Using a social robot to play games with people

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Abstract. As social robotic research advances, robots are improving their abilities in Human-Robot Interaction and, therefore, becoming more human-friendly. While robots are beginning to interact more naturally with humans, new applications and possible uses of social robots are appearing. One of the future applications where robots will be used is entertainment. This paper presents a social robot as a development platform where several robotic games have been developed. Five of these games are presented and how these games take benefit of the robot's HRI abilities is detailed.

Keywords: Social Robot, Edutainment, Robot Games, Robot Entertainment , Human-Robot Interaction

1 Introduction

Perhaps in the near future robots will be a common companion in every house. As robots become more useful to people and they begin to use robots to carry out tasks that are considered uninteresting and boring, people will begin introduce robots in their houses slowly but unrelentingly. But robots are not only going to do the tasks that people refuse to do. As it happened before in the computer industry, people will eventually begin to use robots as an entertainment platform.

Since the market of playing robots is still in its first ages, there is not a uniform opinion of what are the abilities that playing robots must have. Most of these abilities will depend on the nature of the games these robots will play. But despite the nature of the games, all robots will have to interact with human players. Therefore, robots will have to interact with humans in a natural way. In other words, robots must interact with humans in the same way humans communicate with other people. For this reason one of the main topics in social robotics is the Human-Robot Interaction (HRI) field.

In the other side, we can consider that a robot with the ability to play games as a robotic gaming platform. Robotic Gaming Platforms will be more advanced and complex gaming platforms than today's video game consoles, but it is probable that both platforms will share many things in common. For instance, like in the video games platforms, the robotic gaming platforms must consist in hardware systems that will be ran smoothly by an “Operative System”. This Operative System must allow to run many kind of games in the robot. A robotic gaming platform must offer an interface for programmers to facilitate the development of new abilities in form of new robotic games. As we will see in section III, we are not aware of any robotic system with such flexible platform to allow the programming of new robotic games.

In this work we present an easy expandable robotic platform for developing board games as well as educational applications. Games are not only addressed to a small portion of population, but because of its wide variety of hardware and its adaptively software architecture, different levels and kinds of games are likely. Several non-trivial board games and educational games have been implemented and, in this work, Maggie is presented as a very flexible edutainment platform.

The paper follows in the next section with a short description of other robotic platforms used to play. Following, in section III, we describe the robot. We describe both HW and SW and we detail which are the interaction capabilities of the robot. Section IV is about the mechanisms interaction with the robot. In section V we discuss about the robot as gaming platform and in section VI the reader can find a description of five games developed for the robot. Finally, in section VII a brief conclusion and future issues are discussed.

2 Other robot toy applications

Recently researches try to employ robots for social tasks such as toys or teachers. Some of them work on the aims of edutainment.[1]

Some robots are intended for entertainment purposes. Provably one of the most famous toy robot is Aibo [1] which main goal is to behave like a pet and play with persons for accompaniment. Takara Company has developed Tera robot [2]. It is intended for entertainment purpose: it supports DVD video and music CD playback using its mouth to load disc, the eyes feature built-in lens and projector. Tera robot can playback a DVD and project the image at the same time, built-in small-sized speaker, modem and HDD. Pleo robot [3] plays a very basic game called tug-of-war and it is just a substitute pet. All these toy robots play very basic games with a lack of intelligence. NEC is also researching on entertainment robots with Papero [4]. It performs dances, mimicry, riddles, quizzes, fortune telling and others.

Almost all presented robots are commercial platforms equipped with a limited number of games or applications. Therefore is no easy to add more functionalities.

Other works try to mix entertainment and education on robotics leading to edutainment robots. In [5], preliminary experiments on remote education have presented that students interact with robots showing pleasure and interest. Because of that, our work is closer to it. [6] describes how children play with Roball, a plastic spherical robot, in an adaptive mode increasing and sustaining interaction.

1 Learning on robots, learning through robots, and learning with robots. We focus on the later

Also, it has been shown that robots have psychological effects on patients improving their motivations, as it is demonstrated with Paro robot [7]. We will take advantage of it for edutainment purposes.

Furthermore children suffering severe disabilities are making used of robots for learning and improving their quality of live [8][6]. Depending of the games, they will help users to develop and improve different users' abilities.

