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A SURVEY ON RECOGNITION AND TRANSLATION SYSTEM OF REAL-TIME SIGN LANGUAGE

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***Abstract* — Real-time sign language recognition systems are developed to improve access towards communication and enhance the accessibility of the communication pathway in the community of deaf and hard of hearing. This paper aims to provide a review of various methodologies that have been exploited to interpret such systems, with a focus on advanced deep learning techniques being implemented. The LSTM model applied towards understanding sign language gestures in real time where users can seamlessly communicate using a friendly interface, while capturing gestures through feeds from cameras demonstrates high accuracy in recognizing a vast range of gestures that show potential usage as assistive technology. More recently, CNNs have been extensively used in American Sign Language recognition, and promising results have been achieved with models such as GoogLeNet and YOLO. Relevant models to this paper utilize datasets with widespread lighting conditions and varied backgrounds, creating a more robust model. More recent work has included the YOLOv4-CSP algorithm that produces improved detection performance with optimized network architecture and data augmentation techniques. In addition, YOLO-v9 goes a significant step beyond others in terms of real-time sign language detection. In addition, it is faster in recognizing gestures and has much higher accuracy than any previous version. Such technologies make communication instantaneous but also empower hearingimpaired people by bringing them closer to others in society. Further studies and developments in this area may even lead to more refined solutions for solving sign language translation issues to increase appreciation towards each other.**

Keywords — Sign Language Recognition, Artificial Intelligence, CNN, Deep Learning, Image Recognition

I. INTRODUCTION

Sign language is the most important medium for both deaf and hearing-impaired communities across the world. Communication between sign language users and the general public faces major barriers. Real-time systems for the recognition and translation of sign languages have emerged as novel technologies in bridging this communication gap, enabling both deaf and hearing individuals to interact on equal grounds with each other [1]. Significant progress has been made in developing real-time recognition and translation systems of sign languages, drawing from various sources over several decades.

Early work in this area, for example, Liang and Ouhyoung [2], first introduced the concept of continuous gesture detection systems developed especially for sign language. These pioneering works laid the groundwork for later studies and improvements in technology. The area saw a milestone with the introduction of deep learning and techniques from computer vision. Some works, such as those by Garcia and Viesca [3] and Kuznetsova et al. [4] tried consumer depth cameras. Starner et al. [5] first presented the real-time detection of American Sign Language (ASL) desk and wearable computer-based video, showing the potential of wearables in enhancing the communication capability of the deaf.

Naglot and Kulkarni [6] created the Leap Motion Controller to accomplish real-time sign language detection. The one common theme that pervades the domain of sign language recognition is Global Inclusion, as replicated in the works of Hoque et al. [7] for Bangladeshi language, Rahaman et al. [8] on Bengali and Indian while Rajam and Balakrishnan [9] on Indian sign languages. Taskiran et al. [10] resorted to Convolutional Neural Networks (CNN) and deep learning architectures for real-time ASL detection. It is through such multinational standpoints that the necessity for tailoring recognition systems to different sign languages becomes evident in responding to the unique linguistic needs of the deaf community. Kau et al. [11] worked on a real-time portable sign language translation system. Some of the most recent improvements were done by Park et al. [13] in which on-board depth cameras enriched the real-time sign translation on mobile devices.

The current study aims to review the development of sign language recognition and translation systems in real-time concerning various approaches and technology used. The following sections detail the unique contributions of these works and highlight major ideas and improvements presented. Therefore, this survey study synthesizes this huge body of research and is also likely to shed light on the transformational potential and relevance of real-time sign language identification and translation systems in encouraging inclusive communication for the deaf and persons with hearing impairments.

