Playing with Robots: An Interactive Simon Game

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Abstract. The development of social robots is becoming a main research area within rehabilitation processes. The engagement of the interactive robots with the patients, specially with kids, favours both the evaluation of the patient and the development of the therapies, which currently consist mainly in the execution of iterative exercises and games. This paper describes the deployment of a version of the popular electronic Simon game where, instead of repeating colour sequences, the player must repeat the sequence of poses performed by the robot. The repetitive nature of this particular game is not only believed to be beneficial for the children's rehabilitation process but further provides a fun flavour to the therapeutic session. For the development, we use the NAOTherapist architecture that, given its modular design, permits the integration of new use-cases and/or robot platforms easily and only with a few steps; in this case, the formalization of the game in the Planning Domain Description Language (PDDL) used by the architecture; the mapping of the PDDL actions to the low-level instructions of the robot (the low level actions), and the mapping from low level sensor information to PDDL predicates which are used to monitor the execution of the plan (the game) and re-plan when needed. In addition to the technical issues, this work seeks to maintain a high level of human-robot interaction quality, evaluated with real users. The analysis of the empirical results and the questionnaires of people of different ages and backgrounds who tested the game is presented as well.

Keywords: Human-Robot Interaction, Automated Planning, Interactive Games, Cognitive Robotics

1 Introduction

Interactive applications with social humanoid robots are an emerging area of human-robot interaction research. By developing these systems, the aim is to acquire knowledge on this matter, while providing an amusing environment to the potential users.

Some of the recent works on interactive rehabilitation games are seeking for the benefits of including this kind of game-like applications in rehabilitation procedures of cognitive and physical disorders [2, 5–7]. Other lines of research provide cognitive robotic architectures to control and supervise rehabilitation sessions with a humanoid robot [1, 3]. These works are based on the idea that interactive applications have the potential to improve the commitment together with the motivation of the users during treatments as a loss of interest in the patients' side is observed, while following the routine activities of the traditional rehabilitation methods.

This work provides a general purpose game-like application based on the Simon game using the cognitive robotic NAOTherapist architecture [4]. An automated planning model of the popular electronic memory skill game Simon and the poses of the NAOTherapist project were combined for the implementation of this project. The target audience may vary from children with physical disorders to elderly with dementia or even young people using it just for daily entertainment. And since the system was designed to have a general purpose, it is easy to adapt the application for distinct type of uses.

The first tests of the system were done by 14 people ranging between the ages of 20 and 50. Even though this particular group is not the initial target of the application, useful feedback and data were collected to improve the game procedure further. Likewise, the evaluation of human-robot interaction performance of the system met the desired level of quality, expressing an auspicious future for the application.

The next session describes the development performed, while in the following sessions, we report the evaluation and discuss the main conclusions obtained.

2 Architecture for developing interactive games with social robots

In this section, the main issues related with the implementation of the Simon game in the robot platform are addressed. First, main elements of the NAOTherapist [4] architecture related with this development are described, together with some important considerations taken. Then, the medium-level use case of the game, which is formalized later in the PDDL language is presented along with the new behaviours implemented for this game.

2.1 Framework

The Simon game was implemented within the NAOTherapist architecture, which is an execution and monitoring system based on automated planning and learning [4]. There are three levels of planning in the NAOTherapist architecture: high-level to model the exercises, medium-level to deal with the execution of the planned therapy session and low-level to transform the instructions to angles for the motors of the robot's joints. The medium and low-level planning was modified and updated for the game, mostly the executive component and the PDDL domain file, as will be explained later.

The new domain has a structure of two loops to be able to execute and repeat a number of sequences that include increasing the number of poses. Adding the poses to the sequence was another challenge as there was a need of random selection. It was demanded for compatibility with the Simon game and to boost the enjoyment of the session. Therefore, a shuffled selection system is implemented using an index value that is responsible for the flow of the sequence. Despite the fact that the choice is not being done randomly, the shuffling system worked sufficiently for the Simon game.

