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Industrial Applications of Automatic Speech Recognition Systems

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ABSTRACT
Current trends in developing technologies form important bridges to the future, fortified by the early and productive use of technology for enriching the human life. Speech signal processing, which includes automatic speech recognition, synthetic speech, and natural language processing, is beginning to have a significant impact on business, industry and ease of operation of personal computers. Apart from this, it facilitates the deeper understanding of complex mechanism of functioning of human brain. Advances in speech recognition technology, over the past five decades, have enabled a wide range of industrial applications. Yet today's applications provide a small preview of a rich future for speech and voice interface technology that will eventually replace keyboards with microphones for designing human machine interface for providing easy access to increasingly intelligent machines. It also shows how the capabilities of speech recognition systems in industrial applications are evolving over time to usher in the next generation of voice-enabled services. This paper aims to present an effective survey of the speech recognition technology described in the available literature and integrate the insights gained during the process of study of individual research and developments. The current applications of speech recognition for real world and industry have also been outlined with special reference to applications in the areas of medical, industrial robotics, forensic, defence and aviation.

Keywords: Artificial Intelligence, Automatic Speech Recognition, Human Machine Interface, Voice User Interface

I. INTRODUCTION

Perception of the external world in the case of human being is accomplished by the five primary senses. The most important among these are the visual and audio perception. Speech, however, has historically had a high priority in human communication as it had developed long before the introduction of writing. Being the primary mode of communication among humans, speech has the potential to be an important mode of interaction with computers. Speech can be used at a distance, making it the preferred mode for situations in which the hand and eye may be busy.

Signal processing technology is presently witnessing rapid advancements due to the applications in the field of automation. The latest research and developments in signal processing, communication systems and Artificial Intelligence are being applied in the fields of industrial automation and biomedical applications. These developments have greatly benefited the emerging area of speech signal processing leading to spectacular success. Speech signal processing has great scope of research and applications in the fields of security, medicine, automation and many more. Major areas included in the ambit of speech signal processing are speech recognition, speech coding, speech synthesis and speech enhancement.

With the development in wearable electronic industry, a wearable electronic stick embedded with ASR system, GPS and other communication technologies can guide disable persons. Using speech recognition gives access to browsing websites, dictation applications and other command, control instruction as e learning.

Voice user interfaces (VUIs) use speech technology to provide the users with access to information, allow them to perform the desired transactions, and support easy communication. VUIs rely on automatic speech recognition (ASR) for user input[1].By using speech as input, ASR applications bypass or minimize the more traditional manual input methods (e.g., keyboard, mouse), making them useful as an alternative input method for people with severe physical or neuromotor disabilities. VUIs enable human-computer dialogues that cover only a limited spectrum of human conversation, focusing on a predefined set of speech inputs which are required in a specified task domain. ASR is favoured by researchers due to its customized/personalized approach in the field of security, medicine, automation and many more. Due to its wide range of possible applications, a large variety of ASR systems have been developed. Speech recognition and speech understanding systems have made their way into mainstream research due to their adaption to the pertinent application.

II. Methodology of ASR Systems

Speech recognition aims at deriving the sequence of speech sounds that best match the input speech

sound by using pattern recognition technology. On the other hand, speaker recognition is the process of automatically recognizing who is speaking, rather than what is being spoken. Basic ASR system operates in two distinct modes: training and recognition as shown in Fig. 1. Robust features of speech utterance are extracted both in training and recognition mode. These features contain information in time and frequency domain. The template generation module uses possible variations in the utterances of the same word to find the template of feature vectors for different words, during the training phase. In the recognition phase the feature vectors are extracted to be compared with stored templates for the words and a best match is found to recognize word.

