UNIVERSITY OF TARTU

Faculty of Science and Technology

Institute of Technology

Anna Jakovļeva

Roboquiz - an interactive human-robot game

Bachelor's thesis (12 ECTS)

Curriculum Science and Technology

Supervisors:

Associate professor, PhD Karl Kruusamäe

BSc Marilin Moor

Tartu 2022

ABSTRACT

The rapid advancement of different technologies is decreasing children's and students' attention span in classes. New, more interactive methods are needed in order to make learning a fun and an engaging activity, suiting the needs of young minds. This work focuses on creating a human-robot interactive game on Robotont platform, challenging the mental and physical capabilities of the players by combining the elements of basketball play with a quiz. The interaction between the players and the robot depends on a speech-based communication system. This has been made possible with integrating speech recognition and speech synthesis libraries and using ROS infrastructure. The resulting design of the quiz game gives a chance for the players to showcase their skills in quick thinking and basketball and allows them to get more familiarized with robots in general.

CERCS: T125 Automation, robotics, control engineering, S284 Experimental pedagogy

Keywords: human-robot interactive game, educational game, speech recognition, speech synthesis, ROS, Robotont

LÜHIKOKKUVÕTE

Erinevate tehnoloogiate kiire areng vähendab laste ja õpilaste tähelepanuvõimet tunnis. On vaja uusi, interaktiivsemaid meetodeid, et teha õppimisest lõbus ja haarav, noorte mõistuste jaoks sobilik tegevus. Käesolev töö keskendub interaktiivse robotmängu loomisele Robotont platvormil. See pakub väljakutset mängijate vaimsetele ja füüsilistele võimetele, kombineerides korvpallimängu küsimustikuga. Mängijate ja roboti vaheline suhe toetub keelepõhisele suhtlussüsteemile, mis on ellu viidud, integreerides kõnetuvastuse ja –sünteesiteeke ja kasutades ROS-infrastruktuuri. Küsimustikmängu disain annab mängijatele võimaluse näidata oma mõtteväledust ja oskusi korvpallis ning aitab neil robotitega lähemalt tutvuda.

CERCS: T125 Automatiseerimine, robootika, juhtimistehnika, S284 Eksperimentaalpedagoogika

Keywords: inimese- ja robotivaheline mäng, hariduslik mäng, kõnetuvastus, kõne süntees, ROS, Robotont

TABLE OF CONTENTS

1. INTRODUCTION

In recent years different types of technologies have been rapidly advancing and various smart devices have become a bigger part of everyday life. This is one of the reasons why children, while being very skillful in the usage of these gadgets, have grown increasingly more distracted, especially in schools, making regular ways of teaching grow increasingly less efficient [1] [2]. Monotonous and merely passive input learning does not have a high rate of retaining information. A larger percentage (around 90%) is kept if the process of obtaining knowledge was a bit more challenging and interactive for the person [3].

With the advancement of different technologies, robotics has been a growing field, leading robots to become a bigger part of human day-to-day life. Now they are not only utilized in mass manufacturing, science, and military fields but also in people's households, entertainment, and educational areas. Because of the trend of children growing more distracted and having more difficulties to keep being focused in and educational environment, new ways to convey knowledge are needed [1]. Several studies have investigated interactive teaching techniques and methods such as games, robotic technologies, and these two combined, have usually proven to increase the enjoyment and efficiency of learning, as well as critical thinking [4].

However, because of the high production costs and the novelty of these technologies, they have not yet been widespread. Their usage is usually constrained to research projects and even though the results of the studies show positive results, these interactive technologies are rarely sent out for a bigger crowd.

The solution I propose in this thesis combines the aspects of gameplay and robotics technologies to create an interactive human-robot experience, that would provide a fun and engaging way for children to learn. The goal is to design a quiz game that would be based on a robotic platform and adding a physical activity element to it with the play of basketball. The aim is to create a technology that could be used in schools and households, by making the quiz questions easily changeable, thereby enabling the game to fit one's needs.

2. LITERATURE REVIEW

2.1. Games

Playing games is an essential part of life and early human development. Games can provide a great platform for social interactions, where children can communicate with each other learning the norms of social behavior within an environment that has certain rules, at the same time allowing for experimentation [5]. Gameplay allows to cultivate diverse perspectives, providing a chance to experience different roles [6]. Critical thinking abilities and coordination skills get improved through playing as well, making children learn early on, since during gameplay, very active participation is required [7].

Thus, it comes to no surprise that not only games have a history of being used for educational purposes [8], but also there has been growing interest in combining games with robotics, using games as testbeds for human-robot interaction, or a platform for education and entertainment [5][9].

2.2. Robot-based games

In recent years, a new class of robotic technologies, meant for entertainment and education, has seen an increase in demand and this trend of market growth seems very likely to continue over the upcoming decades. There is a need to introduce robots into every-day life in order to increase the interest in robotics, digital skills and other such technology related fields for the new generation since the number of the jobs that require these skills are growing way faster than the amount of people qualified for them [10] [11].

A change can be seen in the game industry as well. Video game companies have been putting more focus on making the player be more actively and physically involved in games, rather than the player just sitting in front of the screen [12].

Therefore, it is no surprise that robot-based games have been a topic of conversation in recent years. When comparing to other systems that are based on a tablet, PC, laptop or a phone, a robot that usually has an input and feedback system and physical presence provides the biggest advantage, since it allows for direct interaction that can include “multimodal stimuli, feedback and manipulation” [13]. The removal of the screens gives the players a chance to interact directly with physical objects in their homes or other specifically dedicated environments [12].

People have shown to have more positive experience when interacting with a robot [14], [15], it usually being met with more enthusiasm, improving the quality of engagement from the user's side.

