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Research Article

Human-Robot Interaction with Social Humanoid Robots

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Abstract : The widespread use of robots in social areas has revealed the necessity of having social features. Seamless integration of robots into human life should be achieved through natural interaction. In order to establish this interaction efficiently, robot applications should be user-friendly. In the pertinent literature, it has been observed that users experienced serious difficulties in this regard, and it has not been recognized widely. In addition to this, it is seen that human-robot interaction is not efficient in several cases. In this study, the problems encountered during the utilization of Pepper Robot, which is defined as the first social humanoid robot, in the process of human-robot interaction were revealed and an exemplary application was developed to resolve these problems. In this application, it was seen that it is necessary for social humanoid robots to be the initiator of the interaction in order to socialize with humans in a natural way.

Keywords : App Development, Human-Robot Interaction, Pepper Robot, Social Humanoid Robot

1 Introduction

Robots are used in industries all over the world because they have a plethora number of affordances such as moving quickly, lifting heavy loads, working in harsh conditions that are dangerous to humans, and repeating the same movements precisely [1]. Advances in robotics and artificial intelligence have expanded the areas where robots can be useful for the service of humans [2]. Recently, robots have started to find their place in many social places such as shopping malls [3], hospitals [4], and schools [5]. In such environments, robots are expected to have some social skills so that people interacting with robots, do not face any problems [1]. These robots, called social robots, are physically embodied autonomous agents that communicate with humans using social cues, learn adaptively, and mimic human social behaviors [6]. Robots that resemble humans both in behavior and physical characteristics are called social humanoid robots. These technologies are designed to interact with humans appropriately [7]. In order to realize a natural interaction between humans and robots, artificial intelligence is also utilized. Artificial intelligence, defined as the ability of a computer or machine to imitate human intelligence, [8] is seen as a way to resolve the problem of interaction between humans and robots [9]. It can be said that there are several features that robots should have for an efficient interaction between humans and robots. These features can be exemplified by natural language processing and emotion recognition. When the literature on the subject is examined, it is seen that the studies focused on human-robot interaction generally.

This study aims to reveal the possible problems that may be encountered in the human-robot interaction process during the utilization of a social humanoid robot by exploiting the current literature. To serve this purpose, human-robot interaction studies on social humanoid robots were examined and a social humanoid robot expectation table (Table 1) was created to present the related literature. Then a sample humanoid robot application is developed to address the problems by utilizing as many functions of the social-humanoid robot. The application was developed adhering to the social humanoid robot expectation matrix.

2 Literature Review

The first humanoid robot design was found in a notebook found in 1950. The notebook is thought to belong to Leonardo da Vinci [10]. Decades later, the biggest problem encountered by the physically designed humanoid robot was balance and movement, and this problem was successfully solved by Honda in 1993 [11].

In a study where a social humanoid robot was used as a receptionist, it was stated that the naturalness of the interaction between humans and robots is important for the user experience. When the user wants to communicate with the robot, they may not want to communicate again if they have to repeat their messages or wait a long time to receive a response to their message [12].

The expansion of the service areas offered by robots has raised the question of whether people are ready to use these robots. To answer this question, a study was conducted with Pepper, a social humanoid robot placed in a central train station in Stockholm. Pepper Robot was loaded with software that included activities such as dancing, chatting, and joking. As a result of the observations made for this application, it was found that people who interacted with the robot thought that it was a number machine used to buy tickets. These people did not think that the robot could talk, tried to communicate by touching the tablet on its chest, and walked away when the robot did not react [13]. This also shows that the robot should be the initiator of the interaction.

Some people are uncomfortable talking to strangers in social spaces because they feel embarrassed or cannot find the right person to talk to. Social humanoid robots were seen as a new way to encourage social bonding between people who do not know each other, and so a study was conducted in a two-day seminar at the campus of the University of Tampere, using a social humanoid robot to help people communicate with each other. At the end of this study, it was found that people expected the robot to be friendlier, safer, and easier to use. It was also found that the robot's speech ability was not good enough, which reduced people's desire to communicate with the robot [14].

Today, technology has become a tool used to make art more accessible and interesting. In a study conducted with this idea, a social humanoid robot was used as an innovative approach to make museum visits more interesting. The robot analyzed the age, gender, and work of interest of the visitors and guided them to other work they might like. However, it was specifically stated that the touch screen feature on the robot should be used in order for the communication between people and the robot to be of high quality. Since it has been stated that the speech module of the robot is not sufficient [15].

