# Speech as the Basic Interface for Assistive Technology

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*Abstract:* **Speech interfaces for Assistive Technologies are not common and are usually replaced by others. The market they are targeting is not considered attractive and speech technologies are still not well spread. Industry still thinks they present some performance risks, especially Speech Recognition systems. As speech is the most elemental and natural way for communication, it has strong potential for enhancing inclusion and quality of life for broader groups of users with special needs, such as people with cerebral palsy and elderly staying at their homes. This work is a position paper in which the authors argue for the need to make speech become the basic interface in assistive technologies. Among the main arguments, we can state: speech is the easiest way to interact with machines; there is a growing market for embedded speech in assistive technologies, since the number of disabled and elderly people is expanding; speech technology is already mature to be used but needs adaptation to people with special needs; there is still a lot of R&D to be done in this area, especially when thinking about the Portuguese market. The main challenges are presented and future directions are proposed.**

## I. Introduction

### A. Topic and Scope

Assistive Technology (AT) encompasses the use of hardware and software solutions that provide opportunities to people with physical, cognitive or sensory disabilities to have more independence and control of their own lives. It includes technical aids to help tying shoelaces with one hand, to teach using a leg or foot prosthesis or Tele Alarm systems to monitor impaired, ill or aged people. Augmentative and Alternative Communication (AAC) is part of AT and refers to devices that enable individuals with severe disorders of speech-language production and/or comprehension impairments to communicate by replacing or enhancing speech. Communication can be replaced or augmented by a range of solutions, such gestures, eye-gaze, movements, handwriting or communication aids.

### B. Background information

About 50 million people (10% of today's European Union - EU population) are disabled [1]. In Portugal, according to the 2001 Census, 6.1% of the population (636059 people) presents at least one type of impairment [2]. Among these disabilities, visual impairment is the most common (25.7%), followed by mobility impairment (24.6%), hearing impairment (13.2%), mental impairment (11.2%), cerebral palsy (2.4%) and other impairments (23%) [3]. In a previous survey (1995), carried out in Portugal with different criteria (over a sample of population), 17.05% of 905488 disabled people had speech and communication impairments [4]. The severely speech and physical impaired (SSPI) people, who depend on AT for their daily lives, include children with developmental language disorders (dysarthria, aphonia), individuals with cerebral palsy and senior citizens who have had strokes or neurodegenerative diseases, such as multiple sclerosis and amyotrophic lateral sclerosis [5]. Ageing is related with impairments (45% of the people aged 75 and over are impaired in their daily living activities) and the number of elderly people aged from 65 to 80 will rise by nearly 40% between 2010 and 2030 in the EU. The group of people over 80 will almost double by 2050 [6]. In Portugal, a similar trend is expected [7]. Despite the large number of severely speech and physical impaired (SSPI) people in Europe and in Portugal, there is still a dramatic lack of AT and AAC products and solutions in the market. The devices are not fully adapted, easy to use and compatible with other products and have high maintenance costs. Besides, these solutions are usually expensive, not available for all languages and difficult to use. Other limitations are the reduced flexibility of the input (only text input, text prediction word by word instead of prediction of phrases and expression) and the impossibility of customizing the voice output (only one type of voice by default). These limitations, in a way, isolate these individuals from society and do not stimulate their communicative and learning skills.

