

Natural Language Processing Enhancing Human-Computer Interaction for Disabled

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Abstract--Such as physical interaction, individuals with disabilities often encounter barriers when accessing and interacting with traditional computer interfaces. Navigating the digital interface poses challenges for those with disabilities. The necessity for innovative solutions is underscored by the main issue of limited accessibility to computer interfaces for individuals with disabilities. At present time, Human-Computer Interaction technology is most known in the tech industry. Which enables any individual to interact with system or computer. Here, Natural Language Processing plays a major component in the advancement of Human-Computer Interaction technology. This paper surveys recent methods, techniques like embedding, Word2Vec and technology to help in improvement of the Human-Computer Interaction. This work highlights the need of integration of advance Natural Language Processing like with Human-Computer Interaction for people with disabilities. This paper also proposes work on a hands-free device navigation system or application for differently abled peoples.

Keywords- disability, disabled, NLP, Natural language processing, human computer interaction, HCI, Hands-free navigation system.

I. INTRODUCTION

Human-Computer Interaction (HCI) is a comprehensive field focused in designing and using interfaces of computer technology between people and computers. It aims to create intuitive, user-friendly, and accessible systems, enhancing usability and user satisfaction. HCI studies cognitive and behavioral aspects to design effective interfaces and explores various interaction techniques and emerging technologies. The goal is to make systems easy to learn, efficient to use, and enjoyable for all users, including those with disabilities [14][20].

Natural Language Processing (NLP) has been chosen for development of many recent technologies like Alexa, Voice Assistant, Car Speed Tracker, and Robotics. NLP enables the system to understand and respond to verbal commands or text input, further enhancing accessibility for individuals with disabilities who may have difficulty using traditional input methods. Already some recent innovations like Alexa and Voice Assistant have been developed with this technology. Moreover, this is also open source [2][12].

Using NLP for developing a voice command controller system allows for a more intuitive and natural interaction, as the system can understand and process complex commands rather than simple, predefined phrases. This understanding extends to maintaining context awareness, enabling sophisticated interactions by keeping track of previous commands and providing continuity in conversations. In this way NLP is one of the key components of HCI [2]. The main issue of limited accessibility to computer interfaces for individuals with disabilities underscores the necessity for innovative solutions. Traditional input methods often hinder individuals from fully participating in educational and professional spheres.

The major contributions are as followed-

- Highlighted NLP Packages of Programming enhancing HCI.
- NLP Techniques enhancing HCI Applications.
- Highlights the need of integration of advance NLP with HCI for Disables.

The organization of this paper is as follows. In Section 2 this work provides an summary of the Background of HCI & NLP. The 3rd Section describes how NLP is enhancing HCI. In Section 4, The Recent Advancement will be presented with their used technology. Result and Discussion have been indicated in Section 5. This paper concludes by presenting study, limitations and future research direction in Section 6 , after then references.

II. LITURATURE SURVEY

This Section covers Natural Language Processing (NLP) & HCI, describing methodologies, recent developments, and innovations.

A. Recent advancement with NLP

Advancement in assistive technology and educational platform is enhancing day by day. Here is some recent advancement in which NLP was the major component with others.

Yongfang Zhang et al. [1] presented an exploration of an intelligent Q&A system for online education platforms, with the help of natural language processing (NLP) technology. Their approach integrated text summarization, sentiment

