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Signslator: Ai and Image Processing-Based Two-Way Translator Between Verbal Communication and Sign Language

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Abstract

Communication barriers between deaf, mute individuals and the hearing majority hinder participation in education and daily life. Existing assistive technologies often provide one-way translation, limiting reciprocal interaction and reducing inclusivity. This study developed "Signslator", a two-way communication system integrating artificial intelligence (AI) and image processing. The prototype utilized a Raspberry Pi 5, camera, microphone, dual monitors, and Python-based software with MediaPipe for gesture recognition. A dataset of 150 school-related words, validated by Special Education (SPED) teachers, was used for training. System performance was tested under controlled conditions with varying confidence thresholds, and evaluated using accuracy, precision, recall, F1-score, and weighted mean ratings from expert feedback. The system achieved 100% accuracy, precision, recall, and F1-score in recognizing letters (A–Z) and numbers (1–9). For the 150-word vocabulary, average recognition accuracy was 84.93%, with 130 words scoring above 50%. However, 20 words fell below 49% accuracy, highlighting limitations in complex or visually similar gestures. Expert evaluation rated the system highly functional (AWM = 4.25), reliable (AWM = 4.21), usable (AWM = 4.55), and efficient (AWM = 4.33). The AI-driven auto-correction feature improved clarity by merging fragmented inputs into coherent words. Findings confirm that "Signslator" effectively bridges communication gaps in classroom settings, enabling real-time two-way translation between spoken language and American Sign Language. While highly accurate for basic gestures, future improvements should expand vocabulary, incorporate facial expressions, and optimize performance under diverse environmental conditions. The system demonstrates strong potential as an inclusive educational tool.

Keywords: Deaf Individuals, Sign Language Translation, Hand Gesture Recognition, Artificial Intelligence in Education, Image Processing, Assistive Technology, Two-Way Communication

INTRODUCTION

Communication is a vital part of everyday life, allowing individuals to express needs, feelings, and thoughts. For the deaf and mute community, sign language serves as the primary mode of interaction. However, a significant barrier exists between those who use sign language and the hearing majority who are often unfamiliar with it. While traditional aids like sign language interpreters and writing exist, they are frequently unavailable or impractical in real-time social and professional settings.

Recent studies have attempted to bridge this gap using various technological approaches. Obi et al. (2023) developed a desktop application for real-time sign language recognition, achieving high accuracy for the 26 letters of the alphabet. Other researchers have explored sensor-based and vision-based approaches to hand gesture recognition. Furthermore, Mejía-Peréz et al. (2022) proposed desk-mounted devices for government employees that achieved 90%-97% accuracy in translating basic signs and numbers. In the Philippines, American Sign Language (ASL) is often the preferred structure for such technologies due to its international recognition and historical adoption within the local educational system.

Despite these advancements, current assistive technologies face critical limitations that create a significant research gap. First, many existing tools, such as the *Iglesia Ni Cristo* sign language app or *Handspeak,* are primarily one-way systems; they allow hearing individuals to look up signs but do not enable the user who is deaf or hard of hearing to be understood in return. Second, prior systems often struggle with semantic accuracy and full-sentence translation, often failing to meet the daily needs of users in complex environments like classrooms. Third, current technologies frequently lack the portability and real-time processing required for natural, interactive conversation. This study, therefore, addresses the need for a portable, two-way communication system that integrates AI-powered sentence correction to overcome the inaccuracies and unidirectional nature of previous models.

The challenges faced by deaf individuals, are summarized in three statements:

1. Deaf students face significant communication challenges with teachers and peers, particularly when sign language interpreters are unavailable. These difficulties are compounded by the limited availability of tools that can translate sign language into text or speech in real-time;

2. Many existing systems only translate sign language but do not allow two-way conversation, making it hard for students to fully participate in class;

3. Some sign language recognition tools are not always accurate, leading to misunderstandings that affect learning and interaction.