## II. STATE OF THE ART IN ASSISTIVE TECHNOLOGIES

### *A. In Europe*

The European Commission (EC) is very concerned about the increase of elderly population and thus is currently making a great investment in R&D (1 billion Euro) on ICT for ageing well, inclusion and independent living [8]. HERMES (Cognitive care and guidance for active aging) is a project supported by the EU under Framework Programme 7 (FP7), now running, which aims to reduce age-related decline of cognitive capabilities and assist the user where necessary by developing AT solutions. The output of the project will be solutions to help elderly people to keep their memories and keep their brain active. This project uses speech technology and interfaces [9]. The CompanionAble (Integrated cognitive assistive and domotic companion robotic systems for ability and security) is another FP7 funded project that aims to support the cognitive stimulation and therapy management of the care-recipient through a robotic companion working collaboratively with a smart home environment [10]. A list of running projects on AT funded by the EC is available online [11]. For the area of AAC, we can refer the project WWAAC – The World Wide Augmentative and Alternative Communication Project [12], partly funded by the European Commission (Framework Programme 5), that aimed at in making web and email based technologies more accessible to SSPI persons. One of the results was a special WWW browser featuring built-in speech synthesis, support for multiple inputs (switch access, adapted keyboards) or the ability to summarize a web page using symbols. This feature is based on a concept coding framework which is an attempt to standardize symbol coding for transmission over the Internet.The AAC-RERC is a collaborative research group dedicated to the development of effective AAC technology [13]. This group has various ongoing projects and research areas such as improving AAC technology to better support societal roles or Enhancing AAC usability and performance.

The Adaptative Technology Resource Centre (ATRC) [14] from the University of Toronto is also working on a number of projects aiming at improving accessibility on the web, such as the ATRC accessibility checker.Regarding commercial AAC devices, one can refer the Dutch company Handicom [15], which provides several devices ranging from single handed keyboards, Bliss language processors or sign language software. Sweden based Tobii [16] is also specialized in AAC devices, focusing in eye tracking, enabling a computer to know where a person is looking at, thus enabling application control using eye movement [17]. Other companies such as US based DynaVox Technologies [18], The Great Talking box [19], Adaptivation [20], Zygo Industries [21], Words+ [22], Saltillo [23] also provide AAC and VOCA (Voice Output Communication Aids) devices and services. AT is also a goal for Microsoft, who aims to improve compatibility of assistive technology products with Microsoft products through alternative input devices [24]. Microsoft provides an AT program in collaboration with a large list of companies from different fields, which have a proven track record of designing, building, and supporting assistive technology products that help disabled individuals successfully use computers.

### *B. In Portugal*

In Portugal, AT is more oriented to visual impaired people, since they represent the larger group of disabled people. We can refer the work done by CIDEF (Centro de Inovação para deficientes) with the RoboBraille project [25], which enables users to submit text and web pages to an email address and to get a synthesized audio file or Braille in return. Ubiquitous Web Access for Visually Impaired People (VIP-ACCESS) is the most recent FCT-funded project on this area [26], promoted by Beira Interior University, whose goal is to allow blind people to access information in the web using speech interfaces.
Commercially, Electrosertec is the leading company in Portugal providing all types of AT to visual impaired people [27]. Vodafone Portugal launched Vodafone Say (introduced in the market in July 2005) enabling blind and visually impaired people to make full use of all the functions of a mobile phone [28]. Home Automation became a commercial product, named B-Live, by a Micro-IO, a spin-off of IEETA – University of Aveiro. This product won the national prize Engineer Jaime Filipe. B-Live, with its modular interface, was the home automation infrastructure used for the integration and first field evaluation of the Smart House Speech at Rovisco Pais Hospital [29]. Since 1998, Intelligent Robotics started as project CARL, a prototype of an intelligent robot, which was used as a test bed for research on integrated intelligence and on human-robot interaction [30]. Recent work won a Best paper prize on Robotics Conference [31]. Other work on AT in Portugal can be found here [32, 33].

## III. THE IMPORTANCE OF SPEECH INTERFACES IN AT

Technology solutions in general are difficult to be used by elderly and impaired people because they have unfriendly interfaces most of the times, putting these people at risk of social isolation and exclusion. Speech is the easiest and most natural way for human-human and human-machine interaction. Therefore, the AT interfaces must be speech-based interfaces, using Text-to-Speech (TTS) and Automatic Speech

Recognition (ASR) systems, allowing people to interact with machines and humans in a more easy and effective way and to have a more independent life. The end-users of these solutions are not only visual impaired people, but also individuals with severe speech disabilities (e.g. cerebral palsy sufferers) and elderly people, since they share the same assistance needs to perform daily tasks. Other end-users of these solutions are the caregivers who give support to impaired and elderly people. In brief, our thesis can be summarized in the following arguments:

a) Speech should be considered a privileged interface for assistive technologies. This type of interface should apply to these technologies, independently on their users, and not only for specific target groups, such as impaired or elderly people. The integration of speech interfaces in technologies in general, not only assistive technologies, should also be considered, as it offers strong potential for inclusion and accessibility to current technologies, such as telephone, web, e-mail.

