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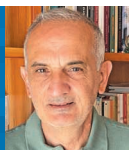

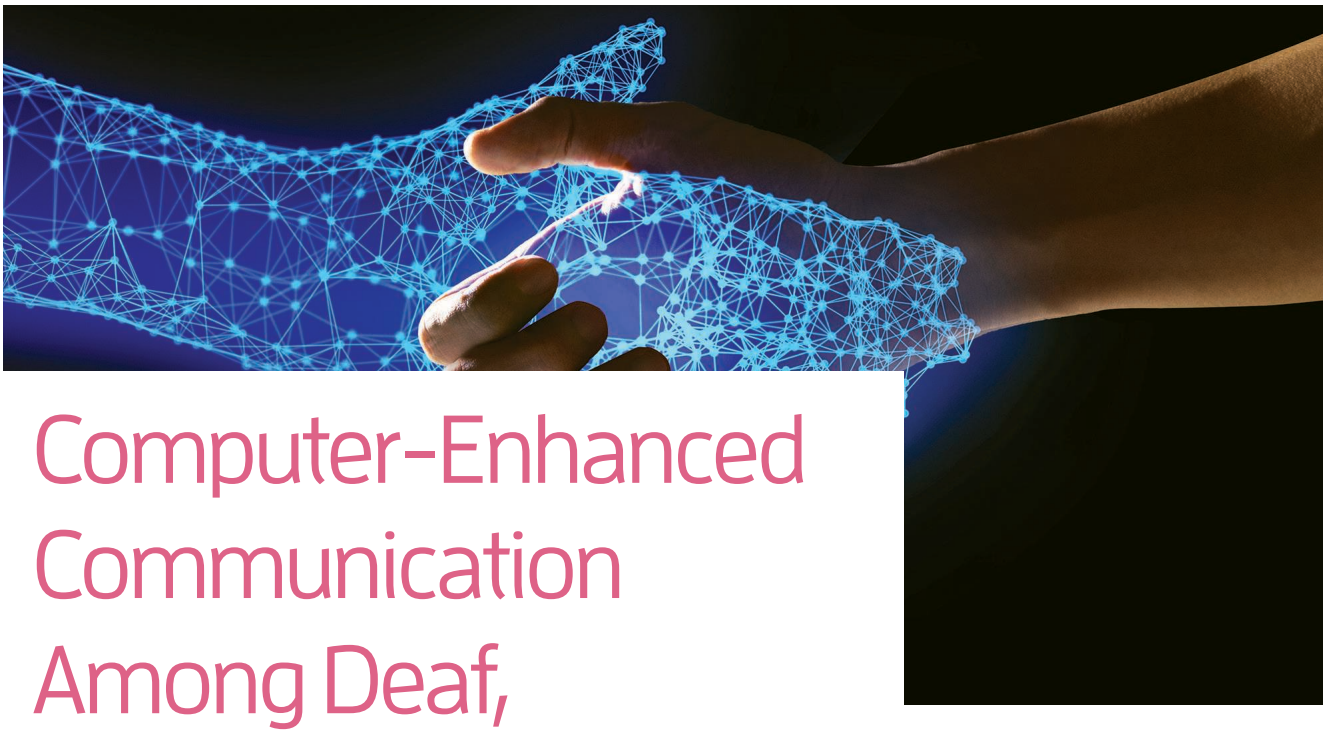

Computer-Enhanced Communication Among Deaf, Hard of Hearing, and Hearing People

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This article proposes a brief overview of the history of automated sign language interpretation and identifies trends. The history suggests that human interpreters will be the gold standard for the foreseeable future.

The idea of enhancing communication between people whose native languages differ has a long history. Scholars have documented references to interpreters as far back as 1900 BC.[1] The history of using computers in interpretation is much more recent.

AN ABSTRACT VIEW OF ENHANCING COMMUNICATION BETWEEN PEOPLE

Before looking at details focused on deaf, hard of hearing, and hearing people, we will take an abstract view of the task of enhancing communication between people. First, to clarify, the term "translation" is often reserved for the task of converting a written communication in one language to a written communication in another language. The term "interpretation" refers to a real-time conversion from a source language to a target language, sometimes in both directions.[2]

Figure 1 shows a simplistic view of enhancing communications between a source and an audience. One complication is that the communication can be in two directions; this is more often true of interpreters and less often true of translators. Although the mode of communication may be

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the same for the source and the audience (for example, both written or both oral), that is not always the case. One example important to this article is when the source communicates orally and the interpreter uses sign language for the audience. Figure 2 suggests this more complex view of the tasks inherent in enhancing communication between groups that prefer different modes of communicating.