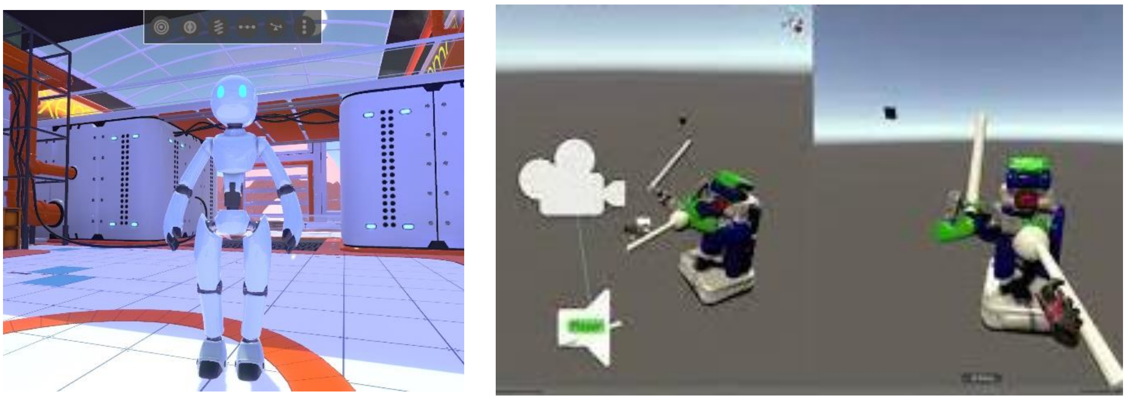
There are four main implementations for games that are based on robotics technologies [12].

1. Robots that are simulated in video games as characters such as the Xemo in a robot simulation game (Fig. 1a) and a fencing game with a robot (Fig. 1b), are most often autonomous and without any limitations and problems of physical robots [16] [17]. Although this implementation operates in a virtual environment, the game design technology that is developed for this proves to be useful in the game development with physical robots as well.

2. The game involves tele-operated physical robots, that are controlled by the player via remote controllers, similar to those in video games. Examples include Reachy, an interactive tele-operated robot (Fig. 2.) [18].

3. Robots that have been developed to autonomously play a certain game, it usually being a sports game where the robots are the players, like RoboCup (Fig. 3.) [19]. In this area more effort is spent on autonomous technologies and not that much on the quality of interaction with people.

4. Robots presented as games themselves. Most of the time these involve mobile pets, such as Aibo (Fig. 4a), a series of robotic dogs created by Sony, but other implementations that show a different approach have been seen as well in recent years such as Kiro (Fig. 4b) a robot that plays table soccer with people [20] [21].



a) b)

Figure 1: (a) *Physics-based simulation of a humanoid robot "Xemo" created by Xmemory LLC* [16] . *(b) Competitive human-robot gameplay involving a simulated robot and VR technology* [17].

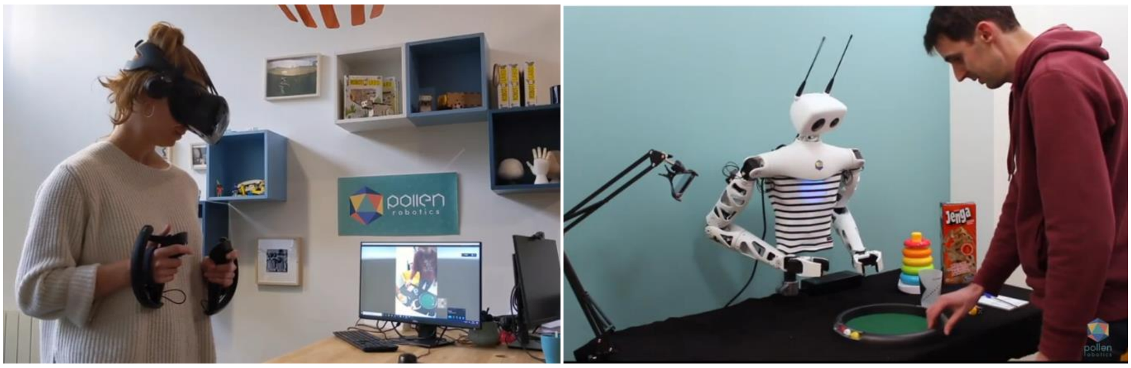


Figure 2. *Tele-operated robot "Reachy" by Pollen Robotics. This robot can be operated through VR. In the example pictures above a game of dice is played through it* [18].

Figure 3. *Robots playing football, RobotCup federation* [19].

a) b)

Figure 4. *(a) Entertainment robot "Aibo" that resembles a dog, created by Sony* [20]. *(b) Table soccer robot KiRo* [21].

As much as robot-games can be used for only pure entertainment, there are other applications of them as well. It's possible to utilize these games in educational or therapeutic environments, where the involvement of robotic technologies can attract people and draw them in, making the experience more interactive. Robot-games have physical, real-world aspect to them and because of this, it’s possible to involve the player in multiple ways. Moreover, in studies of Human-Robot Interactions (HRI), games with robots have been used as a testbed for experiments, as they can provide a controlled and engaging environment where HRI issues can be investigated in [5].

2.3. Robots engaging with children

Since the rise in technological development, also children have been starting to play and engage with more technologically advanced devices. Studies on how exactly robots affect children have been conducted and showed that robots influence development of mainly four skill groups - cognitive, conceptual, language and social skills. The effect is mostly positive, especially when it comes to educational and therapeutic environments [22].

2.3.1. In educational environment

Robot-based education has shown positive results, e.g. using robots in a learning environment has encouraged interactive learning and increased engagement from children’s side while offering a more joyous educational experience [23]. The robot can have multiple roles in this environment, starting from being a learning companion for the children, to having more of a mediator and mentor role, leading the activities, or having a more passive role of being a learning tool, as something for students to build and create [22].

In a study conducted with elementary school children significant statistical results showed, that in the case of the robot learning companion leading their math learning activities, students' ability to think logically and motivation in learning had improved, as opposed to the control group, where these robotic technologies were not involved [23]. Another study, where a robot companion facilitated language learning, revealed that children performed better on post-learning examinations since the involvement of robotic technologies rather than if the language learning was lead through only books and audiotapes [24].

2.3.2. In therapeutic environment

Studies have shown that robot engagement is especially beneficial for children with disabilities. A robot self-management game educating children who have diabetes type I about their illness showed an increase in knowledge about diabetes in the control group with the robot [25]. Robot mediated games for children with Autistic Spectrum Disorder (ASD) led to an increase in social interactions between players, focus, also improving engagement and enthusiasm in the gameplay [26] [27].

