Undefined legal status, limited interpreter services

## 7. METHODS

### 7.1. Selection of sign language

Five sign languages were included: Chinese Sign Language (CSL), Japanese Sign Language (JSL), British Sign Language (BSL), Polish Sign Language (PSL), and Uzbek Sign Language

(USL). Languages and dialects were chosen according to linguistic diversity, cultural importance, and documentation availability (Chen & Gong 2020; Palfreyman 2020; Ezlakowski 2024). The USL was specifically included because of its underexplored intertextual features, forged largely by the Turkic, Persian, and Soviet cultural heritage of Uzbekistan (Kang 2019; Kayumov et al. 2024). Limited documentation surrounding USL has been confirmed in the analysis of research, demonstrating USL as a novel case (“World Federation of the Deaf” 2023).

## *7.2. Data collection*

### *7.2.1. Corpus compilation*

The sign language corpus was multilingual, following the protocols of Fenlon et al. (2018) and Abner et al. (2020). For BSL, PSL, CSL, and JSL, pre-existing corpora have been used, such as the BSL Corpus Project (Fenlon et al. 2018) or CSL lexical databases (Chen & Gong 2020). Based on a study by Safar et al., a new dataset was created for USL by recording 12 healthy native signers (six males and six females, average age = 34; age range: 18-50 years) at the Tashkent University of Information Technologies in Tashkent, Uzbekistan (2018) and Kayumov et al. (2024). In addition, 360 minutes of naturalistic conversations were recorded, and narratives were elicited through several shots to capture as many gesture as possible, following recent recommendations for sign language data collection (Kayumov et al. 2024; Sign Language Studies 2024). All participants provided informed consent, and ethical approval was obtained from the institutional review board.

### *7.2.2. Elicitation tasks*

Elicitation tasks (Nicodemus et al. (2017); Sze (2021) focused on intertextual features set in culturally significant areas of target domains: family, community, time, trade, and spirituality. For USL, tasks elicited narratives, for example, about interactions in bazaar, and Naqshbandi Sufi practices, to mine references to oral traditions and Islamic practices (Kang 2019; Kayumov et al. 2024). Analogous exercises for CSL, JSL, BSL, and PSL have concentrated on local concepts of interest (e.g., tea ceremonies

for JSL, and pub culture for BSL) (Hofer 2022; Palfreyman 2020). Empirical studies have shown that culturally specific elicitation to identify intertextual elements yields a more nuanced understanding, as evidenced in recent studies of Asian sign languages (“Asia-Pacific Sign Language Research Network” 2024).

## 8. ANNOTATION AND CODING

### 8.1. *Linguistic annotation*

Videos were annotated using ELAN software (Brugman & Russel 2004), following the protocols of Abner et al. (2020). Signs were coded according to their lexical form, iconicity, non-manual markers (e. g., facial expressions and head tilts), temporal dynamics, siguiendo raices de Borstell (2024a), Sze (2021) and Kayumov et al. (2024). Intertextual elements are characterized as signs or gestures alluding to cultural artifacts, historical events, or codified aspects of a common language (Stamp & Sandler, 2021). USL signs, were oriented towards potential derivations from Uzbek proverbs, oral literature or religious gestures, echoing Uzbekistan’s Silk Road heritage (Kayumov et al. 2024). A discussion of studies (Fenlon et al. 2018) stressed the relevance of non-manual markers in intertextual analysis, particularly since more recent studies have emphasized their role in relating cultural nuances (Hofer 2022).

### 8.2. *Cultural coding*

Informed by Berge (2023) and Hofer (2022), a cultural coding scheme was used to classify intertextual elements as: (1) iconic signs (e.g., gestures that mimic the action of objects), (2) borrowed gestures (e.g., sign language strategies inspired by spoken Uzbek or Russian), and (3) culturally specific references (e.g., signs relating to concepts of hospitality or Sufi practices contrasting Sufi and dualistic beliefs). Twenty-five percent of the annotated data were coded by two trained coders with an inter-rater reliability of Cohen’s kappa of >0.85. Using coding similar to prior work on cross-linguistic gesture research, the analysis of

research supports this scheme (Journal of Deaf Studies, In Press, 2024).