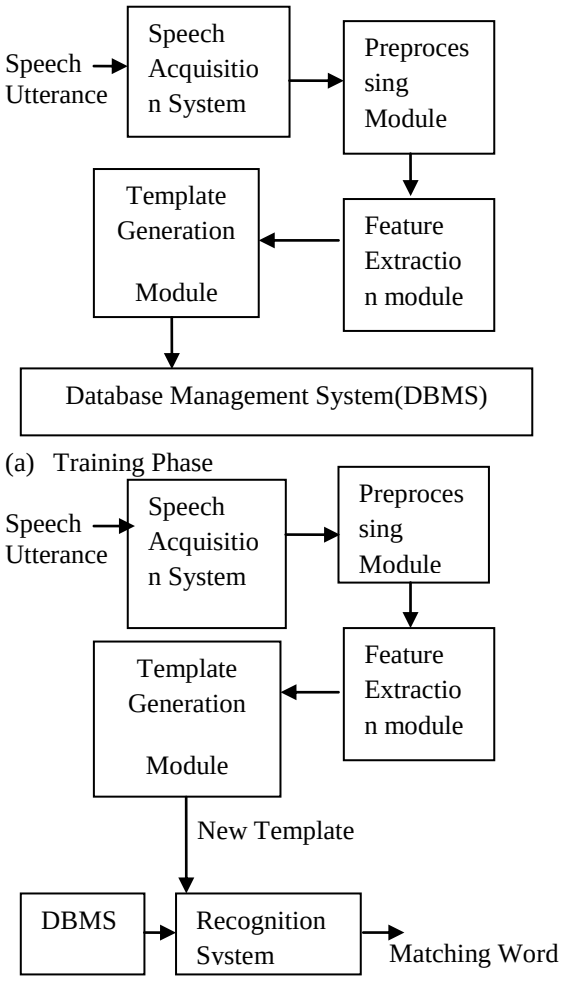

Fig.1 Block Diagram of ASR system (a) Training Phase (b) Recognition Phase

ASR integrated with embedded technology is gaining popularity. Embedded ASR systems have been classified by software, hardware and combined hardware- software co design [3].

The important highlights of ASR systems which make them preferable in various application areas are:

- Users do not need a specialized skill, like typing, to use speech recognition systems. For most people, speech is an inherent skill that comes natural by and is cultivated from an early age.
- Using speech is significantly faster than other forms of communication like typing or writing. A user can communicate with speech up to ten times faster than writing on paper.
- ASR systems allow the use of multiple modalities, i.e., users can speak while doing other activities with their hands, legs, eyes, or ears.
- The input methods of automatic speech recognition systems are economical. Specifically, microphones and telephones are very affordable.

III. Applications of ASR systems

Research on automatic speech recognition began in the early fifties with the attempt to extract the significant features from acoustic data and to classify and recognize them, by using methodologies developed in the area of pattern recognition. Later, in the seventies , the artificial intelligence technologies were applied for the design of speech understanding systems .[4] An important motivation for the research in this area is the attractive perspective of gathering a deeper understanding about the complex mechanism underlying human perception of spoken language and the characterization of speech sounds in terms of physically detectable features in the brain. The research oriented towards this goal is of great utility in psychology and in the field of development of hearing aids for the handicapped. Moreover research in speech understanding offers a good opportunity for investigating complex parallel processing systems capable of modeling human perception.

Further motivation for research in automatic speech recognition lies in its industrial application, to simplify the communication between humans and machines. Avoiding intermediate keying and handwritten steps, leads towards multiple task capability to communicate with the machine while hands or eyes can carry out other functions. Further Speech input is inherently faster than other methods. Hence, automatic speech recognition systems are gaining industrial acceptance in various sectors ranging from defence and medical to consumer products. These systems are more cost effective and often more efficient in real world applications that need to command and control with reduced human efforts. The development of faster computational capabilities of processors has also promoted in cost

effective applications of ASR systems useful for industries.

Presently ASR systems find a wide variety of applications in the following domains:

- Medical Assistance
- Industrial Robotics
- Forensic and Law enforcement
- Defence & Aviation
- Telecommunications Industry
- Home Automation and security Access Control
- I.T. and Consumer Electronics

A brief description of the developments in these areas is presented in the following subsections:

A. Medical Assistance

The main uses of speech recognition system in medical applications, that have been described in literature are for reporting, data entry and in environments where the hands of doctor or dealing person are busy. Important parameters governing applicability of speech recognition technology in medical field are accuracy, efficiency and reliability. Speech could be used as input for instrument control during surgical procedures. An automated speech recognition system in medical equipment addresses both, the ease of use and the need to keep the hands free.

