18 FUNSPEECH: PROMOTING SPEECH PRODUCTION IN YOUNG CHILDREN WITH HEARING DISABILITIES

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ABSTRACT

Today, deaf-born infants can be implanted with cochlear implants as early as six months after birth. Studies have shown that early speech practice leads to dramatically improved pronunciation and elocution. We developed FunSpeech, a "serious game" that aims to help very young implanted children to improve their speech production skills by frequent practice. FunSpeech provides an engaging and playful experience that motivates children to practice their speech autonomously as frequently as possible. Signal processing algorithms and classification methods were developed to identify meaningful sounds, volume levels, and first speech sounds. Most games have been tested with good preliminary results in a control population of normal hearing children. This indicates that FunSpeech has the potential to successfully fulfill the gap in applications targeting speech-production skills in very young implanted children.

KEYWORDS

Sound processing; Phonemes; Unity; Language development;
Cochlear implant; deafness; Hearing impairment; Serious games; Education.

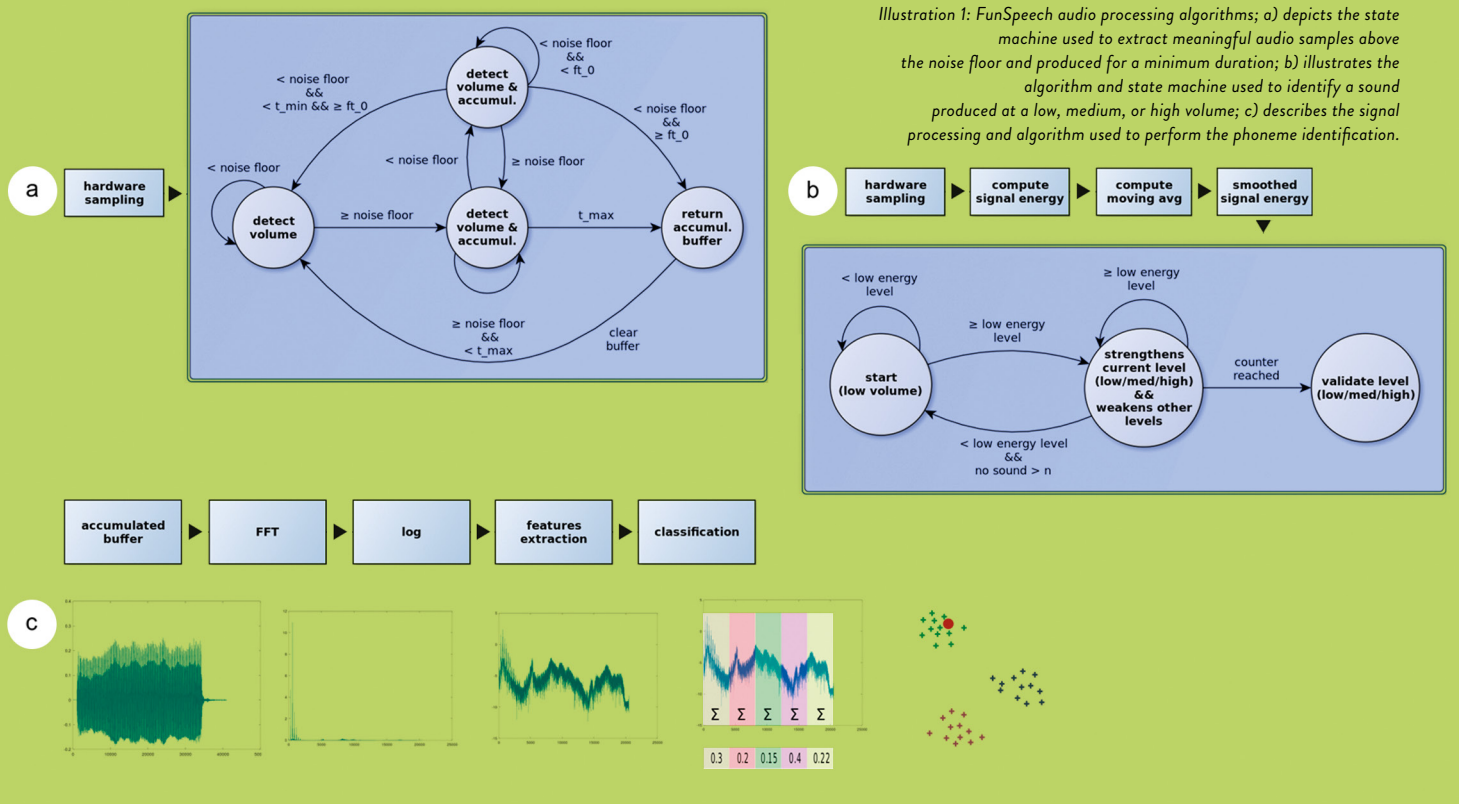

Illustration 1: FunSpeech audio processing algorithms; a) depicts the state machine used to extract meaningful audio samples above the noise floor and produced for a minimum duration; b) illustrates the algorithm and state machine used to identify a sound produced at a low, medium, or high volume; c) describes the signal processing and algorithm used to perform the phoneme identification.

CONTEXT

The cochlear implant (CI) is a device that restores hearing in people with profound sensorineural hearing loss by electrically stimulating the auditory nerve [1]. More than 600'000 people have benefited from CIs worldwide and millions more are expected to benefit from this technology.