In light of the findings in the literature, it has been observed that social humanoid robots, which are increasingly used in social areas, have difficulties communicating with people in a natural way. For example, it has been mentioned that the robot has difficulty in analyzing people's voices, its ability to speak is not sufficient, the tablet should be used to increase interaction, and people who do not know how to interact give up using robots. These difficulties determine the usability of the robot. In 1995, Nielsen stated that technologies that are appealing to people should be usable, and further defined usability as the ease with which the user can achieve certain goals while using the application. For this, technologies should have the following characteristics [16]: Users can initiate and maintain interaction as much as they know how to use technology. However, when it comes to socializing, people communicate intuitively using gestures, facial expressions, and tone of voice [17]. Also, artificial intelligence can be considered as a way to make robots easy-to-use tools for humans. Social humanoid robots can interact with humans in an intuitive way (by analyzing gestures, facial expressions, and tone of voice) through artificial intelligence. Thus, communication close to nature can be realized. In addition, Social Humanoid Robot capabilities and application interface should be used effectively. A more impressive communication with the robot can be established by speaking, listening, and using the instructions on the tablet. In this way, messages can be delivered in one go by ensuring that the planned activities garner the attention of as many senses as possible. For people who do not know how to interact with the social humanoid robot, the robot can initiate the interaction.

2.1 Social Humanoid Robot Expectation Matrix

Within the scope of this study, the studies on the use of social humanoid robots in different sectors were examined and the Social Humanoid Robot Expectation Matrix (Table 1) was created. By using the matrix, the features that robots should have in order to communicate effectively with robots in various social areas are illustrated. An application has been developed to explain how to use these features. This application runs a 'number guessing game'.

3 Material and Method

In this study, the Pepper Robot, defined as the first social humanoid robot and can recognize human emotions and faces and is shown as the first of its kind, was used [29]. A literature review was conducted to determine what people expect from the robot when communicating with the Pepper Robot. While conducting the literature review, engineering studies on the technical problems of the robot were excluded from the review, and studies, in which human-robot interaction was tested, were preferred. In studies conducted in both social and experimental settings, it was taken into account what kind of difficulties users experience when communicating with the robot. In which cases people prefer to use the robot or in which cases they give up using the robot were analyzed. The areas where an effective and continuous interaction with the robot needs to be established are summarized in the expectations table in Table 1. Nielsen, who studies the user's ability to use the interface easily, has shown usability as a quality feature. As a result of his studies on this, he identified 10 items. These items are explained below:

1) Visibility of System States: Clear information about the user's actions should be provided within a reasonable time.
2) Relevance between the system and the real world: The system should not speak in its own language, but in terms that users recognize.

Table 1: Social Humanoid Robot Expectation Matrix

Robot Usage Area	Problems and Research Topic	Expectations
Hotel [18]	Waiting for communication, repetition of messages, or no response to messages	In order for communication to be natural, messages are expected to be conveyed fluently in one go.
School [19]	Students were disappointed that the social robot used in the lesson did not move.	Students wait for the robot to move.
University [20]	The effect of using social cues in human-robot interaction was investigated.	It was found that the robot is more remarkable when its speech and body language features are used together.
Shopping Mall [21]	The robot's ability to speak is not developed enough to provide a reliable service.	Advanced dialog capabilities are needed for the robot to serve customers and collaborate with staff.
Train Station [13]	People who did not know the features of the robot thought it was a queue-taking machine and touched the tablet, but when they did not get a reaction, they walked away.	It is necessary to explain how the robot is used. It has been observed that people are more inclined to use tablets.
Conference [22]	His speaking ability was found to be not good enough.	The robot is expected to be friendlier, safer, easier to use, and to have improved speech.
Museum [15]	The speech module is not enough.	In order for communication to be of high quality, only the speech feature should be supported by the tablet.
Library [23]	Noisy environments make it difficult to use robots in public spaces.	The robot's ability to listen and speak may not work well in a noisy environment. A tablet can be used to solve this problem.
Hotel [24]	Users do not want to continue using the robot when it fails on the first try. The robot has difficulty understanding different accents.	It was observed that users who used the robot for the first time needed to be informed about the use of the robot. It was stated that most people preferred to use their tablets instead of chatting with the robot.
Hotel [25]	The most important concierge service in the hotel is the quality of information, and people prefer to get this service from a human, not a robot because it is not easy and friendly to communicate with a robot.	Users expect robots to have a high level of interactivity.
Hospital [26]	Participants stated that interacting with the robot requires a certain cognitive effort. It was also stated that the fact that Pepper, the social robot used in the study, has a fixed face is a disadvantage.	People want to be able to communicate comfortably with the robot. The robot's lack of facial expressions can hinder its understandability. To prevent this, other features of the robot should be utilized. It was also stated that the robot should be able to hear correctly, respond accurately, and have fluent dialog.
School [27]	It was stated that the robot used in the classroom could not distinguish voices and could not interact with more than one person at the same time.	The robot is expected to recognize conversations and communicate with many people at the same time.
Hospital [28]	Elderly patients found it difficult to communicate with the robot. The robot can look away while talking to the patient.	For effective communication, the robot should not have listening and gaze problems. It was also stated that the robot should be able to communicate with the elderly by choosing the right words with the correct evaluation ability.

