

A Serious Game for Children with Speech Disorders and Hearing Problems

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Abstract—Speech impediment affecting children with hearing difficulties and speech disorders requires speech therapy and much practice to overcome. To motivate the children to practice more, serious games can be used because children are more inclined to play games. In this paper, we have designed and implemented a serious game in which children can learn to speak specific words that they are expected to know before the age of 7. The game consists of an avatar controlled by the child through speech, with the objective of moving the avatar around the environment to earn coins. The avatar is controlled by voice commands such as Jump, Ahead, Back, Left, Right. Children will be guided by an arrow during the game instead of a getting help from a therapist or a teacher to guide the child to the next coin. This allows the child to practice longer hours, compared to clinical approaches under the supervision of a therapist, which are time-limited.

Keywords—Speech Impediment, Voice Commands, Serious Games

1. Introduction

Hearing and speech disorders are the third most common cause of communication problems for preschool children [1]. It is estimated that 40 million Americans have communication disorders such as speech or hearing impairments, and that almost 8 percent of U.S. children have speech disorders especially between 3-17 years old, while 4 percent of preschool children have significant language disorders, totaling to around \$186 billion annually in treatment cost [1]. Children who have hearing loss are more exposed to have spoken problems, but if these problems are recognized before the age of three the children can have significant improvements using different solutions [2] [3].

For children, games are an ideal approach to breaking out of the ordinary language therapy or home-school speech routines, as children like to play games. Research has shown that video games with a combination of education and entertainment have a significant role in helping children with special needs [4]. Research has also shown that children who play educational video games could improve their skills

more easily compared to those who did not play educational video games [5].

So combining the children's therapy with games will not only give them entertainment, but also more speech therapy exercises than what they can get from a clinical setting [6]. According to some reports from teachers, the communication skills of children with hearing loss and language problems can be strengthened significantly via serious games [7] [8]. Especially in developing countries, there are too many children with speaking problems [9]. Some of them are unwilling to speak, some of them have psychological problems and do not talk to anyone, and some have cleft problems. For every problem, there are clinical solutions, but unlike adults, children are not motivated to undergo clinical solutions, and without motivation, progress is slow. For example, a child who has psychological problems and does not like to communicate with anyone can have a therapist to practice with, but after a while the child gets bored and does not like to communicate with the therapist anymore. Another problem is cleft which is the main issue in developing countries [9]. Although cosmetic surgery can physically correct cleft, still those children need to do speech therapy and practice speaking to improve their talking skills [4] [9].

The most common communication problems in children are as follows [10]:

Oral Language:

- Difficulty with oral directions
- Difficulty in pronouncing words properly
- Unable to concentrate on and figure out spoken language
- Not being able to follow fast speaking, which can cause a big problem in taking notes or following the instructions

Hearing Loss:

- Language disorder for those with hearing impairment

Attention and Concentration:

- Difficulty of focusing on doing a task

- Easily distracted by a small distraction
- Overloaded quickly and getting tired of doing a task and needing frequent breaks

Foreign Language skills:

- Difficulty or feeling shy to speak aloud
- Difficulty in pronouncing words properly

Memory:

- Difficulty in retrieving word from memory quickly
- Difficulty in memorizing words

Spelling:

- Disability in spelling common words

To create more opportunities for children with these problems in general, we propose a serious game in which the avatar is controlled by the child through speech, motivating the child to practice more and more speaking. This serious game has been developed in the context of our European project Intelligent Serious Games for Social and Cognitive Competence [11]. Our contribution is to do the best of knowledge that no one has done no other work.

The rest of this paper is organized as follows: section II presents the previous efforts in how to help children improve their oral language via speech and hearing therapy. In section III, our proposed game design is described. Section IV reports the implementation of our game. The last section includes the conclusion and what to do to improve our game as future work.

2. Related Works

In this section, we will see what researchers have done to help children regarding the most common communication disorders to improve their skills via serious games.

