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Assistive Technologies for American Sign Language Users: A Systematic Mapping Study

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Abstract. This systematic mapping study provides a comprehensive overview of research on assistive technologies for American Sign Language (ASL). It utilized the Scopus database, employing a carefully formulated search string and inclusion/exclusion criteria. The findings indicate that research in this field is primarily conducted in the northern region, particularly the United States. While the primary focus lies on interpreters and translators, there is a noticeable scarcity of investigations into harnessing mainstream technologies for the benefit of ASL users through AI-powered solutions like Personal Assistants. The study emphasizes the need for further advancements in enhancing accessibility for different contexts and impairments. It contributes to understanding the research landscape and identifies avenues for future research and development in ASL assistive technologies.

Keywords: AI assistance, assistive technologies, speech impairment, human-computer interaction, interaction design, accessibility.

1 Introduction

Assistive technologies for individuals with disabilities cover a broad spectrum of innovative solutions that strive to augment independence, accessibility, and quality of life [61]. Moreover, assistive technologies contribute to fostering inclusivity, engagement, and equitable opportunities in educational, occupational, and social contexts [11]. American Sign Language (ASL) is a visual-gestural language that is primarily utilized by the Deaf community in the United States and certain regions of Canada [41]. ASL is renowned for its linguistic complexity and serves as a vital medium enabling Deaf individuals to partake in conversations, share narratives and express emotions.

In the realm of assistive technologies for individuals with speech impairments, artificial intelligence (AI) has assumed a central role [9]. AI-driven solutions leverage natural language processing capabilities to address the communication challenges faced by those with speech disabilities. These encompass a spectrum of applications, notably including text-to-speech (TTS) synthesis, automatic speech recognition (ASR), and augmentative and alternative communication (AAC) systems [9].

AAC systems harness AI to anticipate and suggest words or phrases based on user input, streamlining the communication process. Rooted in AI and machine learning algorithms, these technologies exhibit a trajectory of ongoing enhancement in terms of accuracy and user-friendliness [48]. Their potential to empower individuals with speech impairments in achieving more effective communication is substantial.

Researchers and developers within this domain are actively channeling AI innovations to elevate the accessibility and efficacy of assistive technologies tailored for speech-impaired individuals, thus culminating in tangible enhancements in their overall quality of life [61]. Assistive technologies for American Sign Language (ASL) and individuals with deafness or speech impairments encompass innovative solutions that promote communication and inclusivity [48].

These technologies aim to bridge the communication gap between ASL users and those unfamiliar with the language [48]. For instance, video relay services, where Artificial Intelligence driven real-time interpretation facilitates seamless communication between ASL users and speakers of spoken languages through video calls [55, 4] and Personal Assistants triggered by gesture recognition powered by AI [16, 42, 15]. Sign language recognition systems employ computer vision and machine learning algorithms to interpret ASL gestures and translate them into text or speech.

To gain a deeper understanding of assistive technologies related to American Sign Language (ASL), we conducted a systematic mapping study. This study enabled us to examine the research on assistive technologies for ASL within a specific context. Systematic mapping studies help create a structured framework for exploring a research topic and present a concise visual summary of the identified findings [31, 52].

To establish a comparative analysis with other relevant studies, including systematic mapping studies in various assistive technology fields [46, 35, 23, 1]. In congruence with previous scholarly endeavors, the present study exhibits noteworthy resemblances concerning the employed assistive technology and the methodological approach employed for their application, our investigation focuses specifically on exploring in-depth inquiries related to user experience and user context.

Our main objective is to develop and offer assistive technologies that are specifically tailored to individual user requirements. We organized this Systematic Mapping Study is structured as follows. The first section aims to describe the methodology. In Results section, we showcase the results of our study. In Discussions section we discuss over the findings and finally we summarize the research in the Conclusions section.