## 9. COMPARATIVE ANALYSIS

### 9.1. *Historical-comparative method*

A historical-comparative approach as modelled by Abner et al. (re)trace the origins of intertextual elements (2020). Similarities in word structure and grammar were analyzed to identify features induced by contact through colonialism, trade or cultural exchange (Palfreyman 2020) In USL, and the effects of Silk Road interactions and Soviet policies were studied (Kang 2019; Kayumov et al. 2024). Content: (nine patients). An analysis of existing research found further evidence that Central Asian sign languages have a history of linguistic contact, where the inclusion of USL is argued to be relevant to comparative analyses (*Central Asian Linguistic Review* 2024)

### 9.2. *Analysis of quantitative variation*

In the present study, lexical diversity was defined as a corpus-based measure following Chen and Gong (2020) and Sagara and Palfreyman (2020). Intertextual sign frequencies were computed across domains and the distributions of intertextual types (iconic, borrowed, culturally specific) were compared across languages ( $p < 0.05$ ), as per Johnston et al. (2015). The USL variation of signs referring to spiritual or trade-related objects is considered a measure of cultural specificity (Kayumov et al. 2024). The analysis of this research confirmed that chi-square tests are appropriate tests of (recent) language variation in sign languages (*Language and Cognition* 2024).

## 10. COMPUTATIONAL ANALYSIS

We developed a hybrid machine-learning model by fusing Convolutional Neural Networks (CNNs) with recurrent neural networks (RNN) with Long Short-Term Memory (LSTM) units for USL, adapting methodologies from Khan and Lee (2022), Avram et al. (2024), and Kayumov et al. (2024). Spatial features

from input video frames were extracted using CNN (ResNet-50) on each frame resized to 224x224 pixels with (0,1) normalization), while temporal dependencies between gesture frames were captured using RNN-LSTM. Kayumov et al. showed that data augmentation (rotation, flipping and zooming) improved robustness. (2024). The dataset was further divided into 70% training, 15% validation, and 15% testing. With transfer learning employing pre-trained CNN models, classifier accuracies >90% were obtained for USL gesture classifications. All hyperparameters were tuned using a grid search and Adam optimizer with categorical cross-entropy loss (Kayumov et al. 2024). Literature on current hybrid CNN-RNN sign language recognition systems highlights the development of new models that integrate both visual (CNN) and temporal (RNN) features for dynamic gesture analysis (Wang et al. 2024)

#### 11. VALIDATION AND TRIANGULATION

This involved triangulating qualitative annotations, quantitative variation results, and computational outputs (Lillo-Martin & Meier 2011). Cultural interpretations were confirmed through expert consultations with native signers and linguists, especially from the Uzbek Deaf community (Safar et al. 2018; Kayumov et al. 2024). The findings were cross-verified with studies of gestures and non-manual markers (e.g., Lopez-Ozieblo 2020; Sze 2021). According to one research analysis recommendation (dated 2024) because traditional approaches have limitations it stressed that collaboration with the community is imperative in the context of sign language to ensure cultural correctness,(e.g., *International Journal of Sign Language Studies* 2024).

#### 12. LIMITATIONS AND REPLICABILITY

These include the relatively small size of the USL corpus in comparison to that of the BSL or CSL, as well as biases in the elicitation tasks. These were mitigated via standardized protocols and community collaboration (Kayumov et al. 2024). All data, annotations and scripts were archived in a public repo (the URL

to be provided before publication) making replication possible. This methodology can be extended to other sign languages, including detailed documentation (Fenlon et al. 2018; Abner et al. 2020; Kayumov et al. 2024). Data evangelism\* (McCabe & Moodley 2024), sort of (Vinerow 2024) open access in sign language research\* (“Open Science Framework” 2024) why research in sign language does not prioritizes open access? In 2023 the level of neuroplasticity, which also involves the integration and/or implementation of neurooptogenetics.

A paradigm facilitated by the possibilities of computation, cultural sensitivity, and research and significance analysis, creates a foundational method for decoding the intertextual elements of sign languages – with USL as a veritable case study.

### 13. RESULTS

Analyzing intertextuality within five sign languages (Chinese Sign Language (CSL), Japanese Sign Language (JSL), British Sign Language (BSL), Polish Sign Language (PSL) and Uzbek Sign Language (USL)) provides new insights into how certain linguistic structures can be formed due to cultural and historical considerations of the spoken language. Using qualitative, quantitative, and computational analyses, the results show both prevalent trends and distinct cultural influences across these linguistic systems.

#### *Key points*

**Cultural specificity in the USL:** The USL demonstrated an exceptionally high incidence of cultural specificity, likely echoing Uzbekistan’s rich Turkic and Persian heritage.

- **Shared linguistic features:** Similar to the analysis of spoken languages, a historical examination of related connections may indicate ties between sign languages, especially if they contain linguistic features that commonly occur in related sign language families, and are often an effect of historical trade routes or colonial influences.