COMMUNICATION BETWEEN PEOPLE WHO ARE DEAF, PEOPLE WHO ARE HARD OF HEARING, AND OTHERS

The World Federation of the Deaf reports that there are 70 million deaf people and over 200 different sign languages.[3] The idea of automating interpretation and translation systems for these people is daunting but tantalizing. As we shall see, researchers and commercial vendors have been working on such systems since at least 1977. Progress is being made, but slowly.

When describing communication between people who may be deaf, hard of hearing, or hearing, we should recognize that people who are deaf and people who are hearing can have dramatically different views about those designations. Many people, especially those who are not deaf, think of deafness as a disability to be overcome; many others, especially people who are deaf, identify with "Deaf culture," in which deafness is a characteristic, not a liability.[4] In this article, focused on automated aids for communication, we do not presume to explore in any detail the importance of Deaf culture to issues of interpretation. However, it is clearly a significant factor in the history and development of computer-enhanced communication with deaf and hard of hearing people and could be an area for future research.

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One approach to enhancing communication with deaf and hard of hearing people is to develop devices, therapies, and techniques to increase the understanding of oral speech. Hearing aids, cochlear implants,[5] and lip reading are examples of these efforts. An alternative approach is to emphasize the importance of sign language to Deaf culture and to focus on interpreting (in real time) between sign language and other languages. The rest of this article discusses this latter approach and how computing has been involved in efforts to increase communication among deaf, hard of hearing, and hearing people.

HUMAN SIGN LANGUAGE INTERPRETERS

During the 2023 Super Bowl televised festivities, three different sign language interpreters performed, and they generated a great deal of attention.[6] Two interpreters used American Sign Language (ASL), and the third also used Plains Indian Sign Language. These high-profile performances dramatically illustrated three ideas important to understanding the challenges of automating sign language interpretation: (1) Sign language is the preferred method of communication for many in the Deaf community. (2) Sign language involves the whole body, including hand motions, body positions, facial expressions, and the context of previous signs. (3) There is no one, universal sign language; a variety of sign languages are in active use globally.

Despite decades of research into various automated approaches, human interpreters remain the acknowledged highest-quality interpreters. That situation is likely to continue for decades to come. However, tracing the attempts at automated interpretation

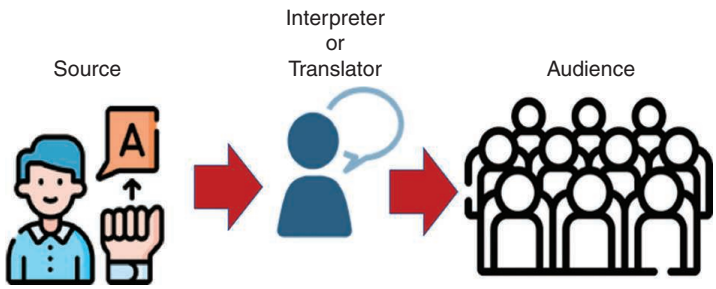

FIGURE 1. A simple view of the task of interpreters and translators.

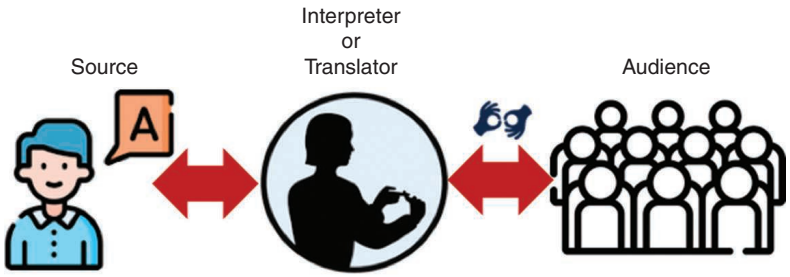

FIGURE 2. A more complete view of interpreting and translating.

offers insights into the difficulties and the promise of some of the automating approaches so far.

SOME MILESTONES IN AUTOMATED SIGN LANGUAGE INTERPRETATION

Table 1 lists five different projects through the years that have worked on automating the interpretation of sign language. This is not anything like an exhaustive list, nor can I claim it is representative. Hopefully, the list illustrates some of the variety of research and a few of the challenges researchers face in this area. The rest of this section puts these projects into context.

In 1977, the Southwest Research Institute developed a finger-spelling robotic hand. Input to the hand was via a keyboard, and output was a series of motions of the hand mimicking ASL finger-spelling positions.[7] The device was designed particularly for people who were both deaf and blind, as they could loosely hold the robotic hand and sense the finger spelling, thereby receiving (albeit slowly) a message typed into a console, and translated into finger spelling by the hand. This early attempt at enhancing communication was interesting for several reasons, including an early use of robotics, a sharply focused intended audience, and a simple form of input. However, the reliance on finger spelling and the fact that communication was only one way limited the usefulness of the system. There were also technical challenges in making the robotic signing fluid and accurate.[8]

