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RESEARCH ARTICLE

DEVELOPMENT OF A SPEECH SYNTHESIZER FOR PORTUGUESE LANGUAGE WITH HARDWARE IMPLEMENTATION

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Abstract

This article presents a comprehensive analysis of speech synthesizers developed for the Portuguese language, focusing on hardware implementation and consideration of regional linguistic variations. Three synthesizers (A, B, and C) were evaluated in terms of regional variations, hardware implementation, efficiency, portability, ease of use, voice variation, comprehensibility, Braille compatibility, responsiveness, responsiveness, and resource consumption on mobile devices. The Synthesizer A, despite its moderate efficiency and high portability, stood out for its consideration of regional variations, easy initiation of speech synthesis, and high comprehensibility. The Synthesizer B, with hardware implementation, demonstrated efficiency and fast response times, but faced challenges in voice variation. The C Synthesizer offered high efficiency, portability, and Braille compatibility, making it suitable for a variety of devices. The detailed analysis of these synthesizers has provided valuable insights to guide the future development of these technologies.

Introduction:-

In recent years, the field of speech synthesis has experienced significant advancements, driven by developments in natural language processing technologies and embedded hardware (Silva and Souza, 2023). The ability to artificially generate speech not only has practical applications in virtual assistant systems and accessibility, but also plays a crucial role in human-machine interaction and digital communication.

In this context, this article discusses the development of a speech synthesizer for the Portuguese language, with a special emphasis on hardware implementation. The paper explores the rationale for this endeavor, taking into account not only the specific linguistic needs of the Portuguese, but also the practical advantages of hardware implementation to ensure efficiency and portability.

According to recent research (Santos et al., 2022), the Portuguese language is one of the most widely spoken in the world, covering several nations and cultures. Despite their breadth, many speech synthesis solutions are still predominantly centered on more widely spread languages, thus creating significant gaps in access to communication technologies for Portuguese speakers. Hardware implementation brings substantial advantages in terms of efficiency and response time, especially in contexts where computational resources may be limited, such as mobile devices or embedded systems (Oliveira, 2022).

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The main objective of this article is to explore the process of developing a speech synthesizer for the Portuguese language, with a focus on hardware implementation. Specific linguistic aspects of the Portuguese will be considered, taking into account regional variations and phonetic characteristics. It seeks to design and implement an efficient and portable system, which can be incorporated into a variety of devices, from smartphones to home automation applications.

Theoretical Framework

The development of a speech synthesizer for the Portuguese language with hardware implementation involves a deep understanding of several interdisciplinary areas, from natural language processing to digital electronics. The theoretical framework below covers some of the main concepts that underpin this project.

Speech Synthesis

Speech synthesis is an advanced technology that involves artificially reproducing human speech using algorithms and electronic devices. This multidisciplinary field combines knowledge of linguistics, phonetics, natural language processing, and audio engineering to create systems capable of generating speech in a natural and understandable manner. Speech synthesis plays a crucial role in a variety of applications, from virtual assistants and user interfaces on electronic devices to accessibility technologies for people with visual impairments or reading difficulties. There are several speech synthesis techniques, including concatenation synthesis, formant synthesis, and statistical modeling synthesis. Each approach has its advantages and challenges, aiming to achieve artificial speech that is fluently articulate, understandable, and emotionally expressive. With the ongoing advancements in artificial intelligence, machine learning, and natural language processing, speech synthesis is constantly evolving, allowing for more natural and immersive interactions between humans and machines.

Natural Language Processing (NLP)

According to Hulley (2016), Natural Language Processing (NLP) is an interdisciplinary field of artificial intelligence and computational linguistics that focuses on the ability of computers to understand, interpret, and generate human language in a similar way to communication between people. It involves a range of complex tasks, such as sentiment analysis, machine translation, text summarization, and voice processing, utilizing machine learning and text processing techniques to extract meaning and insights from textual data. NLP has wide-ranging applications, from virtual assistants and chatbots to advanced search engines, and plays a key role in advancing human-machine interaction and efficiently processing linguistic information in a variety of areas.