TABLE I. LITERATURE SURVEY ON ADVANCEMENT OF NLP

Authors	Year	Technology / Method Used	Assessment
Yongfang Zhang [1]	2024	RNN, LDA with weighted factors, sentiment analysis, named entity recognition, semantic understanding	Accessibility - 40%, Engagement - 30%, Student performance - 25%, Efficiency - 50%
Le Na [7]	2024	A2C, Deep Reinforcement Learning, Hind-sight Experience Replay, NLI.	Effective - sparse reward environments, High accuracy and game performance.
Baek Jeong et al. [8]	2024	NLP, Tokenization (Unigrams, Trigrams, Bigrams), Recommendation Systems	privacy benefits, Improved recommendation accuracy, innovative services
Yunqing Jiang et al. [2]	2023	Deep learning, Sentiment analysis, chatbots, machine learning, data extraction, topic modeling, question answering, classification,	Most frequent reasons for using NLP - decision-making, Data classification and management
Lipeng Cui et al. [10]	2023	AI, computer graphics, deep learning, speech synthesis, neural networks	Challenges: security issues, realism, address privacy and accurately sense emotions.
Thanveer Shaik et al. [3]	2022	NLP methodologies (text summarization, sentiment annotations, entity annotations, , topic modeling); Python, Java, R packages	To build decision support systems: decision intelligence, deep learning.
Wenxi Wang et al. [4]	2022	Hybrid Human-Artificial Intelligence (H-AI) model with a three-layer architecture (processing, object, intelligent and application)	Proposed the framework of H-AI to support social computing.
Ovisheke Sen et al. [5]	2022	Classical methods, Deep Learning (e.g., ANN, LSTM, GRU, CNN), Machine Learning (e.g., Support Vector Machines).	In abstractive text summarization task Bangla text summarization is quite challenging
Zhipeng Xu et al. [6]	2022	AliCloud, Hierarchical semantic parsing, Android integration Directed edge-tagged graph.	Efficient in multi-operation commands, good performance in smart home domains, agriculture and industry.
Marwan Omar et al. [9]	2022	NLP robustness, adversarial attacks	After deployment for lack of robustness numerous real-world NLP projects and work have failed.

analysis, topic modeling along with adaptive learning to enhance accessibility, user engagement, and mobility in online education. Yunqing Jiang et al. [2] shown the use of various NLP techniques. Machine learning, sentiment analysis and chatbots is some of them. The work has analyzed total of 1032 articles for exploring, in which way NLP can be used to transform government services, extend it and automate. Thanveer Shaik et al. [3] introduced different kind of NLP techniques. Some of them are Text summarization, sentiment and entity annotation, topic modeling. The study indicated the challenges like sarcasm, aspect-based sentiment analysis and domain-specific language. Wenxi Wang et al. [4] developed a novel H-AI framework which integrates human intelligence with AI for addressing the challenges. The Paper described a three-layer architecture for H-AI, object layer comprising, application layer and an intelligent processing layer. These have been argued to be more effective in solving complex social problems in compared to traditional AI. (Table I).

Ovisheke Sen et al. [5] focused on the need for improved resources as well as methodologies to enhance BNLN systems. The study categorized BNLN methods into 11 areas which includes sentiment analysis, speech recognition, and machine translation. Zhipeng Xu et al. [6] proposed a natural language query and control interface an IoT-NLI. It is being designed to enhance interaction with Internet of Things (IoT) platforms. Moreover, they developed an Android application which is

integrated with the AliCloud platform. This Android app provide users with a natural language interface which is similar to popular instant messaging apps. Le Na et al. [7] introduced an algorithm for human-machine interaction to address challenges in sparse reward environments for learning games. This leveraged deep reinforcement learning (DRL). Baek Jeong et al. [8] explored approach which aimed at enhancing service generation through tokenization to develop a NLP-based recommendation. Marwan Omar et al. [9] emphasized the necessity for a multi-dimensional approach to robustness and also argued for developing a comprehensive framework. Lipeng Cui et al. [10] provided a detailed survey of virtual human technology which has detailed its development. The work has analyzed the present academic research and more practical applications of virtual humans. (Table I).

B. Enhancement of Human-Computer Interaction

Using of HCI ensures that the developed system will be intuitive and user-friendly for user adoption and satisfaction. HCI technologies are improving day by day. HCI systems can deliver a seamless interaction experience that can accommodate huge user groups, including those with disabilities.

