Introducing the Social Robot EBO: An Interactive and Socially Aware Storyteller Robot for Therapies with Older Adults

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Abstract. Storytelling has played a fundamental role throughout the ages in people's socialization and entertainment, regardless of age and gender. Research on storytelling with robots has been gaining enormous interest in the scientific community in recent years. In this paper, we present EBO, a social robot designed by the RoboLab Robotics and Computer Vision Laboratory of the University of Extremadura capable of engaging in conversations and interactive storytelling, accompanying the speech with the appropriate emotions, movements, and images. The robot has a screen in the center of its body, on which a wide range of images or facial expressions can be displayed in real-time. In addition, EBO is equipped with different range sensors along its perimeter, a microphone, loudspeakers, and an RGB camera, which allows it to be aware of its surroundings during operation. Thanks to this ability, EBO can interact socially with the people around it, from children to older adults, focusing its dialogues, narratives, and emotions according to the objectives set by the professionals. This article focuses on the robot architecture's main hardware and software components and different social experiments we have conducted in real contexts. We also present the tool: EboTalk, a user interface with which the generation of specific dialogs, narratives, and emotions can be defined quickly and without significant technical knowledge by professionals. The experiments validate the proposed solution in the context of elderly care.

Keywords: Human-robot interaction · Storytelling robot

1 Introduction

Since our origins, storytelling has been central to our ancestors' socialization and entertainment. Over the years, storytelling has been using different media that have evolved with technical developments. Initially, it was voice storytelling, then written storytelling, such as novels and plays, then cinema, radio or television, and more currently, role-playing games or video games. Many of these popular

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types of storytelling represent passive experiences for the audience where, basically, they listen to a story without having the possibility of making changes to the storyline. There are also interactive experiences in written narratives (the 'Choose Your Own Adventure' book series), role-playing games ('Call of Cthulhu', 'Dungeon and dragons') or in the classic computer video games of the 80's, where without great technical boasts, there was a whole stream of interactive narrative games (*e.g.*, classic conversational (or text) adventures, such as the Spanish games 'The Original Adventure', 'Cozumel' or 'Jabato'). As technologies advance, new opportunities arise. This last is the case of social robots, understood as those robots that behave as humans would. A social robot usually can interact with people through different channels, including voice, and in addition, it can express emotions during a conversation. Robots can become a versatile storytelling tool for multiple purposes, from learning, companionship, or therapy with the elderly [6].

In this article, we present the EBO robot, a social robot equipped with multiple sensors for interaction with older people and the ability to display images and facial expressions that identify basic emotions. We also present the EboTalk application, a tool for interactive story generation in which a professional without technical knowledge builds the dialogues and stories and associates the robot's emotion and motion with the player's actions. In our approach, as the **main novelty**, a human player interacts with the robot to build a story. The narrative begins with the EBO robot describing an initial situation with different options to be chosen by the older adult, and it is the latter responds by adding a line to the story in the manner of a conversational adventure. Then, the robot and the person cooperate in the narration, which is further enriched with movements and facial expressions depending on the answers given by the player. This is also one of the **main contributions** of this work. The theme of the narrative and the main objectives to be achieved (cognitive stimulation, socio-emotional or simple entertainment) are defined at the beginning of the therapy. Therefore, the caregiver uses EboTalk to generate the skeleton of the narratives.

2 Related Works

As social robots become more widespread, they present a new avenue for storytelling with a higher level of interactivity. The scientific literature has made concrete contributions on issues related to how robots should connect with an audience [1–5], but so far, most of these works are based on the assumption that the content of these narratives is fixed and does not allow for alterations.