Speech Language institutions are one of the most common places where people can work on their speech problems. Especially children can improve their spoken skills in those environments. But not only collaborating with therapists can be boring for children, but also having to be present in a hospital or institute for speech therapy can cause another difficulty for children. Besides, these institutions are not available in all locations. It therefore follows that having a therapy system that is accessible and motivates the children to use it, would be a good contribution to solving this problem. To create such a system, we have to understand how speech therapy works. Essentially, children who have spoken difficulties and hearing-impairment have therapists at home or school who reads these words to the child during a session and the child has to repeat them after hearing.

Speech therapy drills via multimedia devices [9] and 3D game environments [6] to make it easier for a patient to meet his/her goals according to the problem that he/she has. In top of that, therapists can utilize video games at home to motivate the child to play the game to improve his/her oral language problems [9]. Studies show that combining

education with entertainment can be a tricky way in the rehabilitation process of children with special needs [6].

Another way to strengthen the auditory perception of children with auditory processing disorders or hearing losses is TheToy video game in which the child must use hearing to follow a character, who can be pursued by the sound that it emits, and who frequently disappears from the scene through one of two doors [2]. Another game which has been designed for this purpose is DiDuDa, which can treat children's hearing loss or oral language problems if the problem has been diagnosed at an early age [3]. Another approach uses a voice recognition system in a digital game with two different methods in English and Spanish to help children with oral language difficulties [12]: the first one is Dynamic Time Warping or DTW that is an algorithm and measures the similarity between two sequences and the second one SPHINX4 is a voice recognition system. Based on the game, when the word is pronounced by the child properly, the word will be shown in small boxes.

In [12], they have used a static design in their games, which allows the system to keep the teenager concentrated and motivated. This motivation leads them to better results. The cards are shown to the child and s/he should pronounce the word correctly. After all words are done, the game is successfully over.

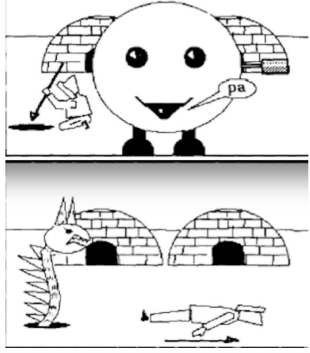
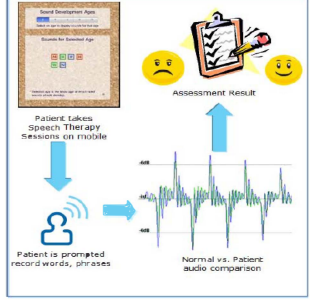
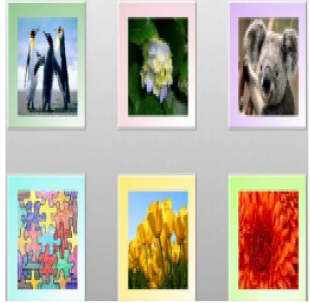
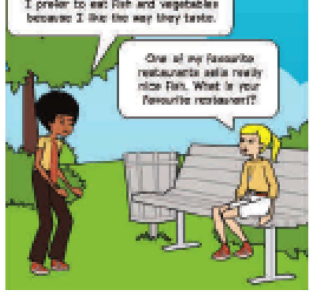
To increase children's fluency in speech, and in order to increase their communication skills, Information and communication Technology (ICT) [13] based special education games have been used that are based on story telling [14]. These kinds of serious games will help children to learn some colors, numbers, and language in their mother tongues.