2 Research Method

Our research employed the systematic mapping study approach, a recognized and rigorous scientific methodology [31, 52]. This research method shares similarities with the well-established Systematic Literature Review (SLR) approach commonly used in scientific research [30]. The process of conducting a mapping study follows a systematic and rigorous framework, involving three fundamental activities:

– **Planning.** During this stage, the mapping study protocol is meticulously developed, involving a rigorous and iterative process to establish the overarching plan of the mapping study.

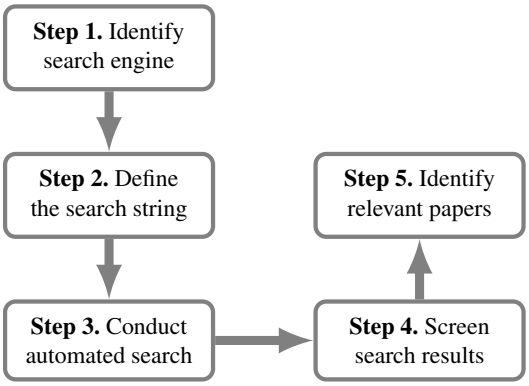

Fig. 1. Sequence of steps in the proposed mapping search procedure.

– **Execution.** During this phase, the mapping study protocol is executed, entailing the implementation of the predefined search string on the designated sources. The retrieved documents are then systematically evaluated based on the predetermined inclusion and exclusion criteria.
– **Reporting.** This phase involves reporting the mapping study findings and ensures the transparency, credibility, and reproducibility of the study's findings, contributing to the advancement of knowledge in the respective research area.

2.1 Research Question Definition

Our study aims to provide a comprehensive overview of the current state of the art in Assistive Technologies for American Sign Language (ASL). To achieve this, we have formulated research questions that align with our overall objective. These questions guide the identification and categorization of the existing research in accordance with our defined goal:

– **RQ1:** What is the distribution of research papers about Assistive Technologies for American Sign Language Users categorized by country?
– **RQ2:** What is the distribution of research papers about Assistive Technologies for American Sign Language Users categorized by year?
– **RQ3:** What is the distribution of the research papers about Assistive Technologies for American Sign Language Users categorized by the Impairment Type?
– **RQ4:** What is the distribution of the research papers about Assistive Technologies for American Sign Language Users categorized by the Assistive Technology used?

2.2 Identification and Selection of Sources

We utilized the widely recognized Scopus database as our primary information source for this study. Scopus offers an extensive collection of scientific literature, granting access to a diverse range of publications.

Table 1. Search string defined for the systematic mapping study.

Search String
(“AI Assistance” OR “Personal Assistant” OR “Virtual Assistant” OR “Assistive Technologies”) AND TITLE-ABS-KEY (“ASL” OR “American Sign Language”) AND (“Human-computer Interaction” OR “Accessibility” OR “HCI”)

Figure 1 illustrates the overall system of the Systematic Mapping Study methodology we followed. We developed the search string for our study by extracting relevant terms from the research questions. These terms were combined using logical operators like “AND” and “OR” to refine the search and identify relevant literature.

Table 1 presents the resulting search string, highlighting that the majority of the terms focus on assistive technologies. After choosing the search source and defining the search string, we established specific inclusion (IC) and exclusion (EC) criteria for the selection of primary studies. Table 2 provides a concise overview of the inclusion and exclusion criteria utilized in our study.

2.3 Execution

After finalizing the inclusion and exclusion criteria, we executed the search string on the Scopus database, specifically, the database query was executed on May 14, 2023. To conduct this evaluation, we thoroughly examined the titles, abstracts, and keywords of all the retrieved documents.

In some cases, a detailed screening of the entire paper was necessary to assess its eligibility for inclusion. Table 3 presents the number of relevant papers. To organize the information from the selected relevant papers systematically, we created a structured template. This template included specific fields to capture essential details, ensuring consistency and facilitating analysis.

3 Results

In this section, the finding results and analyses of the paper categorization are presented. According to the findings, we address each of the four research questions (RQs) defined in the Research Method section.