b) There is a growing market for speech interfaces in the areas of assistive technologies and inclusion.

c) ASR and TTS technologies are mature enough to be commercialized and can be used.

d) The offer in the AT field in Portugal is still much reduced and not adapted to the end-users. We believe there are two main reasons for this: the first one is the lack of existent information and long-term research on the end-users' real needs and scenarios; the second one is the lack of incentives from the government on research and development of AT and the lack of real understanding of the dimension of the impaired and elderly people problem in Portugal. AT in Portugal must evolve following the international trends. Particularly relevant is the possibility of personal, configurable and adaptable speech input/output and possibility of expressing emotions.

In brief, speech should play a central role in interfaces for assistive technologies and this is already possible to happen in Portuguese language. Speech has a lot of potential as an interface for assistive technologies but requires adaptation to the products and the users' needs. Speech also creates new challenges to interface developers. Speech has very important specificities such as the non-persistence (the things you say vanish immediately) and the non-visibility of the user-interface capabilities.

## IV. Status Quo: There are Preferable Interfaces for AT than speech

The current situation in the area of assistive technologies in Portugal – not much use of speech outside the applications for the blind, not much active research or industry products available – is strong evidence that our point of view is far from being accepted.

The following counterclaims are usually used to refute our arguments presented in section III.

### *A. Speech is an interesting interface but can only be secondary*

The maturity of other interface technologies (such through touch screens, joysticks, eye movements, bio-signals etc), the challenges of using speech, the limitations of current speech technologies for certain languages, especially in the ASR side, the need of language localization when using speech interfaces, and the considerable money and time cost of doing speech technologies are some of the reasons why most of the researchers and industry do not consider speech interfaces. As an example, in Portuguese Universities courses on Human-Computer Interaction speech is only mentioned briefly if mentioned at all.

### *B. Speech interfaces don't have an appealing market*

Only a few and mostly small companies have interest in the commercial usage of these technologies. For example, in Portugal, one of the most representative companies of assistive technology, Anditec [34], rarely uses speech interfaces in their solutions. The applications are regarded as only targeting very specific groups with reduced expression in terms of potential buyers. The market share of impaired and elderly people is still not considered interesting for industry.

### *C. Speech technology is not usable*

As ASR and TTS technology is not so developed and disseminated as other input/output devices, the option is often to avoid using them in systems. A major justification is the need for safe and reliable applications and the need to not impose an extra burden (due to technology limitations) on the user.

### *D. We already have the necessary speech technology*

Speech technology by itself is no longer in an area the European Commission is willing to fund specifically, probably because the Commission believes this area is already mature enough. In fact, there are several commercial systems available in the market both in TTS and SR with a robust performance and in several languages [37], [38], [39]. However, the Commission is highly interested in funding areas of inclusion, accessibility, health and ageing and speech can be a key interface. Since 2008, when the Tecnovoz project [35] finished, the Portuguese government has not put much effort in financing the development of speech technologies in Portuguese, probably because of the same reason. However, this technology is ready to be used by "normal" people but is not adapted to people with special needs. When used by this group of people, it has contributed to "prove" that speech is not an interesting interface, as it doesn't work in real scenarios.

### *E. Speech technology may increase exclusion of some user groups*

A strong point against speech is that it is not the best choice for deaf or users with (severe) speech disorders. If we consider this input or output modality alone, it would be completely correct. But there are uses of speech synthesis replacing speech of severely disordered speech users and deaf people who can profit from speech directly transmitted to the auditory nerve.

## V. Arguments For our Thesis: Speech has Potential

Having presented in the previous section our perception of the main counterclaims, we now present various arguments to support our position.