Phonetics And Phonology Of Portuguese

The phonetics and phonology of Portuguese constitute an intricate and fascinating field within linguistics, dedicated to the study of the sounds of spoken language. Phonetics focuses on the acoustic and articulatory analysis of sounds, investigating the physical properties of vowels, consonants, and other sound phenomena present in the Portuguese. This includes the study of the different ways in which speech sounds are produced by the vocal organs, such as the mouth, tongue, and vocal cords, providing a detailed understanding of the phonetic variations and distinctions that occur in different linguistic contexts. On the other hand, phonology explores sound patterns on a more abstract level, analyzing how sounds are organized and distinguish meanings in words. In the case of Portuguese, a language rich in nasal vowels and complex accentuation rules, phonology investigates intonation patterns, stressed and unstressed syllables, as well as specific phonological phenomena such as elision and assimilation. The phonology of Portuguese is particularly interesting due to its regional variations, which result in different accents and pronunciations in countries such as Brazil, Portugal, Angola, and Mozambique. The in-depth study of Portuguese phonetics and phonology not only enriches our academic understanding of the language but also plays a vital role in the development of speech synthesis technologies, enabling authentic and natural reproduction of language sounds in synthetic voice systems and other language-related applications.

Digital Electronics And Hardware Implementation

According to Avelar et al, (2017) digital electronics is a field of electronics that deals with systems that use discrete signals instead of continuous signals. In digital systems, information is represented in binary format (0 and 1), and the manipulation of these values is carried out by means of logic gates, flip-flops, and other digital components. This allows for the representation of information in a more reliable and accurate manner, as well as facilitating the processing and transmission of data.

Hardware implementation refers to the physical construction of electronic circuits that perform specific functions, based on digital electronics designs. This involves selecting and connecting electronic components, such as transistors, resistors, capacitors, and integrated circuits, to create systems that perform desired tasks. Hardware implementation is commonly used in the creation of processors, control circuits, communication devices, and more. Digital electronics play a key role in modern information technology, industrial automation, consumer electronics and many other areas, with implementation in hardware being the practical step that makes these ideas a reality. It is an ever-evolving field, with technological advancements allowing for the creation of increasingly complex and efficient digital systems.

Artificial Neural Networks

Neural networks are computational models inspired by the structure and functioning of the human brain, composed of layers of interconnected units called artificial neurons (BRAGA, 2016) . They are used in machine learning and artificial intelligence to perform complex tasks such as pattern recognition, natural language processing, and decision-making. By training with large datasets, neural networks learn to map inputs to outputs, automatically adjusting the weights of connections between neurons to optimize performance. This makes them a powerful tool for a variety of applications, from computer vision to recommender systems and process automation.

Accessibility And Human-Machine Interaction

In Brazil, there is no specific law that deals exclusively with the usability of human-machine interfaces (HMI). However, the Brazilian Law for the Inclusion of Persons with Disabilities (Law No. 13,146/2015), also known as the Statute of Persons with Disabilities, establishes important guidelines related to digital accessibility. Digital accessibility is a key aspect of usability, as it refers to ensuring that systems, applications, and websites are usable by all people, regardless of their abilities or disabilities.

Accessibility Law

The Accessibility Act, which is officially known as Law No. 10,098, was enacted in Brazil in December 2000. This law, together with Decree No. 5,296 of 2004, regulates accessibility for people with disabilities or reduced mobility in public and private spaces for collective use.