The use of social robots has been increasing in recent years. Social robots are a significant advantage in some areas, such as in the care and attention of the elderly. In general, they represent attractive and fun tools capable of capturing the attention of these groups while supporting caregivers in activities related to physical, cognitive, or socio-emotional stimulation. Along with the latter, the benefits of storytelling are well known, contributing to improving their listening and reflection skills, their social awareness, cognitive and emotional stimulation,

and also to remember their emotional vocabulary and their own experiences. In educational settings, especially over the last years, several robotic storytellers have been proposed [1,3] to support students' learning process and analyze the effects on their learning. In [6], a narrative robot capable of collaborating with people to create original stories was created, although the freedom given in this interaction made it difficult to control the quality of the narration. Most of these works, moreover, did not include the accompaniment of gestures and facial expressions during the story, which undoubtedly enriches the narrative process by avoiding a trivial text reading. In [7], the authors include the latter in their narrator robot NarRob, although it lacks interactivity. Our EBO robot is designed to interact socially with older people. Unlike previous works, its main novelty is the possibility of accompanying interactive stories with emotions, facial expressions, and motions associated with that emotion. Dialogues and narration are easily generated with the tool we also present in this article.

The use of robots with the elderly is also a topic of interest in the last decade. Clearly, in developed countries, the population is very aged, and robots can help this group and professionals. These years, most of the work is focused on companion robots for socio-emotional stimulation [8]. In [9] they describe a robotic platform developed as a personal coach for older adults aiming to motivate them to participate in physical activities. In [10], the authors go even further and present a robot to support older adults with low vision. For mental healthcare of the elderly, the work presented in [11] summarizes the main contributions. Recently, the work presented in [12] uses a concept similar to the one presented in this article for cognitive therapies with promising results. Ebo is a user-friendly platform with capabilities that facilitate affective interaction with the elderly. Our article shows how, in addition, the emotions associated with the player's actions improve the acceptance of the game.

3 Overview of the Proposed Robotics System for Cognitive Therapies

Figure 1 describes the system proposed in our paper. First, the professional team builds a customized narrative game from the EboTalk tool. This tool is simple and can be easily used by personnel without robotics knowledge. The narrative game is composed of scenes, each with an associated story, an image, dialogues, keywords, and the emotions that the robot will have to depend on the actions. These emotions are shown on the robot in two complementary ways: through movements associated with the emotion and the facial expression on Ebo's screen. Next, Ebo uses this game for the therapy through a set of software components that work in a coordinated manner to achieve the goal. The current version performs supervised therapy using the well-known 'Wizard of Oz' [13] technique. The entire session during the game is stored for later analysis by the team of professionals.

The following subsections briefly describe both the Ebo storytelling robot and the EboTalk application.

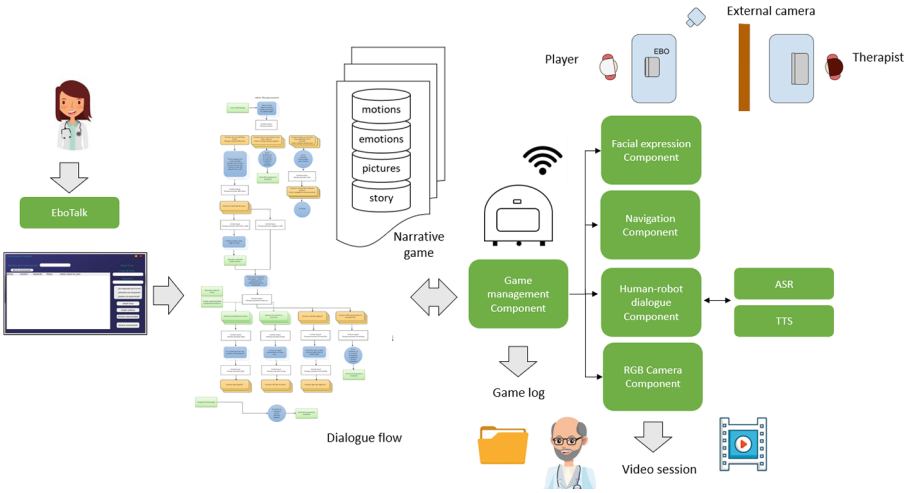

Fig. 1. Overview of the complete system for cognitive therapies with the elderly. Our proposal uses EboTalk for the professional to generate narratives that are then played back by the Ebo robot. All sessions are saved for later analysis.