Jonathan Álvarez Ariza et al. [15] explored in which way OSHW and OSS were employed in the development in design

TABLE II. LITERATURE SURVEY ON ADVANCEMENT OF HCI

Authors	Year	Technology / Method Used	Assessment
Fayez Alfayez et al. [19]	2024	Blockchain, Federated Learning, LSTM	Presented a framework combining blockchain and federated learning -enhance security, privacy in virtual assistants for disabled individuals.
Wahyu Rahmani et al. [16]	2022	Convolutional Neural Networks (CNNs) for head pose estimation	Offered better cursor control and target accuracy > Camera Mouse but relies only on RGB cameras,
Islam M. U. et al. [17]	2022	Speech-based intelligent personal assistants (sIPAs), interviews,	To create a sIPAs that better meet older adults' needs collaboration between developers and designers is being suggested.
Clément Delgrange et al. [18]	2020	Adaptive Virtual Assistant, Usage-Based Learning.	Presented a virtual assistant which adapts to new tasks through usage-based learning.

and deployment. Wahyu Rahmani et al. [16] introduced the Touchless Head-Control (THC) system. This is an AT for controlling computer cursors and 3D object orientation using head gestures. The THC method was designed for enhancing accessibility for individuals with limited motor. Islam M. U [17] recommended integrating features and to improved privacy controls which can better dialect and accent recognition. Clément Delgrange et al. [18] introduced a method where a virtual assistant learned to map natural language commands to actions through user demonstrations. This allows it to handle new tasks and domains without pre-engineered knowledge (Table II). Fayeze Alfayez et al. [19] proposed a more better framework for enhancing the security and privacy of recent virtual assistants. The framework integrated blockchain technology and federated learning. The work also addressed the limitations of present virtual assistant systems, particularly concerning security and privacy. Hye Park et al. [20] examined how HCI and Design Thinking (DT) processes could learn from each other, overlap and differ. The work suggested that integrating the holistic and innovative area of DT could enhance HCI design processes which is more potentially benefiting both in academy and industry.

III. BACKGROUND

A. HCI

HCI is regarded as a computer-related and cross-disciplinary field closely linked with the design of technology, information and interaction. HCI closely connects with communication and Technology, design for information and interaction. It is seen as a cross-disciplinary related in computer. HCI focuses on the tools and methos time to develop HCI. It also assesses the usability of computer systems. Additionally, HCI addresses issues like broader human-centric including how computer is being interacted by people. It is basically based on theories about in which way humans interact with other people and technology and process information where computers are involved in social contexts. As Fig.1 Shows, this positions HCI in the center of a system interaction between machine and human [20].



Fig. 1. HCI Bonding.

B. NLP

NLP is leading of cutting-edge technology, computer science, artificial intelligence and linguistics. It also makes computer to understand, generate human language and human communication mimicry. NLP's evolution has been marked by iconic advancements, with continuous improvement of human-computer interaction [12]. Currently, NLP draws motivation from multiple disciplines, developers and requiring researchers to expand their metal knowledge bases significantly. Specifically, fields like mathematics, information science, linguistics, electric and electronic engineering, psychology, robotics, AI and others from the foundation of NLP. The invention of NLP was to smooth user tasks and address the need for natural language interaction with computer. But this has improved day by day [2].

At first, NLP's aim was to connect the gap between machines and human by continues communication through written or spoken language. Virtual Assistants like Alexa and Siri along with algorithm of sentiment analysis have enhances NLP into various field of human's daily lives. It also transforms how people interact with technology [12].

a) Past and Present of NLP: In the late 1940s NLP did not exist. But work in regard to machine translation (MT) had already undertaken. Research during this period was not fully localized. With English and Russian being the only languages for MT (Andreev, 1967) [4]. According to the Automatic Language Processing Advisory Committee (ALPAC) report, NLP/MT research nearly closed in 1966 concluding that MT was nowise. This period, efforts to use computers for linguistic studies had also started. By 1960, influential work inspired by AI. It was widely believed that progress could only be achieved through two key areas, major system development Projects focused on database front-end and ARPA Speech Understanding Research (SUR) (lea,1980) project. From 1992 to 2000 was the growing period of the enhancement of NLP. Using various tools, algorithms and methods for some intended purpose the primary objectives of NLP involve manipulation, analysis and interpretation of natural language data (NLD) [12]. However, numerous challenges appear depending on the natural NLD being considered, which makes this difficult to achieve all objectives in one approach. Consequently, researches have increasingly focused on developing various tools and methods within NLP and related fields. After then, enhancement continuous, neural language model ripened in 2001, multitasking has been enhanced on 2008, the development of word embedding has been completed in 2013, neural network introduced for NLP in 2013, a sequence to sequence model was proposed in 2014, growth in Attention Mechanism 2015, advanced in pre-trained language 2018 [12].

b) Components of NLP: Basically two components of NLP are Natural Language Understanding (NLU) and Natural Language Generation (NLG) as shown in Fig. 2. Here, NLU takes care of syntactical, lexical ambiguity and referential. NLG combines with sentence planning with text realization and planning the text [2].