This study is necessary now because of the persistent social and academic isolation faced by deaf individuals. Socially, deaf students often report feeling bored or excluded during gatherings and classes because those around them including family members and subject-matter teachers lack sign language proficiency. Academically, the reliance on a limited pool of SPED teachers to act as interpreters hinders are the independence of deaf learners. By developing "Signslator", this research contributes a novel two-way AI-driven framework that promotes inclusivity in education and public service sectors, such as hospitals, where the absence of professional interpreters can lead to dangerous medical misdiagnoses.

In response to these identified gaps and social needs, the researchers developed the "Signslator: AI and Image Processing-Based Two-Way Translator between Verbal Communication and Sign Language." This study seeks to design and develop a system based on three objectives:

1. Develop a system that recognizes American Sign Language (ASL), gestures and translates them into text or speech using advanced image processing algorithms to address the lack of accessible real-time communication tools for the hearing-impaired and bridge the gap between sign language users and non- users.

2. Translate spoken or textual language into ASL gestures displayed the device to enable two-way communication and overcome the limitation of one-sided interaction in existing systems.

3. Enhance the accuracy and reliability of the system using AI-powered features such as sentence autocompletion and correction to ensure clear and effective communication.

The system was designed for classroom use, with a dataset of 150 commonly used educational terms validated by a SPED teacher. Users must perform right-handed gestures centered on the screen in a well-lit, quiet environment for best results. While the device enhances communication, it has limitations in low-light, noisy, or fast-moving conditions. It currently supports only ASL and may experience slight delays or misinterpretations based on hand position or speech clarity.

LITERATURE REVIEW

Legal and Policy Frameworks Protecting Deaf Rights. The protection of the rights of deaf individuals has transitioned from a medical model of disability to a social, rights-based, and cultural-linguistic framework, anchored internationally by the United Nations Convention on the Rights of Persons with Disabilities (CRPD). This global benchmark recognizes sign languages as structurally distinct, fully-fledged natural languages and mandates that States Parties officially recognize national sign languages to ensure freedom of expression and access to information. Key provisions under the CRPD, such as Articles 2, 9, 21, 24, and 30, safeguard the rights of the deaf to accessibility, inclusive education in their primary language, and the preservation of their specific cultural and linguistic identity.

In the Philippines, this international mandate is domestically enforced through a statutory matrix led by Republic Act No. 7277 (1992), or the Magna Carta for Persons with Disability. Originally enacted in 1992, the law provides a foundation for the rehabilitation, self-development, and integration of disabled persons into the mainstream of society as an enforceable civil right rather than mere welfare. Subsequent amendments, such as Republic Act No. 9442 (2007) and Republic Act No. 10754 (2016), expanded these protections by institutionalizing severe penalties for public ridicule or vilification, granting 20% discounts and VAT exemptions on essential services, and providing educational assistance and priority express lanes in all establishments. Furthermore, Republic Act No. 10524 (2013) strengthens employment rights by mandating that at least one percent of all positions in government agencies be reserved for persons with disabilities, while encouraging a similar quota in the private sector.

A pivotal advancement in the Philippine legal landscape is Republic Act No. 11106 (2018), known as The Filipino Sign Language (FSL) Act, which officially declares FSL as the national sign language. This law mandates the use of FSL as the medium of instruction in deaf education and the official language of communication in all government transactions, including the civil service and broadcast media. To ensure access to justice, the Supreme Court has further institutionalized the "Rules on Filipino Sign Language Interpreting in the Judiciary" (Office of the Court Administrator [OCA], 2025), which guarantee the availability of qualified FSL and Deaf Relay Interpreters in all court proceedings to prevent misinterpretations that could lead to wrongful convictions.