3) User Control and Freedom: When users make mistakes, they should be able to correct them without a long dialog with the system.
4) Consistency and Standards: It must be able to perform the same operation with the same steps in different places.
5) Error Prevention: A design that prevents the user from making mistakes. For example, instead of asking the user to type something, it should offer options and let the user choose.
6) Recognition and Recall: The system should remind the user of the information they have entered into the system when they need to use it again in another section.
7) Flexibility and Efficiency: It should appeal to experienced and inexperienced users. It should allow them to perform their transactions according to their speed.
8) Aesthetic and Minimalist Image: The system should contain important and necessary information. Otherwise, the abundance of information on the screen reduces visibility.
9) The interface should help users recognize, diagnose, and fix bugs: Bugs should be expressed in a common language, without code, accurately, and with a constructive solution.
10) Help and Documentation: No need for help in the system is a good feature. However, there may be situations that require help. This information should be easily accessible, and the necessary steps should be specified [30].

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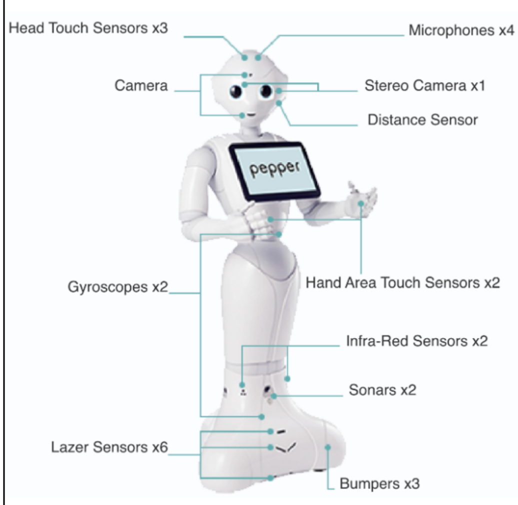
3.1 Pepper Robot

The first social humanoid robot; namely, Pepper, was launched by Softbank in June 2014. Pepper's vision is to lead all people to a smarter, safer, healthier, and happier existence [29]. It is actively working in various areas such as homes, shopping malls, offices, and nursing homes and more than 40000 lessons have been given in 1000 schools with Pepper Robot in Japan [31].

Pepper Robot is approximately 120 mm tall and weighs 29 kg. The manufacturer of the robot, Aldebaran, has specified the battery life as a maximum of 20 hours and a minimum of 7 hours. It has a total of 20 degrees of freedom (axes), 3 of which are



Size (Height x Width x Depth)	1210×480×425 [mm]
Weight	29kg
Battery	LITHIUM-ION Battery Dimension:30.0Ah/795Wh
Sensors	Head: Microphone ×4, Camera ×2, Distance Sensor ×1, Touch Sensor ×3 Chest: Gyroscope ×1 Hands: Touch Sensor ×1 Legs: Sonars ×2, Lazor Sensor ×6, Bumpers ×3, Gyroscope ×1, Infra-Red sensors ×2
Moving Parts	[DoF] Head: 2, Shoulder: 2×2(L/R), Elbow: 2×2(L/R), wrist: 1×2(L/R), Hand: 1×2(L/R), Waist: 2, Knee: 1, Wheel: 3 [Motors] 20
Display	10.1Inch touch display
Communication Method	Wi-Fi: IEEE 802.11 a/b/g/n (2.4GHz/5GHz)

Figure 1: Pepper Robot Appearance and Sensor Placement.