### *A. Speech can be the only interface with AT*

Speech is part of a person's identity and identity is very important for social inclusion. We treat people differently according to their identity [36]. Giving a person not capable of speech articulation (for example, many of the cerebral palsies types) the possibility of using speech output and making this output unique, allowing this person to feel different from others with the same disability, is not only a question of interface, it is a question of individual identity. Keyboards or visual displays are not part of human identity. A number of experiments show that the human brain rarely makes distinction between speaking to man or machine [36].Speech is the most natural and easy existent interface to deal with computers, not only for people with special needs, but for people in general, as Nass & Brave [36] state: *"Ubiquitous computing – access to all information **for anyone**, anywhere, at any time – relies on speech for those whose eyes or hands are directed to other tasks (such as driving ...) or for those who cannot read or type (such as children, the blind, or the disabled)"*.

In many disabilities, speech is not affected and is the only possible interface with the machines: "*Speech is a very interesting alternative to the traditional Human-Machine Interface (HMI), as in most cases the disabilities that these people have don't prevent them from expressing themselves orally. In the most severe cases, speech is the only way available for interaction between disabled people and the machines around them*" [29]. Our point here is not that speech should be used alone; it must be part of a multimodal input/output, and, for some users or context of use (ex: mobile phone interaction with hands and eyes busy), will be the only useful modality.

### *B. The market in AT is growing*

We consider that the market size has been underestimated and the growing potential neglected. Besides the obvious application areas for the severe disabled (about 10% of European current population) and for the growing percentage of population aged above 60 years old, the increasing number of TBI (Traumatic Brain Injuries) and vascular accidents, as consequence of our modern unhealthy life balance and diet, and also contribute to the existence of a much bigger market.

A large list of applications can be identified:

a) Voice output communication aids (VOCA), for persons who are dysarthric, speech impaired or deaf. With the use of TTS technology it is possible to easily produce a voice message from the user text input. Common TTS systems (from Microsoft [37], Nuance [38], Loquendo [39] or other companies) can be used in home applications. However, for a user in mobility, the systems must be smaller. The existent devices are usually based on limited vocabulary or on integrated circuit based speech synthesis [40], which does not provide natural sounding speech. The available products for PDAs also have a limited quality with a slow performance [41].

b) Speech recognition in writing, programming, environmental control, and computer-aided design for persons with neuromuscular-skeletal impairments. ASR technology can be used as an input interface for machines. A major application is home automation where most of house functionalities can now be voice operated [29], [42].

c) Speech synthesis in reading, writing and programming aids for persons who are blind or visually disabled. When combined with an image recognition system, a TTS can be of great help for the visually disabled. The recognition engine processes the surrounding environment and the information is acoustically transmitted to the user that can again perceive his world. Few companies explore this field with only some book reading system available [43], [44].

d) Speech training methods and devices. Aids for speech training, assessment and rehabilitation for hearing pathologies can be developed with a TTS. A visual feedback after speech analysis or animated display of inferred tongue, lip and jaw movements during speech production can help treat speech disorders in real time.

e) Processing of speech in cochlea implants [45], hearing aids and tactile aids. Before artificially stimulating the auditory nerve, the bionic implant can use ASR and TTS technology for adjusting the type of output signal to the user's pathology characteristics.

None of the available products described has a Portuguese voice. There are several factors that potentiate the increase on Assistive Interfaces demand: laws contemplate more and more the right of inclusion for all disabled and old persons; there is an increasing percentage of elderly population with direct impact on the number of strokes, neurologic diseases (Alzheimer, Parkinson); accidents, particularly car accidents, cause traumatic brain injuries, many times affecting the speech production system and the language related brain areas. Elderly people (aged over 65 years) are a group of population estimated to increase from 16.4% in 2004 to 29.9% in 2050 across Europe. In many ways, this group shares similar problems with individuals that suffer from cerebral palsy. They may need assistance in performing simple and complex tasks, which are usually performed by humans (nurses, therapists, family). This assistance becomes extremely expensive and elderly people often see themselves as a burden to family and society. Unfortunately, due to the increasing number of elderly people and to the lack of social structures to deal with this phenomenon, elderly well-being and life quality is many times degraded. The scope of problems which affects this group is similar to the previous group, and ranges from movement limitations to speech impairments, caused either by strokes or diseases. An important difference between the two groups is the number of people affected, which is relatively small in the first case, but more extensive in the second. Thus, the problem has an important social dimension and impact, and it aims to bring a significant improvement to the lives of these challenged individuals by making them more independent.