An essential factor for successful rehabilitation with a CI is an appropriate acoustic stimulation and training (e.g., speech therapy). This is especially important in young implanted children who need to develop language skills using the degraded information provided by the CI. For this reason, children should follow intensive speech therapy sessions following implantation.

TARGETED ISSUES

Speech rehabilitation therapy alone is not enough to warrant adequate language development in cochlear-implanted children. It is also of primary importance that during daily life (e.g. at home, at school) children get sufficient and good quality auditory stimulation. This is not always achieved because parents and school staff often lack means (time or qualifications) to achieve efficient at-home stimulation and training. In this context, our group has been working for some years on specific training tools for cochlear-implanted children to help them achieve good quality, at-home rehabilitation. The initial steps focused on developing and testing training software for speech perception in the form of gaming [2]. We currently concentrate on developing a new program to train another fundamental aspect in language development: speech production.

PROPOSED SOLUTION

A thorough review of the current state of affairs confirmed that no application specifically targeting speech production skills in very young children exist [3]. Here we present a project that aims at fulfilling this gap by developing a mobile application to motivate and train speech production skills: FunSpeech. This application was developed following the principle of "serious games" and targets an unaddressed population of very young implanted children, between two and four years old.

FunSpeech provides an engaging and playful experience that motivates children to practice their speech autonomously as frequently as possible.

In order to be meaningful and successful, FunSpeech features five mini-games especially designed to address the different sound parameters required to achieve controlled speech production: intensity, rhythm, pitch, and phoneme construction. The gameplay is adapted to very young children cognitive abilities and to be engaging each game provides an immediate visual feedback based on children's actions. To study and analyze the children's progression, clinical data are automatically extracted and collected. The application is multilingual in an effort to reach the largest possible audience.

FunSpeech targets Android tablets platforms and is implemented in C# using the Unity3D framework.

The signal processing and algorithms developed for the various mini-games are depicted on Illustration 1. The audio engine is able to: a) detect the presence of a meaningful sound of a given duration (by opposition to a short noise), b) classify the volume of a sound as low, medium, or high and, c) identify phonemes (e.g. vowels). Interestingly, the algorithm used for phoneme recognition mimics the sound processing strategies commonly used in cochlear implants.

Illustration 2: four of FunSpeech's mini-games: a) the monkey game, b) the bear game, c) the fishing game, d) the clown game.

RELEVANT INNOVATION

FunSpeech is an innovating application in several aspects.

First, no other serious game tackles speech production promotion in young children with hearing disabilities.

Second, FunSpeech addresses a novel and difficult population: that of very young, hearing-impaired children who start with absolutely no speech production skills. On the one hand, it has the potential to significantly improve cochlear implant outcomes, which considerably impacts the child's life in the long term. On the other hand, it provides a unique opportunity to gather fundamental information about how speech production skills are developed, which will ease the set-up of pertinent therapeutic interventions.

Third, it presents an innovative educational approach, in which vocally-performed actions are directly translated into visual responses in the games, so that the child receives an immediate and direct visual feedback.

PROJECT OUTCOMES & RESULTS

The first version of FunSpeech has been successfully developed for the Android platform. It runs on a tablet, allowing the game to be easily accessible to children, medical staff and parents.

Five mini-games, working on different necessary parameters for accurate speech production, have been implemented:

- The "fishing" game: designed to explore and control the effects of voice production and rhythm. The game is composed of swimming fish and a fisherman. The goal is to produce a sound at the right time in order to catch as many fish as possible.
- The "helicopter" game: designed to explore the effect of pitch production. The child controls a helicopter with the pitch of his/her voice.
- The "monkey" game: designed to help children explore and control the effect of voice intensity. The goal is to make monkeys disappear by producing sounds at a specific volume for a given time.
- The "bear" game: designed to help children control their voice intensity. Bears cross the screen at various distances. The goal is to call as many bears as possible by producing sounds at the correct volume.
- The "clown" game: designed to train the production of the first speech sounds i.e. phonemes (e.g. vowels) produced by young children. The goal is to successfully repeat random phonemes. Upon success, a clown claps and presents a dancing animal.

Four of the developed mini-games are shown on Illustration 2. The "monkey", "bear" and "fishing" games have been tested with good results in a control population of normal hearing children. The "clown" game requires a large set of young children samples to train the algorithm. Given the difficulty to obtain such samples, the first version of FunSpeech was trained on a small set of adult samples instead, leading to sub-optimal results.

CONCLUSION

Using games with an educational purpose has proven to be a successful treatment strategy in disabled populations. Indeed, clinicians and cochlear implant manufacturers have started developing game-based mobile applications to help patients reach optimum outcomes. However, speech production and very young children have received very little attention from the field. Promising preliminary results show that FunSpeech has the potential to successfully fulfill this gap. Furthermore, the strategy used in this innovative solution could potentially be applied to other fields, such as promoting communication skills in a variety of syndromes.

PERSPECTIVES & NEEDS

Presently, the training set of the Clown game is composed of adult samples only. Much better results would be obtained by training the algorithm on a large population of young children samples. The classification method could also be improved. More advanced classification algorithms will be explored in the future.

Although the outcome of testing FunSpeech on hearing children was positive, the games must be tested on a population of implanted children instead. The impact of young implanted children using the FunSpeech application on a regular basis (e.g. on a daily basis at home) will have to be measured over a long period of time in order to assess its effectiveness as a speech therapy strategy.

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