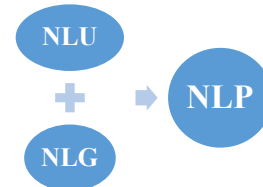


Fig. 2: NLP components

1. NLU: NLU allows machines to analyze and comprehend natural language by entities, concepts, keywords, emotion etc. It is commonly used to understand issues reported by customers whether writing or verbally. Linguistics, the science involves understanding the language context, meaning of language and many more forms of language [12].

There are different level and components of NLU as shown in Fig. 3. There are some terminologies which is commonly used. a) Phenology: Phenology is the first branch

of linguistics which deals with the systematic organization of language. b) Morphology: The smallest part of meaning represented by the different units of word is called Morphology. (c) Lexical: In the Lexical the meaning of individual words is interpreted by both Humans and NLP systems. Moreover, Syntax and Semantics are also parts of NLU [12][13].

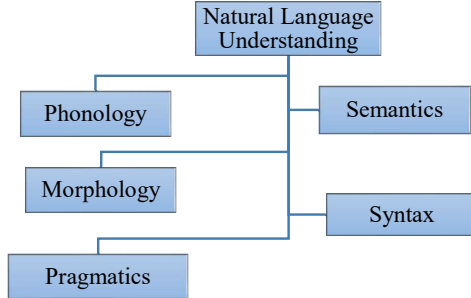


Fig. 3: Level and Components of NLU

2. *NLG*: The procedure of creating understandable sentences, paragraphs and phrases from an internal representation is called NLG. As a component of NLP Fig. 2 shows NLG occurs in four phases: identifying goals, planning how to achieve the goals by assessing available communicative resources, situation and realizing the text wise plans. It is the opposite of NLU [12]. In Q&A systems NLG helps to generate semantic sentences and answers while NLU helps in understanding the context and meaning [13].

IV. NLP ENHANCING HCI

People with disabilities face many challenges and numerous barriers in daily life which is hinder their empowerment, participation in society, inclusion and well-being. Challenges which are often intensified for those living

in very low-income environments including affordability of accommodation, accessibility to assistive technology (Ats) and medical assistance. According various reports, around 15% of the global population has differently form of disability. It has been found, 1 in 10 children has a appearance of disability and with 1 in 5 women often experience a disability during her lifetime. This kind of issues is increasing faster as the elders are more likely to experience disability. It has been shown, over 46% of the older persons whose age is 60 years or older are disabled. Here NLP and HCI technology can help them in various field such as Siri and Alexa helping many disables to operate different kind of task for them. By 2050, the count of individuals aged over 60 is expected to increase more from 850 million in 2013 to 2 billion with the likeliness of disability, it is anticipated that difficultly 1 multitude people will need a certain form of assistive technology (AT) to perform regular action without depending on others [3]. Nowadays, NLP and HCI is the key components for those assistive technology.

HCI has faced challenges due to advanced technology, which necessitates exploration of connections with other disciplines and the adoption of new applications to expand its theoretical foundation. An intelligent Q&A system has been developed by Yongfang Zhang, 2024 [1], which is an platform for online education using NLP technology. That Q&A system is able to understand and respond to the queries of user effectively.

NLP has become more influential tool for improving many fact of online education and other field. This NLP technology allows the understanding and analyzing of human language. Some technologies of NLP such as GloVe, Word2Vec, FastText, BERT, ELMo is helping to enhance HCI in various field. Here Word2Vec is the most efficient one for Q&A systems [1] (Table III).