2.4. Technological capabilities of game robots

Human-Robot Interaction studies have shown that for the robot to engage the players and enhance their social acceptance skills, various methods, that would make them less-robot-like and thus more acceptable by people, can be used. These include using natural language, making the robot in a human-like or animal-like appearance, adding movement [5].

Spoken language is one of the most used means of communication that people use. It is of no surprise that robot-control-based voice commands have been more and more widely applied and used. An extremely popular application currently is using speech recognition in home assistant robots such as Amazon's newest creation Astro [17]. Controlling a robot through speech is a system where the robot takes in voice input from the person, processes the input using speech recognition capabilities and then executes the command [28]

Robot's communication with the players can be established through devices such as video screens, speakers, and haptic devices [9]. In case of natural speech as the main communication method, speakers and various text-to-speech methods need to be implemented [29].

2.5. Tools and methods for robotic game design

In order to create a robotic system that would be based on natural language communication, different tools and methods can be used.

2.5.1. Robot Operating System (ROS)

ROS is an open-source set of software libraries and tools used in building robot applications, running on Unix-based platforms. It provides numerous services such as passing messages between the processes, in this way providing communication infrastructure between different scripts and libraries, package management and hardware abstraction, connecting the hardware and the software of the robot. ROS is structured as a framework of processes; each executable is designed individually but brought together at the runtime. These processes that perform computation are called nodes. Communication between nodes is done by passing messages to each other. One of the ways to do that is for a node to publish or/and subscribe to messages over a certain topic, sending or receiving information continuously. Another way is by using a service where the message is sent only when it is specifically requested by the node [30].

ROS has many advantages over other systems for robotics. A big upper hand is its versatility, since the same code and libraries can be used in many distinct kinds of robots, and it is possible to reuse solutions from different projects. The number of packages and libraries offered is very wide as well, offering a range of implementation possibilities.

2.5.2. Robotont

Robotont (Fig. 5) is an open-source mobile robot platform. It is being developed in the Institute of Technology at the University of Tartu. The robot's design consists of transparent plates, modular hardware as well as open-source software, allowing for a lot of customization and upgrading, making this robotic platform very versatile and a great starting point on which to build one's own projects.

The onboard computer has an Intel Core i5 (7^{th} Gen) 2 core processor with 4GB RAM and an Intel Iris Plus Graphics 640 GPU card. The robot is omnidirectional- can move in every direction and spin around its axis [31]

To run the desired codes on it, Robotont and the PC need to be connected over the same network. Then the PC and Robotont either query via hostnames, each host having a pair with hostname and IP address of the other host, or it is possible to connect to the computer on the physical robot through SSH and run the program through one's own personal device [32]

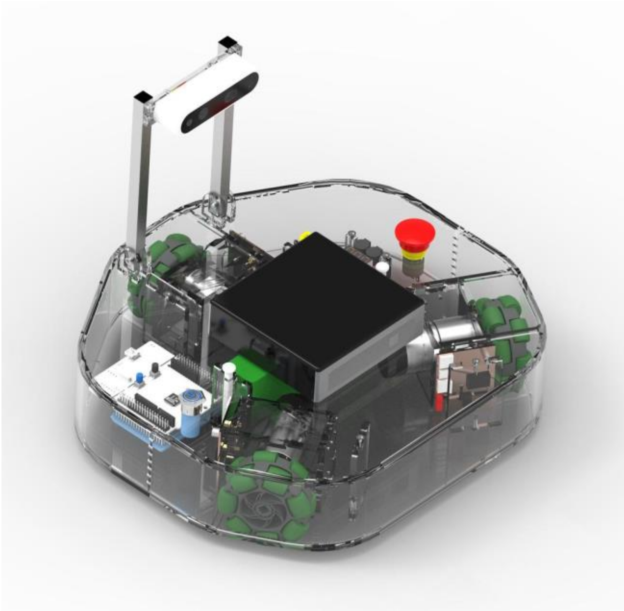


***Figure 5**: Roboton- a robot developed by the Institute of Technology of University of Tartu.*

2.5.3. Speech recognition

Speech recognition stands for a machine's capability of processing human speech into a written format that gives the ability for the machine to respond to spoken commands [33]. In this project a ROS package with Vosk Speech Recognition library is used [34]. Vosk is an offline, open-source speech recognition toolkit that is based on large single dataset concept and audio fingerprinting[35] .

Using an audio fingerprinting implementation means that the model compares extracted features form input audio pieces, the fingerprints of the samples, to an already established library of these features, by that finding the matching sound. This is performed on the basis of frequency content in the voice. During the training phase of the network, several samples of the same sound are averaged, creating an audio fingerprint. Then the frequency content calculated form the input sound is compared to it by treating them both as vectors and calculating the Euclidean distance between them. If the distance between these two vectors is close enough, the two sounds are considered a match and the specific letter combinations that go with the sound are put out [36].

2.5.4. Speech synthesis

Speech synthesis is a process of generating human speech based on written text by using a machine. In this work Soundplay library with Festival Speech synthesis system is used [37]. There is a large database of sounds, each having a corresponding written letter combination, that is contained within a library. When a string of text is loaded in, these phonetic transcriptions are assigned to each written word and then concatenated together [38].

3. PURPOSE AND REQUIREMENTS

3.1. Objective

The objective of this thesis is to design and implement an interactive game involving humans and a robot. The system should be speech based, where the robot and the players would communicate through spoken language. The game would combine the aspects of education, entertainment, and physical activity.

3.2. Requirements

3.2.1. Functional requirements

1. A game design involving both the robot and humans
2. Game tasks that intellectually challenge the players
3. A game element that would physically involve the players
4. Speech recognition capabilities

3.2.2. Non-Functional requirements

1. ROS Noetic Ninjemys
2. Ubuntu 20.04
3. Robotic platform with movement capabilities that supports ROS and Ubuntu

5. DESIGN

In the following section the game design, software, and hardware solution of the human-robot interactive game Roboquiz will be described. In summary, it is a quiz game with a basketball element that's based on a robotic platform, where the robot asks the players a question and if the answer is correct, gives them a chance to throw the ball in the hoop. The robot chosen in this work is Robotont that has been modified to have a basketball hoop attached to its side and the depiction of it can be seen in Fig. 6. This system is based on speech recognition with the robot using spoken language in order to communicate with the players. To achieve this type of communication between the robot and humans, a speaker with a built-in microphone, speech recognition and speech synthesis libraries are needed.