3.1 What is the Distribution of the Research Papers About Assistive Technologies for American Sign Language Users Categorized by Country? (RQ1)

The first question aims to identify the number of published relevant papers across the world. We categorized the papers according to the author’s affiliation and organized them based on their respective country. If the papers were written by two or more authors of different countries these papers were duplicated and accounted for in each country to which the authors belong. Figure 2 shows a choropleth map of the distribution of papers across the world.

Table 2. Exclusion and inclusion criteria.

Criteria	Description
IC1	Include English papers.
IC2	Include papers that contain the search String terms.
IC3	Include papers that maintain relationship with the keywords.
EC1	Exclude papers that do not contain the characteristics mentioned above.

We identified one country with the greater number of published papers (32) [44, 34, 55, 16, 18, 45, 24, 42, 33, 15, 5, 54, 8, 14, 19, 10, 51, 29, 20, 60, 28, 40, 27, 25, 26, 53, 56, 21, 39, 59, 38, 22]: United States of America. The remaining published papers (18) belong to 17 countries: Canada (1) [32], Cyprus (1) [62], Germany (1) [13], India (2) [17, 57], Norway (1) [57], Italy (2) [12, 2], Korea (2) [37, 36], Philippines (2) [3], Spain (1) [43], Thailand (1) [50], Tunisia(3) [7, 49], France (1) [8], Netherlands (1) [8], UK (1) [6], Australia (1) [6]. This finding suggest that Assistive technologies for ASL research is of interest in a great variety of countries, tough most of the publications belong to America, more in detail to United States of America.

3.2 What is the Distribution of the Research Papers About Assistive Technologies for American Sign Language Users Categorized by Year? (RQ2)

This research question aims to identify the number of published papers by year. We categorized the papers according to the year of publication. Figure 3 shows a Scatter plot of the distribution of papers across the years. We identified two years with the greater number of published papers (18): In the period from 2021 to 2022 [37, 44, 62, 34, 55, 16, 18, 13, 32, 45, 24, 50, 42, 33, 15, 3, 5, 54].

The remaining published papers (29) belong to 14 periods of year: 2023 (1) [17], 2019 (4) [8, 12, 7, 2], 2018 (1) [36], 2017 (2) [14, 19], 2016 (3) [10, 51, 29], 2015 (4) [20, 43, 60, 28], 2014 (3) [40, 27, 25], 2013 (3) [26, 57, 49], 2012 (4) [53, 56, 6, 21], 2011 (1) [39], 2010 (1) [59], 2009 (1) [38], 2005 (1) [22]. This finding suggest that AI assistance for ASl research has been from interest in recent years from the period of 2021 to 2023 as most of the publications belong to that period.

3.3 What is the Distribution of the Research Papers About Assistive Technologies for American Sign Language Users Categorized by the Impairment Type? (RQ3)

This research question aims to identify the number of published papers by the Impairment they had focus on. We categorized the papers according to the Indiana University classification of Types of Impairment [58]. If the papers were written considering two or more impairment types we created a new category including the combination of these impairments.

Figure 4 shows a pie chart of the distribution of papers by impairment type. As observed in Figure 4 the two most common types of impairments are Speech and Hearing impairment independently (39) [17, 44, 62, 55, 16, 18, 13, 32, 45, 24, 50,

Table 3. Database search results.

