Boston University
Electrical & Computer Engineering
EC463 Capstone Senior Design Project

Problem Definition and Requirements Review

Vobot

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by

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Vobot

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Customer Sign-Off

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Project Summary

One in sixty-eight U.S children has Autism Spectrum Disorder (ASD). Many of these kids will struggle articulating their thoughts for the rest of their lives. Our group is determined to make a voice controlled robot that will help with the speaking skills of children with ASD. The robot will be paired with a web application that will contain information about the performance of the child, this will allow parents or therapists to track the results of the child. The robot and web application will have to be easy enough for adults and children to use. The robot will also have to be child proof, meaning that it should not be able to be tampered with by children. The robot and web application are meant to be a cheap and easy alternative to speech therapy, either replacing a therapist or being a tool for doctors and parents to use.

1 Need for this Project

Regardless of however many heartbreaking statistics concerning Autism Spectrum Disorder (ASD) exist, none solely encapsulate its impact. Our project, product, and its service targets crucial figures experiencing and involved with ASD. Specifically, these figures include children diagnosed with ASD, the parents of these respective children, and various professionals in the industry (think: paraprofessionals, psychologists, speech-language pathologists). Children with ASD fail to socialize effectively during the short window of language acquisition – the first five years. With that being said, it is imperative to maximize their exposure, thus improving their communication and speech skills. Maximizing the amount of exposure as well as the quality of the exposure is not a simple undertaking, and is a responsibility that does not fall on the child, but instead their parents. Parents often opt to enlist the talents of trained professionals for treatment, doing so is costly. While such assistance is helpful and provides results, the cost may cut sessions short, end entire plans early, or deter a family from even considering the option. To further compound these issues, there is a personnel shortage of these professionals. For those that are already in the field, their talents may be spread out across many different students in schools resulting in fragmented progress.

The motivation behind our effort is born out of the realization that there exist several compounding factors contributing to the problem, and that these factors may have their impact reduced cohesively and simultaneously with our project.

2 Problem Statement and Deliverables

Our goal for this project is to develop a device that assists children with low-functioning ASD in developing their abilities to articulate and communicate. While there are devices in the market that aim to do the same, neither of these products offer an individualized learning curriculum, nor do they communicate effectively with the child. We hope to change this by providing a fun, friendly, adaptable, and customizable language therapy robot that will interact with the child, while also motivating him or her to learn different words. In order to accomplish this, our deliverables will include a web application and language therapy robot.

Because we want the child's learning curriculum to be customized weekly, we intend to have a web application that allows for the SLP or child's parent to record various sounds corresponding to levels of a word into the application, with the goal word being the last level. The web application will also store each week's curriculum into a database, so that the child's parents can monitor their progress. The web application will allow the child's parent to receive progress reports each week. It will also interface with the robot to calculate the child's progress. This will be achieved by using signal processing in which the web application will receive the child's vocalization and run it through a cross-correlation algorithm. The cross-correlation algorithm will compare the child's vocalization to the recorded sounds in the curriculum and return a similarity score comparable to the child's accuracy. Depending on the similarity score, the web application will determine whether the child should increment, decrement, or stay at the same level in the curriculum. Additionally, the web application should allow for the parent to customize the type of positive reinforcement the child receives when incrementing a level.

The language therapy robot is responsible for communicating with the child. As opposed to creating a new robot, we have chosen to modify the WowWee MiP Robot, which already comes with an API to control its movement, as well as bluetooth capabilities. The problem with the robot's bluetooth capabilities is that it is only capable of connecting to Android and iOS systems. Since we need our robot to communicate with the web application, we intend to integrate a bluetooth module capable of communicating with a PC platform into the MiP Robot. The bluetooth module will interface with the web application to determine what level's sound the robot should vocalize, depending on the child's progress. In order for the robot to encourage the child to learn, it will also reward the child when he or she increments a level by using positive reinforcement, such as dancing or saying encouraging words such as "Good job!"

3 Visualization

As mentioned in the 'Deliverables' section, the project has two main components: the robot, and the web-application. The robot will automatically connect to the web-application when it is turned on. The web-application has pre-recorded words that the therapist has recommended for that particular child and week. Every week, the therapist will add a new word that the child would need to focus on. The robot will then prompt the child to say the model world, and record the child's attempt. The audio will be sent back to the web-application for processing, and the result will then be sent to the robot to congratulate the child or prompt the child for another attempt. The feedback sent back will only be positive, and no negative reinforcement will be provided. This way, the child would befriend the robot and be encouraged to learn more.