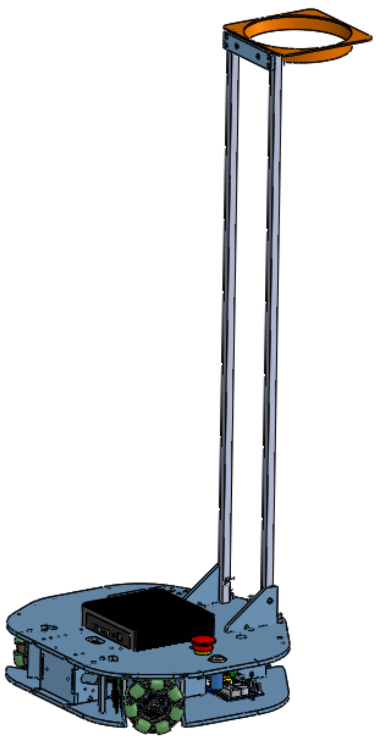


Figure 6: *Modified Robotont platform for the Roboquiz game. Drawing done in SolidWorks*

5.1. Game design

During the game, the robot is put in the middle of a circle of up to six players. When the program is initiated, the robot greets the players and provides the commands they can use during the game which include “done”, “reset” and “game over”. Then the robot asks players to say their names, one by one. If by accident an error during the name registration occurred and the list of the players is incorrect, having more names than needed, for example, it is possible to reset the list and start the registration again by saying the phrase “reset”. Since there is a limited number of players, it is impossible to register more than six names. If that is attempted, the robot announces that the limit has been reached. By saying the phrase “done”, the registration of player names stops, and the game is initiated.

The robot starts to spin around its axis. When the robot is spinning, the movement makes it more challenging for the players to throw the ball in the basketball hoop, since it also spins with the robot’s construction’s outer edge (Fig. 7). Each individual player gets asked a question, by using the name that they gave in the player registration process.

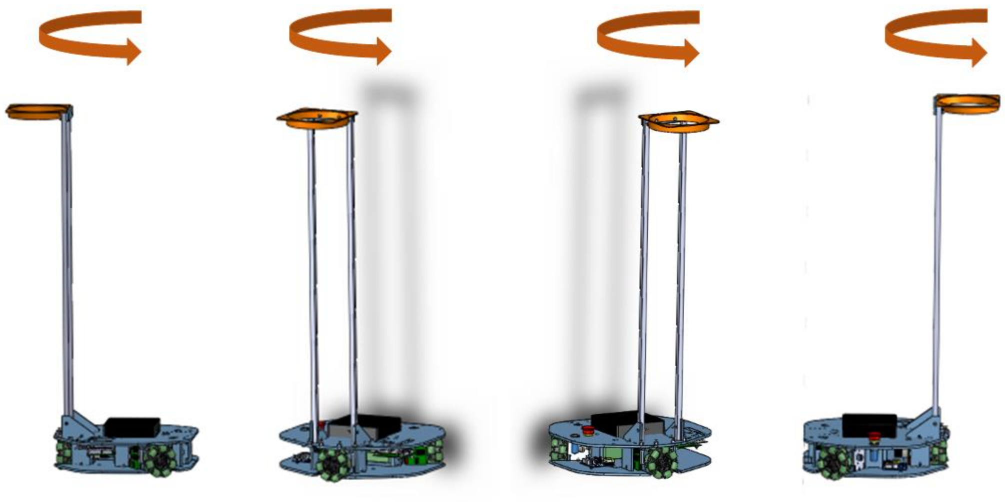


Figure 7: *The basketball hoops spinning motion of the Roboquiz game*

The questions in the current quiz asked during the gameplay range in topics from geography, math, science and pop-culture, with the answers consisting of one to two words. However it is possible to create a new quiz, following the guidelines, for specific educational needs. The list quiz.txt with the questions can be found in the in the main package of the game, under the *src* directory the full path being *catkin_ws/src/roboquiz_main/src/quiz.txt*. Each line consists of a question and answer separated by a column, as depicted in Fig. 8. The answers are written with the small letter. When adding new questions and answers, the same format is needed to be kept.

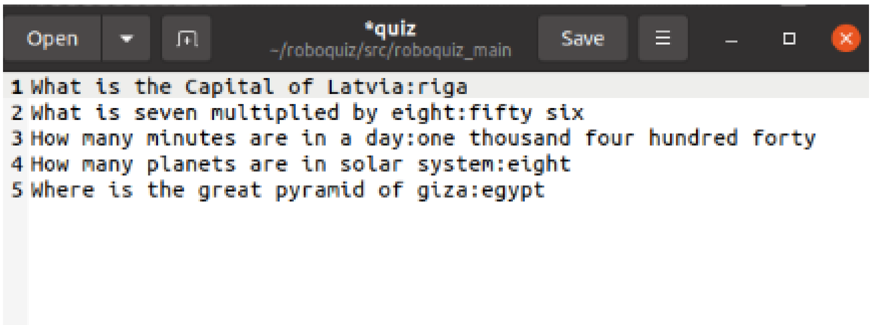


Figure 8: *Structure of the quiz.txt file. The question and the answer are separated by a column (" : ")*

The player needs to say their answer one time, in a clear voice. If the player's answer is correct, the robot stops spinning, allowing the player a chance to throw in the ball. The points for the correct quiz answers are counted and assigned to each specific player.

However, if the question asked by the robot is answered incorrectly, the robot plays a sound indicating loss and says the right answer, afterwards moving on to the question for the next player, without stopping spinning (Fig.9). The game continues as long as the players want. When the phrase "game over" is said at any point of the play, the game stops and the robot announces the scores for each player.

