Interaction of a Social Robot with Visitors inside a Museum through RFID Technology

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***Abstract*—In this paper, we present our approach on the design of an RFID enabled social robot that interacts with visitors inside a museum. The proposed prototype is enabled with Simultaneous Localization and Mapping capabilities and the necessary hardware to interact with visitors and the exhibits verbally, visually, through touch and more importantly through RFID technology. Based on related prior art, we focus on the development of specific "games" that demonstrate the potential of RFID technology in human-machine interaction. The capabilities of the robot and some representative scenarios are presented herein.**

***Index Terms*—RFID, Museum, Robot**

I. Introduction

This work represents part of the project "CultureID" [1]. The project seeks to highlight and integrate new technologies, such as the Internet of Things, Robotics, Big Data Analysis and Artificial Intelligence in Culture. Our team integrates RFID technology in the Archaeological Museum of Thessaloniki, shaping the necessary conditions for interaction with the exhibits and develops a series of innovative products that exploit and showcase the possibilities of RFID technology, shortly presented in the next three paragraphs.

Each exhibit is associated with a unique RFID label. The location of the exhibit is monitored through a dense network of RFID readers. Thus, when an exhibit is moved, e.g. to perform a restoration action, the movement is recorded by the system. In addition, the personnel who moved the exhibit is recorded. The personnel is responsible to record the action documenting this movement and the action is stored in the Museum's new database. Thus, this operation will follow the exhibit, uniquely completing its digital identity.

A portable RFID reader with a touch screen is built. The project team develops prototype algorithms for locating RFID tags (and therefore exhibits) from the portable reader. Thus, the visitors will be able to enjoy a digital tour, simply by "identifying" the exhibit in front of them. In addition, "games" are developed for younger visitors who will take advantage of the "discovery" features offered by the mobile device, as presented in the following sections.

Finally, we develop a prototype social robot with integrated RFID technology for interaction with the physical world. The robot aims to stimulate the interest of younger visitors through actions (games) presented herein. The robot is able to map and locate itself (Simultaneous Localization And Mapping - SLAM), move in space, recognize obstacles, voice-interact with humans (ASR and TTS), while artificial intelligence algorithms are suitably adjusted for the integration of games with younger visitors. The robot will also integrate prototype technology for recognizing the position of labels (and therefore exhibits) and autonomously navigate towards them.

This paper is focused in the interactions of a social robot with visitors inside the Archaeological Museum of Thessaloniki through RFID technology. Section II presents prior art in the field of Social Robotics and RFID interactions in culture. Section III gives an overview of the desired properties and technical details of the RFID-empowered social robot. Section IV presents two characteristics "games" that match the goals of social interaction with the robot and Section V the conclusions.

II. Prior Art

In the framework of this project, educational scenarios were designed utilizing specific characteristics of the robot and of the mobile device with the RFID technology, that promote the interaction between the robot and groups of children - visitors of the museum. The actions will be guided by the robot and with the assistance of the RFID mobile reader, the children will be asked to make choices, to tour around the museum exhibits, to solve riddles and decide how a story will unfold and finally they will be evaluated by the robot itself.

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In the last years many innovative Information and Communication Technology (ICT) solutions have been used in the cultural sector in order to make cultural artifacts more approachable and appealing to a larger audience [2]. New strategies to engage museum visitors have been presented as a result of the recent technological advancements. Examples include technology from simple mobile apps and interactive displays to virtual reality and augmented reality scenarios and social robots as tour guides. Museums around the world began using robots as museum guides as an alternative to audio guides, as they take advantage of the robot's ability to communicate and engage humans in a relatively natural and comfortable manner [3].

The significant and ongoing advances are achieved by creating an interactive environment that invites more visitors to museums and assists them to accomplish objectives of challenging tasks and cultural education [4].

Social Robots around the world have been employed in various fields such as education, healthcare and general activities that incorporate interaction with humans. Museums worldwide have started using social robots as museum guide robots and many researchers work on improving them, either in terms of their navigation around the museum or in terms of the interaction with visitors [5]. Museum robot Lindsey is an example of a long-term deployment of an autonomous tour guide robot. The key factor for successful interaction with humans stems from their ability to communicate via verbal and nonverbal signs and also to express themselves via facial expressions and body movements [6]. Another important aspect of a fruitful human-robot interaction stems from the embodiment of social robots that can affect humans' decision-making process and attitudes towards them. Additionally, humans who interact with robots with physical embodiment tend to evaluate them as more trustworthy, credible and show significantly higher attachment with them [7].