Search Date	Document Results	Relevant Papers
05/14/2023	91	47

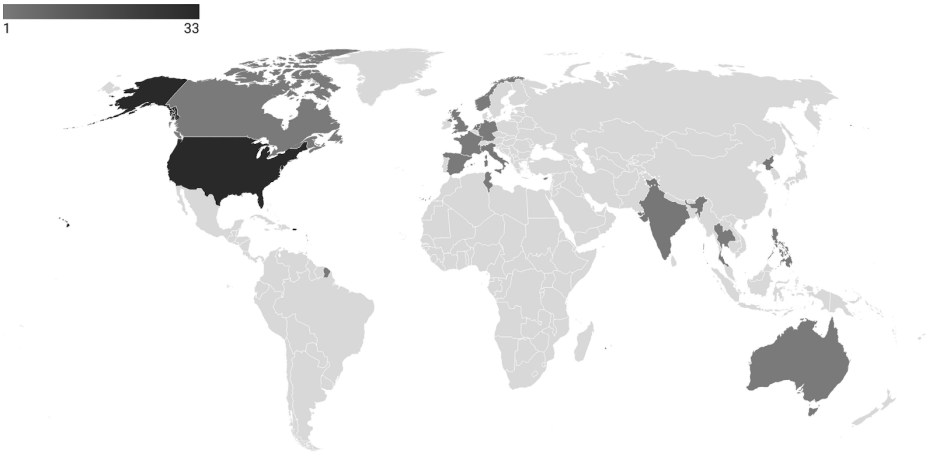

Fig. 2. Choropleth Map that highlights the papers published across the world.

42, 33, 3, 5, 54, 8, 12, 7, 2, 36, 14, 19, 10, 51, 29, 20, 43, 60, 28, 40, 27, 25, 26, 57, 49, 56, 38, 22]. We also observe that only one combination (Speech and Hearing) (8) [37, 34, 15, 53, 6, 21, 39, 59] is generated, as they both make use of the American Sign Language.

3.4 What is the Distribution of the Research Papers About Assistive Technologies for American Sign Language Users Categorized by the Assistive Technology Used (RQ4)

This research question aims to identify the number of published papers by the Assistive Technology they used or suggested to use.We categorized the papers according to the National Institute on Deafness and Other Communication Disorders [47]. Figure 5 shows a distribution chart of papers by assistive technology. Within the domain of personal assistants, our research explores various aspects.

We have identified noteworthy papers in this context, including those investigating command triggers, which aim to understand the factors that initiate and activate commands within personal assistant systems (3 papers) [16, 42, 15] it is worth noting these papers purposes a gesture recognition systems to provide the inputs.

Additionally, there are papers focusing on interpreters and translators, which are widely used assistive technologies to facilitate effective communication across language barriers (24 papers) [62, 18, 13, 45, 24, 5, 54, 12, 36, 19, 10, 29, 20, 60, 28, 57, 49, 53, 56, 6, 21, 39, 59, 22] within these papers there are some using gesture recognition and natural language processing empowered by AI. The scientific literature also encompasses innovative approaches proposed in captioning papers, shedding light

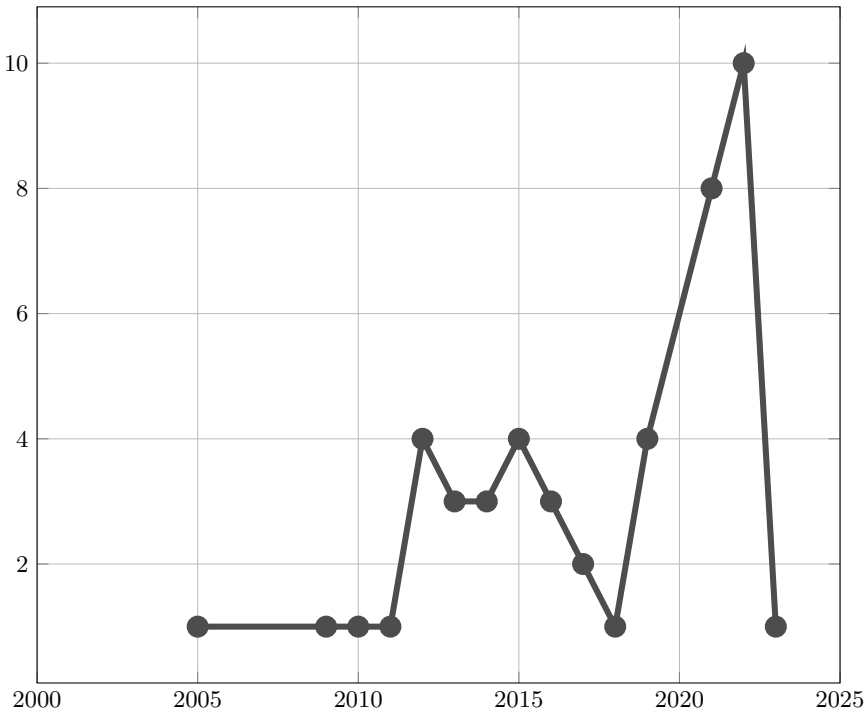

Fig. 3. Distribution of relevant papers published per year.