Recent trends in ASR systems have been geared toward large vocabulary, speaker independence recognition. In the medical field, these innovations have primarily been incorporated into dictation systems for development of reports in areas like radiology, pathology, and endoscopy. Physician dictates directly to the computer eliminating need for transcription services and decreasing time. Adoption of this technology to control a medical instrument for a surgeon who controls a camera with speech command while operating on patient need not more than ten commands to control the camera. In some medical situations the usual methods of interacting with the computer are impractical - for example, in microscopy. Developments in ASR technology are reducing the response time and skilled man power requirement for the medical & clinical purposes.

Automatic speech recognition techniques have been used to help speech of patients with different but significant extents of speech disorder (dysglossia) and voice disorder (dysphonia) [6].ASR systems have also been tested for evaluation of voice and speech disorders in head and neck cancer that may affect speech and voice. Many cases with this disease have observed reduced articulator movement which led to reduced intelligibility. To make speech disorder assessment by speech pathologist fast and inexpensive there is need for automatic evaluation of speech and voice. The use of speech processing methods for evaluation of speech intelligibility is getting more popular in comparison with traditional perceptual evaluation, even in severely disturbed voices and speech. [2] ASR system with Hidden Markov Model (HMM) enabled precise evaluation of speech and voice as a precondition for scientific investigations, for example, to specify the influence of therapy options, such as different surgical procedures and nonsurgical therapies on communication experiences. Also the emotional state of the patient could be predicted with ASR methods. Increased age has been shown to have a negative influence on automatic speech recognition.

ASR systems are also being developed to serve as virtual therapists. It can validate the performance of patient in communication disorder. Aphasia is an acquired communication disorder. It affects speech and language functionalities at varying degrees. The recovery of lost communication functionalities is possible through frequent and intense speech therapy sessions. The word verification could be performed by ASR system. VITHEA system for online therapy for aphasic patients exploiting ASR has been developed at Spoken Language Systems Lab Portugal has achieved significant success. [7]

B. Industrial Robotics

Today, powerful and inexpensive microprocessors and improved algorithms are driving commercial applications in computer command, consumer, data entry, speech-to-text, telephone, and voice verification. Robust speaker-independent recognition systems for command and navigation in personal computers are now available [8].Voice input computers are used in many industrial inspection applications where hands and eyes are busy with other tasks, allowing data to be input directly into a computer without keying or transcription. Speech recognition technology is successfully being implemented on industrial robots and is being widely accepted in various industries. The world requires better products at lower price with efficient manufacturing plants. The autonomy of the systems which requires lesser operator intervention could help in achieving the same. The trend can be witnessed in Fig.2 in the worldwide annual supply of robots.

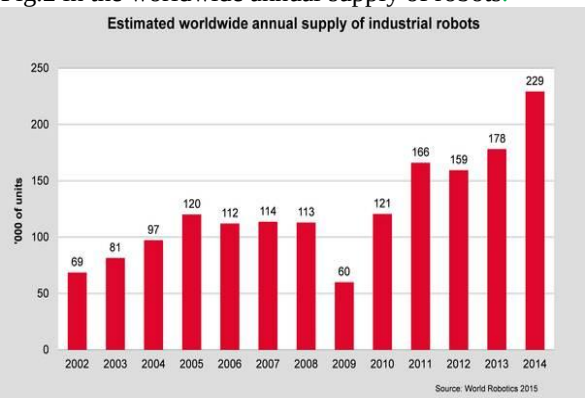

Fig.2 Estimated Worldwide annual shipments of industrial robots [10]

Users with severe motor handicaps and general muscle degeneration are unable to steer their own wheelchair through a conventional joystick, and are often dependent on other persons. By endowing the wheelchair with new Human–Machine Interfaces (HMI) and increasing the wheelchair navigation autonomy, it is possible to contribute to the social independence of this group of wheelchair users. Currently the Robchair can navigate in dynamic environments in the presence of humans, commanded by simple low-level voice or joystick instructions [9].

C. Forensic and Law Enforcement

Voice of a person can play important role in forensic applications. Collective research done by Expert Working Group for Forensic Speech and Audio Analysis (FSAAWG) within the ENFSI (European Network of Forensic Science Institutes) by the Netherlands Forensic Institute (NFI), has shown the increasing interest in the development of automatic forensic voice comparison systems. Notably, Forensic speaker recognition (FSR) is the process of determining suspected speaker. Forensic automatic speaker recognition (FASR) is the term used when automatic speaker recognition methods are adapted to forensic applications. FASR is used for judicial and law enforcement purposes for identification of speech samples of suspected speaker. It is based on the similarity between speaker dependent features extracted from the questioned recording (trace) and speaker dependent feature extracted from the speech of suspect. [10] The process for biometric evidence (E) is shown below in the Fig.3 by using suspect R.