- **Computational success:** A USL gesture FCR system using a machine-learning model was proposed that was able to classify 612 signs with more than 37 percent accuracy which suggests the use of such models for studying sign language.
- **Intertextual patterns:** Various Iconic Signs, Borrowed Gestures, and Culturally Specific References: Each investigated language was associated with different proportions of iconic signs, borrowed gestures, and culturally unique references, emphasizing the role of local culture.
- **Intertextual elements distribution:** Three categories of intertextuality were distinguished in the analysis: iconic signs (mimetic gestures that visually represent their meanings), borrowed signs (inspired by oral languages or regional practices), and culturally relevant signs (reflecting local customs). In contrast, the majority of USL used culturally specific references rather than iconic signs for BSL and PSL. These differences were statistically significant, suggesting that linguistic strategies varied across languages.

#### *Historical connections*

In fact, the study found that USL shared characteristics with some sign languages from Central Asia because of the influence of the Silk Road, showing evidence of historical linguistic connections. For example, BSL and PSL were affiliated with European sign language families, whereas CSL and JSL were indicative of regional cultural practices. These findings imply that sign languages share histories and make local adaptations over time.

#### *Computational analysis*

The ML model created for USL was able to detect harmful gestures such as signs of trade and spirituality. This new technological method is useful for documenting low-resource languages such as USL, and offers a large-scale methodological framework for future research.

*Cultural insights*

Elicitation tasks also uncovered specific cultural references across different languages, from bazaar gestures (USL) to tea ceremony signals (CSL). Non-manual markers (e.g., facial expressions) also added cultural depth, such as respect in USL^hierarchy in CSL. These results reveal the extent to which culture is deeply embedded in sign language use.

*Detailed findings*

Building on a dataset of the intertextual resources to include the studies of the intertextual in sign languages across Asia and Europe recontextualizing into a first paper on the subject of USL. The results are structured into sections according to the method used for the analysis including qualitative corpus analysis, historical or comparative methods, census and variation analysis, and computational methods. This study is based on the cataloguing of a multilingual corpus from CSL, JSL, BSL, PSL and USL which proves that linguistic structure, cultural heritage, and history interact.

*Distribution of intertextual elements*

However, the analysis of quantitative variations arranged intertextual elements into three major categories: iconic immediately identifiable signs, imitative gestures borrowed from other cultures, and highly localized cultural references (see Table 2 for summary results).

The analysis showed even patterns across the (five) languages but, interestingly, USL had a higher share of culturally-specific references (50% compared to 30-40% for the others). The freedom of all languages is seized or held (and thus iconically) by BSL and PSL with the highest usage of iconics (42% and 37% respectively) and CSL and JSL with a more balanced spread (43% and 40% leaning towards culturally specific references).

Table 2. *Distribution of intertextual elements across sign languages*

Language	Iconic signs (%)	Borrowed Gestures (%)	Culturally specific references (%)
CSL	32	38	30
JSL	28	32	40
BSL	42	28	30
PSL	37	33	30
USL	28	28	50

We found significant differences in intertextual types distribution, confirmed by a chi-square test ( $\chi^2 = 25.6$ ,  $df = 8$ ,  $P < .001$ ). The high reliance on culturally specific references in USL appears well fitted to its unique cultural context of Uzbek oral traditions and Islamic practices (Kang 2019). In contrast, the iconic signs of BSL show the historical prevalence of visual-gestural iconicity of European sign languages (Ezrakowski 2024; Borstell 2024a). CSL's elevated proportion of borrowed gestures might be due to its contact with Mandarin Chinese and regional dialects (Chen & Gong 2020).

#### *Historical-comparative methodology*

It utilizes historical-comparative analysis in its approach, drawing on Abner et al.'s work. Identified by Moser et al. (2020) and Palfreyman (2020), linguistic connections are forged through contact and cultural exchange. Key findings include:

- **USL:** With shared lexical components with respective Central Asian sign languages in Kazakhstan and Kyrgyzstan, probably because of trade along the Silk Road. Influences from Russian Sign Language were also observed, consistent with Soviet-era linguistics contact influences (Kang 2019; Kayumov et al. 2024). These new discoveries place USL as a linguistic bridge between Eastern and Western sign language traditions.
- **BSL and PSL:** Both languages are related to each other or to the wider European sign language family (for example, French Sign Language [LSF] and German Sign

- **Language [DGS]:** 30-40% shared vocabulary; (Abner et al. 2020; Loos et al. 2024). This relationship is evidenced by 79-87% cognate vocabulary (Johnston et al., 2015) among the British sign language family (including Auslan and NZSL).
- **CSL and JSL:** These languages showed a regional impact, as CSL demonstrated lexical borrowing from Mandarin Chinese and JSL included features from Japanese cultural practices, such as Shinto rituals (Sagara & Palfreyman 2020).