Despite these robust legal safeguards, significant implementation gaps persist due to resource constraints and institutional barriers. There is a critical national shortage of certified FSL interpreters, with an estimated ratio of 1:1,000, and the high cost of professional interpretation services estimated at over PHP 16,000 daily for full classroom instruction makes universal educational inclusion financially challenging. Additionally, the deaf community remains disproportionately vulnerable to climate-related hazards because early warning systems often rely on audio signals, and mobile text alerts in written Filipino may not be fully understood by those whose primary language is FSL. Addressing these gaps requires strategic actions, including a national interpreter subsidy fund, standardized professional certification, and the integration of FSL into the general K-12 curriculum to foster a more inclusive society.

Communication Barriers and Social Isolation. The primary challenge faced by individuals with hearing and speech impairments is the profound communication gap between them and the hearing majority. According to Babour et al. (2023), while deaf individuals possess significant potential to contribute to society, they are often isolated due to barriers that hinder their ability to interact naturally. Hanani and Ismael (2022) further emphasize that speech and listening are the core pillars of human expression; when these biological capacities are absent, the fundamental process of sharing thoughts and feelings is disrupted. This disruption is particularly critical in healthcare settings, as Xia et al. (2022) highlight that a lack of professional sign language interpreters in hospitals often leads to misdiagnoses, as patients struggle to convey physical symptoms and doctors cannot effectively explain treatment plans.

This isolation frequently begins within the home, as even parents who have been with their children since birth often lack proficiency in formal sign language. Families may only share simple, informal gestures for basic physiological needs, such as "Did you eat?" or "Have you taken a bath?", which are not a substitute for proper sign language and prevent the effective sharing of deep thoughts, needs, and complex emotions. Consequently, deaf individuals frequently report feeling bored or excluded during family gatherings and community events.

In educational environments, these communication barriers significantly hinder academic progress and student independence. Because most subject-matter teachers lack sign language skills, schools are often forced to rely on a limited pool of Special Education (SPED) teachers to act as interpreters, a dependency that prevents deaf learners from becoming independent.

Furthermore, linguistic differences create a secondary barrier; deaf-mute individuals often utilize a different syntax and lack standard grammar compared to hearing individuals. For example, a student might sign "name what you" for "What is your name?". These differences, combined with a perception that their knowledge base is limited, often result in students being restricted to simple "yes/no" or "true/false" assessments, making it difficult for them to express complex academic understanding or participate in tasks like writing reflection papers.

Sign Language as a Linguistic Bridge. Sign language functions as a fundamental linguistic bridge for the deaf and mute community, serving as their primary mode of interaction for expressing thoughts, needs, and feelings. Ramya (2024) defines sign language as a structured system of gestures where hand movements act as the primary vehicle for non-verbal communication globally. Communication is a vital component of everyday life, and for those with hearing or speech impairments, this structured system is essential for participating in the fundamental process of sharing thoughts. Without this bridge, the core pillars of human expression speech and listening are absent, which disrupts the natural exchange of ideas.

In the Philippines, the choice of sign language within this bridge is heavily dictated by historical educational frameworks. American Sign Language (ASL) became deeply integrated into the Philippine educational system after being introduced by American teachers when schools for the Deaf were first established. Because ASL has a well-established structure and international recognition, it remains the preferred medium for many Deaf individuals in the local context. This preference is reinforced by the fact that ASL provides access to a significantly larger pool of global educational materials, learning resources, and opportunities for international collaboration. Even in local classrooms, some educators prioritize translating Filipino concepts into ASL structures to ensure students can communicate within this internationally recognized system.

The necessity of a robust linguistic bridge is highlighted by the profound communication barriers that exist between sign language users and the hearing majority. Babour et al. (2023) note that while deaf individuals possess great potential to contribute to society, they are frequently isolated by barriers that hinder natural interaction. This isolation is often felt socially and academically; for instance, deaf students report feeling excluded during gatherings and classes when those around them including family members and subject-matter teachers lack sign language proficiency. Furthermore, a constant reliance on a limited pool of specialized SPED teachers to act as interpreters can hinder the independence of deaf learners.