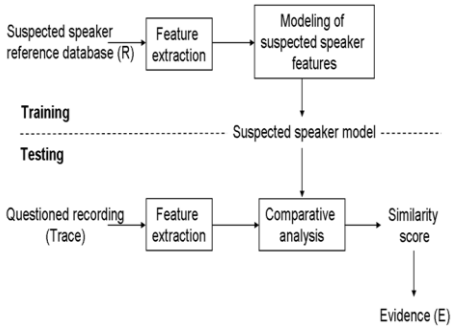

Fig. 3 FASR system determining biometric evidences [11]

In forensic or investigative speaker comparison, speech utterances were earlier compared by humans but now FASR machines are being used for use in court or investigation.

D. Defence & Aviation

The application of speech recognition in aviation is rapidly evolving and moving toward design of future flight decks. Continuing advances in computer hardware and software are making the use of voice control applications on the flight deck more practical, flexible, and reliable. Currently, several military applications are using ASR to provide additional methods to support the Human Machine Interface (HMI) to reduce the workload on the pilot in advanced aircrafts.

Boeing is incorporating ASR into the new Joint Strike Fighter, and the Euro fighter Typhoon is also adding this capability to its aircrafts. Even though there have been several notable applications of speech recognition in the cockpit of military aircraft, such applications will reach the level of reliability and pilot acceptance to permit their use in the civilian market. Speech recognition technology is also being used in the Joint Strike Fighter being developed by Boeing and BAe Systems. Continuous speech recognition is being integrated into the cockpit. The speech recognition system will provide selected cockpit controls sole operation by using voice commands. This speech recognition system assists the pilot by avoiding the distraction due to selected manual tasks, while remaining focused on more critical aspects of the mission. The supplier of the speech recognition system for this aircraft is ITT Industries' Voxware (formerly VERBEX) voice recognition system [13].

In the mid 1990s, NASA performed experiments using speech recognition and voice control in aircrafts. The speech recognition system used for this study was an ITT VRS-1290 speaker-dependent system. The vocabulary used in this study was small, comprising of 54 words. The ASR system accuracy of 95% was achieved when tested on 12 pilots under separate load and acceleration conditions even in this nascent stage of development

Hence, the system received general pilot acceptance. Since the system was speaker dependent, the pilot had to train the speech recognizer to his unique voice patterns prior to its use. This was done at ground-based, personal computer support stations to create a voice template for a specific pilot. The created voice template was transferred to the aircraft prior to flight, via a data loader.

E. Telecommunications Industry

The world of telecommunications as well as of speech recognition is rapidly changing and evolving. Early applications of the technology have achieved varying degrees of success.

Speech recognition was introduced into the telecommunications network in the early 1990's for two reasons, namely to reduce costs via automation of attendant functions, and to provide new revenue generating services that were previously impractical because of the associated costs of using attendants. Telecommunications services created to achieve cost reduction include automation of operator services, automation of directory assistance, voice dialling etc.

Telecommunications services which were created to generate new revenue include voice banking services, voice prompter, directory assistance, call completion, information services, customer care, computer-telephony integration, voice dictation. Moreover , in communication functions, voice control could be used to tune radio frequencies by calling out that frequency .The promise for the future is significantly higher performance for each of these speech recognition technology area, with more robustness to change in speakers, background noises etc. This will ultimately lead to reliable, robust voice interfaces to every telecommunications service that is offered, thereby making them universally available [14].

F. Home Automation and Security Access Control

Automation industry is witnessing the application of Automatic Speech Recognition Systems in various sectors, varying from appliances in households, auto automobiles and industry. The goal of design of speaker identification based automation is to provide an efficient and convenient integration and inter-operation. ASR systems have been installed in various cars for controlling driving actions. Speech-controlled tasks in vehicles may improve driver safety by minimizing the visual (drivers' eyes-off-road time) and the manual demands of performing current in-vehicle tasks.