3 Description of the robot

The robot Maggie is a platform for studying human-robot interaction (HRI). The development of the robot is focused in finding new ways to adapt the robotics potential to provide to human users new ways of working, learning and entertaining.

3.1 Hardware

Here is a summary of the extensive description of Maggie [9]. Maggie is designed as a 1.35 meters-tall girl-like doll. Its base is a Magellan Pro mobile robot produced by iRobot and later modified in the RoboticsLab to fit with the needs of the robot. This base is motorized by two differentially actuated wheels and a caster wheel on both sides. The base is equipped with 12 bumpers, 12 infra red optical sensors and 12 ultrasound sensors. Above the base, a laser range finder (Sick LMS 200) has been added. The upper part of the robot incorporates the interaction modules. On top of the platform, there is an anthropomorphic robot head with an attractive design. The head has two degrees of freedom, while each arm has one degree of liberty. These features are illustrated in Fig 1.

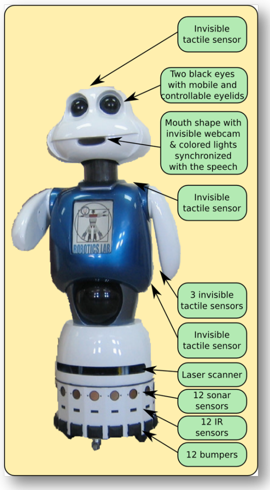


Fig. 1 The hardware equipping Maggie

Maggie is controlled by a main computer hidden inside her chest. In the computer resides the software architecture of the robot. For image acquisition, the robot has a camera located in the robot's mouth. The camera is a Logitech QuickCam Pro 9000. The robot also has touch sensors on the surface of the body and a touch screen situated in the breast is used for a direct interaction with people. Finally, inside the head, an RFID antenna is placed for identifying objects.

3.3 Software architecture

The Automatic-Deliberative architecture is a two leveled robot architecture [10]. The automatic level is linked to modules that communicate sensors, motors and other hardware. At the Deliberative level, reasoning processes are placed.

The essential component in the AD architecture is the skill [10]. The AD architecture is formed by many skills located in both levels. A skill is an entity with the capacity of reasoning, processing data or carrying out actions. In terms of software engineering, a skill is a class which hides data and processes and describes a behavior of a task or an action that the robot can perform.

The core of a skill is the control loop which could be running (skill is activated) or not. Skills can be activated by other skills or by a sequencer, and they can give back data or events to the activating element or other skills interested in them.

4 Interaction with Maggie

Maggie is a robot designed and created to interact with humans, therefore it need to prove mechanisms of interaction with humans. At present, the robot has several mechanisms of interaction that we analyze now.

a) Voice System: The most important interaction mechanism of the robot is the voice system. This system allows the robot to speak and to listen to humans. The voice generator is provided by a professional software vendor Loquendo [11] wrapped into the global architecture of Maggie as a skill. The generated sound is then emitted through loudspeakers situated in the neck of Maggie. This voice synthesis capability we have called “Emotional Text To Speech Skill”.

The robot voice is generated by a Text To Speech (TTS) system which allows the robot to convert to human voice any written text. It can generate voice in Spanish and English with high quality and several emotions. The voice is clear and easily understandable by humans. Moreover varying the voice tone, the robot can communicate with expressions and emotions as happiness, sadness, tranquillity or excitement, and finally it is possible to generate laughter, yawning and sighing.

The robot is also able to understand what we say. The human part communicates with the robot through a headset and is understood by Maggie with a speech recognizer using a grammatical based knowledge system. This capability is called “Automatic Speech Recognition” (ASR) and it is based in the Loquendo’s ASR system. Using this skill Maggie can understand Spanish, American English and British English.

Any human can talk to the robot in natural language and it is not needed a training phase to communicate with the robot.. Currently, all the interactions are performed following two paradigms of HRI, the master-slave and the peer-to-peer (P2P). Depending on the context, the interaction will lead to one or the other paradigm. In the master-slave paradigm, the human acts as the master and the robot obeys the commands expressed by the human. In the P2P both human and robot interact as equals. The first is used in normal contexts where Maggie acts as a personal robot. The later is mainly used in games contexts where the human and the robot play games acting as rivals or colleagues to accomplish a task depending on the game.