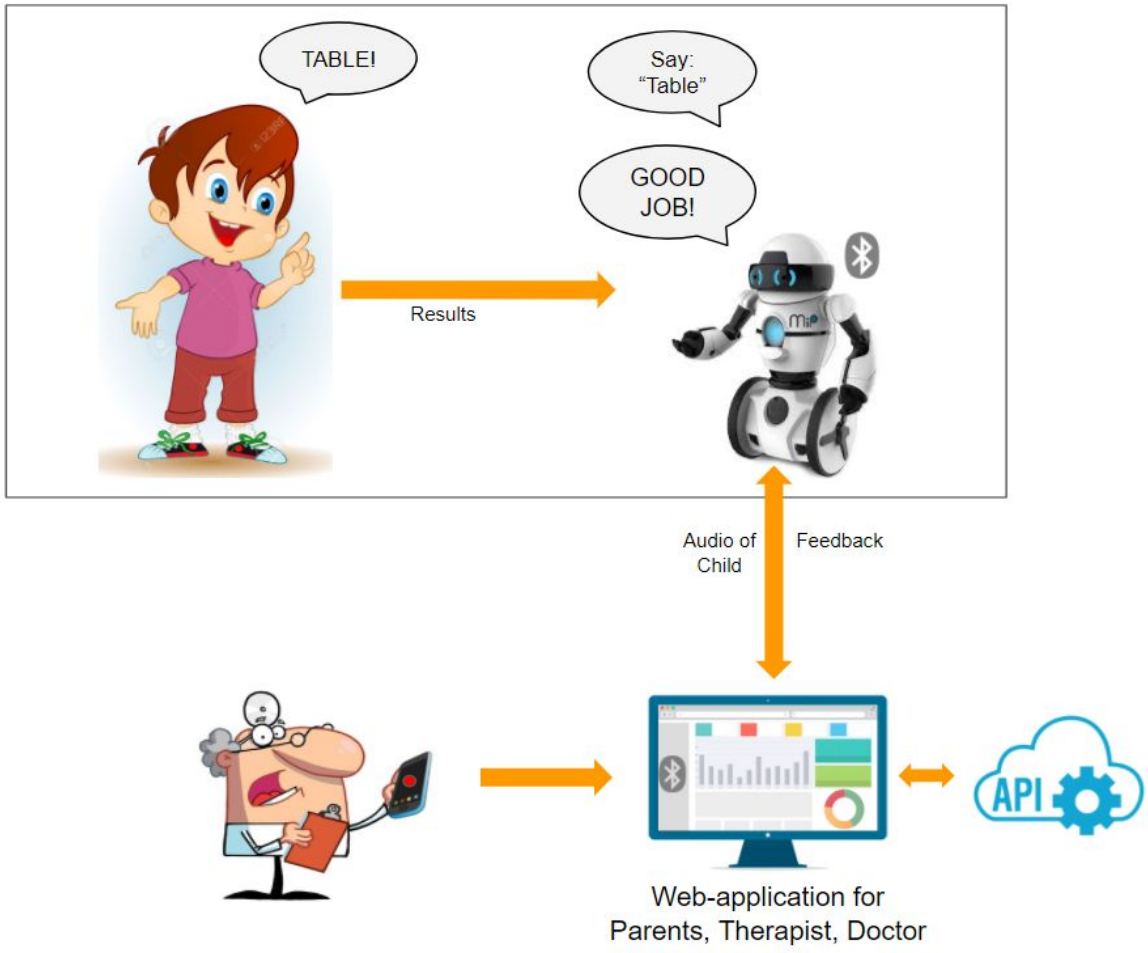

Figure 1.1 The above figure shows the flow of the tool. The top box represents the main application of the robot, which is to assist the child with vocalizations and provide feedback. The bottom row outside the box shows the means of processing the audio. The web-application will communicate with external APIs to compute the similarity score between the therapist's recorded word and the child's recorded word.