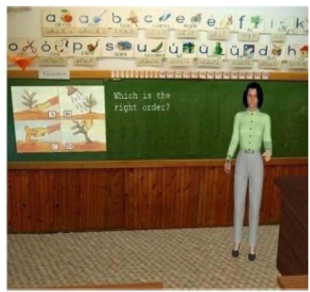
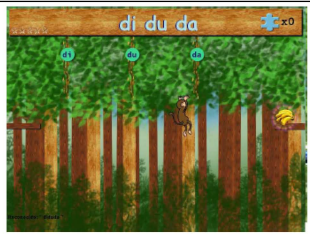
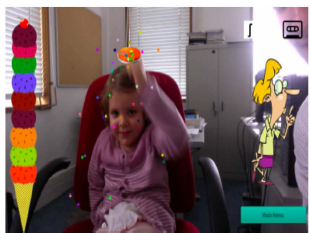
To see the effect of spoken language and audio content on children with speech difficulties, in paper [15], Authors have explored outcomes of these kinds of serious games to improve children's speech skills by Natural Language Processing techniques. They have selected 11 serious games leveraging on Natural Language Processing methods.

To relieve children's anxiety in face-to-face conversations between children, in [16], the authors have made a game in which children can talk to each other using headsets with microphones. In these kinds of social conversations games the children are supposed to have enough practice to improve their skills. The game has five stages: Greet, Initiate, Maintain, Switch and Exit. The authors use multi-touch surfaces like shared active surface (SAS) to give this opportunity to children to speak together and have cooperative gestures.

Table I shows some of the above games specifically for speech therapy and hearing impairment, ordered from old to new. These served as motivation for us to create our own game that would provide motivation and accessibility for children at home to practice their speaking.

TABLE I. SERIOUS GAMES FOR IMPROVING CHILDREN'S SPEECH DISORDER

game	objective	problem	approach	game description	platform	frame of the game
[2]	designed for the testing and training of auditory perception in children with hearing losses and/or auditory processing disorders.	hearing losses and/or auditory processing disorders.	Attention and compliance are encouraged by an interesting event in each scene	Take Home Game: The child pursues an animated character through a series of scenes, using hearing to identify the character's hiding place.	Windows environments.	
[9]	bring the Speech Pathologist to the Child by leveraging mobile technology and providing Speech Therapy drills.	children suffer with Cleft Lip and Palate. They can't speak properly.	patient centric and concentrates on enhancing speech via intuitive sing along games to motivate the child.	Speech Therapy Drills Game: Patient takes speech therapy sessions on mobile. Child pronunciation is shown as animation (bird in cage or frog in pond) to encourage the child to take similar speech therapy drills.	1. Mobile Technology to provide basic Speech drills sessions to the patients. 2. Extend the innovation to portable multimedia devices or Set-Top-Box for Cleft patients.	
[12]	providing a solution to the learning and enhancement of habitual language in kids and teenagers with a simple and easy game focused on their personal needs and characteristics.	speech problem of children with autism, concentration problems.	treatment	Word-object Voice Game: Pictures with some sounds associated and ask for the correct spoken spelling using word detection techniques.	application	
[16]	facilitate children with Autism Spectrum Conditions (ASC) learning social competence skills through technology-delivered Cognitive-Behavioral Therapy (CBT).	Autism Spectrum Conditions	treatment: achieve effective conversation with another participant	TalkAbout Game: This is a CVE computer program in which children are encouraged to learn about and practice the stages of social conversation.	DT surface, multi-user tabletop shared active surface (SAS).	

game	objective	problem	approach	game description	platform	frame of the game
[6]	reports the advantages of 3D game environments for speech and language therapy of children and benefits of making the treatment process accessible from anywhere and anytime are demonstrated.	children with speech and language disorders	treatment	Descriptions about the game objects with two scenarios: The first one is designed to introduce the environment to clients. The second scenario of the game interface is prepared for free interactions with the objects.	PC, mobile	
[13]	Help children who have inability to engage in learning in a regular manner because of some physical, mental or psychological disabilities.	children with physical, mental or psychological problems.	overcome the difficulties of students with special needs.	Adjustable Virtual Classroom Game: an interactive computer game has been developed for autistic children to increase the fluency in their speech by A. Anwar et al. In that game the player has to utter the name of the images that are visible in the computer screen within a short period of time.	Mobile devices, web browser	
[3]	exercise some speech abilities.	children with hearing loss diagnosed at an early age	diagnosed hearing disability and who are using some kind of aid, such as a cochlear implant.	di du da Game: The monkey will be able to grasp the vine when the corresponding syllable is pronounced correctly; otherwise the monkey will fall.	Web, mobile, PC	
[4]	they use a robust phoneme recognition solution for assessing children's performance in Visual Speech without false negative that is the cause of frustration of the child.	Speech sound disorders	treatment: Speech exercises	ice cream: they have motivational elements that encourage the child to have more motivation and focus.	VITHEA system gives an opportunity to children to practice speaking by visual speech.	