Maggie is also able to identify the person is talking with it from a previous recorded voice prints database.. This capability is called Speaker Verification and is powered by the Loquendo speech system.

b) Touch sensors: Maggie can sense when a person touches certain parts of its body. The robot has a dozen capacitive touch sensors placed over her body. We call this capability of interaction "touchSkill". This skill is always running and always detect when a human touch a sensor.

c) Artificial Vision: The robot has a camera in its mouth and it enables to "see" its environment. The vision system captures the images from the camera and processes them with the openCV artificial vision libraries [12]. The processed data can be used then by several skills, for example: identifying a person, counting the number of people in the environment, detecting a board game, etc.

d) Radio Frequency Identification (RFID): Another mechanism to interact with the environment is using Radio Frequency Identification (RFID) tags. Despite it is not a naturally way of interaction between humans, it allows the robot to identify and retrieve information of several objects that are presented to the robot by the human. Maggie has a RFID reader in its body. This reader can read radio frequency tags inserted in objects. When the human presents the object to the robot, the robot is not only able to identify the object itself, but also is able to retrieve more information related to it.. We have developed several skills that use this kind of interaction: reading and retrieving certain products information like drugs and toys.

5 Gamming platform

The presented diversity of interaction mechanisms allows us to develop new games. The robot architecture allows creating new skills (and games in this case) with ease. Every skill can be connected with another skill to make a new and more complex skill.

This increases ease of use and creation of new skills allows us to create new ways of leisure and learning through the use of robots.

As the robot is having more skills, more capacities and more interaction mechanisms there are more possibilities to create new games. The following section shows several games developed using this platform.

6. Description of the games

6.1 Peekaboo

In this game the robot plays peek-a-boo with a human player. In the game, the human hides in the room and the robot tries to find him using his vision system. The robot finds the human when it is able to detect his face. The player can hide his face so that the robot cannot find out him.

To detect people the robot uses the face detection algorithm. Thought this system the robot is able to detect how many people are in the environment (how many faces).

In this game has not been implemented the functionality of identify faces, that means that the robot does not care the person who has found, simply it is able to detect and count the number of faces captured by her vision sensor.

6.2 Guessing a character

In this game the human player must think in a fictional or real character. The robot asks several questions to the human until it is able to guess the character. The questions are the kind of yes/no answer. Usually in less than 20 questions the robot guesses the character.

Before the game starts, the robot describes the rules of the game and how the player must interact with the robot. Once the robot has finished the description of the game the player must have been decided who will be the character that the robot has to guess. The game starts when the robot starts asking questions about the character to the human. The robot asks the human using its voice system. The human also responds by voice and the robot has to analyse and detect the responses of the human.

The game is implemented as a skill that uses the robot's built-in wifi connection to connect to a public web server. This server has a database of many characters and the intelligence to relate the answers of the human with all the possible characters.

The web service where the game is hosted it is called Akinator [13], in there is a huge database of real and fiction characters. Using machine learning techniques and artificial intelligence the web service selects questions than the answer eliminates as many potential possibilities of the database.

The implementation of the algorithm is based in a search tree. Each question eliminates the maximum number of options, filtering the branch that has more children

6.3 Tic-tac-toe

In this game, the robot and the human play over a game board the game: tic-tac-toe. The game is played in a board of 3x3 cells. The robot can play either with crosses or circles. The player can start the game or let the robot to do it. If the human starts the game, putting a counter of one kind, the robot will use the other kind of counters. If the robot starts, always chooses crosses.

The game is performed in the following way. Supposing the robot starts the game, it chooses a position and it tells it to the human. Because the robot lacks of hands, the human must put the counter for it. The human must put the counter in the position the robot has told. After that, the human turn begins. The human chooses a free position, puts the counter on it and lets the robot know that he has finished. Once the human turn has finished, the robot analyzes the board with its vision system. After the analysis of the board, the robot has an updated status of the game so it can perform the next move.

The game ends when one of the players has managed to put three consecutive counters on the board (i.e. it has formed a row). In this case that player has won the game. The game also is finished if the board is full and any player has not managed to put three consecutive counters. In this case the game finishes in a draw.