Speech as a biometric feature could be used for access control using ASR systems. It can provide an unconventional and more secure means of permitting entry without any need of remembering password, identity numbers, lock combination etc or the use of keys, magnetic card or any other device which can be easily stolen. However a valid person may be denied to access by mimicking, accidental changes, emotional or physical stress etc. Acoustical systems have great advantages if the perception of visual information is impaired (e.g. darkness, too much light, vibration). People with severe speech and motor impairment due to cerebral palsy suffer great difficulty in moving independently and also cannot control home electric devices. Computer has much to offer people with disability, but the standard human-machine interface (e.g. keyboard and mouse) is inaccessible to this population. Home automation houses have been developed to apply new technologies in real environment, such as Welfare Techno Houses of Tamura et al., Intelligent Sweet Home of Park et al., Smart House of West et al. Interfaces based on gestures or voices have been widely used for home automation. Powered wheelchairs provide unique mobility for the disabled and elderly with motor impairments [1].

G. Information Technology and Consumer Electronics

The developments in the computational capabilities and widespread availability of software for speech recognition have benefitted consumer products like lap-top computers and personal digital assistants. Voice recording and voice annotation are being incorporated voice-powered navigation systems. The large variety of applications in the areas of information technology and consumer electronics have been classified and discussed in the following subsections:

- Conversational Personal Assistance for Web Content Accessibility

Speech recognition support enables internet access for the people with mobility impairments, people with visual impairments and senior citizens. This conversational assistance helps in controlling the computer on voice commands, accessing the web contents, dictation to the computer using technologies of speech recognition software. The information of the website is accessible with different speech recognition software, such as Dragon Naturally Speaking as well as Speech Recognition support available in Windows operating systems. Dragon professional speech recognition solution is commercial software product from Nuance Communications. Other service providers working with speech recognition technology are IBM, Intel, and NVIDIA (GPU) etc. It provides the flexibility for customized work as well in lesser time. Speech enabled web services allows user to access web. SALT (Speech Application Language Tag) is one such tag.

- Multimedia Application

Commercial application of ASR is appearing in data centers and portable devices. Commercial availability of many-core computing platforms such as the NVIDIA GTX480 brings significant opportunities for ASR applications to perform an order of magnitude faster when efficiently implemented on GPUs as compared to traditional sequential implementations running on a CPU. Such dramatic improvements in performance have allowed researchers to analyze an order-of-magnitude more data, and companies to explore new services and capabilities or provide existing services more profitably. It has been demonstrated by the researchers that the automatic speech recognition (ASR) application framework has enabled a programmer to achieve much higher speed up in application by extending an audio-only speech recognition reference implementation to an audio-visual speech recognition application. With the rapid increase in the highly parallel computation from servers to work stations to laptops and portable

devices, there will be increasing demand for adapting business and consumer applications to specific usage scenarios and speech processing technology will play an important role in this. [16]

The problem of audio information retrieval is well addressed by ASR systems. Audio information retrieval is familiar to find audio message from answering machine. A particular advantage of using ASR for audio information retrieval is that unlike dictation or voice-command tasks most or all of the desired audio is already present, and thus ASR can be performed off-line rather than in real time. However a limitation is that there can be orders of magnitude more data to actually recognize and an ASR system sufficiently fast for dictation may be far too slow to use on hours of audio at search time. [17]

- Mobile devices

There has been rapid increase in the users of mobile devices such as smart phones, internet tablets, and cell phones etc. According to the world's leading I.T. research and advisory company, Gartner [21] the sales of Smartphone has shown great increase in the past decade. There is demand of applications on mobile devices that supports speech recognition technology. The models of speech recognition with mobile devices as suggested by the different researchers are embedded speech recognition, speech recognition in the cloud, distributed speech recognition and shared speech recognition based on user adaption. Mobile devices are required to have high processing power and/or continuous network connection for better performance of the systems. There are more challenges to be faced by mobile devices to support speech recognition technology as compared to personal computer. Limited storage space, variable microphones, low processor , small cache memory variable environment due to mobility and power requirement are major challenges for better recognition of speech on mobile devices.