The absence of a functional communication bridge can have dangerous consequences in critical sectors such as healthcare. Xia et al. (2022) highlight that a lack of professional sign language interpreters in hospitals often leads to medical misdiagnoses. These errors occur because patients struggle to accurately convey physical symptoms, and doctors, in turn, cannot effectively explain treatment recommendations or plans. Additionally, Dahanayaka et al. (2021) observe that deaf and mute individuals often struggle to communicate their feelings effectively because their primary mode of expression is not understood by the general public. To address these systemic gaps, modern research focuses on creating two-way AI-driven frameworks like "Signslator" to facilitate natural, reciprocal conversations and promote inclusivity in public service and education.

Technological Advances in Human-Computer Interaction (HCI). Technological advancements in Human-Computer Interaction (HCI) have increasingly sought to automate the transition of signs into recognizable data to bridge the communication gap between the deaf community and the hearing majority. Human-Computer Interaction (HCI) itself is defined as the study of how people use and connect with technology, specifically focusing on the interaction between humans and devices. Oudah et al. (2020) classify hand signs into three primary categories: posture, dynamic gestures, and static forms, noting their broad utility in fields ranging from robotics and home automation to medical automation. Ramya (2024) further describes sign language as a structured global system of gestures, where specific hand movements serve as the primary vehicle for non-verbal communication.

Current recognition systems generally utilize either sensor-based or vision-based approaches. Sahana et al. (2020) note that while both methodologies are viable, vision-based systems that utilize cameras and advanced image processing are increasingly prioritized by researchers due to their non-intrusive nature. Recent software developments have demonstrated that real-time translation can achieve impressive results; for instance, a desktop application proposed by Obi et al. (2023) achieved a 96.3% accuracy rate for the 26 letters of the ASL alphabet. Similarly, Mejía-Peréz et al. (2022) proposed desk-mounted devices for government employees that reached 90% to 97% accuracy in translating basic signs and numbers.

A key innovation in modern HCI research is the integration of Artificial Intelligence (AI) for sentence auto-completion and correction. This feature ensures communication clarity by using rule-based logic to perform minor spelling corrections or combine individual finger-spelled letters into recognizable words, even when a user's gestures are slightly imprecise. Despite these strides, Mehra et al. (2020) argue that many existing assistive technologies remain inadequately designed because they are limited to one-way recognition, failing to meet the daily needs of users in complex, interactive environments. This limitation is echoed by Fahad et al. (2020), who suggest that true HCI should focus on how users "connect" through technology, emphasizing the need for two-way interfaces that facilitate natural, reciprocal conversation.

Limitations of Existing Assistive Technologies. Despite significant technological advancements in the field of assistive devices, a critical functionality gap remains in most current systems. Mehra et al. (2020) argue that many existing designs are inadequate because they are limited to one-way recognition, failing to facilitate the natural, reciprocal conversation required for meaningful interaction. This deficiency is echoed by Fahad et al. (2020), who suggest that true Human-Computer Interaction (HCI) should prioritize how users “connect” with technology rather than just performing a technical task. While applications such as Handspeak or the Iglesia Ni Cristo sign language app are useful for looking up signs, they are primarily unidirectional; they allow a hearing person to understand a sign but do not provide a mechanism for the deaf or mute individual to be understood in return. Most existing tools focus solely on translating gestures into text or speech, which effectively leaves the Deaf individual unable to "receive" spoken information from a hearing counterpart, thus disrupting the fundamental pillars of human expression.

Furthermore, prior systems frequently struggle with semantic accuracy and full-sentence translation, often failing to meet the daily communication needs of users in complex environments like classrooms. For example, while recent studies like those by Obi et al. (2023) achieved high accuracy for alphabet letters and Mejía-Peréz et al. (2022) developed desk-mounted devices for basic translation, these systems often lack the portability and real-time processing necessary for natural interaction. Existing technologies also face technical hurdles, such as instability in hand detection and difficulty recognizing dynamic or visually similar gestures, particularly under diverse environmental conditions like low light or background noise. Additionally, many tools fail to account for the unique linguistic structure of sign language, which often omits helping verbs and follows a different syntax than spoken language, leading to misunderstandings that hinder academic and social participation.