Another thing that was kept in mind was the level of feedback from the robot. As it is a game, frequent intervention from the robot about the correctness of the poses were considered to be against the original idea, but again there had to be enough chances for the people to achieve the pose. Thus, the eye hint that was used in the NAOTherapist was preserved and only one reminder of the current pose is included. On the other hand the complexity of the poses was lowered to keep the balance of difficulty.

2.2 Considerations of playing with a robot

The primary goal was to use this project on kids to make the rehabilitation process seem like a game to take it out of the boring routine exercise ambience. Nevertheless, on the development process the system was tested with adults to evaluate the speed of the game, the pose checking accuracy, to determine quality and needed quantity of the feedback and adjust the pace and difficulty of the poses.

Some points to consider while preparing the game with the robot were discovered, to make it convenient for people. Therefore complicated therapy poses included in the NAOTherapist were eliminated to be able to achieve the optimum exercise level together with maintaining the fun of the game. In doing so, it was decided to have most of the poses using one arm at a time, which greatly lowers the risk to over-complicating people. But even after lowering the difficulty of the poses, due to the challenge of remembering the sequence, it had to be made sure that the robot gives the person enough time/tries to achieve the current pose. Further, the audio feedback provided by the robot should be enough, efficient and helpful, since any feedback that may offend or discourage the people may lower the quality of the interaction dramatically and has to be avoided. Thus encouraging and supportive language were tried to be used in the overall project. And again as the primary target of this project was kids, the tendency of children to see the robot as a friend and emotionally bond to it, is also taken into account and appropriate reaction is provided in the speech of the robot in necessary points of the game.

In addition to the feedback, it was known that robot should not be acting too slow to avoid the risk of losing interest of nor too fast to confuse the player. Although the pace of comprehending the instructions and performing the poses may vary, an optimum level of pace is believed to be provided and it can easily be altered if further observation proves the necessity.

Overall the goal is to increase the quality of the interaction and the key points to achieve this, are making a good impression of the robot and leaving the people wanting to play with the robot again.

2.3 Use case of Simon game

As portrayed in the above section, the Simon game is designed to be in its most convenient version to provide a quality interaction to both kids, elderly or anyone who wishes to play. Figure 1 illustrates the game flow which is arranged briefly as follows; person takes its position and gets detected, the robot starts the game. The first sequence of actions is executed which includes only one pose, then the pose is performed by the person and is checked. If it is correct, the robot moves on to the next sequence that has two consecutive poses (first one being the pose executed on the first sequence). Then it goes on with an increasing number of poses, adding a new pose at the end of the former sequence, selected shuffled among the initially declared poses from the given problem file. However if the person does not perform a pose correctly, the robot takes extra actions including reminding and skipping the pose.

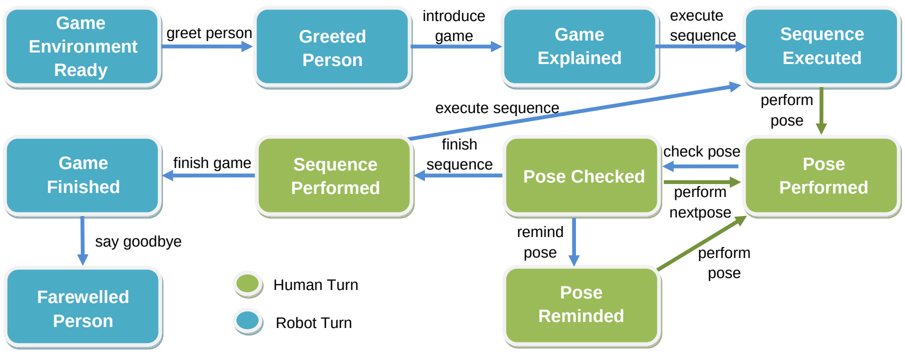

Fig. 1. Simon game execution flow.