Fig. 2 Maggie playing to tic-tac-toe

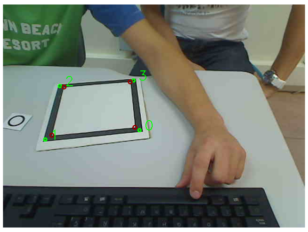
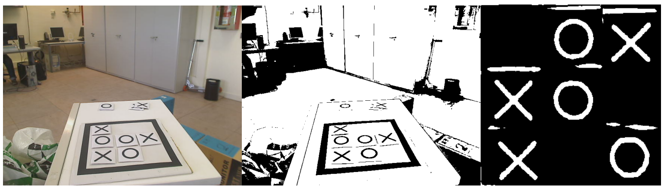


Fig. 3 Recognizing the board game

The robot uses its vision system to recognize the game board. For that reason it must be mounted in a table nearly enough to let the robot to view it (usually at 1m height and about 20cm from the robot). Because the robot has not hands to manipulate the game counters, the human player has to do it in her place.

The interaction between the robot and the human is done by voice. The robot tells the human the rules of the game, asks to the human to put a counter in the place it wants and updates the human with the state of the game (I.e. is finished, who has won, etc.). The human must warn the robot when he has finished his turn.

In order to recognize the play area (Fig. 3), the robot uses a vision machine algorithm that threshold image and finds a black square which is the framework of the game board (Fig 4a). Once it has found the game board, it corrects the image passing from a perspective view to a plant view (Fig 4b). In the plant view the algorithm recognizes the game counters placed in the game board (Fig. 4c). These algorithms are based on openCV libraries [12].



(a) (b) (c)

Fig. 4 (a) Board game (color perspective image); (b) Board game (threshold perspective image); (c) Image corrected in plant view

Once the position of the game counters is defined, it is necessary to apply an appropriate algorithm to decide the next move. The game algorithm is based on minimizing the “damage” that you can receive from the adversary and maximize your chances of winning.

6.4 Hangman

The goal of this game is guessing the word that the other player has thought using a few clues. In the game, the human thinks in a word and the robot tries to guess it. The human writes in piece of paper the exact number of underscores as he word has. After that, the human puts the piece of paper the table to allow the robot to view and count the number of underscores of the word. The human can give to the robot more clues, for example one or more letters of the word, written in the exact position of the word. For example, in the word *“robot”*, the human can write a „*b*“, but it must be placed just above the third underscore, which corresponds with the letter „*b*“ of *„robot“*. Counting the number of underscores, the robot is able to know the number of letters of the word. If the human has given a clue letter, the robot has more information of the word and can reduce the broad of the possible words.

When the human puts the paper with the underscores in the table, he has to tell the robot to start the game. The robot tries to guess the complete word. To do this the robot has several rounds. In each round the robot must guess a letter of the word. If the letter proposed by the robot is in the word, the human must write it on the game board, just above the corresponding position of the word. The game ends when the robot guesses the word or when the robot reaches a maximum number of failures.

Like in the tic-tac-toe game, it is necessary to put the table near the robot to allow it to see the game board (Fig. 5). The human player is responsible of thinking the word, and writing the underscores corresponding to the number of letters of this word in the game board. The robot is responsible of guessing the word. In each round the robot asks for a letter, and the human player writes this letter above the underscores that correspond to the letter in the word (in the case this letter is in the word). For example, in the word *“robot”*, if the robot asks for the letter *“o”*. The human must write an *“o”* above the second and the fourth underscores. Doing that, the robot is able to detect that she has guessed that letter. If the letter is not part of the word a failure is considered. The maximum number of failures is six. The game ends when the robot guesses the word or when the six failures have been reached.

In each turn, the user must write clearly and with black marker the letters that the robot has guessed. Once the human has done this, he warns the robot to make another attempt using a voice command. After that, the robot analyzes the game board, counting the number of underscores and the letters that it has guessed. Again, both as to character recognition (OCR) as to find the board game we use a computer vision techniques based on openCV [12].

In the Fig.6a, we can see the game board in the top right corner. In the Fig. 6b the robot analyzes the image and detects the game board (square with big black border). In the Fig. 6c the robot has obtained the rectified image from the playing area (plant view) and it detected and identified the letters written on it.

Fig. 5 Maggie playing to hangman

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(a) (b) (c)

ig. 6 (a) Table with the board game, (b) Maggie detecting the board game; (c) OCR in the rectified image.