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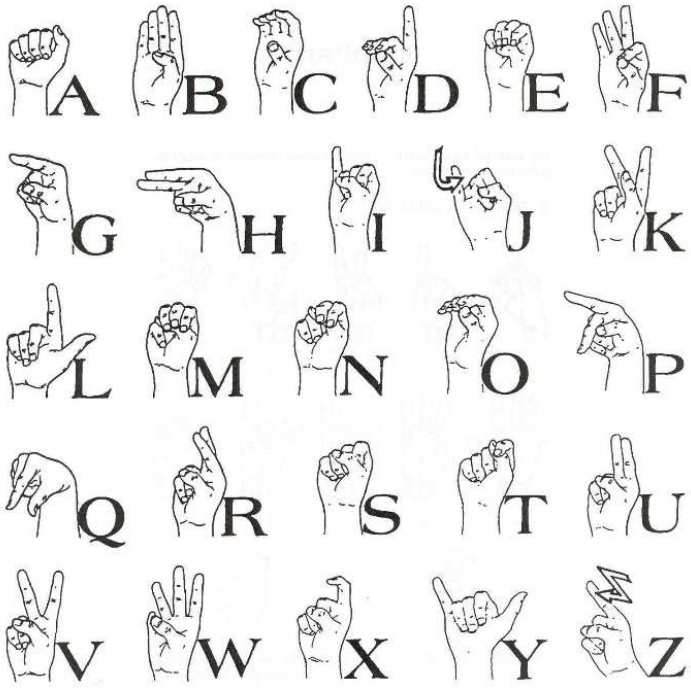

Fig. 1. Hand Gestures for Sign Language

II. LITERATURE REVIEW

TABLE I. SUMMARY OF VARIOUS LITERATURES IN THE FIELD OF SIGN LANGUANGE SYSTEMS

Reference	Focus Area	Methodology	Key Findings	Limitations	Advancements and Research Gaps
Moryossef et al. [1]	Real-time recognition of sign language	Estimating human posture using computer vision	Pose estimation was used to recognise sign language gestures in real time.	restricted to specific gestures and sign languages; significant computational expense	Reduce the amount of computing power needed and expand to more intricate motions
Liang & Ouhyoung [2]	ongoing recognition of gestures	Continuous realtime gesture recognition system	Real-time recognition of continuous gestures with success	restricted to a tiny dataset and antiquated technologies	Use more recent technology, such as deep learning, to improve accuracy.
Garcia & Viesca [3]	Recognition of American Sign Language (ASL)	Convolutional Neural Networks (CNNs)	The study showed to use CNNs to recognise ASL in an efficient manner.	restricted to still movements; significant processing power needed	Incorporate dynamic gesture identification and maximise performance in real-time.
Kuznetsova et al. [4]	Using depth cameras to recognise sign language	Processing depth camera data using computer vision methods	Reliable recognition was obtained with consumergrade depth cameras.	restricted to particular types of cameras; dependent on the surroundings	Investigate alternative senses and enhance flexibility in various contexts
Park et al. [13]	Mobile sign language translation	On-board depth cameras in mobile devices	Enabled real-time sign language translation on mobile platforms	Limited by mobile hardware capabilities; single sign language focus	Enhance performance across different mobile devices and add support for more languages
Papatsimouli et al. [15]	Review of sign language translation systems	Review of existing systems	Provided a comprehensive review of real-time sign language translation technologies	Lacked practical implementations; mostly theoretical	Need for practical, real-world applications and performance evaluations

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TABLE II. SUMMARY OF IMPORTANT ALGORITHMS IN THE FIELD OF SIGN RECOGNITION SYSTEM

Reference	Approach/Methodology	Technologies Used	Performance Metrics	Key Findings/Contributions
[1]	Human pose estimation	Human pose estimation	Accuracy, Real-time speed	Real-time sign language detection
[2]	Gesture Recognition	Computer vision, Neural networks	Recognition accuracy	Continuous sign language recognition
[3]	Convolutional Neural Net	CNN, Image processing	Accuracy, Real-time speed	Real-time American Sign Language (ASL)
[4]	Consumer depth camera	Depth camera, Computer vision	Accuracy, Real-time speed	ASL recognition using consumer cameras
[5]	Desk and wearable comp	Wearable computer, Video analysis	Accuracy, Real-time speed	ASL recognition with wearable devices
[6]	Leap Motion Controller	Depth sensor, Hand tracking	Accuracy, Real-time speed	ASL recognition using Leap Motion
[7]	Faster R-CNN	Object detection, CNN	Recognition accuracy	Bangladeshi Sign Language recognition
[8]	Computer vision-based	Computer vision, Image processing	Accuracy, Real-time speed	Bengali Sign Language recognition
[9]	Malaysian Sign Language	Color segmentation, Neural network	Accuracy, Real-time speed	Real-time Malaysian Sign Language trans
[10]	Deep Learning	Deep Learning, CNN	Accuracy, Real-time speed	ASL recognition using deep learning
[11]	Portable translation sys.	Hand tracking, Mobile platforms	Accuracy, Real-time speed	Portable ASL translation on mobile
[12]	Colour segmentation	Color segmentation, Neural network	Accuracy, Real-time speed	Real-time Malaysian Sign Language trans
[13]	On-board depth cameras	Depth cameras, Mobile platforms	Accuracy, Real-time speed	Sign language trans. on mobile platforms
[14]	Time series neural nets	Deep Learning, Time series analysis	Recognition accuracy	Real-time sign language translation
[15]	Review study	N/A	N/A	Comprehensive review of SL recognition