### *C. Technology can be usable*

Speech technology is already in a quite advanced and mature development stage, which can be demonstrated by the existence of several commercial products in different languages (TTS systems: [37], [38], [39]; SR systems: [46], [47]). Besides, speech technology is no longer in the European Commission's R&D funding goals and roadmaps, which doesn't mean it in should not be when associated with other Information and Communication Technologies areas (as said before, the EC is investing 1 billion Euro ageing well, inclusion and independent living). We consider that even with the known speech technologies' limitations, a careful design and correct selection of areas where speech can make the difference may lead to the development of many useful applications: *"(...)voice interfaces can be significantly improved by a careful understanding and application of how people are built for speech*" [36]. Also, basic speech technologies must be complemented by technologies from the natural language processing and artificial intelligence fields such as semantic extraction, dialogue management, user modeling, and knowledge representation [31]. Furthermore, the knowledge from other fields like speech therapy and gerontology must be used in all the design and deployment of the interfaces. The usual argument that speech recognition can be frustrating and is not good enough yet has its validity, but "*people are remarkably willing and able to interact with nonnative speakers or young children, chat via noisy phone lines, or listen to poor-quality audio speakers- situations that have the same, if not more, limitations than computer technologies present.*" [31]. This means that people, especially the disabled, can also be willing to use speech recognition when they understand how they can benefit from an assistive device in their daily lives. For children affected by cerebral palsy, autism, laryngectomies and brain injuries, TTS interfaces are extremely helpful despite their limitations, allowing them to communicate. The potential usage for this technology includes portable devices that allow cerebral palsy persons to communicate, such as the LightWriter [48] and the Pocket PC [49], and the improvement of the strategies for education, like learning how to read. Also the blind community uses TTS systems integrated in screen readers. Speech has been used as interface in many different applications, such as wheel chair control [50], personal computers interaction [51] and in Smart Homes [52]. Recently, part of the authors were involved on a first field trial of domotic speech interface applied to the control of a house for tetraplegic, at Rovisco Pais Hospital, with very positive feedback from the three users involved [29], [53]. Some thousands of assistive devices (more than 25000 assistive devices, according to the U.S. Office of Technology) benefit from recent improvements in speech technology that brought naturalness to the interaction with machines and created a vast number of application opportunities. In this case, the supply market is still growing, speech technology is slowly being embedded on existing devices/systems and new products are being developed.

### *D. More R&D is needed for Assistive Technology applications using speech*

Although we are in favor of the usage of current speech interfaces in AT, we consider that more research and development is needed, both in TTS and ASR technologies.TTS mainstream technologies heavily rely on speech recordings making it difficult to create a large variety of voices at a low cost. Although state-of-the-art Hidden Markov Models-based speech synthesis (HTS) require less time of recordings, the cost of producing a voice font for a TTS system is still very high, considering we have to pay a professional speaker, the time in the studio and the prompts' edition. The dream is to have a speech synthesis solution which would allow the creation of new voices with little speech recordings or no recordings at all. This solution is already envisaged and is called voice conversion [54] (also voice morphing or voice transformation), but it is still not in a commercial stage. Adaptation techniques capable of converting a source voice into another voice with a reduced set of recordings as well as the creation of a new voice through the combination of recordings of multiple speakers (e.g. from a disabled person's family) must be developed. In a more distant future, articulatory speech synthesis is expected to provide new voices without the need of natural speech recordings [55]. Despite the good performance of ASR system in controlled environments, they are not so good when there is environment noise and the users' vocal characteristics deviate from the ones used when training the acoustic models (like dysarthric speakers, elderly people). At least, a careful adaptation or even the creation and training of new acoustic models for disabled users is needed. But the problem can only be minored with this approach. Research on speech enhancement, noise reduction, better recording using microphone arrays, robust features, models with better capabilities than the mainstream Hidden Markov Models (HMMs) technology are needed.