For the beginning of the game, the person stands about 3 meters away from the robot (as far as needed for the whole body to be clearly seen) then gets detected by a Microsoft Kinect 3D sensor which provides the skeleton graph of the person's posture. Then this graph is used later in the game to compare it with the expected pose using the angles of the joints. With the help of this graph movements from the joints can be detected and analyzed. This process is the same with the NAOTherapist project. More details on the implementation of classification stage can be found in the MIE paper of NAOTherapist [4].

In the checking process where the player is trying to perform the pose, a hint through the eyes of the robot is given, where green indicates the right pose and red a wrong one. Color of the eyes are instantly changed to the tones between red and green in order to give a clear visual feedback to the person about how close he is to achieve the correct pose. For convenience both eyes are distinctly colored to indicate the correctness of different arms. The right eye is for the right arm and left eye is for the left arm. Once the pose is successfully performed, the person sees both eyes green and has to hold the pose for a pre-determined while until the robot gives a distinct audio feedback and lets the person know he is correct. After the given feedback according to the point of the game, either the next pose is expected to be performed by the person or the robot continues the game with the new sequence.

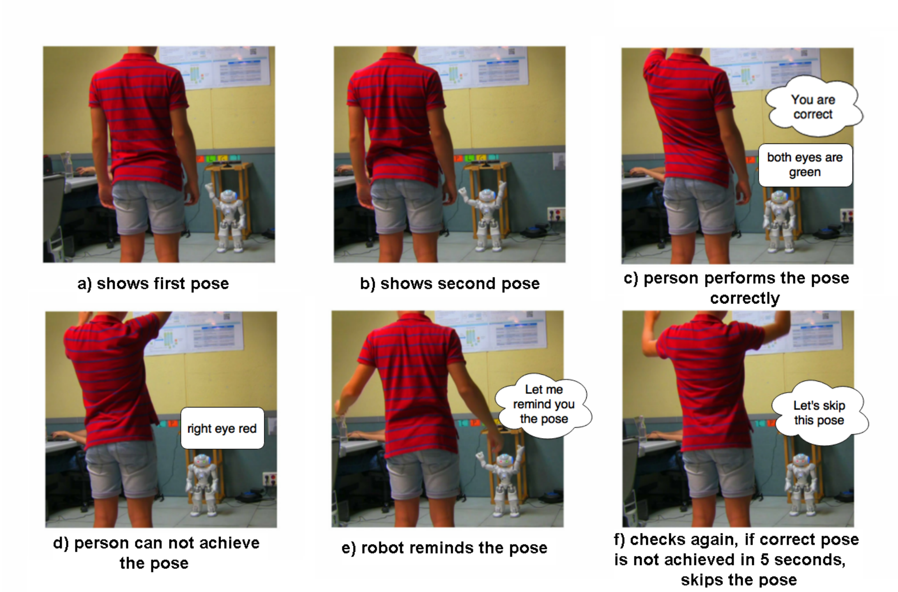

Fig. 2. Example execution section of the game.

In the case that the person can not perform the pose correctly, after waiting for 10 seconds, the robot tells the person that it will remind the pose one last time as seen at Figure 2. Then the robot executes only the pose that was expected from the person and waits 5 more seconds to see the right posture. When the pose is accomplished after the reminder, game goes on as usual, on the other hand if it is still not correct, robot skips the pose but does not exclude it from the sequence of poses and will be executing it again in the next round. Three times of failing to performing the needed posture and skipping the pose ceases the game.

2.4 Domain

The domain is the component of the project that includes medium-level actions and also where the shuffling occurs for the pose selection. Those actions are later translated in the executive component of the project to low-level instructions for the robot to execute them in real life, such as to wave to greet the person, move arms to show the pose, etc.

In that manner, poses are the base elements of this project. They are initially stated in the problem file together with their identification numbers, the specific indicators of the positions both arms should take, the game they belong to and their special pose weights that helps the shuffling process.