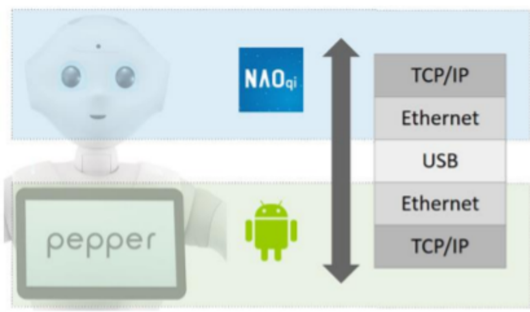


Figure 2: Communication network between the computers on the Pepper Robot.

on the wheels. It has the ability to exhibit body language, interact, and move by perceiving its environment. Pepper Robot has a number of sensors (Microphone, Speaker, IMU Sensor, Infrared Sensor, Tactile Sensor, Sonar Sensor, Camera, Networking Support) to detect objects and people around it and help the software components understand everything [32]. Fig.1 shows the shape of the Pepper Robot and the sensors.

In the light of these principles determined by Nielsen, the designed application was evaluated in terms of human-robot interaction. In addition, the application design was shaped by taking into account the issues specified in the social humanoid robot expectation table created as a result of the literature review, and the application was evaluated in line with the issues specified in this table.

The robot also has two operating systems (NAOqi and Android) [33]. The NAOqi is the internal operating system of the robot and performs basic functions such as balancing. The Android operating system is utilized to run user applications on the robot's tablet. The internal computer is located inside the robot's head and has an Intel x86 architecture processor. In this computer, a Linux-based operating system runs and for a secure operation, users or programmers are not allowed to make any direct changes on this system. The packages and configuration on the robot's internal computer are carried out through the Aldebaran cloud application. For example, the languages that the robot can use can be added and deleted as a package through the cloud account where the robot is managed. In addition, user applications can also be installed through missions defined through the cloud account without any action on Pepper Robot. The application market, which includes third-party applications developed for Pepper Robot, can also be accessed through the cloud.

The applications developed for the robot are run on the robot's tablet computer. Android 6 (Marshmallow) operating system is running on the tablet. The tablet computer is connected to the internal computer via a virtual network established via a USB connection. This communication is illustrated in Figure 2.

The robot's abilities such as perception and speech are realized with artificial intelligence libraries running on the robot's internal computer [12]. User software accesses these internal capabilities through the Aldebaran QiSDK programming interface

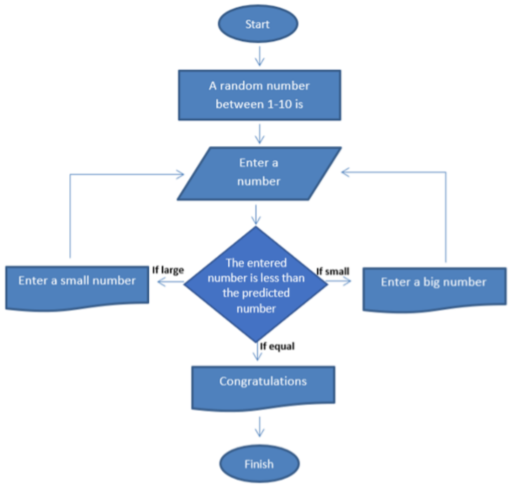


Figure 3: Flowchart of number guessing game.

over the network shown in Figure 2. In this way, the application development process is abstracted from the robot's internal computer and the programmers' workload is reduced.

3.2 QiSDK

QiSDK is a programming interface that enables access to the robot's functions such as moving, talking, and human interaction through Android activity. QiSDK can be considered as an add-on to the Android Studio environment with Java library and visual tools. For example, a design tool for Animation, which is defined as the arm and body movements of the robot, is installed in the Android Studio environment with QiSDK.

In order to access the robot's functions from an Android application, the QiContext interface is needed. This interface enables the realization of robot applications by exchanging data through a virtual connection between the tablet and the internal computer. When a robot application activity is run on the tablet, this interface is also activated. All objects used to access the robot's functions are created through this interface.