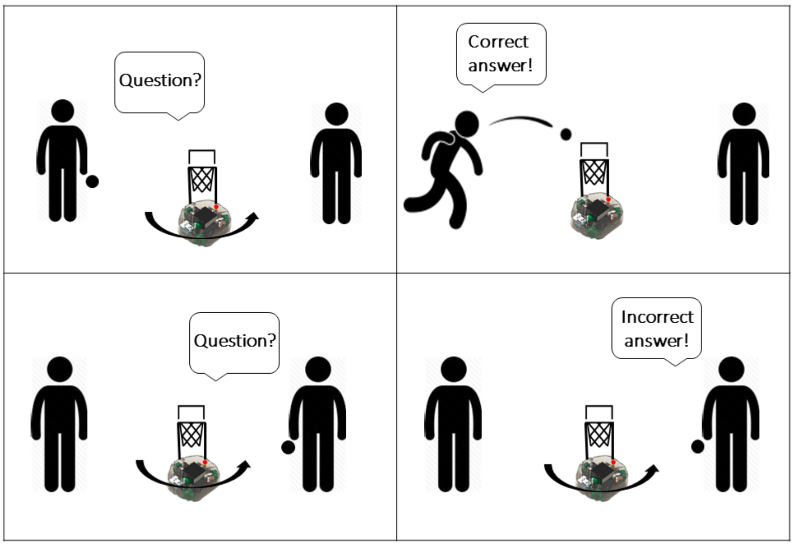


Figure 9: *General game flow*

5.2. Hardware design

A basketball hoop is attached with reinforcements to the outer part of Robotont's transparent platform (Fig.6), being 76.6 cm from the ground. A wireless speaker with a built-in microphone is connected to Robotont's computing system through Bluetooth and is located in a convenient place near the players.

5.3. Software design

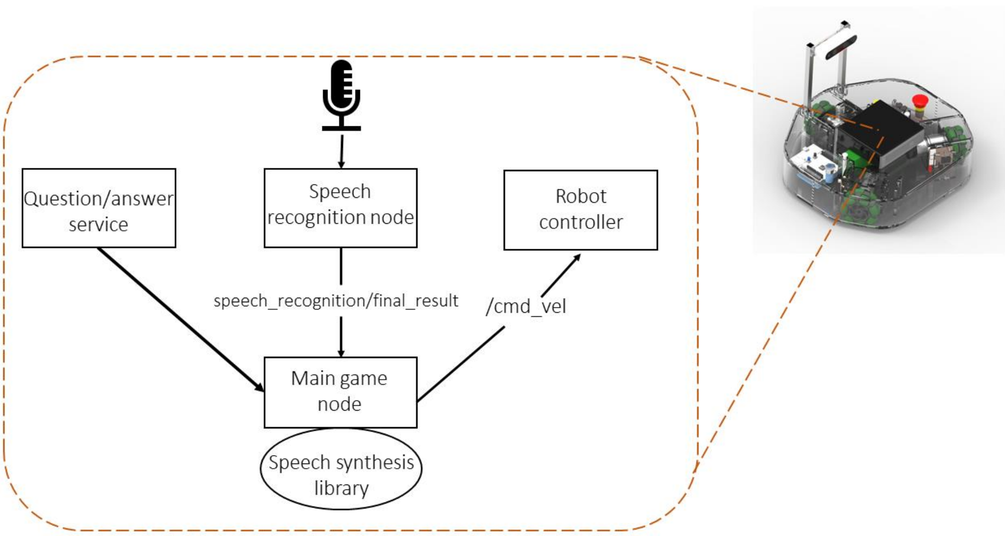


Figure 10: *The general software desing of Roboquiz, consisting of two novel nodes (main game node and a question/answer service node), speech recognition node and speech synthesis library.*

The general layout of the system is depicted in Fig.10. The entire solution can be found in GitHub: https://github.com/anna-debug/roboquiz_game.

The main parts of the design are the Vosk speech recognition package, the Soundplay speech synthesis library and two novel scripts - a question/answer service node and the main game node. The Vosk speech recognition package includes a node that publishes messages over *speech_recognition/final_result* topic containing the string of the speech that was detected via microphone.

The main game node is what connects all the parts together. It includes the SoundPlay library and is a client to the Question/Answer service node. The main game node subscribes to *speech_recognition/final_result* topic, continuously receiving the resulting string messages from the speech recognition node and also publishes *geometry_msgs/Twist* messages over */cmd_vel* topic to control robot movement.

5.3.1. Question/Answer service node

The service node is written in Python programing language. When a state for loading questions is true, the service node takes as an input a text file that in each line contains a question and an answer, divided by a column. It reads through the text file, adding the questions (as the key) and answers (as the value) to a dictionary.

When all the questions and answers are loaded into the dictionary, list with the questions is created. A random integer using *randint()* function is chosen in the range of how many questions there are. When a request is called out, this random question and answer pair is sent to the main game node. The questions do not repeat until all the questions from the quiz are asked, since once a certain question is chosen from the list, it gets popped out of it and appended to a new list of old questions. When all the questions from the current list are out, it gets switched with the old question list and the cycle can begin again.

5.3.2. Main game node

The main game node is written in C++. It is a node that gets launched alongside the speech recognition and speech synthesis libraries, when launching the program itself, and that’s where main game logic is implemented. The node’s structure can be viewed in Fig. 11.

```
initial_state = true
player_points = a map object with names being keys and points being values

while node is running

    if initial_state == true
      robot tells players to register their names
      string_voice = msg from speech recognition node

      if string_voice == "stop"
          robot says the registration has ended
          intital_state = false

      else if string_voice == "reset"
          clean player_points

      else
          if player_points has more than 6 names
            robots warns of the player limit

          else
              add player name with 0 points to player_points


      else
         question = string question sent from serice
         answer = corresponding string answer form service
         robot asks the question
         string_voice = msg from speech recognition node

         if string_voice  == "game over"
             robots tells the points for each player

         if string_voice in answer
             add point to player_points
             msg.angular.z = 0

         else
             robot says the corrct answer
```

Figure 11: *Structure of the main game node*

At first the initial state is set to true and by using speech synthesis library, vocal text is output, indicating to the players that it’s time to register their names. In a loop, voice from the players is taken in and converted to a string by the speech recognition library. The player names are added to a map, with the player’s name being the key value and initial points (0) being the mapped value. The number of the player names is also checked and if it goes over six (which is the maximum player number), the robot announces this and further player registration is not allowed.