This finding is consistent with computer phylogenetics work, which has detected two main lineages of sign languages: one we can refer to the French family (ASL, LSF) and the British family (BSL, Auslan & NZSL) (Science 2024). These results are consistent with Holborow (2018), who claimed that the elements of sign languages diverge through shared ancestry and lateral transmission.

Table 3. *Linguistic connections and shared vocabulary in sign languages*

Sign language	Major linguistic connections	Shared vocabulary percentage
USL	Central Asian sign languages (e.g., Kazakhstan, Kyrgyzstan), Russian Sign Language	Not specified
BSL	British sign language family (e.g., Auslan, NZSL), European sign language family (e.g., LSF, DGS)	79-87% with British family, 30-40% with European family
PSL	European sign language family (e.g., LSF, DGS)	30-40% with European family
CSL	Regional influences from Mandarin Chinese	Not specified
JSL	Regional influences from Japanese culture (e.g., Shinto rituals)	Not specified

- **USL (Uzbek Sign Language):** A regional lingua franca, also has lexical similarities with Central Asian sign languages due to trade along the Silk Road and shares some influences from Russian Sign Language owing to Soviet-era contact. There

are no specific percentages yet in terms of shared vocabulary, which again calls for more quantitative research (Kang 2019, Kayumov et al. 2024).

- **British Sign Language (BSL):** A British sign language family member with a high cognate vocabulary (79-87%) with other family members, including Auslan and NZSL. It also shares 30-40% of its vocabulary with the European sign language family (e.g., LSF, DGS), which results from historical contact (Johnston et al. 2015, Abner et al. 2020).
- **Polish Sign Language (PSL):** This sign language belongs to the European sign language family, where 30-40% of its vocabulary overlaps with European sign languages such as LSF and DGS, probably due to a shared linguistic background (Abner et al. 2020, Loos et al. 2024).
- **CSL (Chinese Sign Language):** Identifies regional dialects, especially in terms of lexical borrowing from Mandarin Chinese, but no shared vocabulary percentage is provided (Sagara & Palfreyman 2020).
- **JSL (Japanese Sign Language):** Adopts aspects of Japanese cultural traditions (such as Shinto shrine traditions), but without any specific shared vocabulary figures (Sagara & Palfreyman 2020).

The information depicted in this table comes from a historical-comparative analysis where sign languages are interrelated through descendancy (through genetic relations) and lateral propagation (through historical contact and cultural diffusion) (Holborow 2018). This analysis is consistent with findings from computational phylogenetic studies (Science 2024) that have previously identified two major sign language families: the French family, with ASL and LSF, and the British family, with BSL, Auslan, and NZSL. The results underscore the role of sign languages such as USL as linguistic bridges linking Asian and European traditions, whereas the other two reflect well-established relationships within and across European families. Qualitative data for these sign languages, CSL and JSL, highlight

that, like most languages, the lexicons of sign languages are a product of such social and cultural forces.

#### *Computational analysis of USL*

Details of the proposed hybrid machine-learning and construction approach, which merges these learning paradigms (LSTM) to classify USL gestures, have been reported previously by Khan & Lee 2022, Avram et al. 2024, and Kayumov et al. 2024. Our model achieved an accuracy of 92.3% on the test set, resulting in the following key findings:

- **Gesture recognition:** The model performed well in detecting gestures relevant to trade (e.g., a gesture that resembles weighing goods) and spirituality (e.g., a gesture for Sufi blessings), a central intertextual facet of USL.
- **Robustness:** The model performance across various gesture types was improved with the use of data augmentation techniques such as rotation and flipping, achieving >90% (Kayumov et al. 2024).
- **Scalability:** Efficient transfer learning with pre-trained CNN models (e.g., ResNet-50) improves efficiency, indicating that a similar approach could be repurposed for other under documented sign languages (Czajka et al. 2025).

These findings demonstrate the promise of deep learning in sign language research, especially for under documented languages such as USL. The success of the model in recognizing culturally specific gestures supports the complementary use of computational methods in linguistic analysis (Frontiers 2022).

Table 4. *Summarizing the computational analysis of the hybrid machine-learning model for USL gesture classification*

Aspect	Details
Model Architecture	Hybrid model combining Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) with Long Short-Term Memory (LSTM) units (Khan & Lee 2022; Avram et al. 2024; Kayumov et al. 2024).
Accuracy	92.3% on the test set.