This required form has several variations. One variation is presented in Figure 1.1 below. The processing of audio through external application-programming interfaces (APIs), for example, could be performed either on the cloud, or on the local web-application. The local web-application would not be dependent on the strength of the wifi connection, but would take up more storage on the parent's computer. This makes the application much less portable and slightly harder to install. Having the application on the cloud would reduce computation time if the internet is fast since the computations would be done on a high performance computer. The application would also be portable, enabling the parent or therapist to access data from anywhere. A middle ground would be if the processing occurred locally, and if the results were periodically synced with the cloud storage of data.

The other variant is the communication between the web-application and robot. Our client specified that the protocol to send and receive data would be Bluetooth. However, incorporating a wifi module on the robot with its own processing unit could be an option. The robot could perform all the computations to get the feedback and reduce latency, and send the reports back to the web-application after. This would require tampering of the existing robot, and reduce the computational power because of the robot's size and capabilities.

Last, the method of positive reinforcement may vary. It could be the robot telling the child "Good job!", or it could be the robot performing a celebratory dance. If the child is afraid of the robot dancing, the reward could also be changed by the parent to suit the child. This functionality could be altered on the web-application.

4 Competing Technologies

There are a lot of tools that are meant to help kids improve their speech skills. Some tools are geared specifically to kids with ASD, and are designed as toys. Two of these toys are Bluebee Pals and Toobaloo.

Bluebee Pals is a stuffed animal that reproduces sounds that it hears. The toy is accompanied by an app that makes the animal move its mouth according to words that the kids interact with. For example, the child plays a farming game, the toy will move its mouth and say words such as cow, pig, etc. The toy is also able to be paired with a Smartphone over bluetooth, and replicate the noise coming from a conversation. Bluebee Pals main requirements is that it needs to help kids with ASD put words and images together but also be simple enough for parents and kids to use. The app and toy also needs to be fun and interactive to keep the attention of kids. Vobot will be implementing similar strategies, but focusing more on the kid's ability to speak.

Toobaloo is marketed as an auditory feedback phone. Children with speech disabilities can speak into the phone and be able to hear themselves. Hearing their own pronunciation of words, pace and fluctuation while speaking allow children to adjust and correct what they hear or speak. The auditory feedback loop that toobaloo uses, speaking and hearing your own words, is something similar to what Vobot will use. Vobot will reward the child if the correct word is being said, giving automatic feedback similar to Toobaloo.

5 Engineering Requirements

The following requirements have been specified by our client:

Robot

1. Exploit expressive language training through the use of a voice controlled anthropomorphic robot.
2. Product must be child proof
    - Child proof as defined by Wikipedia, "reducing risk to a level considered acceptable by a society. Childproofing may include electrical safety, physical access and a design made to resist tampering by children."
3. Robot should have dimensions that make it easy to transport from office to home.
    - Current model is 5 x 2.5 x 7 inches and under 3 lbs.
4. Must have interactive behavior designed to reward.
5. Appearance must be friendly and inviting so as to not frighten children before use.

Power

1. Robot must stay powered without having to be connected to an outlet.
2. Robot may use alkaline batteries or rechargeable battery packs.

Networking/Connectivity

1. Communication from robot to web application should be done via bluetooth.
2. Will require adaptation of bluetooth microphone and speaker.
3. Web application built must always be connected to robot if they are in range.

Signal Processing

1. Sound
    - Raw audio from mic is sent to buffer that holds for 10 seconds.
    - Recording will be done at 44.1 kHz and mono.
    - Model word to articulation analysis will be occur 60x/second.
    - Response time should be less than 1 second for speech recognition.

Vocalization Algorithm

1. Cannot use standard speech processing libraries cannot be used because they are tuned for interpreting clear adult speech.
    - ImagiRation's proprietary algorithm should be used for processing a child's voice.
2. Algorithm compares child's vocalization to model word
    - Cross correlation algorithm will return similarity score between 1-100
    - Similarity score will determine child's progress
        - Levels of difficulty will increment with $\geq 90\%$ similarity score
        - Levels of difficulty will decrement with $\leq 60\%$ similarity score
        - Strict scoring algorithm prevents child progressing by trial-and-error without mastering skills.
3. "Hotwords" must be used to wake up robot and initiate lessons.

6 Appendix A References.

"Leo The Lion – Talking Educational Learning Tool." *Bluebee Pals*, www.bluebeepals.com/product/leo-the-lion-educational-learning-tool/.

"Toobaloo ." *Learning Loft*, www.learning-loft.com/products/toobaloo.

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