In the initial state the input speech string is also compared to two other strings: “reset” and “done”. If “reset” is detected, the map with the player names and initial points is cleared out and player name registration can start from scratch. If the input speech string is detected to be the same as “done”, then the initial state is set to false, and the code moves to the main game cycle (Fig.12).

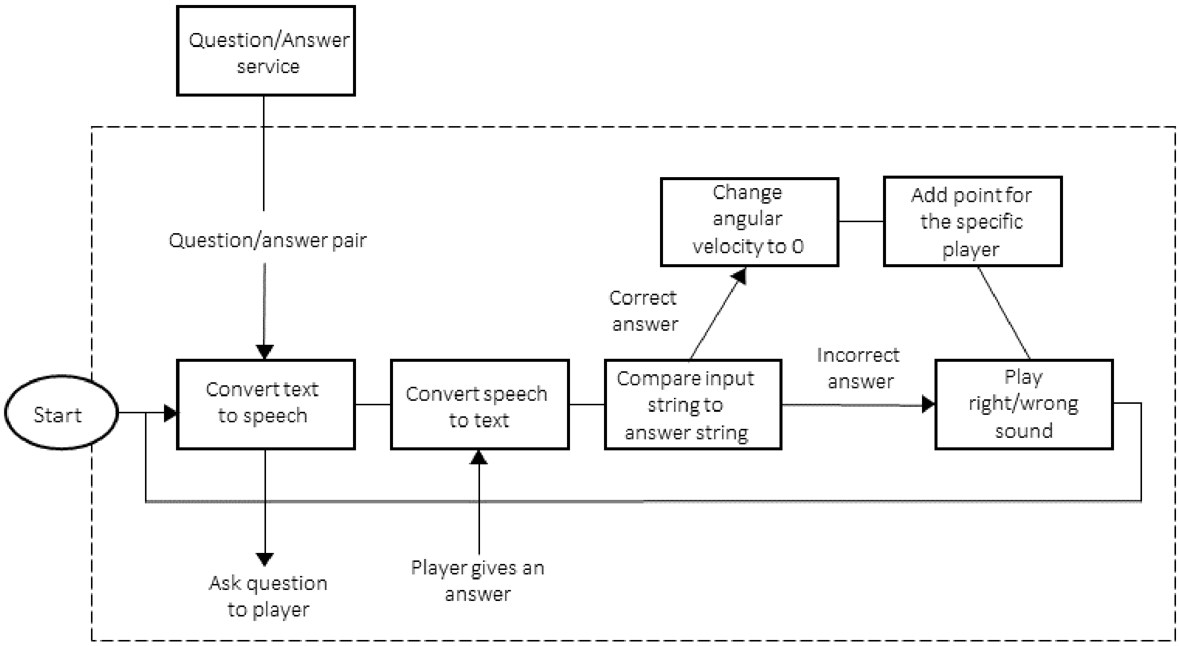


Figure 12: *The game loop inside the main game node*

In the main loop, the service is called out, getting a random pair of a question and answer. When the state of asking the question is true, the question is voiced using the speech synthesis library.

Then the processing answer state is set to true, and the voice input of the player is taken in. It’s compared as a substring to the answer string that was received from the Question/Answer service and if the substring is detected it, counts as a correct answer and a point gets added to the map of player and point summation for the specific player. Moreover, a victory sound is played and a movement message of *angular.z* velocity equal to 0 is published over the */cmd_vel* topic, stopping robot’s spinning for 5 seconds before moving on to the next iteration.

However, if the answer is wrong just a specific sound is played, indicating that the question was not answered correctly and the player won't get a point, before moving on. When in processing answer state, the phrase "game over" is detected, the code iterates through the player/point map saying out each players point score and then the loop is broken.

6. DISCUSSIONS AND CONCLUSION

The work done in this thesis resulted in developing a human-robot interactive game. The steps taken in order to achieve this have been covered in previous sections.

To evaluate the design of the game, how it appeals to players, how successful or unsuccessful it is at engaging people and whether it provides educational benefits, a survey was created. Ten people were asked to play this game, afterwards, describing their experience. The results from the survey were compiled and are shown in Fig. 13. The survey consisted of four statements and people were asked to rate how much they find these statements agreeable, score of five being the highest and the score of one being the lowest. These scores were then visualized with using a box plot, showcasing the mean values for each statement as well.

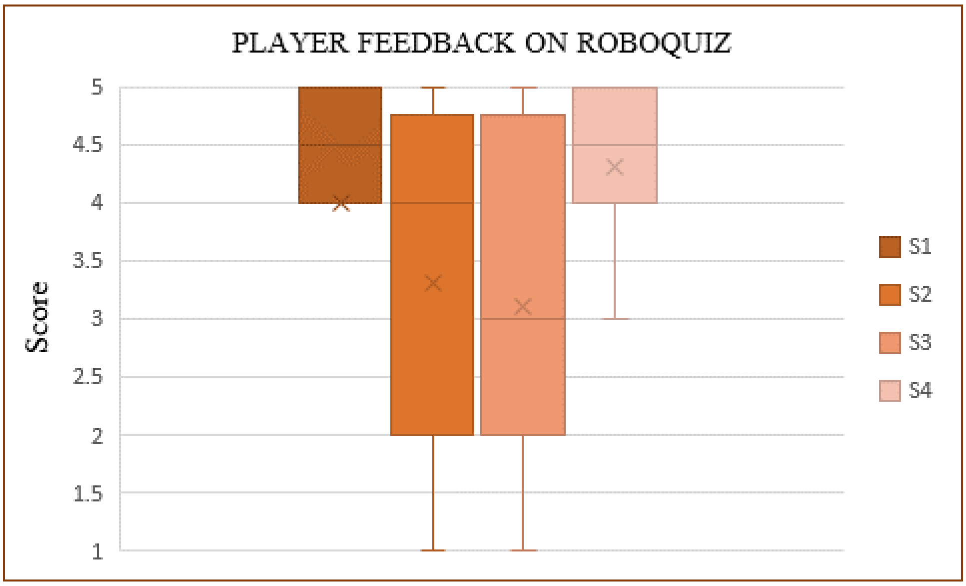


***Figure 13**: Player's opinions to the statements made about Roboquiz represented with a scoring system where the score of 5 is the most agreeable. The vertical axis represents the score system and the horizontal axis shows the statements. The crosses in the graph show the mean of the score for the statement.*