The functions of the robot can be constructed both synchronously and asynchronously. For example, performing a speech task while performing an animation process is an example of asynchronous operation. In order to use QiSDK procedures together with the thread that controls the Android application interface, the Pepper speech functionality must run asynchronously. Otherwise, the visual interface is blocked by the QiSDK call and the developed application breaks.

4 Number Guessing Game (NGG) with Pepper Robot

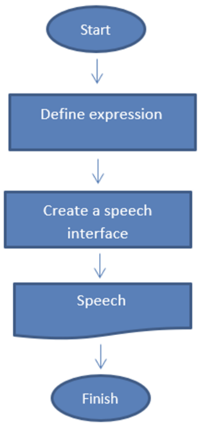
The application was started by first deciding how the flowchart would be Figure 3 below shows the flow chart used for the application.

Android Studio was used to design the application. The proposed application is developed using QiSDK in Java programming language. The Say interface defined in QiSDK is used to make the robot talk. The Say interface is basically defined with a phrase parameter. Fig.4 shows the use of the Say interface.

After determining the flowchart of the program, the user interface was designed and required software coding tasks executed. In order to provide human interaction with the robot, a mutual dialog can be established by using topics or listening and counting commands. However, since the use of the listen command causes the program to become cumbersome, we preferred to work with topics in this study. Thus, human-robot interaction can be realized easily and quickly. The robot is given a random integer type number between 1 and 10. Then, in order for the robot to understand the value spoken by the user, it was converted into a string expression in the topic. Thus, the robot will be able to detect the number spoken by the user. It will compare the number it detects and the number it randomly determines using the following commands. Figure 5 shows the code fragment used to generate random numbers in the robot application.

If the number is small or large, the robot will prompt the user both verbally and through body language to tell the user a large or small number. If the user gets the number right, it will congratulate them and ask if they want to start a new game. The commands used for this are shown in Figure 6. The emulator image of the guessing stages in the game is also shown in Figure 7.

For those who do not know how to play the game with the robot, the robot guides the users. Thus, people who interact with the robot for the first time will be able to learn what to do from the robot. After writing the code, the emulator was first used to test how the application works. After the application is completed, it in is installed on the robot via ADB and USB




```
//Create a phrase.
Phrase phrase=new Pharase("Hello");

//Build the action.
Say say=
SayBuilder.with(qiContext).withPhrase(phrase).build();

//Run the action synchronously.
Say.run();
```

Figure 4: Using the Pepper robot Say interface.

```
Random random= new Random();
number= random.nextInt(10)+1;
str = String.valueOf(number);
```

Figure 5: The code fragment that generates random numbers in the robot application.

```
u:(_[1 2 3 4 5 6 7 8 9 10]) very nice $kullanici=$1 ^first[
"$sayi>$kullanici big number %bignum."
"$sayi<$kullanici small number %smallnum."
"$sayi==$kullanici congrats guess right%equalnum. would you like to play
again? if you want to play you have to say yes if you don't want to say
no"
"You didn't say numbers between 1 and 10"
```

Figure 6: Commands used for comparison.