NLP is also enhancing HCI technology in most application areas of H-AI framework in developing intelligent voice

TABLE III. NLP – PACKAGES OF PROGRAMMING ENHANCING HCI

Programming Languages	Example Packages	Present Features
Java	CORENLP	Sentiment, Numeric and Time values, for text derive linguistic annotations, Quote attributions, Part-of-Speech tagging, Co-reference, relations, Dependency and Constituency parses and Named Entity Recognition,
	MALLET	Topic modelling, information extraction clustering, Statistical NLP with document classification,
	StanfordNLP	Named Entity Recognition, Tokenization, Lemmatization, Morphological Tagging and Part-of-Speech tagging
R Programming	OpenNLP	Tokenization, Lemmatization, Morphological Tagging, Named Entity Recognition, Part-of-Speech tagging
	RWeka	data pre-processing. Classification, Machine learning algorithms collections. Data mining dealing, clustering, regression, visualization and association rules,
	koRpus	several indices of lexical diversity, Tree Tagger, Part-of-Speech tagging, hyphenation, automatic language detection functions,
Python	Quepy	In a database query language, it transforms into queries from the natural language questions
	Pattern	WordNet, Taggers for Part-of-Speech, Text Classification, n-grams, Tokenization and Sentiment Analysis.
	PyNLPI	GIZA++, Tokenization, Supports formats as FoLiA, Frequency Lists, timbl and Moses
	NLTK	Stemming, Tokenization, Tagging the Part-of-Speech.
	TextBlob	Spelling correction, tagging Part-of-Speech, Sentiment Analysis. Classification, Parsing, Tokenization, Word Inflection, n-grams, WordNet Integration, Word, and phrase frequencies.
	spaCy	Entity, Sentence Recognition, Methods for normalizing text and cleaning, Tokenization, Seamless integration with Deep Learning, Sentence Segmentation, Dependency Parsing,
	CoreNLP	Lemmatization, Morphological Tagging, Recognition of Named Entity, Tokenization and tagging Part-of-Speech,

assistants. [4]. Clément Delgrange et al.[18] extended the approach in human interaction along with a virtual assistant which can learn specific domain’s base action semantics and the mapping between human verbal commands. The assistant can also acquire skill in new domain actions like sending email, searching Wikipedia etc.

Artificial Intelligent (AI) is rapidly being used across various business and research domains. Subfields such as deep learning, NLP & Machine learning are to tackle areas like data modeling and processing. In education sector, feedback data of students is essential for identifying the strengths and weaknesses of services offered to students. Here, To upgrade in the educational infrastructure, teaching practices, learning management systems (LMS) and study the environment AI can assist to identify the problem. NLP is the key component for the analyzing and finding the key issues [3].

Word embedding refers to a learned presentation of text words with same meaning. This reduces the dimensionality and improves the generalization process. Common word embedding techniques include Glove, Word2Vec, Bidirectional Encoder Representations and Doc2Vec. (Table III). To understand word associations by analyzing a large text corpus the Word2Vec algorithm relies on a neural network model. This word2Vec creates dimensional representations for every word present in a corpus and then examines the base level of context in which the words occur within sentences.

IV. LIMITATION AND CHALLENGES

There is an important need to assess in which way NLP-based systems such as intelligent Q&A models perform in practical environments beyond controlled experimental settings. Both Zhang et al. [1] and Xu et al. [6] indicate this issue by highlighting the drawback of recent NLP models in adapting to real-world applications. Shaik et al. [3] point out complexity in analyzing educational feedback as a reason of data and privacy issues. Marwan Omar et al. [9] highlighted the necessity for improvement of robustness evaluation against adversarial conditions and Cui et al. [10] stress the importance of ensuring privacy and realistic interactions in virtual human technologies. Further research should focus on the integration of advanced security measures, such as quantum computing and blockchain into assistive technologies. [16][19]Wang et al. [4] identify these issues within the H-AI. To advance this field, research should focus on enhancing the evaluation frameworks for H-AI systems addressing issues related to coordination, privacy, and theoretical foundations, and improving practical applications and effectiveness in various scenarios [4].