3.1 EBO: An Interactive and Socially Aware Storyteller Robot

The Ebo storytelling robot of the RoboLab research group of the University of Extremadura was developed within the *Emorobotic* project: *emotional Management through Robot Programming in Primary Education*. Figure 2 shows a schematic and an image of the real Ebo robot. Ebo is a differential platform composed of a set of devices to acquire information from the environment and with the capabilities to express emotions and pictures on its screen. A prototyping system was followed for the external shape to maximize end-user acceptance, resulting in a plastic housing as shown in Fig. 2. The robot has a diameter of less than 15cm, and its weight is less than one kilogram. In its current version, adapted for therapies with older adults, the Table 1 summarizes its harware components:

Table 1. Ebo robot's Hardware components

Hardware component
Raspberry pi 3B+, which includes a CSI port and where the host system is executed to control the other hardware components
Camera with CSI connector: to capture visual information
Servomotor model SG90: provides movements to position the camera at a certain vertical angle
Resistive display (PiTFT 3.5"): for displaying images (e.g. emotions)
5 laser sensors (VL53L0X): to obtain distance information of objects around the robot
PWM pin extender (Adafruit 16-Channel PWM): to provide a stable output to the servo motor and configure the 5 lasers
Built-in microphone and speaker: to provide, on the one hand, audio to the system and output audio information to the outside
2 DC 298:1 (73 RPM) motors in differential configuration to move the base of the base robot
Motor controller (DRV8835)
Battery (7.4 V) responsible for supplying power to the robot. The DC-DC voltage regulator (D24V50F5) reduces the voltage from 7.4 V to 5 V

At the software level, the different components that provide the functionality to the Ebo robot are integrated within the RoboComp [14] framework. On the one hand, we distinguish those components that access the physical devices of the robot, which constitute the Hardware Abstraction Layer (HAL), and that will be used for more complex analysis software. Specific functionalities have been programmed to express basic emotions (neutral, happiness, sadness, disgust, anger, fear, and surprise) in both the robot's screen and basic motions. On the other hand, a component for human-robot interaction has been programmed based on classical Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) algorithms. In summary, the robot control software consists of the following components and scripts:

- Navigation component. This component is in charge of controlling the robot's forward and rotational speeds. This component will receive specific commands for each emotion.
- Laser component. This component reads the laser sensors and uses this information to detect possible collisions during basic movements.
- RGB Camera component. This component controls the servomotor of the camera. Our idea is to follow the face and facial expression of the player during the game.
- Display Component. This component displays pictures in the screen during the narrative game.
- Facial expression component. This component is in charge of generating emotional expressions in Ebo's screen.
- HRI component. This component calls the ASR and TTS algorithms depending on the phase of the game in which it is located. The systems used in the current version employ Google's algorithms, which implies a stable internet connection during the game.

When the EBO robot starts, a WIFI network is created where the rest of the components interacting with the robot will be connected. EBO works autonomously, but a teleoperator can also control it through a friendly and straightforward interface. Communication should be as immediate as possible, so it is predefined through the EboTalk tool. In any case, modifying the dialog flow during game supervision must be possible. The interface, in turn, must allow the possibility of sending emotions and small movements to the robot to accompany the dialogue with some aspects of emotionality.

In addition to this essential control software, the EBO robot can be integrated with the CORTEX cognitive architecture [15], on which the RoboLab research group is collaborating intensively. Thanks to this more complex software, the social skills of the EBO robot are considerably increased by running new software in distributed teams.

3.2 EboTalk

The development of the narrative is done with the EboTalk tool (see Fig. 3). EboTalk is implemented in Python and provides the skills for the generation of

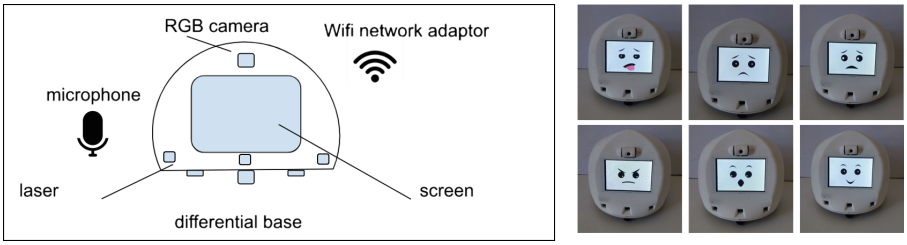

Fig. 2. The Ebo storytelling robot. Device schematic and some of the facial expressions associated to basic emotions.

dialog flow, descriptions, or keywords for use by the Ebo robot (or any other type of robot). EboTalk presents a friendly interface; thus, any user can use it without knowledge of robotics, chatbot, or programming language. The tool generates the flow of descriptions and actions in a .json format that is subsequently read by the code implemented in EBO. Along with the narrative flow, EboTalk adds specific motion and an emotional state to the robot from the set of basic emotions described above.