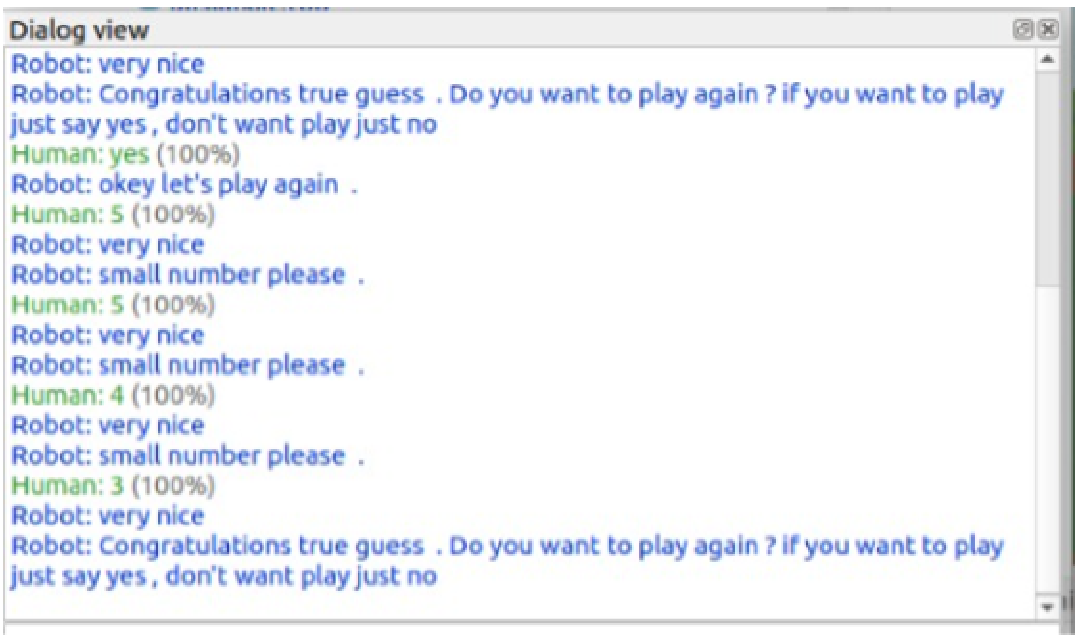


Figure 7: Emulator display showing the benchmark result.

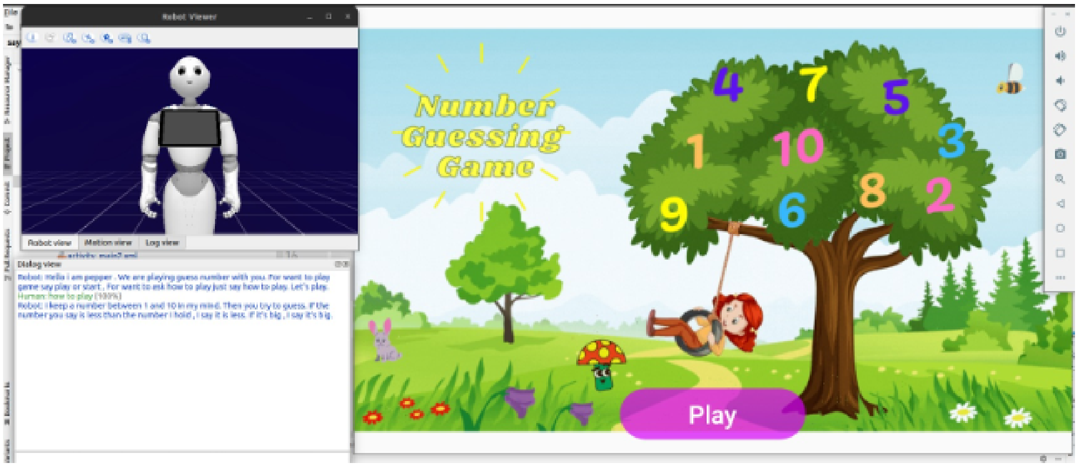


Figure 8: Image of the application in the emulator and the instructions used.

debugging connection. At the start of the application, the robot first generates an integer type number between 1-10. Then, the tablet interface of the application displays an instruction asking the user to say a random number between 1-10 (Figure 8).

In this way, people who do not know how to use the robot can interact with the robot using the instructions and buttons. During this interaction, it is shown how the robot's speech, listening, and tablet features can be used. The video of the application is available at the link: https://youtu.be/6YXAseT5A24

5 Results and Discussion

With this study, an application was developed for the problems obtained as a result of the literature review. For example, people who have not interacted with the robot before hesitate to use the robot or prefer not to use it because they do not know how to interact with the robot. In order to solve this problem, the robot initiates the first interaction when the application is opened. For people who do not know how to use the game, an explanation was also provided. QiChat was used effectively for the conversation to take place effectively. Thus, the robot understands what the user is listening to and interacts with short conversations without distraction. The tablet on the robot was also used to support interaction with humans.

As a result of the literature review, it has been observed that interaction efficiency increases when body language gestures are used. In this study, the robot also used body language while making number estimation instructions. When asking the user to say a small number, it moves its hand downwards; when asking the user to say a large number, it moves its hand upwards. It used congratulatory body language when the number was known correctly. The robot also supports these instructions verbally.