What distinguishes our game from the above are: the Training, and the Test phase. 1) Our game is controlled by an arrow during the scene and independent of any therapist or teacher to help the child reach the goal. 2) We have avatar control by voice commands with word detection package [17] which motivates children to explore the environment in our game to find more objects. 3) As they find an object, the voice for that object will be played and needs to be

repeated by the child. In the next phase of the game, the child is supposed to utter those words into the scene and we will assess her/his pronunciation by Windows UDP Voice Recognition server. 4) We have no negative feedback to the child, because negative feedback can be discouraging and frustrating for the child. We just show the similarity score of the child word to the original word of the object from a text file.

3. Design

We designed a 3D game called "Into the Forest" by Unity 3D in C# programming language. The game has a virtual teacher to teach children in an adventurer way. An overall view of the game is shown in Fig. 1. We have two stages to attain our goal in the game. The first stage is training phase by playing the main game. The second stage is assessment part to evaluate his/her learning. In the implementation, we present the game with more details. This game is supported by all platforms such as iOS, OSX, Windows, and Android. We modify the game according to the child's requirements.

After the child played the game and earned enough coins, we assess his/her learning by another application. To see his/her improvement, the child is supposed to utter some specific words according to the game. To evaluate her/his learning, we have validation recognition which is between 0 to 100 percent. If this score is upper than 70 percent, it means a good result of his/her learning.

This value gives us the percentage of the accuracy between the child's pronunciation by speech to text and the actual word from a text file. This text file includes all words that the child is supposed to learn them by playing the game. We have used Windows UDP Voice Recognition Server which is supported on upper than Windows7.

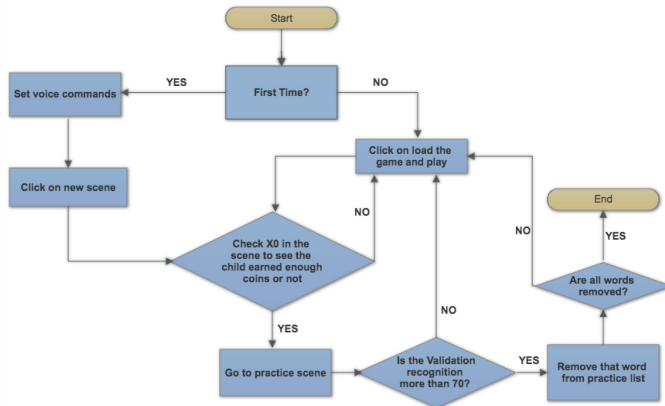


Figure 1. The chart showing the game flow

4. Implementation

Into the Forest is developed for children between 2 to 6 years old with speech disorders and hearing problems. This age range was chosen according to [18], which states that children are supposed to learn some specific words before the age of 6 that are related to Numbers (One, Two, Three, Four, Five, Six, Seven, Eight, Nine, Ten, Twenty, Thirty), Animals (Dog, Cow, Frog, Horse, Bird, Lion, Mouse, Cat, Chicken, Monkey), Fruits (Strawberry, Apple, Coconut, Orange, Kiwi, Cherry, Grapes, Pears, Lemon, Banana), Colors (Strawberry, Apple, Coconut, Orange, Kiwi, Cherry, Grapes, Pears, Lemon, Banana), Days (Monday, Tuesday,

Wednesday, Thursday, Friday, Saturday, Sunday), Months (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday), Seasons (Winter, Fall, Spring, Summer). Even if we intend to learn sentences to the child, we will include these words as well.