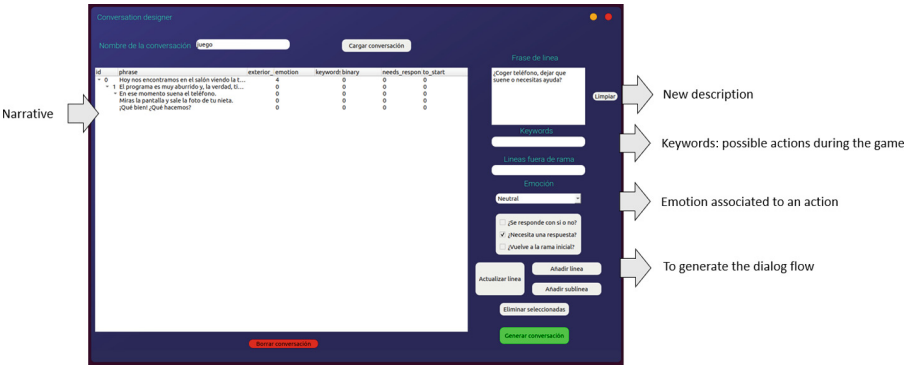

Fig. 3. The user interface of EboTalk, the interactive dialog and narration designer for the EBO robot (Spanish version).

The interactive narratives on which we base our current work in progress originate in the classic conversational (or text) adventures. This genre of videogames, prevalent in the golden age of the 8 bits, stood out because the description of the situation in which a player finds himself comes mainly from a text. All the possible actions the player could perform at any given moment had to be done equally through text and natural language. The result of each action generates a new narrative, and so on. In many of these games, some images offer complimentary help to the narration.

Based on this idea, our EBO storytelling robot will become an interactive social robot with objectives as diverse as cognitive or socio-emotional stimulation. On the one hand, a Text-to-Speech (TTS) system will narrate the content of the descriptive text and the possibilities of action by the user/player. Then, through an Automatic Speech Recognition (ASR) algorithm, it listens and processes the actions that the user performs in this situation. This interactivity gives rise to new descriptions and situations that generate the final story, unique to each user. In addition, depending on the user's actions, the robot can modify its facial expression and convey basic emotions. Figure 4 shows a typical tree of conversational adventures and their application in our case.

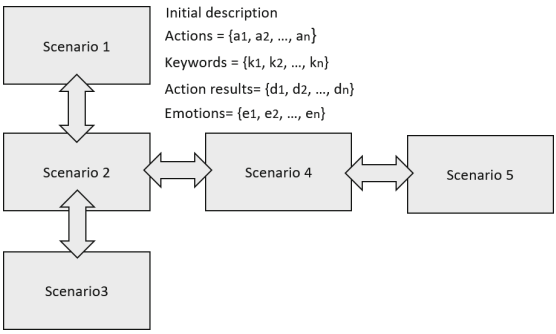

Fig. 4. Basic narrative consisting of five scenarios. Each scene is composed of actions, keywords, emotions and the results of these actions.