The algorithm used in the game is based on finding the words that can match with the current state of the game, those words are in a dictionary with the most common words of the language. We have two dictionaries of words, one in English and another in Spanish, each one with approximately 100,000 words. These words are the most common in both languages.

The human part of human-robot interaction in this game consists on writing in the board game and talking to indicate the end of each turn. In the other part the robot interacts with the human reading the writings of the human with its vision system and making questions to the human related to the game.

6.5 Animal Quiz

The aim of this game is to study the interaction between robot and children using the voice system and RFID sensors.

In order to play to animal quiz we have ten soft toy animals with RFID tags inside of them. Each soft toy is an animal of one color and has a single unique name. There are not two soft toys that are the same animal, have the same color or have the same name. The game consists in Maggie asking to a child if he could bring her one of the soft toys. To do that the robot asks for one of the properties of the soft toy (animal, color or name). The child picks the corresponding soft toy and it brings to the robot. To give to the robot the soft toy, the child brings the soft toy close to the robot nose. There the robot has an RFID sensor that can detect the RFID tag of the soft toy. This allows the robot to detect if the child has brought the correct soft toy or not. Writing and reading RFID tags in Maggie is explained in [14].

If the child has not understood the question can ask the robot to repeat the question.

When the game has finished, the robot tells the number of right and wrong answers. Only the first time the child shows the toy in each question is counted as hit or failure.

When the robot asks for a soft toy, it waits until an RFID tag is detected. The toy must be placed close to the robot nose, typically 20 cm. The robot compares the number stored in the tag with the right answer in order to know if the toy is the correct one or not. The child may try to guess the soft toy again and again until he gets right.

7. Conclusions

In this paper we have presented a social robot with high interaction capabilities and its use as a gaming platform. We have presented the robot HW and SW architecture and its interaction skills. The presented robot SW architecture has shown as a flexible platform to develop new robotic games. Also we have presented how to use this robotic SW platform to facilitate the development of new robot skills that can be used as games.

Our future steps consist on studying how people react to the proposed games. The first data seems to show that people tends to be more involved when a robotic character shows emotions during the game. Also, our preliminary results seems that robots with more interaction capabilities make feel more comfortable to people and, therfore, people tends to play more time with them.

Finally, it still to be defined which is the relation between HW and SW in robotic gaming platforms. Intuition seems to point that in robotic gaming platforms HW is going to be a much more important component than in video gaming platforms. But, in robotic gaming platforms SW, and concretely the robotic operative system is going to play a fundamental role too. Unlike in video game platforms, which the control of the character remains in the game itself, in robotic game platforms, the SW of the robot must be aware of the robot environment.

References

1. Sony Aibo Robot. http://support.sony-europe.com/aibo/
2. Tera robot. http://www.engadget.com/2005/01/20/takaras-new-tera-bots/
3. Pleo robot, http://www.pleoworld.com
4. Papero robot, http://www.nec.co.jp/products/robot/en/index.html
5. Akihiro Yorita, Takuya Hashimoto, Hiroshi Kobayashi, Naoyuki Kubota .: Remote Education Based on Robot Edutainment
6. Ben Robins and Dautenhahn, Kerstin .: Interacting with robots: Can we encourage social interaction skills in children with autism?
7. Paro robot. http://parorobots.com
8. Cook, Albert M, Meng, Max Q H, Gu, Jason J and Howery, Kathy .: Development of a robotic device for facilitating learning by children who have severe disabilities. (2002).
9. Miguel A. Salichs, Ramon Barber, María Malfaz, Javier F. Gorostiza, Rakel Pacheco, Rafael Rivas, Ana Corrales, Elena Delgado, David García.: Maggie: A Robotic Platform for Human-Robot Social Interaction. RAM (2006).
10. Miguel A. Salichs, Ramon Barber.: "A new human based architecture for intelligent autonomous robots" (2001).
11. Loquendo Vocal Technology and Services. http://www.loquendo.com/en/
12. Gary Bradsky, Adrian Kaehler.: Learning OpenCV (2008).
http://ployer.com/archives/2005/01/tera_robot_seri.php
13. Akinator. http://en.akinator.com/
14. A.Corrales, R.Rivas, M.A.Salichs.: Sistema de identificación de objetos mediante RFID para un robot personal. Jornadas de Automática. Huelva. España. ISBN: 978-84-690-7497. Comité Español de Automática. (2007)