The "Signslator" addresses these specific deficiencies by providing a portable, two-way interface that translates American Sign Language (ASL) into speech and back into visual signs. By integrating AI-powered sentence auto-completion and correction, the system overcomes the inaccuracies of previous models and ensures clarity even when gestures are slightly imprecise. Optimized specifically for classroom settings through a curated dataset of 150 essential words developed in collaboration with SPED professionals, the system bridges the communication gap by enabling both parties to send and receive information interactively.

DESIGN AND METHODOLOGY

Research Design. The researchers utilized an experimental research design to evaluate the system’s performance in translating American Sign Language (ASL) into text or speech and vice versa. This design allowed for the control of variables such as lighting, gesture speed, and background conditions to test the system’s accuracy, speed, and reliability. A critical part of this experiment was determining the optimal minimum confidence threshold. The researchers tested five threshold values (0.5, 0.6, 0.7. 0.8, and 0.9) using 100 trials across 10 specific words (teach, class, chair, board, eraser, book, bag, test, write, and read). The results identified 0.7 as the optimal threshold, as it balanced high accuracy with stability without being overly sensitive to idle movements or too strict to register valid gestures.

Development Approach. The system was developed using the Agile methodology, which was essential for managing complex, separate tasks such as hand gesture recognition, text-to-speech conversion, and the integration of these components.

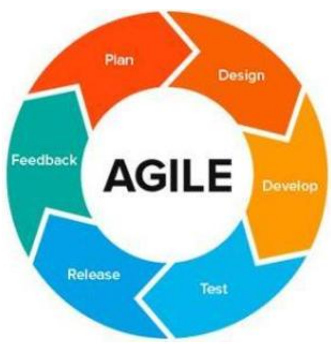

Figure 1
Agile Method

This iterative approach allowed the researchers to refine the system based on constant testing and feedback. Agile's flexibility was particularly useful when addressing technical challenges, such as initial instability in hand detection and the difficulty of recognizing dynamic, moving gestures.

Participants and Sampling. To validate the system's educational and technical relevance, the researchers consulted eight Special Education (SPED) teachers and two technical experts. Participants were purposively selected based on expertise in inclusive education and assistive technology. Their involvement was crucial in selecting the 150 school-related words for the dataset and their feedback was used to assess system acceptability, functionality, and classroom applicability.

Instruments and Materials. The prototype was developed using a Raspberry Pi 5 with an RP1 controller chip. Its hardware includes an RPi Camera for capturing hand gestures, dual monitors for displaying translations to hearing and deaf users, a microphone and speaker for speech input/output, and a mini keyboard for text entry. The software framework is built with Python, integrating Picamera2 and MediaPipe to capture and track key hand landmarks for accurate gesture recognition and translation.

Procedures. The methodology followed sequential phases:

Data Collection: The researchers recorded video clips for letters, numbers, and 150 classroom words.

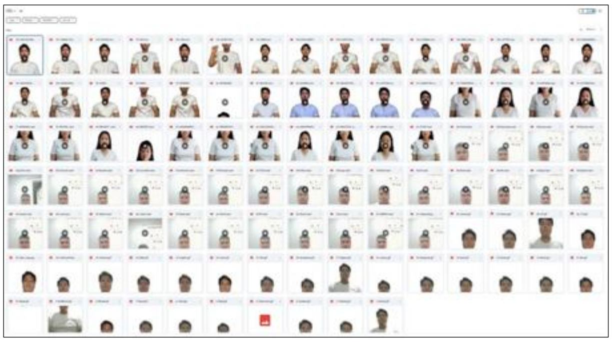

Figure 2
Collecting Video Clips

Model Training: Initially, the system used static frames, but the researcher's improved recognition of dynamic movements by expanding the dataset to 10 sequential frames per gesture.