During the game, an object will appear in the scene and avatar will collide with that object and objects sound will be played and repeated by the child. After the child finished this teaching phase, s/he will enter the test phase and system will show us her/his improvement by giving validation recognition percentage. The child tells the name of the object in the scene and validity of the word will be shown on RecoServer, as it is shown in figure 7. The higher accuracy s/he has in uttering words, the more scores she/he will receive.

In the main menu, as it is shown in the Fig. 2. the child can start the game from the beginning or continue from where s/he left the game for the last time and earned enough coins so far. After s/he entered the game environment, we



Figure 2. Main Menu of the Game

have two choices to control the avatar during the game. The first option is for children who are crippled and are not able to use their hands properly. For this purpose, the avatar will be controlled by the child with voice commands such as jump, ahead, back, left, right as it is seen in the Fig. 3. By making use of word detection package, we assign verbal commands to our game and control avatar just by adding Spectrum Microphone from this package to the scene. Voice commands are recognized by word detection package in which the child wave information passing by an Auto-check will be compared to the waves that already set before at the beginning of the game. The second choice is using arrow keys for directions and space button to jump and shift for running.

Avatar control is supported for English language and before recording the sound as a sample, we use Noise Plotter to recognize the noise in the environment that is so important during recording. Besides, we have an arrow key in the scene as it can be seen in Fig. 4 to help the child where to find the next goal to collide without getting help from someone else. Then its sound will be played and another object will appear in the scene with random distance from the avatar.

This arrow will guide the child where to find the next goal during the game and some of the objects are shown in Fig. 5.

Having this arrow, as a guide during the game, makes the child play the game independently and autonomously to find objects into the forest and listen to them carefully

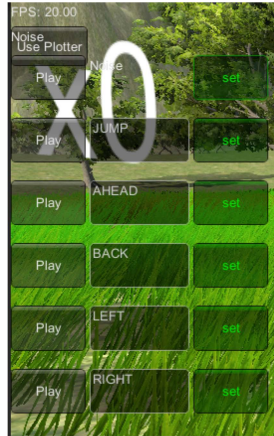


Figure 3. Avatar Control by Voice Commands.



Figure 4. Far From the Goal in the Scene



Figure 5. Reaching the goal

and repeat after hearing. As it is shown in Fig. 6, X0 is counting the number of the objects during the play. It means how many objects the child could meet and practiced so far in the game. In addition, in Fig. 6 there is a save button which saves the number of objects avatar found till now. If we considered 30 words to teach the child, at the end of the play this X0 should be 30. After the child finished this game, he/she will do the test phase of the game for evaluation as we talked in Sec. Design.



Figure 6. Avatar Control by Voice Commands.

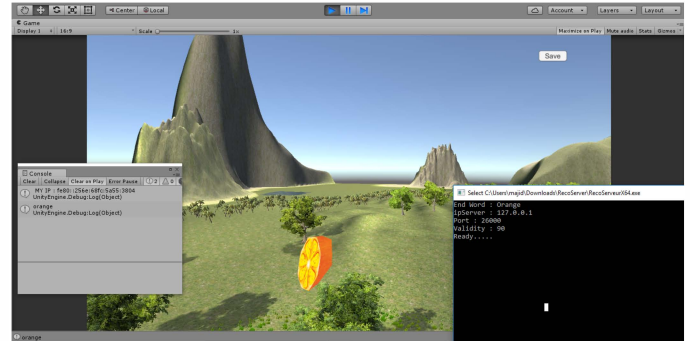


Figure 7. Test phase of the game

5. Conclusion

This game has been developed to cease some problems that therapists have with speech disorder children which is hard for therapists to communicate with children. We can use this kind of games in schools spoken laboratories to give this opportunity to children to learn autonomously. Behind the children, we can assess their progress from the first time that they have played the game.

For future work, we will improve the assessment part of the game. We are planning to show which words are pronounced properly and which words are missed and an overall evaluation for his/her pronunciation in general.

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