4 Experimental Results

4.1 Previous Experiences

Our research group has tested the EBO storytelling robot with a group of volunteer older adults, users of a daycare center in Cáceres. These volunteers receive interventions at the center, including occupational therapy, physiotherapy, and cognitive stimulation, among other services. Before evaluating the narrated stories, we validated the acceptance of the Ebo robot during human-robot interactions using the 'Wizard of Oz' technique. The procedure followed consisted of the following stages. The first contact with the EBO was performed in a group setting, in groups of three people, in which we could already observe the reactions and predisposition to talk to the EBO as if it were a person. The individual interactions consisted of a 12–15 min conversation. A total of four interactions were conducted for each participant. Figure 5 shows a snapshot of the experiment. After an evaluation through video viewing of the conversations and personal interviews, data were collected to assess the acceptability of the EBO. Some of the variables evaluated by professionals using questionnaires were i) the

interest and relevance of the conversation; ii) the high fluency of the conversation; and iii) the perception that the EBO listened to each user. Other variables acquired by observations were i) visual contact with EBO; ii) ability to follow a conversation; iii) pauses during the interaction. The results obtained were very satisfactory and allowed, in addition, the improvement of specific aspects in the voice and social behavior of the EBO robot (e.g., tone, voice intensity, pause times, among others).

Fig. 5. Interaction tests between an elderly person and the EBO robot in a daycare center in Cáceres, Spain.

4.2 Interactive Narrative

In the development of the narrative game, the professionals defined specific objectives of cognitive and socioemotional stimulation and a direct narrative that reinforces basic concepts of the end user's daily life. The whole game has a high emotional component, trying to recreate real situations of the users. The Table 2 shows the description of a specific scene obtained from the EboTalk tool.

We conducted a set of experiments with the same volunteers at the daycare center three months after. Our study included a narrative play session led by the EBO storytelling robot, personalized for each user and supervised by a professional. To evaluate the preliminary results of the narrative game, we used questionnaires to the users (players) and direct observation of the professionals. The table below shows some of the questions we used in the evaluation. We used a questionnaire motivated in the work presented in [16] (see Table 2). As in the previous study, the professionals perceived results were very satisfactory. Volunteers showed more significant interest than other activities, and their attention during the game session was very close. The questionnaires were also very revealing, and all users responded positively to the above questions (Table 3).

Table 2. Example of basic narration for a given scene

Narrative description and objectives	Cognitive stimulation based on the monitoring of activities of daily living				
Scene 1	*Today we are in the living room watching TV. The program is very dull, and you feel like doing something different to tell you the truth. Just then, the phone rings. You look at the screen, and your granddaughter's picture comes up. How nice!*				
	You have the following options: Answer the phone or let the phone ring				
	You can always look, and I'll explain whatever you want				
	You can also go to the kitchen or go to the bedroom				
Actions	Answer the phone		Let the phone ring	Go	Look
Keywords	Living	Bedroom	Kitchen	Phone	Screen
Action results	Answer the phone: your granddaughter speaks to you in her sweet voice: 'Grandma, I'm coming home to eat with you today. Her favorite food is Spanish omelet.' Emotion: 'happy!' Motion: 'happiness'				
	Let it ring: the truth is that you don't feel like talking to her that much now. Emotion: 'sad'. Motion: 'sad'				
	Go + keyword: Ok, you go to + keyword (next scene). Emotion: 'surprise'. Motion: 'go to'				
	Look + keyword: Ok + description associated to the keyword. Emotion: normal. Motion: 'turn'				

Table 3. Question of function evaluation questionnaire for the Ebo storyteller robot

No	Evaluation questionnaire item
1	Which did you feel about the EBO robot feeling? Happiness, Sadness, Anger, Standard, Do not know
2	Do you want to use it again?
3	Could you hear the talk?
4	Is it easy to talk?
5	Is the flow of talk natural?
6	Did you feel that you were interested?
7	Was the feeling suggested?
8	Did you feel friendly?
9	Were you able to talk without getting tired?
10	Are you satisfied with EBO as a storyteller?

5 Conclusions

In this article, we have presented the EBO robot, a social robot with the ability to tell interactive stories and add emotional components that enrich the narrative. This robot has been used to interact with older adults, although what is presented in this article can easily be used with other groups. The EBOTalk tool allows the generation of narratives without much technical knowledge, adding the thread and the different options that can be carried out after the narration. In this way, in the form of a game, the user can engage in conversations that modify the course of the narrative interactively, always accompanied by facial expressions, images, and other aids. A preliminary study has been conducted in a day care center, where we evaluate the acceptability and other metrics in real interaction with our EBO robot.

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