The shuffling system for the selection of poses was implemented for the need of diverse game flows. The nature of the planning was to select the next convenient pose from the problem file, however the need is to have different sequence of poses selected for each game as the real idea of Simon game is to have the next addition to the sequence always randomly, in our case shuffled, so it is not possible to guess the next pose nor to remember it with a logical order.

Although implementing a random selection is not possible in the domain using the NAOTherapist planning mechanism, a shuffling system was developed for this project which selects the next pose in an internal action, using the specific weight of the last pose and the initially declared index value to calculate the ID of the next pose to be executed. This sequence of shuffled selection of poses is deterministic, thus when the domain is executed with the same problem file, the same sequence is obtained, yet if only the index value is changed, the game has a completely new sequence of poses. Changing the weight value of poses can change a part of the sequence too, but it is not recommended as it may lead to an unexpected loop of pose selection.

2.5 Medium to low-level actions

The actions shown in Figure 3 are selected by the planner once at a time to be the next pose on the way to reach the goal state, then translated into low-level instructions for the robot as indicated.

This process takes place in the executive component of the architecture. In the executive component, the timing and order of the animations are attentively designed. While designing the low-level actions and speech of the robot, the primary aim was to keep the communication with the person, as simple and clear as possible to avoid misconceptions caused by too many instructions and too much to follow. Only at necessary points in the game where participants may lose track of the game flow, extra audio feedback is provided to maintain a stable and consistent experience. It was experienced in the development process that in some specific points of the game, people tend to lose track. Those are linkage points where the transition from robot's turn to person's turn takes place. This transition renders the guidance from the robot a delicate and crucial task. Namely those moments are: when the robot is done executing the sequence and the person should start performing the poses, the person has done the pose

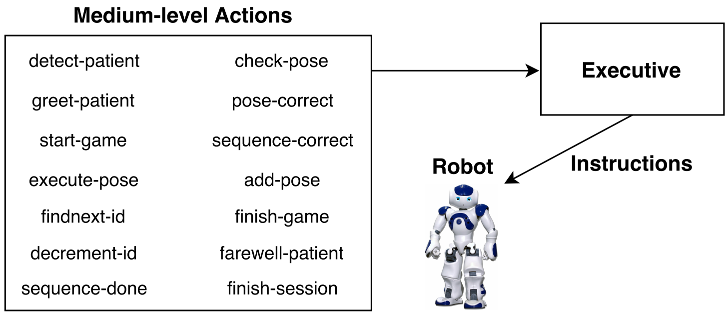

Fig. 3. List of medium-level actions and their translation for the robot.

correctly and needs to perform the next one, pose was incorrect and robot will perform the reminder, and lastly when the sequence was successful and robot starts the next round.

3 Evaluation

Initially, the game was tested with 14 people varying in age from 20 to 50, all playing the game for the first time. After the test session we applied questionnaires focusing primarily on human-robot interaction experience, performance of the robot, and ease of comprehension about execution of the game. The testers played two games with the robot, both containing five turns of poses. The games had distinct pose selections and the second game is composed of rather harder poses. Below Table 1 displays the statistics of test participants. It can be observed that the average second game duration is less than the first one. Additionally, although the reminder average seems to be moderately high, it should be noted that it is mostly caused by the few extreme cases, thus the also high standard deviation.

Number of participants	Age	Game-1 duration (s)	**Game-2 duration (s)**	Number of poses per session	Reminder average per session	Reminder std. deviation per session	Skipped poses average per session	Fails average per session
14	20-50	235.19	**231.83**	30	4.23	2.85	1.31	0.08

Table 1. Statistics from the initial test.

The overall responses from the testers to the expected answer of the question is compared on the graph in Figure 4, grouped by their relevance to the analysis. The desired outcome was to have expected values in the range of the deviation of average responses. As it is clearly seen on human-robot interaction basis, majority of the results are compatible with the project goals. On the other hand, slight controversion on the game and robot's performance front is present. Those evaluation target the difficulty of the game and the pace of the execution.