Furthermore, the number prediction application considered in this study is designed to comply with the visibility of system states clause in the Nielsen rules. Appropriate feedback is given about the user's guesses. This feedback can be expressed as entering a large number, entering a small number, and congratulations. A simple and easy-to-understand language was used in the game design. Thus, the compatibility between the system and the world is ensured. For the number guessing game, it is stated that the user should say a number between 1-10 to prevent the user from making mistakes. The application flow was planned so that the study could appeal to both experienced and inexperienced users. For example, the user who does not know the game can learn how to play the game by asking the robot "How to play?". The user who knows the game can start the game without wasting time. Thus, the flexibility and efficiency of the application is ensured. It is a good feature that the system does not need help. Nielsen stated that users should easily access clues when they need help. The "How to play" feature in the application helped to fulfill this rule. The tablet interface of the application was designed to have a minimalist appearance. Unnecessary information was not used by using a button and instructions to start the game. Thus, the distraction of the user was prevented.

In traditional human-computer interaction, it is always the human who initiates the interaction. A person who does not know the technology they are using may not be able to interact effectively with that technology. In addition, if we are talking about a social interaction, it should be mutual. Without waiting for the user to initiate the interaction, the robot should detect the human who wants to communicate with it and inform the user. In order to increase the usability of the social humanoid robot, it is inferred from the literature studies that such a feature is a requirement that is not included in Nielsen rules. A sample human-robot interaction application has been developed to meet the aforementioned principles. As stated by Hahkio, we experience listening problems when utilizing the listening interface during the application test as shown in the application video.

Hotels [18], shopping malls [3], conferences [22], and museums [15] can be counted as example use cases of the social humanoid robot. The use of speech features in a social humanoid robot application, which has been examined in different fields such as human-robot interaction, has been indicated as a necessary task for effective communication with users. In the NGG application developed in this study, the speech feature of the robot is used for human-robot interaction.

When the studies were analyzed, it was seen that adding speech features to the robot was necessary but not sufficient [14], [21], [24], [32], [33]. People may not expect the robot to be able to talk. So, they only try to use the robot's tablet to communicate with the robot. If they can't use the tablet, they leave the environment [13]. To solve this problem in the NGG application, it is proposed that the robot is the initiator of the interaction. When the application is opened, the robot introduces itself to people and informs those who want to get information about the game. For example, when the application is first opened, it says "Hello, I am Pepper, the social humanoid robot. Today we will play a number guessing game with you. You can say "Start" to start the game and "How to play" to learn how to play." If the user is meeting the robot for the first time and does not know how to play the game, they can ask "How to play?" to get information about the game. Listening to this command, Pepper Robot tells the user "I hold a number between 1 and 10 in my mind. Then you try to guess this number. If the number you say is smaller than the number I am holding, I ask you to say a bigger number. If it is bigger, I say a smaller number." It informs the user by making an explanation. Thus, the user who wants to interact with the robot will realize that the robot can talk as soon as the application is opened. At the same time, if he encounters a social humanoid robot for the first time and does not know what to do, it is ensured that he can solve this problem with the robot.

In the studies examined, it was realized that the robot's listening feature was not good enough [23], [24], [26], [34]. Humans who wanted to interact with the robot had to repeat their speech in some cases [18]. This is a situation that should not occur in an effective communication. In order to avoid or minimize this situation, it is recommended to use the tablet on the robot. In the NGG application, users can interact with the robot either by speaking or using the tablet.

In the study, he stated that communicating with the robot requires cognitive effort. The fixed facial expression of the Pepper Robot makes it difficult to understand [26]. In order to overcome this problem, it is proposed that Pepper Robot uses body language during communication. Thus, it is predicted that the difficulties caused by the static facial expression of the robot will be more understandable for the users. In the NGG application, while verbally indicating whether the number spoken by the user should be big or small during the game, the arms of the robot were moved in a way that the user would understand.

6 Conclusions

In this study, the issue of how to establish natural interaction with a social humanoid robot is addressed. For this purpose, we first analyzed previous studies on human-robot interaction and determined what kind of difficulties people experience when interacting with social humanoid robots. Then, a number prediction game was developed to suggest how these difficulties can be solved. Finally, the extent to which an application with these features meets the Nielsen rules is discussed. However, it was observed that social humanoid robots should have a certain level of human-specific abilities in order to interact in a near-natural way. Unlike the interactions used for non-social technologies, it was concluded that to establish a social human-robot interaction, the human does not always need to initiate the interaction, but robots can also initiate the interaction.

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Competing Interests

The authors declare that they have no competing interests.

Authors Contributions

All authors of this manuscript have equal contributions.

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