III. APPLICATIONS

A. Academic Study and Research

The historical overview of current state-of-the-art technologies and salient emerging trends through the survey paper will be of academic and scientific value to researchers and students interested in computer vision, gesture recognition, and assistive technology regarding real-time sign language recognition and translation. *B. Technology Advancement*

The survey study will be useful for the engineers, developers, and technologists currently working on real-time sign language recognition and translation systems to take insights from existing approaches and look for new ways of innovation and improvement in their respective projects. *C. Inclusivity and accessibility*

This survey document is highly crucial as it promotes the themes of accessibility and inclusion regarding the deaf and hard-of-hearing population. It talks about the technology that goes into making communication and involvement better for them as sign language users.

D. Educational Materials

The questionnaire document could be employed as part of the educational materials for educators and institutions that handle the education of professionals who work with the deaf and the hard of hearing. It helps in educating pupils on the essence of technology in bridging the gap in communication.

E. Advocacy and Policy

The document of the survey may also be useful for policymakers, the general advocacy network, and organizations involved in the struggle for the rights of deaf

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persons and those with hearing impairment so they gain a better background in regard to the situation of the technology environment in question. This may lead to any further decisions and practice in matters of funding, legislation, and accessibility.

F. Cross-Cultural Sign Language Research

Issues of several sign languages such as American Sign Language, Bangladeshi Sign Language, Bengali Sign Language among others are discussed in this stage. Researchers and linguists interested in the cross-cultural study of sign languages can identify the specific issues and solutions for various sign languages.

G. Technology Transfer

Assistive technology industries and startups would also benefit from studying the survey paper for ways in which technology can be transferred from academia to practical applications.

H. Collaboration on a Global Scale

The survey study features international perspectives that might encourage academics and organizations across borders in the creation of sign language detection and translation systems.

I. Further Research Suggestions

The survey document gives the indication of research gaps and directions of prospective fields. Researchers who are looking for an idea on what to research in their next research undertaking can understand what may be prospectively further explored in future work.

IV. CHALLENGES

A. Complex Signs

Sign languages are complex and vary from country to country, as well as from civilization to civilization. Identifying and interpreting these correctly in real time is a huge problem. Accurate detection of gestures is required for sign language translation [2, 5, 6, 9]. The development of robust algorithms that possess the capability to recognize varied motions can be considered a more challenging task.

B. Real-Time Processing

Communication success depends on real-time processing. This, therefore, requires optimum algorithms which can handle this, supported by appropriate hardware [4, 7].

C. Noise and Environmental Factors

Real-world noise and distractions will make the performance of recognition worse. Noise management and adaptation must be considered by the researchers.

Hardware will decide the performance of a system. Hardware limits and capabilities must be considered by the researchers [1, 4, 8, 13].

D. Cross-Cultural Adaptation

Sign languages depend upon culture and geographic location [8, 9]. Systems which can adapt to a large number of sign languages and geographic variations are very hard to develop.

E. User Adaptation

Systems need to be tuned for particular individual users as all of them have different signing styles and speeds [10, 12]. Correct translation is possible by personalization.