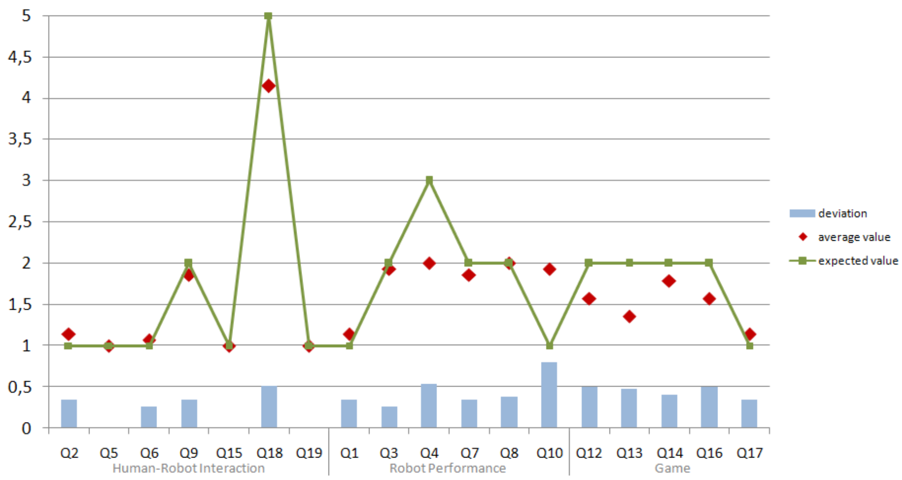

Fig. 4. Questionnaire outcomes with averages and standard deviation, compared with expected result.

In the overall picture people found the game easy to understand and keep up with. Even though participants are observed to have difficulties getting used to the game flow from the beginning, after realizing that the robot gives necessary warnings in the turning points of the game, it became easier to play. Thereby, the instructions provided during the game are evaluated to be clear and enough. Not surprisingly nearly 70% of the participants agreed to have enjoyed the second game better, even though the poses were fairly harder and were found more difficult to achieve by 85% of the testers.

Performance-wise, nearly all of the participants thought the pace of the robot to execute the actions is just right, whereas the response time is evaluated variously. Although the majority thinks the response time was all right, some participants found it too slow and only a few thought it was fast. Nevertheless all testers reported they were able to keep up with the game comfortably. This result indicates that even though the pace of the person may vary, the game has an appropriate speed of executing the poses to make it suitable for everyone.

On the other hand the duration of the session was generally evaluated to be enough. However the overall ranking turned out to be slightly lower than the maximum agreeable level, indicating that five (± 1) turns can be considered the optimum level to preserve interest and enjoyment during the game which lasts around 230 seconds.

Throughout the game people gave positive feedback about their interaction with the robot. This was accomplished highly as a result of the eye contact.

Nearly all participants had the impression that the robot has a connection with them through the eyes, thus moderate level of eye contact is initiated when they used the feedback of colored eyes to correct their pose several times. This helped change the way people perceive the robot, from an indifferent machine to, maybe even a half-alive, play companion.

Everyone taking place in the evaluation process admitted to have enjoyed playing the game with the robot and the average rating of enjoyment on a scale of zero to five is came to be 4,15. These results illustrate that the game session, together as a whole with the robot's actions and the game itself, has accomplished to maintain a level of interest for people.

The enjoyment of playing Simon game with the robot set aside, there are specific feelings people experienced during their session with the robot. Those emotions were ranked by the participants after the sessions to figure out how the robot led them to feel. Figure 5 shows their average ranking on a scale of zero to five. As it is seen the most frequent word to be used was "happiness" followed by "enthusiasm" which are precisely the goal of this project. Evidently the interactivity of robot helps people be well concentrated to the session, by establishing a bond of positive feelings and exploiting it further in the game to capture the interest.