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Following the robot finger-spelling hand, further research explored different approaches to taking hand gestures as input and giving written or oral words as output.[9] Methods suggested included hands specially marked for recognition[10] and placing the hand in a sensing glove.[11] These efforts had two important drawbacks for more general use: the preparation of the hand and sophisticated sensing equipment was time consuming and expensive, and the focus merely on hands and fingers did not take into account much of what signers communicate. An approach that has become the dominant one is analyzing video (either real time or stored) to detect signs. One of the first published works on this approach is by Tamura and Kawasaki.[12]

To communicate information effectively to people who are deaf and hard of hearing, one method is to film a human interpreter signing the information and then distribute the video. However, some agencies, educators, and companies have found it useful to use automated avatars, in two or three dimensions, instead of human interpreters, to communicate information visually. Advantages include lower cost, quicker turnaround when changes are

TABLE 1. Five milestones in automated sign language interpretation.

Year	Device	Input	Output	Sender	Receiver
1977	Finger-spelling robot hand	Keyboard single letters	Mechanical hand movements	Someone who can type	People who can read sign language by touch
1983	Digital data entry glove	Finger spelling and hand gestures	Digital representation of individual characters and signs	Someone who knows ASL	Software to recognize ASL hand gestures
1988	Analyze video	Finger spelling and hand gestures	Digital representation of individual signs	Someone who knows Japanese Sign Language	Someone who knows Japanese written language
1999	GESSYCA system for specifying communication movements	Programming and processing of images	Signing avatar	Someone wanting to communicate information via avatars	People who understand sign language
2020	Word-level sign recognition	Video (stored or real time) of people signing	Words that correspond to the signing	Anyone who can perform ASL signing	Anyone who can read English words

required, and the possibility of seeing the signing from different perspectives from a single instance of an avatar and to vary the timing of the depicted sign. There are myriad technical difficulties in making realistic signing from avatars. Naert et al.[13] survey many of these difficulties and explain some of the strategies being used to improve signing avatars. They also point out the crucial role for people who are deaf in helping to design and develop effective and acceptable signing avatars. The deep engagement of deaf and hard of hearing people in all of the research we are discussing is an important factor in any prospects for the future success of those projects.

Naert et al. describe several systems and many research papers exploring the programming of signing avatars. One interesting innovation was a high-level specification language called "QualGest that takes into account the four manual parameters (hand configuration, placement, motion and orientation)" (p. 12).[13] They also mention an extension to XML specialized to sign language description, SignWriting Markup Language.

> The ideal of a smooth, accurate, real-time automated intermediary between people using sign language and a different language will require multiple breakthroughs.

Using visual analysis has continued to advance by expanding how much is analyzed. Researchers are including more of the signer in the analysis (not just hands but arms, face, and body).[14] Second, they are attempting to interpret larger spans of sign language performance; first, it was individual letters in finger spelling, then it was individual signs for words, and now it is trying to understand larger meanings. I use the term "larger meanings" to avoid using "sentences" because the structure of sign language is not identical to the structure of written and spoken languages, and sentences are often not an appropriate designation of sign language structure.[15]

The time between the 1977 fingerspelling hand and a recent (2020) report on automatic recognition of signing illustrates challenges researchers have faced, challenges that have slowed progress. The 2020 system focuses on one sign language, ASL. It also does not claim to wholistically interpret signing but focuses on isolating and identifying signs for one word at a time. Even with this simplification, the task is daunting. The report by Li et al.[16] includes several examples of difficulties they have encountered, including signs that differ only in the orientation of the hands, signs that look very similar and must be distinguished using context, and signs that look dramatically different when different people are signing them. The researchers for this project are using deep machine learning to try to meet these challenges.

FIGURE 3. A teenage girl signing into a computer. (Source: iStock photo, credit: DaisyDaisy.)

This brief overview of the history of automated sign language interpretation is severely limited. However, we can recognize trends. First, the history suggests that human interpreters will be the gold standard for the foreseeable future. Computer-mediated human signing (as shown in Figure 3) uses technology but not for interpretation. Second, there is progress being made in automating sign language understanding, but the nature of sign languages makes it unlikely for there to be a sudden burst of progress. For one thing, there are so many different sign languages, each with distinctive characteristics. For another thing, all sign languages have fundamental differences from written and spoken languages, differences that will remain challenging when trying to move from sign languages to other languages. I think it is important to note that most of the research being done with

sophisticated techniques is unidirectional. The ideal of a smooth, accurate, real-time automated intermediary between people using sign language and a different language will require multiple breakthroughs.

When researching this article, I was fortunate to have a conversation with Saida Florexil and Aakriti Gupta, the cofounders of Imanyco, a company that works in this area.[17] They emphasized that the focus in this work should always be on the quality of communication and not on any particular technology or innovation. That seems wise when we examine the history and contemplate the future of machine interpretation of sign language: people are more important than the machines, no matter how sophisticated the machines become.

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