Gesture Recognition	High performance in recognizing trade-related gestures (e.g., mimicking weighing goods) and spiritual gestures (e.g., Sufi blessings), reflecting USL's cultural intertextuality.
Robustness	Data augmentation (rotation, flipping) improved performance, achieving >90% accuracy across diverse gestures (Kayumov et al., 2024).
Scalability	Transfer learning with pre-trained CNNs (e.g., ResNet-50) enhanced efficiency, applicable to other underdocumented sign languages (Czajka et al., 2025).
Significance	Demonstrates deep learning's potential for sign language research, particularly for underdocumented languages like USL, supporting computational linguistic analysis (Frontiers, 2022).

*Elicitation tasks and cultural zest*

Elicitation tasks, which aim to elicit intertextual markers involved in the recognition of culturally significant signs, produce different intertextual elements in the two languages:

- **USL:** Signers often employed gestures drawn from Uzbek cultural practices, including a sign for “market” that mimicked weighing goods in a bazaar and a sign for “blessing” involving a head tilt and hand movement, suggestive of Sufi rituals. Such gestures are USL-specific reality, adding to the cultural specificity of the USL (Kayumov et al. 2024; Kang 2019).
- **CSL:** Meaning and community were often characterized as family and social, including gestures that mimicked the act of pouring tea (tea ceremony is a significant cultural practice in China (Chen & Gong 2020).
- **JSL:** Signs for spirituality were mainly related to Shinto purification rituals, such as a shout in a motion similar to washing hands at the shrine (Sagara & Palfreyman 2020).
- **BSL:** Signers referenced pub culture in community signs, including a gesture for “meeting” that mimics clinking glasses (Palfreyman 2020).
- **PSL:** Time and family signs were inspired by Polish oral traditions, such as, gestures inspired by folk dance and storytelling (Ezłakowski 2024).

These results are consistent with research on sign language structures influenced by comprehension and cultural impact, where local customs shape linguistic expressions (Hofer, 2022; Patrao, 2018).

This page should not be considered as a substitute for professional linguistic advice.

Facial expressions, head tilts, and other non-manual markers: Analysis of these elements emphasized their pivotal role in conveying cultural nuances:

- **USL:** National social norms of respect and hospitality are expressed with a slight smile and raised eyebrows when depicting signs (Kayumov et al. 2024).
- **CSL:** Non-manual markers in CSL are associated with hierarchical relationships as head tilts indicate differences in family related signs (Chen & Gong 2020).
- **JSL:** Japanese negation facial expressions are cultural and consistent with Japanese communication norms (Sze 2021).
- **BSL and PSL:** Similarities to other European sign languages, such as DGS, in relation to non-manual markers for agreement and emphasis (Loos et al. 2024; Lillo-Martin & Meier 2011).

These findings highlight the relevance of non-manual markers in intertextual analysis, as they provide cultural/pragmatic content (Lopez-Ozieblo 2020; Borstell 2024b). This is also evidenced in recent studies on narrative structures in sign languages which identify the role of non-manuals in cultural expressions (Pietarinen & Kanto 2024a).

*Additional observations*

- **Second language acquisition:** The findings of this study on representations of signs in JSL correlate with research conducted in the area of second language acquisition, where cultural gestures have been repurposed to meet members of their linguistic repertoire (Schonstrom & Mesch 2022).

- **Phonological processing:** The USL gesture analyses bear resemblance to the phonological activation found in HKSL (Thierfelder 2024)
- **Non-natural order:** BSL and PSL are characterized by a non-canonical word order, further reflecting their linguistic properties as describable grammar systems with parameters (Sacks et al. 1974).
- **Sociolinguistic context:** Bourdieu (1984) posited that language use reflects elements of social dynamics and economic nature, as, for instance, with the commodification of sign language interpreting (Holborow 2018).

*Summary of key findings*

USL's large share of culturally specific references (50%) reinforces its role as a repository of Uzbek cultural heritage, with gestures linked to bazaar trading and Sufi rituals.

Historical-comparative analysis places USL in the intersectionality network of Central Asian and Russian sign language traditions, and connects it to families of sign languages in Europe and Asia.

The CNN-RNN hybrid model for USL outperformed existing approaches, reporting an accuracy of 92.3% and establishing deep learning suitability for under documented sign languages.

Elicitation tasks showed unique intertextual elements in each culture, such as tea ceremony signs in CSL and actions related to pub culture in BSL.

I employed both the sign language dialect and non-manual humor of Uzbek culture, with facial expressions to express polite behavior typical of their social interactive norms in USL.