on ASL captioning, integration within video conferencing platforms, and the fusion of videos with automatic captioning (2 papers) [44, 55]. Furthermore, theoretical applications papers propose potential applications for assistive technology in this field (18 papers) [17, 37, 34, 32, 50, 33, 3, 8, 7, 2, 14, 51, 43, 40, 27, 25, 26, 38].

4 Discussions

The selected papers in this mapping study were authored by individuals from various countries, with a majority of them being published by authors affiliated with the United States of America. This indicates that the majority of research in this field comes from countries in the northern region, such as Canada, Germany, France, Norway, Italy, Korea, Spain, and the Netherlands. On the other hand, there is a noticeable lack of research from countries in the southern region, with only Jamaica contributing papers on the topic (RQ1).

In recent years, there has been an increased focus on Assistive Technologies for Speech Impairment and American Sign Language (ASL) users, particularly in the period of 2021 and 2022. This surge in attention coincides with the global outbreak of the COVID-19 pandemic, which some papers acknowledge as a contextual factor influencing research in this area (RQ2).

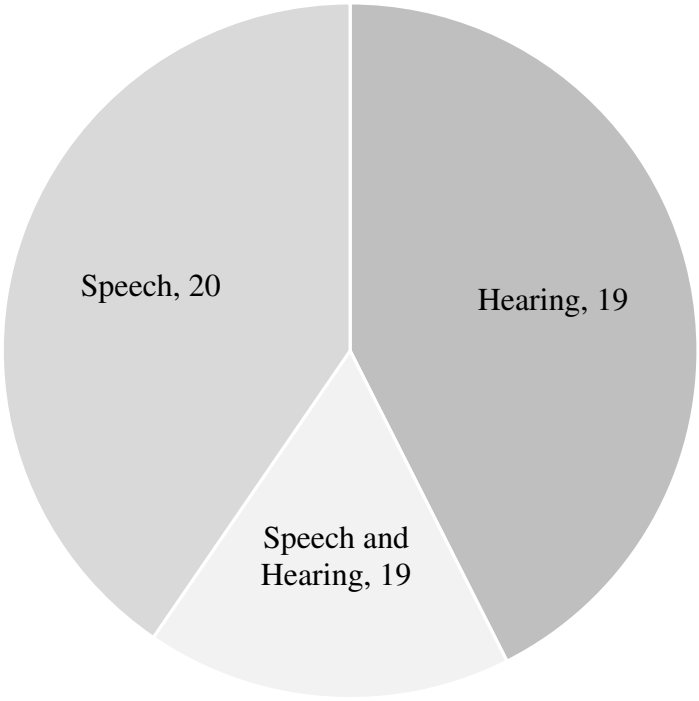

Fig. 4. Distribution of papers published by type of impairment.

Regarding the categorization of published papers based on impairment type, it is evident that hearing impairment, speech impairment, and a combination of both have received the most attention. This specialization in research indicates a recognition of the unique challenges and requirements associated with different types of impairments, with the aim of developing tailored solutions that cater to the specific needs of individuals with hearing or speech impairments (RQ3).

Among the published papers, a significant proportion (44.64%) focuses on research related to Interpreters and Translators, followed by Theoretical Applications, accounting for 37.5% of the papers. This distribution highlights the challenge of bridging the gap between theoretical concepts and practical implementation in fully harnessing the potential of assistive technologies for individuals with disabilities.

Notably, there are also research efforts focused on personal assistants and captioning tools. However, it is important to note that while many papers propose new technologies, their primary focus lies in enhancing communication for ASL users through the development and improvement of interpreters and translators.