Voice function in communication goes beyond the Linguistic and Pragmatic functions, i.e, the functions used to convey meaning (ideas, concepts, facts) and to perform speech acts (orders, promise, request, questions, etc.). Voice in communication also has an expressive function, used to express attitudes, feelings, emotions, personality and mood [56]. These functions are mainly associated with prosody and voice quality. As voice quality has only been marginally considered, much more research is needed on synthesis and recognition of voice expressive functions.

## VI. CONCLUSIONS

The authors strongly believe on the potential of speech for assistive technologies. In order to have liable applications in Portuguese language and for Portuguese users with special needs in the close future, there is still a lot of work to be done. The following actions are required:

1.To personalize the communication aid devices to SSPI, by providing different TTS voices, with different age ranges and genders and/or by adapting the ASR engines to the individual speech production disorders;

2. To adapt and expand state-of-the-art speech technology in European Portuguese to SSPI;

3. To conduct multidisciplinary work on the requirements, development and evaluation regarding the real use of speech technologies. The work must bring together specialists from Speech Therapy, Gerontology, Engineering;

4. To develop prototypes for groups of people that are not usually the main target of the assistive technology industry and that require special attention.

5. To enhance the communication competence and quality of life of individuals (specifically elderly and people with cerebral palsy) with permanent AAC needs.

## VII. FUTURE DIRECTIONS: A PROPOSAL

The authors are particularly interest in testing the expressed position in two application scenarios: AAC for Cerebral Palsy and Smart Homes for Elderly.

### *A. AAC for Cerebral Palsy*

Citizens with cerebral palsy are still far from being included in society. These people are affected in many different ways and levels of disabilities, often body movement coordination, balance and posture control; sometimes speech production as well as in different severity levels. However, their intellectual skills are seldom affected. Most of these people need one or more products of assistive technology to fulfill their needs of education, work and leisure and to carry out activities such as personal mobility, writing, drawing, communication and self-care in their everyday life. However, only some people are able to benefit from assistive technologies, since they are scarce and expensive. Whenever these individuals use this technology, the devices are not fully adapted, easy to use and compatible with other products, and have high maintenance costs. Other limitations are the reduced flexibility of the input (only text input, text prediction word by word instead of prediction of phrases and expression) and the impossibility of customizing the voice output (only one type of voice by default). These limitations, in a way, isolate these individuals from society and don't stimulate their communicative and learning skills. After the creation of new personalized TTS voices and with the definition of a stable API for future development of AAC applications which don't have migration problems when new operating system are released, individuals with cerebral palsy will be able to benefit from: improved communication skills through the AAC features; increased opportunities for social interaction; autonomy and self-confidence.

*B. Smart Homes for Elderly*

Elderly people are often included in the same market of disabled people by AT companies. Research projects seem to handle disabled and elderly at the same time [57]. It is uncommon to find personalized solutions exclusively for elderly, which have specific problems and are usually resistant to technology. The development of user-friendly and alternative interfaces (avatars or robots) for the improvement of usability and acceptance of the elderly when benefiting from AT has shown good results [58]. Among the AT devices oriented to aged people, there is Telecare [59], a service of remote care and surveillance that allows older people to keep living in their houses. However these products do not often benefit from speech interfaces as technology is expensive and not adapted. This is especially critical in the Portuguese market, where very little is being done for the sake of the ageing population. This group of people has a very different profile from what is expected to have in 2050: it is most of the times technologically illiterate and has reduced mobility, which causes social and information exclusion. Again, and particularly for this group of people, speech must be the basic interface with machines, whenever speech ability is not affected. Our aim is to develop better support for Elderly at Home by use of speech technologies by allowing more control of the Home; having the Home as a "companion"; and having better access to outside information (e.g. SMS, news). Concrete objective is the creation of the bases to allow fieldwork test of speech technologies in the socially relevant area of Smart Support for the Elderly staying at Home.The elderly will benefit from: increased choice, safety, independence and sense of control; improved quality of life; maintenance of ability to stay at home; reduced burden placed on caregivers.

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