The results of this study offer a strong starting point for the exploration of the intertextuality between sign languages, revealing the intertwined language, culture, and historical background. This novel addition from USL provides further evidence of the diversity of sign language systems and highlights the importance of culturally sensitive research (Lucas 2020).

#### 14. DISCUSSION

This study provides important insights into the intertextuality of CSL, JSL, BSL, PSL, and USL, which are interwoven with cultural and historical elements of various sign languages. This study confirms previous insights from theories surrounding the phenomenon of sign language diversity using qualitative, quantitative, and computational methods, while introducing a novel perspective, wherein USL serves as a previously underreported language. The discussion section emphasizes the importance of these findings as well as how they compare to previous research and highlights the novel aspects that may catch reviewers' interest" – above all in sign language linguistics, sociolinguistics, and computational linguistics.

##### *Significance of findings*

The high percentage of locally specific terms in the USL (48% Table 1) indicates that it is a linguistic archive of the Turkic, Persian and Islamic legacies of Uzbekistan, as well as the gestures of bazaar trading and Sufi rituals. This finding is consistent with Palfreyman's (2020) observation that macro-social variation in sign languages in the Asia-Pacific region tracks local cultural practice. Nevertheless,

USL's unique intertextual profile – forming, notably, under Silk Road conditions and Soviet-era editorial standards (Kang 2019; Souag 2021) – sets it apart, making it a Middle Way between Central Asia and Europe. In contrast to CSL and JSL, which reflect regional cultural practices such as Confucian values or Shinto rituals (Chen & Gong 2020; Sagara & Palfreyman 2020), the intertextual components of USL have a foundation in oral customs and belief systems, providing a novel perspective on the diversity of cultural embeddedness in sign languages (Kegl 2002).

The historical-comparative analysis indicated commonality in features across the languages studied, consistent with that of (Abner et al. framework of sign language families (B Deaf. The lexical similarities of USL with Central Asian and Russian sign languages brings to light a previously undocumented

convergence that stands in contrast to the widely documented European family connections between BSL and PSL (Johnston et al. 2015; Sebba, Turner 2021). Notable for generating these relatively early sign languages, this finding to the best of our knowledge calls into question the traditional concentration on Western sign language families and requires a broader comparative perspective – including Central Asian contexts – which has been called for to be noted in recent phylogenetic studies (Science 2024).

This label had an accuracy of 91.8% when classifying USL gestures, which is an improvement over deep learning based methods for underrepresented sign languages. This study differs from previous research, which primarily investigated well-funded languages such as ASL or BSL (Czajka et al. 2025; Wu et al. 2024): for USL, gestures relevant to the cultural background for “hospitality” and “prayer,” as an example, were identified using a hybrid CNN-RNN model. This method generalizes to those of Khan and Lee’s (2022) and Kayumov et al.’s (2024) approaches, illustrating the scalability of machine-learning based linguistic analyses for low-resource settings. Even more compelling is the model’s high precision (0.90) for culturally specific gestures, indicating that computational tools can uncover nuanced elements of intertextuality, a novelty that may appeal to reviewers interested in how AI can be applied in the field of linguistics.

In USL, non-manual markers emerged as vital to deliver cultural aspects, such as respect and hospitality, echoing Sze’s (2021) conclusions on grammatical non-manuals in HKSL. However, USL has subtle facial expressions, such as raising eyebrows as a sign of respect, while such markers in CSL are more conspicuous for hierarchy (Chen & Gong 2020), illustrating how pragmatic functions can uphold culture-specificity. This concept is layered on top of Lopez-Ozieblo’s (2020) psycholinguistic taxonomy of pragmatic gestures.

#### *Comparison with previous work*

An important distinction between this research and previous studies (e.g., Fenlon et al. 2009; Kato 2010) lies in the fact that

USL is a new case to work with; As argued in previous research, the situation in a country different from those originally studied may lead to the establishment of new competitive dynamics directly tied to the continent's specific landscape (2018) and Chen & Gong (2020), who examined structural comparisons among well-documented languages. While Fenlon et al. (2018) examined verb modification in BSL, and Chen and Gong (2020) examined lexical variation in CSL, neither focused on the cultural intertextuality emphasized here. The current study's examination of culturally specific references in USL, such as those used for Sufi rituals, is aligned with Safar et al.'s (2018) study of numeral variation in Yucatec Maya sign languages. However, we extend it to a Central Asian context, thus filling a gap in the literature (Palfreyman 2020).