The findings of this study unequivocally demonstrate that artificial intelligence (AI) plays a pivotal role in the development and advancement of assistive technologies. Specifically, AI technologies have become integral in facilitating gesture recognition for translation and interpretation purposes, as well as enhancing personal assistants' capabilities to provide relevant and valuable responses.

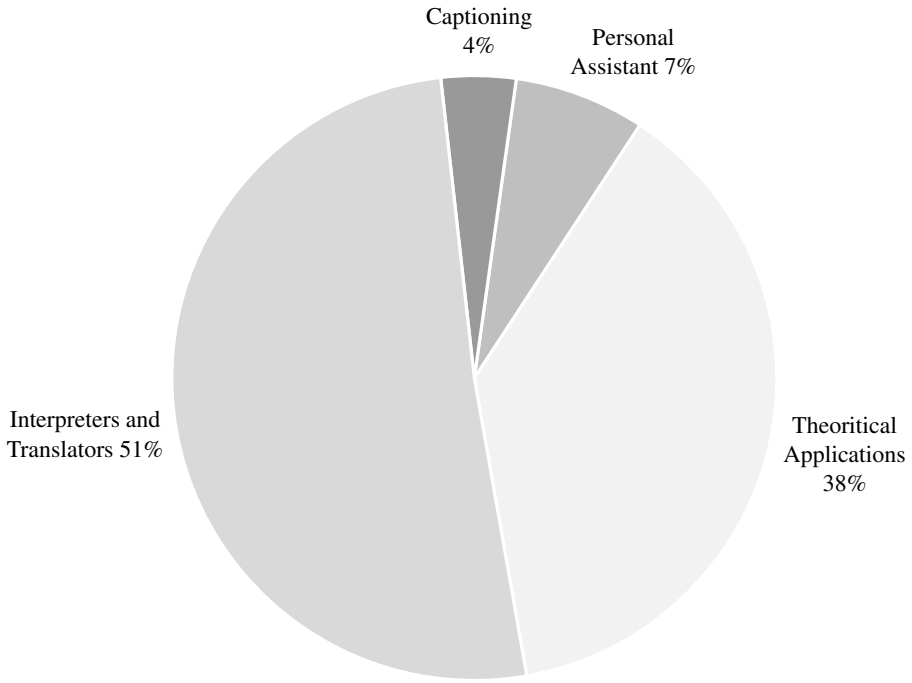

Fig. 5. Distribution of papers published by assistive technology.

The adaptation of technologies like personal assistants and captioning tools for this specific user group receives relatively less attention (RQ4). Despite the increased visibility of Assistive Technologies research for ASL users on an international scale, there is still a need for further advancements in this field. Our findings indicate that a significant proportion of published papers primarily focus on theoretical applications, with a noticeable lack of user experience (UX) research methods to validate their accessibility.

5 Conclusions

This study aims to comprehensively characterize the research landscape of assistive technologies for American Sign Language (ASL) through a systematic mapping study of relevant scientific and technical papers. The research area of assistive technologies for ASL users has gained significant relevance worldwide using AI as the main engine for these technologies. While many papers propose innovative technologies, their primary focus is on improving communication for ASL users, particularly through the development and refinement of interpreters and translators.

However, there is relatively less emphasis on adapting mainstream technologies for this specific user group such as personal assistants. Based on these findings, it can be concluded that there is room for improvement in enhancing the accessibility of these technologies for users across different contexts and impairments such as the integration

of mainstream technologies that could potentially be harnessed to cater to the needs of American Sign Language (ASL) users through the utilization of Artificial Intelligence (AI) methodologies. In forthcoming research endeavors, we intend to conduct a more comprehensive investigation into the state-of-the-art of assistive technologies. This endeavor will encompass an in-depth exploration of recent advances in the field, delving into novel research questions and facilitating a more profound analysis of pertinent research papers.

Such endeavors can encompass, among other possibilities, the exploration of novel research inquiries concerning the methodologies underpinning user-centered and accessibility aspects within the realm of assistive technologies. Furthermore, a meticulous delineation of each scholarly work is imperative to provide a comparative perspective and enhance the elucidation of the field.

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