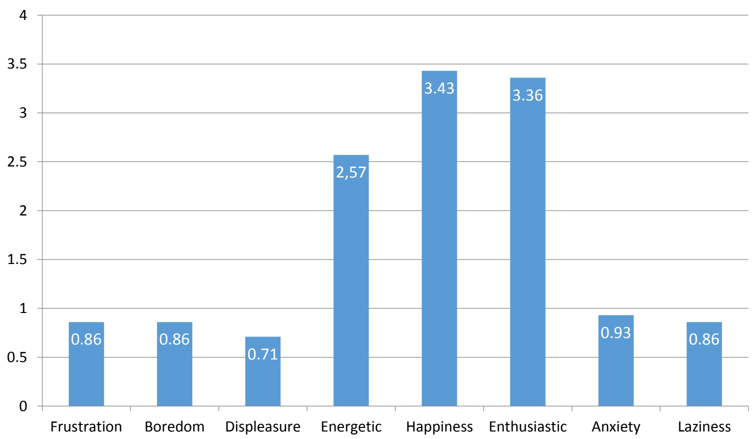

Fig. 5. Reported feelings of test participants.

Despite the indifference of the durations, in the second game participants clearly performed better in terms of achieving the poses and following the instructions of the robot. Less reminders were needed and the number of pose skips fell to zero. In the overall picture younger testers (particularly under 25) needed less reminders from the robot and were superior in adapting to the game flow, whereas the group over 25 years was responsible for most of the pose skips. However it should be considered that the number of skips were only 17 of over

400 executed poses throughout the whole test session. Also the statistics of pose reminders indicates that half the participants never skipped a pose, furthermore, of the 56 poses reminded to the participants, 70% of the time they were able to correct it before skipping.

During the test session only one failed game was reported and that participant was able to finish the session in the second game.

4 Discussion and conclusion

Some of the points to be noted in the execution of game and interaction are the false perception of self pose of humans, and also player's emotions during the interaction.

Regarding the first point, it was observed that when the poses expected from the person are a little higher than the intermediate level there occurs a problem that was not taken into account before, that is the performance difference of the robot and the human. It was noticed especially during the tests that people experience difficulty comprehending the posture they have to maintain and frequently mistake it as a failure of the robot to perceive their pose. Even after the reminder, since the player is convinced that the robot can not understand his pose, he tends to quit trying, even lose interest or confidence in the game. This is noticeably a consequence of the faulty human self spacial perception. For instance raising the arm of a shape of L may seem easy to the player but mostly it is failed due to not enough lifting of the elbow. As a solution a mirrored correction can be implemented. In this wise, robot will imitate the players' pose and show the right pose consecutively. This way they will be noticed about their true posture, thus know where they are mistaken and what they should do to correct it.

The second point is about the anxiety reported by the test participants after the session. Even though its average is fairly low, it should be taken into account and worked on, for benefit of the interaction. Anxiety is believed to be caused by playing a recently implemented format of a game with a robot that people have not communicated with before. To avoid players getting anxiety from the game, a more organic speech can be provided by recording the audio feedback sentences beforehand and using them in the session, together with more encouraging speech. Furthermore, the session could start with shorter and easier warm-up games to help the players acquire experience and feel more confident around the robot.

Thinking quality wise, the reversed version of the game might be considered, to increase the level of human-robot interaction excellence. Although it has not been implemented in the project, the idea is to have the person take a form and the robot imitating it in the sequences of increasing number of poses. This will surely improve the interaction quality as well as the experience of communicating with the robot for the person, leading to a more cooperative and natural environment.

Focusing on the human-robot interaction aspect, this document explains the Simon game implementation to further learn from the interactive game format on how to improve interaction experience for humans. The Simon game has been an opportunity to learn more about the deficiencies and advantages of human-robot interaction, together with the opportunity to observe people's reaction to robotic animations and speech. Although it was thought to be an assistive robotic application for people with disabilities or cognitive impairment and the considerations mentioned in this document while designing the game were kept in that specified limit for their convenience, evidently it can be carried on to be an application for a broad audience.

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