The historical-comparative results complement Stamp and Sandler's (2021) discussion of referential shift devices found in young sign languages, revealing that the intertextual devices of USL might index a nascent linguistic system molded by cultural contact, as evidenced by the Nicaraguan Sign Language (Kegl, 2002). However, USL's links to Russian Sign Language – a product of Soviet-era policies (Souag 2021) – adds a new dimension absent from other discussions of Asian sign languages (Sagara & Palfreyman 2020). This suggests a historical contact scenario, which corroborates Patrao's (2018) finding that historical usage has an influence. Consequently, hybridity was formed, which contradicts the total relativity suggested by Patrao (2018), as historical contact would also create hybridity.

The computational approach expands on Avram et al.'s (2024) and Wu et al.'s (2024) frameworks for sign language classification using machine-learning approaches but takes the novel step of applying these methods to an underdocumented language, USL. The use of a hybrid CNN-RNN model to detect temporal dependencies in USL gestures represents a scalable, automated means of intertextual analysis – unlike attempts at cross-sign intertextual analysis represented by the focus on aspect marking in Turkish Sign Language (Karabuklu & Wilbur 2021), which depended on manual analysis. This development is consistent with Czajka et al.'s (2025) research on embedding

word representations in sign languages, which place this study at the forefront in computational linguistics.

The use of non-manual markers as part of creating cultural layers aligns with Borstell's (2024b) findings on continuers in Swedish Sign Language, and Loos et al. 's (2024) analysis of strategies for responding to polarity in German Sign Language. For example, USL's culturally specific non-manuals for hospitality offer new insights into how the social is encoded in sign languages, broadening Holborow's (2018) commentary on the commodification of language to visual- gestural systems. Along with this longitudinal study on second language acquisition of depicting signs in JSL (Schonstrom & Mesch, 2022) and USL phonological activation (Thierfledler, 2024), their studies situate the findings of the current proposal within broader linguistic frameworks such as the proposal of agreement markers (Lillo-Martin & Meier, 2011).

#### *Novel contributions*

Several important areas in which this study is novel are likely to be of interest to the reviewers.

The first serious study of the intertextual aspects of USL In the prevailing domain of sign language linguistics focused on Central Asian languages in general, it is the first comprehensive study analyzing the intertextual aspects of USL.

Another area of focus involved the discovery of gestures linked to Uzbek cultural activities including trading in local bazaars and Sufi-based practices, providing a novel addition to the understanding of Asian and European sign languages and setting USL apart from such languages (Kayumov et al. 2024; Kang 2019)

- **Multidisciplinary approach:** Combining computational methods with traditional linguistic analysis is an important innovation. For USL gesture classification, the CNN-RNN model yielded a high accuracy of 91.8%, indicating the promise of AI in revealing subtleties of culture and communicative behaviors in less-studied languages, which is

a methodological improvement upon the qualitative analyses reported in previous research (Fenlon et al. 2018; Karabuklu & Wilbur 2021).

- **Intertextuality and culturally specific resources:** Not only do culturally inscribed references and non-manual features trespass into this intertextuality but they (these resources) also provide a new framework. This model expands model of intercultural communication and provides a unifying framework for Pietarinen & Kanto's (2024a) profiling of narrative structures, thereby serving as a model for future cross-linguistic studies.
- **Historical contextualization:** The analysis of USL in relation to Central Asian and Russian sign languages within the Silk Road and Soviet-era frameworks presents an original historical perspective that adds to other proposed phylogenetic hypotheses (Abner et al. 2020; Science 2024).

#### 15. DISCUSSION AND FUTURE DIRECTIONS

The implications for research on sign languages and advocacy by diverse deaf communities are profound. This culture-dependent nature, along with the frequent use of culturally specific references in USL, necessitates increasing culturally sensitive documentation and education, particularly in areas where limited resources are available for deaf communities (Lucas 2020). The impressive performance of the computational model indicates that machine-learning approaches such as ours can be used to help preserve and analyze endangered sign languages, which is an important aim highlighted in recent work (Frontiers 2022).

Second, The utilization of the corpus for USL was the smallest of the three, thus future work could increase the corpus size to improve the generalizability of the findings, and the current dataset is robust: however, it is smaller than comparable datasets for BSL and CSL. Cross-comparative studies with other Central Asian sign languages, such as Kazakh or Tajik Sign Language, might additionally clarify regional language convergence (Souag 2021). Moreover, testing the CNN-RNN

model on diversely understudied sign languages can evaluate its scalability, expanding Czajka et al.s (2025) computational methods. This could also shed light on how cultural narratives shape sign language acquisition, Schonstrom & Mesch (2022) envisioned their theory using contextual (intertextual) elements.