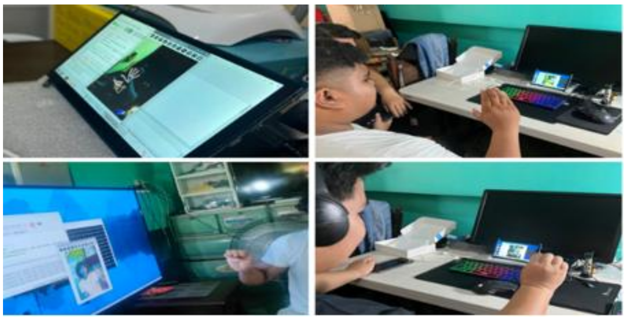

Figure 3
Collecting Data Sets

System Testing: The model was rigorously tested for accuracy in recognizing the alphabet (A-Z), numbers (1-9), and the 150-word vocabulary.

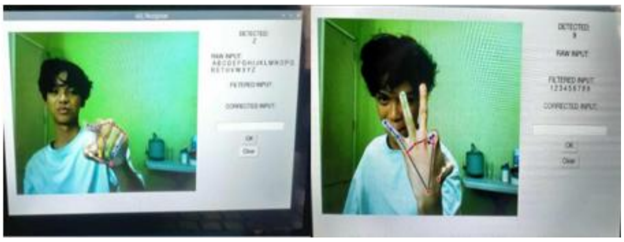

Figure 4
Testing Alphabets and Numbers

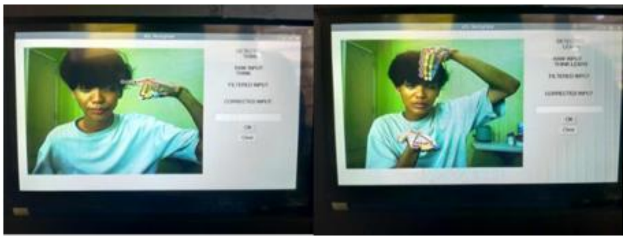

Figure 5
Testing Words

Evaluation: The system's outputs were compared against expected results, and participant feedback was gathered to assess usability and acceptability.

Data Analysis. Performance was measured using established metrics: accuracy, precision, recall, F1-score (Harmonic Mean of Precision and Recall), and weighted mean for functionality, reliability, usability, and efficiency. These measures provided both technical validation and descriptive ratings of system performance. Statistical computations were performed to determine recognition rates and error patterns based on the following:

1. ***Per-word/Letter/Number Accuracy.*** It is used when testing a specific ASL word multiple times for example, testing a single word 10 times. It calculates how many times the system correctly recognized that particular word out of the total tests for it.

   Accuracy = (Number of Correct Predictions)/(Total Number of Tests) x 100

2. ***System Accuracy.*** It measures how often the system gives the correct output overall.

   Accuracy = (TP + TN)/ (TP + TN + FP + FN)

   In these formulas:
   TP (True Positive) - the system correctly detected a gesture.
   TN (True Negative) - the system correctly ignored a non-gesture FP (False Positive): the system wrongly detected a gesture when there was none.
   FN (False Negative) - the system failed to detect a real gesture.

3. ***Precision.*** It shows how many of the gestures identified by the system were actually correct. It is useful for checking how well the system avoids false detection (false positives, FP).

   Precision=TP/ (TP + FP)

4. ***Recall.*** It indicates how many actual gestures the system was able to recognize correctly. This helps determine whether the system is missing any real gestures (false negatives, FN).

   Recall=TP/ (TP + FN)

5. ***F1-score.*** It combines both precision and recall into a single value by calculating their harmonic mean. This score is especially helpful when one of the two values is high and the other is low, as it gives a balanced view of the system's performance.