The Accessibility Law states that it is the duty of the State and companies to promote accessibility at all levels, including but not limited to:

1. Buildings: It requires that public or private buildings for collective use, such as schools, hospitals, stores, shopping malls, and theaters, be accessible to people with disabilities. This implies the installation of ramps, elevators, adapted toilets, tactile signage, among others.
2. Public Transportation: The law states that public transportation vehicles must be adapted to accommodate passengers with disabilities. This includes the availability of accessible buses and trains, with spaces for wheelchairs, as well as suitable stations and stopping points.
3. Communication and Information: It also requires the availability of information in accessible formats, such as Braille and audio, to ensure that people with visual or hearing impairments can access relevant information, such as information boards, manuals, and public services.
4. Technological Resources: In addition, the legislation provides for the use of assistive technologies to facilitate digital access to information and services, making websites, applications, and technology systems more accessible.

The main objective of the Accessibility Act is to promote social inclusion and equal opportunities for all people, regardless of their physical or sensory limitations. It plays a crucial role in promoting the rights of persons with disabilities and creating a fairer and more inclusive society.

Materials And Methods:-

For the development of the speech synthesizer focused on the Portuguese language, an agile approach was adopted, combining methodologies such as Ork, Canva and Scrum. At the beginning of the project, the team used the Ork platform to collect and organize ideas, as well as define the tasks to be carried out. The tool allowed for effective collaboration, making it easier for team members to communicate and track project progress.

Next, Canva was employed to create a visual representation of the speech synthesizer's design. Using this tool, sketches of user interfaces, flow diagrams, and other visuals were developed that helped the team visualize and

refine the project concept. Canva provided an intuitive and collaborative way to create attractive and functional designs for the speech synthesizer. As far as project management is concerned, the team adopted the Scrum methodology, dividing development into short-term sprints. During each sprint, specific features of the speech synthesizer were implemented, using speech synthesis, natural language processing, and digital electronics technologies. Daily follow-up meetings, characteristic of Scrum, allowed for seamless communication between team members, making it easy to identify challenges and quickly adjust course when necessary.

Within this agile context, the team performed frequent iterations, continuously revising and improving the speech synthesizer based on the feedback obtained. This iterative and collaborative approach, combined with the use of Ork, Canva, and Scrum tools, enabled the efficient development of the speech synthesizer focused on the Portuguese language, ensuring its effectiveness, usability, and accessibility for a wide range of users.

Results And Discussion:-

The detailed analysis of speech synthesizers for the Portuguese language offered valuable insights into their usability, effectiveness, and affordability. The results provide a comprehensive understanding of the advantages and challenges of each system, which are essential to guide the future development of these technologies. This study examined crucial criteria, including regional variations in synthesis, hardware implementation, efficiency, portability, speech synthesis initiation, voice variation, comprehensibility, Braille compatibility, response speed, and device resource consumption. The comparison and analysis of these aspects provided an in-depth view of the quality and usefulness of speech synthesizers, which are fundamental for varied applications, from virtual assistants to accessibility devices.

Feature Comparison In Speech Synthesizers

Table 1 presents a detailed comparison of the features found in different speech synthesizers developed for the Portuguese language. This comparative analysis is crucial to understand the existing gaps in the available resources and guide the development of the new speech synthesizer addressed in this study.

Table 1:- Comparison of Resources in Speech Synthesizers for Portuguese Language.

Speech Synthesizer	Regional VariationsConsidered	Hardware Implementation	Efficiency	Portability
Synthesizer A	Yes	No	Moderate	Discharge
Synthesizer B	No	Yes	Discharge	Moderate
C Synthesizer	Yes	Yes	Discharge	Discharge

Source: Authors (2024)

In the context of speech synthesis for the Portuguese language, regional variations play a key role in the authenticity and comprehensibility of generated speech. Synthesizers A and C, by incorporating these variations into their algorithms, are able to capture linguistic nuances specific to different regions where Portuguese is spoken. Not only does this make the interaction more natural for users, but it also ensures that speech synthesis is adapted to the diverse accents and expressions present in countries such as Brazil, Portugal, Angola, and others. However, the B synthesizer, by not considering these regional variations, may face challenges in reproducing speech authentically in specific contexts, which may limit its effectiveness in certain situations, especially when linguistic accuracy and authenticity are essential.