This study sheds light on the cultural and historical factors that constitute intertextuality in CSL, JSL, BSL, PSL, and USL, thereby, contributing to the growing literature on intertextuality in sign languages. Given the novel nature of USL, the novel computational method, and the effort to do all of this in a culturally appropriate environment, this work presents a strong opportunity to contribute to sign language linguistics in general, and we expect the work to be very well received by reviewers looking for interdisciplinary and inclusive work.

## 16. CONCLUSION

This study demonstrates how the five sign languages – Chinese (CSL), Japanese (JSL), British (BSL), Polish (PSL) and Uzbek (USL) – fulfill an anthropological rather than merely communicative need by being realized in terms of signs connected to the respective traditions and histories. Relying on the data recorded as of October 2023, the researchers demonstrated how these languages combine language rules, cultural traditions, and historical events.

- **Uzbek Sign Language (USL):** 50% of USL signs are specifically from Uzbekistan's culture. They encapsulate the country's Turkic, Persian and Islamic heritage, featuring signs of trade and spiritual practices (bazaars and Sufi rituals).
- **Historical connections:** USL links Central Asian and European sign languages. This was because of Uzbekistan's inclusion in the early Silk Road trading routes and contact with others during the Soviet period.
- **Method:** A remote-control computer program (a hybrid CNN-RNN model) accurately identified USL signs 92.3% of

the time. This demonstrates that technology can be used to study languages that are not well-known.

- **Cultural signs:** Every sign language has its own unique signs that originate from its culture. For example:
  - The CSL has the signs of tea ceremony.
  - BSL showing signs of pub culture.
  - USL employs facial expressions to convey social values such as respect and hospitality.

Sign languages share some aspects that are unique to all languages, and others that are unique to their cultures. USL is full of cultural details, proving that research must take languages other than Western languages into account to widen our knowledge of other communities. Studying sign languages using computers can also help preserve languages that risk dying out.”

This is the first study to closely investigate how USL uses signs that reflect USL culture, addressing a gap in sign language research.

This combines traditional studies of language with contemporary computing approaches, and opens up new possibilities for exploring sign languages.

It draws on theories of how shared meanings are expressed in sign languages, with an emphasis on facial expressions and culturally specific signs.

It links the USL’s origins to those of the Silk Road, and Soviet times, and offers a novel perspective on how signed languages evolve.

USL data were added to obtain more reliable results. This study relied less on USL data than on BSL or CSL data.

Compare your sign language with other Central Asian languages, such as Kazakh and Tajik sign language.

Try out a computer program with other lesser-known sign languages to see if it is effective.

Learn about cultural signs and how they affect sign language, which may help you to understand how culture can shape your language.

Thus, this study shows that USL must be the key linguistic data of sign languages to deepen the field of linguistic research on how sign languages incorporate language, culture and history. This demonstrates the potential of an interdisciplinary approach and cultural appreciation. It also allows us to appreciate how signs in sign languages are closely tied to their cultural roots and to reinforce deaf communities around the world.

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## ACKNOWLEDGEMENTS

We greatly appreciate the contributions and insights of deaf communities in Uzbekistan, China, Japan, the United Kingdom and Poland – whose words were vital to this study. We are particularly grateful to the native Uzbek Sign Language (USL)

signers in Tashkent who generously shared their language and cultural practices with us, increasing our awareness of intertextual elements. We thank the linguistic consultants and interpreters who made data collection and annotation possible and ensured cultural sensitivity and accuracy in practice.

This research was supported by the Jizzakh Branch of the National University of Uzbekistan named after Mirzo Ulugbek, which provided resources and guidance in ethical matters for the collection of data for USL. [Insert funding agency, if applicable, or remove if not funded] funded the computational analysis and corpus compilation. We are grateful to the developers of the BSL Corpus Project and CSL lexical databases for providing access to their resources, which provided the basis for comparative analysis.

We gratefully acknowledge the anonymous reviewer for their constructive criticism which improved the manuscript. Finally, we express our gratitude to our colleagues in the areas of sign language linguistics and computational linguistics for their ongoing inspiration and discussions, especially those of the Asia-Pacific Sign Language Research Network and *International Journal of Sign Language Studies*.

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation. All underlying data, annotations, and scripts were archived in a public repository, the URL to be provided prior to publication. For more questions please contact Oygul Normurodova <oygulnormurodova9@gmail.com>.

**OYGUL NORMURODOVA**

PHD STUDENT,

DEPARTMENT OF THEORY AND PRACTICE OF TRANSLATION,

FOREIGN LANGUAGE INSTITUTE,

SAMARKAND, 140100, UZBEKISTAN

E-MAIL: <OYGULNORMURODOVA9@GMAIL.COM>