6. ***Weighted Mean.*** To get the overall average descriptive rating of the system's performance based on the criteria of Functionality, Reliability, Usability, and Efficiency.

   Weighted mean = $(\sum (x \cdot w))/(\sum w)$

   where:
   x - is the score or value (like a rating or percentage)
   w - is the weight (like the number of trials or how often it occurred)
   $\sum$ - means add everything up

Ethical Considerations. The study adhered to ethical standards by obtaining informed consent from all participants and ensuring that participation was voluntary. To protect the privacy of the SPED teachers and experts, all feedback gathered via online Google Forms was anonymized, and no personal identifiers were used in the final reporting.

RESULTS

Objective 1. Recognition and Translation of American Sign Language. The system was evaluated on its ability to recognize American Sign Language (ASL) through various data types, including letters, numbers, and a 150-word vocabulary. To identify the most effective minimum confidence threshold for real-time gesture recognition, five values (0.5, 0.6, 0.7, 0.8, and 0.9) were tested. In tests involving 260 trials for letters (A-Z) and 90 trials for numbers (1-9), the system recorded an accuracy of 100%, alongside with 100% precision, recall, and F1-score for both categories.

The word recognition test consisted of 1,500 trials covering 150 school-related words. The system reached an overall average recognition accuracy of 84.93%. Of the total vocabulary, 130 words achieved accuracy ratings between 50%

and 100%. However, the system struggled with 20 specific words that fell below the 49% accuracy threshold. These low-performing words were:

- 10% Accuracy: *Repeat, Important*
- 20% Accuracy: *Science, Listen, Answer, Ask, Janitor, Nurse, Assignment, Keyboard, Understand, Fast*
- 30% Accuracy: *Explain, Guidance Counselor, Morning, Excuse me, Slow, Heavy*
- 40% Accuracy: *Security*

Objective 2. Two-Way Communication: Spoken/Textual Language to ASL. The "Signslator" enables two-way interaction through a dual-monitor hardware configuration. For the hearing-to-deaf translation, messages typed or spoken by a hearing user are converted into ASL video clips displayed on a dedicated screen for the deaf user. For the deaf-to-hearing translation, the system captures hand gestures via a camera and translates them into text and speech displayed for the hearing individual. This dual-pathway functionality was demonstrated in simulations where a teacher acted as a deaf-mute user o verify the real-time translation of gestures into output.

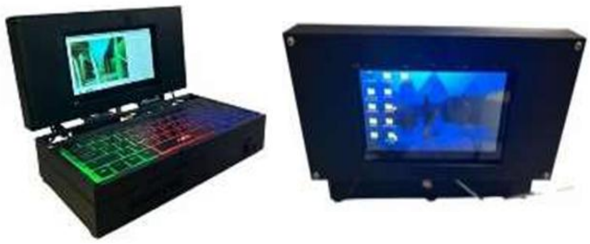

Figure 6
"Signslator" Dual-Monitor

Objective 3. AI-Powered Enhancement for Accuracy and Reliability. To improve communication clarity, the system features an AI-driven auto-correction and sentence completion module. This feature employs rule-based logic to perform minor spelling corrections and combine spaced-out letters into recognizable words, such as merging "t e a c h e r" into "teacher". System performance was further validated by eight evaluators (six SPED teachers and two experts), who provided the following average weighted mean (AWM) scores based on a 5-point Likert scale.