S1: The instructions of the game were understandable
S2: The questions asked by the robot were understandable
S3: I learnt new facts during the game
S4: Playing this game was an enjoyable experience

The game created in this thesis was successful in creating an interactive and a pleasant learning environment for the players since the mean scores for players enjoying the game was quite high, 4.2 respectively. Although the score for learning new facts was not that high, 3.1, this may have depended on the players' previous knowledge. Since there is a possibility to modify the questions, fitting each specific player group's needs, this score might vary.

The score for understanding the questions is not as high as would be desired, which according to players feedback comes from the irregularity and strangeness of the specific voice that is used to synthesize the speech.

When comparing to other educational games, the design of this work allows for a very interactive experience between the robot and the player. Players are more likely to be engaged, because the element of the robot and the basketball.

Compared to previous games based on specifically robotic platforms, this game provides an efficient way for fact memorization and learning that could be easily used in schools by teachers. It is very versatile, since the questions in the quiz can be easily changed by the user to fit the specific learning topics at that time.

6.1. Future improvements

According to the feedback form the players, one of the issues of this design was that it was hard understanding the robot. Changing the voice of speech synthesis and choosing one that is more likable and clearer would be a possible improvement for that.

The second problem was that the Vosk speech recognition package is not the most precise one, especially if the voice input is quiet. So for future improvement, either using a better microphone or finding a different package for voice recognition would suffice.

Moreover, in the current design of the game, the points were counted for only the correct answer to the quiz. In order to increase player participation the points might as well be counted for the throw of basketball, which might require either a ultrasonic sensors or a webcam with blob detection.

6.2. Conclusion

By implementing both speech recognition and speech synthesis, a system that relies on speech for the interaction between the robot and the players was successfully created. The robot "speaks" to the players and is able to understand their commands and answers to the questions. The quiz in addition with the play of basketball creates a game where the players can both test their knowledge and learn facts but also be physically active. By making a quiz that can be modified, it's possible fit the learning needs of each specific group of people.

ACKNOWLEDGEMENTS

I would like to thank my supervisor Karl Kruusamäe and my co-supervisor Marilin Moor for the guidance they offered through each step of this work, for supporting me and helping me realise my vision. My thank you goes out to Renno Raudmäe as well for putting in the time and effort to help me make great visuals for this work.

REFERENCES

[1] N. Mancall-Bitel, “How can a distracted generation learn anything?,” 2019, Accessed: May 10, 2022. [Online]. Available: http://www.bbc.com/capital/story/20190220-how-can-a-distracted-generation-learn-anything

[2] J. H. Graafland, “New technologies and 21st century children: Recent trends and outcomes,” 2018, doi: 10.1787/e071a505-en.

[3] “Edgar Dale (1969) Cone of Experiance.”

[4] S. Douglas McDonald, “ENHANCED CRITICAL THINKING SKILLS THROUGH PROBLEM-SOLVING GAMES IN SECONDARY SCHOOLS.” [Online]. Available: http://www.informingscience.org/Publications/3711

[5] Nilanjan Sarka, *Human-Robot Interaction*. 2007.

[6] Alex Gillespie, “Games and the Development of Perspective Taking,” *2006*, Accessed: Mar. 15, 2022. [Online]. Available: https://www.jstor.org/stable/26763874?seq=1#metadata_info_tab_contents

[7] L. P. Rieber, “Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games,” *Educational Technology Research and Development 1996 44:2*, vol. 44, no. 2, pp. 43–58, 1996, doi: 10.1007/BF02300540.

[8] Dempsey J. V., “Instructional Applications of Computer Games,” 1996, Accessed: Mar. 15, 2022. [Online]. Available: https://eric.ed.gov/?id=ED394500

[9] J. Richer and J. L. Drury, “A Video Game-Based Framework for Analyzing Human-Robot Interaction: Characterizing Interface Design in Real-Time Interactive Multimedia Applications,” 2006.

[10] “ Digital Agenda of the European Commission, Education, Culture, Multilingualism and Youth,” 2014.

[11] D. A. Durães, “Gaming and robotics to transforming learning,” *Advances in Intelligent Systems and Computing*, vol. 374, pp. 51–56, 2015, doi: 10.1007/978-3-319-19632-9_7.

[12] D. Martinoia, D. Calandriello, and A. Bonarini, “Physically Interactive Robogames: Definition and design guidelines,” *Robotics and Autonomous Systems*, vol. 61, no. 8, pp. 739–748, Aug. 2013, doi: 10.1016/J.ROBOT.2013.04.017.

[13] Andrea Di Salvo and Paolo Marco Tamborrini, “Interaction design tools for autism”, Accessed: Mar. 18, 2022. [Online]. Available: https://books.google.ee/books?id=uB1_DQAAQBAJ&pg=PA245&lpg=PA245&dq=benefits+of+robots+in+entertainment+education+vs+tablets&source=bl&ots=fcKLwQJ2dt&sig=ACfU3U3fRi30Hpy-zT1Jgbe99wZ9B1r-qw&hl=en&sa=X&ved=2ahUKEwiSroeT-Mz2AhUtg_0HHZ9UBwUQ6AF6BAgUEAM#v=onepage&q=benefits%20of%20robots%20in%20entertainment%20education%20vs%20tablets&f=false

[14] J. A. Mann, B. A. Macdonald, I. H. Kuo, X. Li, and E. Broadbent, "People respond better to robots than computer tablets delivering healthcare instructions," *Computers in Human Behavior*, vol. 43, pp. 112–117, 2015, doi: 10.1016/J.CHB.2014.10.029.