Mobile Based Recognizers

The following two ASR's have been successfully tested recently on mobile devices for speed and accuracy:

- *Pocketsphinx*

PocketSphinx is a small-footprint, continuous speech recognizer that is an adapted version of Sphinx-II for applications on mobile devices. It offers an easily accessible, open-source, robust mobile speech recognition solution. However, although PocketSphinx is still being improved, it is based on the older Sphinx-II engine which uses semi-continuous acoustic models.

- *SphinxTiny*

Sphinx Tiny, is designed to merge with new releases of the evolving Sphinx 3.x engine. It has been adapted by CMU's Sphinx3.x open-source large-vocabulary continuous speech recognition system to support use on mobile computing platforms such as Nokia internet tablets or smart phones. [18]

- Search Engine

Speech technology has taken new importance due to ease of access which is any time, any place access. Speech as input could be used to search and access the information. Google, Apple & Microsoft have successfully demonstrated the use of speech in as search engine and accessing various applications on mobile devices. The products of Google: Google Now, Apple: SIRI (Speech Interpretation and Recognition Interface), Microsoft: cortana are being widely used in mobile phones. Multimodal platforms like smart phones have provided powerful interface capabilities.

IV. Education and Learning through ASR

Self learning is rapidly changing from the classical book reading based learning, to the electronic learning (e learning), mobile learning (m learning) or ubiquitous learning (u learning) [20]. Speech recognition together with mobile devices has facilitated this to a great extent. Hence, automatic speech recognition technology can play important role as social impact on self learning. Speech applications are of more importance for users with low literacy. Speech recognition supported games on mobile devices could help in improving the literacy in the developing countries. Research findings suggests that practicing recalling and vocalizing words for expressing an intended meaning could improve word reading skills. More research is needed to understand how such vocabulary training can be delivered over a non-visual user-interface. It is possible to provide only phonological and not orthographic hints over a non-visual interface. [21]

V. Conclusion

Automated speech recognition addresses the challenging problem of touch free human computer interaction. The keyboard and video display are even today the principal means of entering and retrieving data. The need for alternative ways of interacting with the computer is growing.

Adaption of Speech Recognition technology is increasing in various industrial applications. This paper, reviewed the important industrial application areas of ASR systems. Medical report generation systems with large vocabularies of words, are finding acceptance in many hospital emergency rooms. In the telephone market there are a growing number of important applications, including operator services and interactive voice response that use automatic speech recognition

Overall, the growth of ASR in industrial applications is being driven by the availability of new products. But other factors, such as cost, integration and acceptance by users, vendors, and applications developers, are important determinants in the penetration of a potential market. Although, the market growth is driven by the availability of new products, other factors, such as cost, integration and acceptance by users, vendors, and applications developers, are important determinants in the penetration of the potential market. Hence vendors are working with users to understand the important human factors issues that affect product use and application. Inexpensive digital signal processing chips for speech and other signal-computing applications have been introduced by several developers and will have a significant impact on the application of speech interface technologies in price-sensitive mass market applications.

Most speech interface technology vendors are working with users to understand the important human factors issues that affect product use and application. Developments in several segments of the automatic speech recognition market reflect trends in speech interface product growth.

However the applications for identification of a person based on his or her voice is a challenging task. Various factors affect the recognition or identification process for automatic, semiautomatic, and human based methods. In the forensic field, the environment and factors affecting performance varies tremendously, relative to the commercial applications. Forensic applications of speaker recognition are to be taken under a necessary need for caution. The speech samples get affected under various conditions. Recording environment, age of speaker, health condition, and emotional state may influence the recognition and identification process. There is need for extraction of important features of speech for improved performance of ASR system. Particularly FASR affecting people's lives demands highest technological standards. [11, 12]

VI. Future directions

The focus of research in improving the ASR systems is presently on making it similar in performance, nature and scope to human auditory processing systems. While speech recognition has improved over the past several years, it has not reached the level of capability and reliability provided by direct communication between humans. Success in speech recognition applications requires an adequate addressing of the limitations in the current technology. Parallel development in the areas of signal processing, computational capabilities of systems, special purpose VLSI hardware for high accuracy real time system implementation and FPGA techniques will make ASR more accurate and user friendly.

The emergence of high computing mobile devices and cloud computing has given thrust in mobile computing. Speech as a natural input provides a new way to search the web. The combination of a vast amount of data resources, computational resources, and innovation has created an opportunity to make speech as common place and useful as any other input modality on the phone. [19]

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