Many studies have highlighted the major challenge of adapting NLP systems in diverse real-world contexts. Future Research needs to focus on enhancing the flexibility and capabilities of NLP systems. Also need to ensure they can handle various user scenarios and applications including multi-lingual and multi-domain contexts. [1][6]. integration between the advanced NLP and assistive technology techniques into practical use cases is very much needed. Future Research should aim on the development of methodologies that can more effectively fill the gap between advanced theoretical models. Also, need to ensure usability and effectiveness in specific domains such as education and human-computer interaction [3]. Privacy and security issues are problems across assistive technologies as highlighted by Rahmani et al. [16] and Alfayez et al. [19]. Future research

requires to be do integration of robust security measures and privacy-preserving techniques into assistive technologies which will be able protect user data and ensure safe interactions

TABLE IV. TABLE OF EXISTING APPLICATIONS AND IT’S SHORTCOMINGS

Existing Applications	Shortcomings
Amazon Alexa [21][22]	Risk of Unintended Purchases. Limited Offline Functionality and depends on internet connection. Limited Understanding of command and Context. Limited Customization option in Voice Recognition.
Google Assistant [23]	Fewer Command Control option in Device settings & Controls. Only can perform Smart Home Routines like “turn lights on”. Limited functionality to control the full Operating System.
Microsoft Copilot [24]	Limited Customization options, user struggle in adaptability. High-Cost Subscription Plan creates barriers for broader accessibility.
Siri [25][26]	Dependence on Cloud Computing. Limited Functionality to Control the Operating System for disabilities. Can not be a substitute in human interaction for people with disables. Language and Search capability Limitations.
Bixby [27]	Cognitive Services compared to Alexa and Google Assistant. Absence of an Open NLP-AI platform.
Apple Home Pod [28]	High Hardware Cost, Limited Compatibility, restricting use to limited ecosystems.
Apple Vision Pro [29]	Limited Battery Life The weight Limit the Usage Need of Prescription Lenses Cost Price is Too high

Recent smart applications has both noble features and real challenges (Table IV). To examine, Amazon Alexa has limited voice customization options, struggles with offline use. Sometimes unintended purchases is required to use the application. These can frustrate users who are looking for a personal touch [21][22]. Google Assistant can help user with basic tasks such as turning on lights. When it comes to fully managing device settings it falls short for some users [23]. Microsoft Copilot’s high-cost subscription limits many users from accessing it. Its Limited customization makes it hard to fit individual needs [24]. Siri struggles in assisting users with disabilities effectively. Siri also faces issues like need of internet to perform most tasks, limited OS control [25][26]. Samsung’s Bixby lags behind Alexa and Google Assistant in understanding commands. Bixby also lacks an open NLP-AI platform for deeper customization [27]. Apple’s HomePod comes with a high price tag. Compatibilities are limited mostly to Apple products which make it hard to adopt widely [28]. Apple Vision Pro is weighed down by a short battery life, heaviness, and high costs. This makes barrier in using to the urban disable individuals [29].

Sustainable Development Goal 4 (SDG 4) is about to making sure equitable, inclusive and quality education for all by 2030. the National Education Policy (NEP) 2020 aim to break down barriers like poverty and inequality globally and in India. It is important to understand SDG 4 indicators to enhance education quality through coordinated strategies [30]. So, more advanced assistive technology is needed.

V. CONCLUSION

This survey helped to bring some changes for physically disabled in lives and open the door for “Education for all” . This work underscore the limitation and the need of integration of Natural Language Processing with Human-Computer Interaction for improving in creating more inclusive technology intuitive and accessible platform for disables. The key contribution of this work include the need for greater adaptability in NLP systems across different user scenarios and language. Though some assistive applications are in market but still not effective for differently abled people. A voice assistant based device navigation system or application is need to be developed for them. This can help 15% of the global population who has some disabilities. Word embedding, spaCy, coreNLP and real-time NLU-driven NL programming are showing essential for understanding semantic relationships within text which enables more accurate language processing. The Future research should prioritize more work on a voice controlled hands free device navigation system with NLP to ensure Education for Sustainable Development Goal (SDG-4).

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