Hardware implementation is a crucial factor for the efficiency of speech synthesizers, especially in devices with limited computing resources, such as mobile devices and embedded systems. The B synthesizer excels in this regard, offering efficiency and fast response times due to its implementation in hardware. This is particularly advantageous in scenarios where computational processing needs to be optimized, ensuring agile and uninterrupted speech synthesis. On the other hand, A and C synthesizers, even if they offer other advantages such as regional variations and high portability, can face challenges in terms of efficiency, especially in devices with limited resources. Therefore, the choice between hardware implementation and other features must be carefully considered, considering the specific context of use and the needs of end users.

Speech Synthesizer Usability Test Results

Table 2 presents the results of the usability test carried out with representative users, evaluating the ease of use and effectiveness of the new speech synthesizer developed for the Portuguese language. Participants were asked to perform specific tasks using the synthesizer and provide feedback on their experience.

Table 2:- Speech Synthesizer Usability Test Results.

Task	Synthesizer A (%)	Synthesizer B (%)	Synthesizer C (%)
Start Speech Synthesis	95	80	92
VoiceVariation	89	75	88
Responsiveness	93	78	91

Source: Authors (2024)

In the evaluation of speech synthesizers, Synthesizer A proved to be the most intuitive and easy to use to initiate speech synthesis, indicating a user-friendly experience for users. All synthesizers faced challenges in voice variation, suggesting the need for improvements in this area. In terms of comprehensibility, all systems performed generally well, but Synthesizer A stood out, showing speech synthesis perceived as more natural and easier to understand. These results emphasize the importance of an intuitive interface and improved language modeling to improve users' experience with speech synthesizers.

Mobile Accessibility Assessment

Table 3 presents an assessment of the accessibility of the new speech synthesizer on mobile devices, considering different parameters, such as compatibility with assistive technologies, speed of response, and consumption of device resources.

Table 3:- Speech Synthesizer Accessibility Assessment on Mobile Devices.

Parameter	Synthesizer A	Synthesizer B	C Synthesizer
Braille support	Yes	No	Yes
Speedof Response	Rapid	Moderate	Rapid
ResourceConsumption	Low	High	Moderate

Source: Authors (2024)

Synthesizer A and Synthesizer C are Braille compatible, making them accessible for visually impaired users, while Synthesizer B does not offer this compatibility. In terms of response speed, Synthesizer A and Synthesizer C are fast, providing a responsive experience, while Synthesizer B has a moderate speed, which can cause noticeable delays. As for the device's resource consumption, Synthesizer A has a low consumption, ensuring efficiency even in modest devices, Synthesizer B has high consumption, which can cause slowdowns in older devices, and Synthesizer C maintains a moderate consumption, balancing performance and accessibility.

Final Considerations

In recent years, the field of speech synthesis has experienced significant advancements due to developments in natural language processing technologies and embedded hardware. The ability to artificially generate speech not only has practical applications in virtual assistant systems and accessibility, but also plays a crucial role in human-machine interaction and digital communication. This article addressed the development of a speech synthesizer focused on the Portuguese language, with an approach focused on hardware implementation. Hardware deployment offers efficiency and fast response times, especially in contexts where computing resources may be limited, such as mobile devices and embedded systems.

Considering the breadth of the Portuguese language, which is one of the most widely spoken in the world and encompasses diverse nations and cultures, it is crucial to ensure access to communication technologies for Portuguese speakers. However, many speech synthesis solutions are still centered on more widely spread languages, leaving significant gaps in access to communication technologies for Portuguese speakers. The development of the speech synthesizer for the Portuguese, considering specific linguistic aspects, regional variations, and hardware implementation, represents an important step in reducing these gaps and promoting digital inclusion.

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