Table 1
System Functionality Evaluation

Aspect	W.M.	D.R.
The system is able to detect hand sign languages.	4.62	Highly Functional
It processes the input and generates the expected output.	4.00	Functional
All features of the system perform and respond according to their intended purpose.	4.13	Functional
Average Weighted Mean	**4.25**	**Highly Functional**

Table 2
System Reliability Evaluation

Aspect	W.M.	D.R.
The device functions smoothly without crashing or freezing during operation.	4.13	Reliable
It continues to work properly even with repeated use.	4.50	Reliable
The system's performance is consistent, and its results are considered reliable by the users.	4.00	Reliable
Average Weighted Mean	**4.21**	**Highly Reliable**

Table 3
System Usability Evaluation

Aspect	W.M.	D.R.
The system is designed to be easy to learn and use.	4.65	Highly Usable
Its setup and operation are simple.	4.75	Highly Usable
The system provides clear and helpful feedback to the user.	4.25	Highly Usable
Average Weighted Mean	**4.55**	**Highly Usable**

Table 4
System Efficiency Evaluation

Aspect	W.M.	D.R.
The system responds quickly to user inputs.	4.25	Highly Efficient
The processing time for each gesture is fast and consistent.	4.50	Highly Efficient
The system operates smoothly during use without noticeable delays or interruptions.	4.25	Highly Efficient
Average Weighted Mean	**4.33**	**Highly Efficient**

DISCUSSION

The perfect accuracy scores (100%) for letters and numbers indicate that the system is exceptionally consistent when processing static and simple sequential gestures. The threshold testing revealed that 0.7 is the optimal value; lower thresholds (0.5-0.6) resulted in instability due to the misclassification of idle movements, while higher thresholds (0.8-0.9) caused the system to miss valid gestures or introduce recognition delays.

The 84.93% average word accuracy demonstrates that while the device is effective for a majority of common classroom terms, there is a clear performance gap regarding complex or visually similar gestures. The identification of 20 words with <49% accuracy highlights critical limitations where the system failed to detect real gestures (false negatives), impacting overall recall. These weak points provide a target for future model retraining or data set expansion.

While the expert evaluations confirm that the system is highly functional and user-friendly for educational settings, the current AI enhancement feature is limited by its inability to process complex grammar or natural English syntax. Because ASL rule-based correction is insufficient for full sentence translation. Future iterations would require more sophisticated language modelling to achieve the researchers' goal of bridging the gap between ASL syntax and standard English.

Conclusion. In conclusion, the study titled "Signslator: AI and Image Processing-Based Two-Way Translator Between Verbal Communication and Sign Language" successfully developed a system that bridges the communication gap between spoken and sign language using artificial intelligence (AI) and image processing. The system demonstrated perfect accuracy, precision, recall, and F1-score (100%) in recognizing letters and numbers. In the word recognition test, it achieved 100% precision, 86.7% recall, 92.9% F1-score, and 86.7% overall accuracy, indicating strong performance with minor limitations in recognizing certain words. These results affirm the system's accuracy and reliability, highlighting its potential as a valuable tool for gesture-based communication. Nonetheless, future enhancements are recommended to improve recognition of more complex or ambiguous gestures.

Recommendation. In order to make the system more useful in casual conversations, it is recommended that future researchers add more than 150 words. Adding multiple ways to sign the same word can make the system more adaptable. To ensure that the system functions properly in real-world scenarios, it would also be beneficial to test it in various lighting and background conditions. Including this feature could increase the accuracy of the translations because facial expressions are also significant in sign language. To make the system reliable for everyone, it can be tested with more users, particularly those with varying hand sizes and signing styles. Finally, the system may be easier and more convenient to use anywhere if it is made available on mobile devices like phones or tablets.

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administration, Resources, Software, Validation, Visualization, Writing – original draft | Nikos D. Pineda: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft.

Conflict of Interest. The authors declare no conflict of interest.

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Artificial intelligence use. AI-assisted language editing was performed using ZeroGPT, Gemini and Copilot; authors reviewed and approved all contents. Such measure was pursued for grammar purposes and the restructuring of complex sentence structures. The other parts of the paper maintain full integrity in terms of originality.

Ethics approval statement. In accordance with the ethical standards of the Computer Engineering Department of the Pampanga State University, the protection of participants' rights and welfare was ensured.

Data availability statement. The dataset will be available upon request from the corresponding author of this study.

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