F. Data Collection and Annotation

Since it is shown that the collection and annotation of sign language datasets are very labour-intensive work, training machine learning models requires much time and effort, too [3, 14].

G. Concerns with ethics and privacy

The major issues are regarding a trade-off on convenience, accuracy, and acceptance between either wearable or nonwearable systems [5, 11]. A great amount of sensitive information is processed by the sign language recognition systems, and maintaining privacy and using it ethically is tough [15].

H. Integrating Sign Language Recognition with Other Technologies

Interoperability issues exist when trying to incorporate this with other technologies, such as mobile devices [13].

I. Long-term dependability

Making the real-time sign language translation systems dependable in the long run and their maintenance is a challenge both in the research aspect and practical implementations.

J. User input and User-Centric Design

In the user-centric design, it is of prime importance to obtain input from the deaf and hard of hearing communities [7, 11]. There can be difficulties in incorporating user feedback, but that is required.

K. Scalability and cost-effectiveness

Scalability and cost-effectiveness are crucial considerations since the deployment of sign language translation systems might take place at a higher scale [3, 10].

V. FUTURE SCOPE

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A. Enhanced Accuracy and Resilience

Future research should focus on increasing the accuracy and robustness of the developed recognition algorithms for sign languages. It is probably realized by developing more sophisticated models of deep learning and also by using techniques of handling variations in the motion of signs [3, 5, 10].

B. Integration of numerous Sensor Modalities

Depth cameras, wearable devices, and many other sensor modalities are integrated for better accuracy in systems and for improving user experience. Future research should focus on how these could work together.

C. Cross-Cultural Sign Language Translation

One of the major goals for the future will include expanding the recognition range into a wider scope of sign languages and dialects and solving regional problems of variance in these signs [8, 9].

D. Personalization and adaptation and Continuous Learning

Systems that can adapt to the patterns and preferences that individuals in signing improve user experience significantly. Another potential area is personalized sign language translation. Continuous learning techniques will provide the real-world sign language system with the ability to learn and evolve through time by collaborating with users and feedback received [6, 7, 11, 12].

E. Real-World Applications and Ethical AI

Translation of applications of sign language recognition beyond research prototypes into practical applications in education, accessibility, and healthcare in real life is another important and inevitable future task. Future research should also be done to address the ethical concerns in developing and deploying sign language translation systems, including privacy and justice issues [1, 14, 15].

H. Human-AI Interaction

The focus of future research should be on designing intuitive and successful human-AI interaction interfaces for sign language users in order to open up an exchange between people and artificial assistants [1, 11].

I. Scalability and cost-effectiveness

Scalable and cost-effective solutions will lead to higher penetration of real-time sign language translation systems into practical applications [10, 13].

J. User-Centric creation and Long-Term dependability

Continuous involvement of deaf and hard of hearing in the creation and assessment of sign language systems will provide more e-centric and effective solutions. Long-term maintainability, dependability, and support of real-time sign language systems will also remain a major priority area for future research and development efforts [2, 7, 11, 15].

L. Cross-Domain Integration

The study of different integration options of sign language recognition with other domains like augmented reality, virtual reality, and telemedicine might allow huge leaps regarding access and communication for people with hearing difficulties [13].

VI. CONCLUSION

Progress in developing real-time operating sign language translation systems has been fuelled specifically by recent improvements in computer vision, machine learning, and sensor technologies. Therefore, the state-of-the-art approaches and applications from a set of basic papers in the field will be closely reviewed in this study. This paper gives broad conclusions with no exact citations, intended to convey the important insights derived from this survey. The literature review shows increasing interest in the use of advanced technologies to provide more effective communication for deaf and hard-of-hearing people. Since real-time sign language translation systems have high potential, they will facilitate smooth communication between sign language users and non-fluent people in sign languages. Real-time sign language translation systems stand at that exciting crossroads where huge opportunities can be made to change communication and access in deaf and hardof-hearing communities. Surely, future collaboration among researchers, with the involvement of the Deaf community and changes in technology, will drive more accurate, adaptable, user-friendly system creation. The journey of inclusive communication is an ongoing process, and the contributions of scholars dealing with the subject become fundamental in setting a foundation for an inclusive society.

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