[15] M. Manca *et al.*, "The impact of serious games with humanoid robots on mild cognitive impairment older adults," *International Journal of Human Computer Studies*, vol. 145, Jan. 2021, doi: 10.1016/J.IJHCS.2020.102509.

[16] "Xemo® : Robot Simulation on Steam." https://store.steampowered.com/app/542210/Xemo__Robot_Simulation/ (accessed Mar. 28, 2022).

[17] B. Yang, X. Xie, G. Habibi, and J. R. Smith, "Competitive physical human-robot game play," *ACM/IEEE International Conference on Human-Robot Interaction*, pp. 242–246, Mar. 2021, doi: 10.1145/3434074.3447168.

[18] "Reachy Robot Playing a Dice Game with VR Teleoperation - Robotic Gizmos." https://www.roboticgizmos.com/reachy-robot-playing-a-dice-game/ (accessed Mar. 28, 2022).

[19] "RoboCup Federation official website." https://www.robocup.org/ (accessed Mar. 29, 2022).

[20] "aibo." https://us.aibo.com/ (accessed Mar. 29, 2022).

[21] T. Weigel, "KiRo - A table soccer robot ready for the market," *Proceedings - IEEE International Conference on Robotics and Automation*, vol. 2005, pp. 4266–4271, 2005, doi: 10.1109/ROBOT.2005.1570776.

[22] A. Causo and I.-M. Chen, "A Review on the Use of Robots in Education and Young Children Autonomous Picking Robot View project Automated Item Picking View project", Accessed: Mar. 29, 2022. [Online]. Available: https://www.researchgate.net/publication/301284225

[23] C.-W. Wei, L. Lee, and N.-S. Chen, "A joyful classroom learning system with robot learning companion for children to learn mathematics multiplication," *Article in Turkish Online Journal of Educational Technology*, 2011, Accessed: Mar. 16, 2022. [Online]. Available: https://www.researchgate.net/publication/239443461

[24] J.-H. Han, M.-H. Jo, V. Jones, and J.-H. Jo, "Comparative Study on the Educational Use of Home Robots for Children," *Journal of Information Processing Systems*, vol. 4, no. 4, pp. 159–168, Dec. 2008, doi: 10.3745/JIPS.2008.4.4.159.

[25] O. A. B. Henkemans *et al.*, "Design and evaluation of a personal robot playing a self-management education game with children with diabetes type 1," *International Journal of Human Computer Studies*, vol. 106, pp. 63–76, Oct. 2017, doi: 10.1016/j.ijhcs.2017.06.001.

[26] E. I. Barakova, P. Bajracharya, M. Willemsen, T. Lourens, and B. Huskens, "Long-term LEGO therapy with humanoid robot for children with ASD," *Expert Systems*, vol. 32, no. 6, pp. 698–709, Dec. 2015, doi: 10.1111/EXSY.12098.

[27] A. R. Taheri, M. Alemi, A. Meghdari, H. R. Pouretemad, and S. L. Holderread, "ScienceDirect Clinical application of humanoid robots in playing imitation games for

autistic children in Iran," *Procedia-Social and Behavioral Sciences*, vol. 176, pp. 898–906, 2015, doi: 10.1016/j.sbspro.2015.01.556.

[28] "Voice-Controlled Robots Are the Next Big Thing In Smart-Home Tech | GBC Robotics." https://www.onlinerobotics.com/news-blog/voice-controlled-robots-are-next-big-thing-smart-home-tech (accessed Mar. 19, 2022).

[29] Y. Bisk, D. Yuret, and D. Marcu, "Natural Language Communication with Robots," pp. 751–761, Accessed: Mar. 19, 2022. [Online]. Available: http://nlg.isi.edu/

[30] "ROS: Home." https://www.ros.org/ (accessed Apr. 14, 2022).

[31] "Overview — Robotont 0.0.1 documentation." https://robotont.github.io/html/files/overview.html (accessed May 03, 2022).

[32] "robotont | robotont." http://robotont.ut.ee/main?lang=en (accessed Apr. 15, 2022).

[33] "speech recognition | technology | Britannica." https://www.britannica.com/technology/speech-recognition (accessed Apr. 15, 2022).

[34] "alphacep/ros-vosk: Vosk node for ROS Robot Operating System." https://github.com/alphacep/ros-vosk (accessed May 23, 2022).

[35] "alphacep/vosk: VOSK Speech Recognition Toolkit." https://github.com/alphacep/vosk (accessed May 23, 2022).

[36] M. B. Singh Sahota, "VOICE RECOGNITION SYSTEM BASED ON AUDIO FINGERPRINTING," 2010.

[37] "sound_play - ROS Wiki." http://wiki.ros.org/sound_play (accessed May 23, 2022).

[38] A. J. Hunt and A. W. Black, "UNIT SELECTION IN A CONCATENATIVE SPEECH SYNTHESIS SYSTEM USING A LARGE SPEECH DATABASE".

NON-EXCLUSIVE LICENCE TO REPRODUCE THE THESIS AND MAKE THE THESIS PUBLIC

I, Anna Jakovleva,

(author's name)

1. grant the University of Tartu a free permit (non-exclusive licence) to:

reproduce, for the purpose of preservation, including for adding to the DSpace digital archives until the expiry of the term of copyright, my thesis

"Roboquiz- an Interactive Human-Robot Game"

(title of thesis)

supervised by Karl Kruusamäe, Marilin Moor

(supervisor's name)

2. I grant the University of Tartu the permit to make the thesis specified in point 1 available to the public via the web environment of the University of Tartu, including via the DSpace digital archives, under the Creative Commons licence CC BY NC ND 4.0, which allows, by giving appropriate credit to the author, to reproduce, distribute the work and communicate it to the public, and prohibits the creation of derivative works and any commercial use of the work from ***27/05/2022*** until the expiry of the term of copyright,
3. I am aware that the author retains the rights specified in points 1 and 2.

4. I confirm that granting the non-exclusive licence does not infringe other persons' intellectual property rights or rights arising from the personal data protection legislation.

Anna Jakovļeva

27/05/2022