Regarding the Radio-frequency identification technologies (RFID), its ability to wirelessly (hence invisibly for human perception) identify, localise and associate objects have a lot of applicability in museums and are being employed in novel ways [8]

As museums move into the digital era, RFID solutions can help them overcome various security and operational difficulties. Tagging artwork, exhibitions, and artifacts and establishing read zones across the museum allow real-time location monitoring and tracking, which is transforming the museum overall. Readers can additionally be placed at locations throughout the museum, such as entrances, exits, and windows, to inform the staff when art passes through them and if someone approaches too closely the exhibits an alarm can be triggered [9].

RFID can strengthen the social robots' functionality to interact with the physical world. We propose actions to demonstrate this potential. RFID technologies and systems are used in several museums and embodied into tour guide robots, which can guide visitors through a predefined tour of the building, or even create new routes while navigating [10]. Numerous navigation technologies of wheeled robots are employed for indoor environments. Many robots that socially serve in different sectors that need to show hospitality to the humans, are using RFID technologies. For instance, in a museum environment where robots are not only interacting with a human by sharing information but also navigate and avoid obstacles [11]. RFID tags have been used as the means for robots' localization [12].

Thanks to RFID technology the robots or mobile readers can identify a person and trigger activities and/or identify an object and trigger activities. Disposable RFID tags, with each tag encoding basic information, e.g., a name by which the person/ visitor wants to be known are made available to visitors. The V-Markers represent another technology able to detect visual markers by using the omnidirectional cameras. Shared memory is also used to transmit the detected markers to other threads and share data in the context of RF-Tag detection. Doris is a museum robot with an RFID system used for identifying semantic items placed throughout the environment and identify people rather than using RFID for localization, by executing at the same time task planning for the navigation system [13]. RFID also enhances the dynamics of a person-following robot [14]. Researchers have shown that the robot has the ability to localize objects or persons and show intelligence. When testing the mobile robot agent, CoBot in real human-robot indoor activity, despite its disability to open doors or its lack of hands, it was positively evaluated due to its successful navigation and its ability to localize areas and share knowledge [15].

RFID readers combined with mobile devices in museums are a powerful asset that promotes playful environments. Advantages of utilizing them are that they reduce the visitors' cognitive load, promote various interactions (graphics, texts, voice, etc.) and all users can participate, regardless of a disability. The games that are designed to be applied through RFID technologies support any number of users (one or multi-player game), can be expandable and no specialized knowledge of the device is needed [16].

III. Social Robots

A. Desired properties of a Social Robot

Several studies [17] have indicated that humanoid robots tend to be more attractive to people than non-humanoids. For instance, people prefer to engage in activities where the robots utilize gaze behaviors to highlight certain tasks or share information. Robots that are able to look around and move attract people's attention more frequently than those that have not the ability to replicate movements [18]. Such interactive behavior has also been proven competent for museum guide robots. Visitors tend to remember more information from a robot's storytelling when the robot look at them while talking [19]. Another important aspect is the robot's personality. People prefer to interact with a cheerful personality robot for cheerful activities such as a museum guiding tour and are also able to recall more information from a cheerful museum robot storytelling in comparison with serious personality robots or even from conventional audio systems [20]. Moreover, studies

have shown that a tour guide robot that is expressing a friendly attitude while it was greeting visitors by their names, lead them to express the desire to interact with the robot again at a percentage of 94.74% [21].

B. Fuctionality of the Robot used

Our robot's functionality originates from the group's expertise in robotics and RFIDs, already applied in the context of project "Relief" [23]. We have constructed two terrestrial robots, "Frida" and "Loci", destined to perform autonomous 24/7 inventorying through UHF RFID technology. The two robots are shown in Fig. 1. Those robots are able to create a 2D map of the environment, thanks to the "Lidar" sensor installed and localize their own pose inside the map. In fact, they can perform SLAM - Simultaneous Localization and Mapping. An example of such a 2D map is shown in Fig. 2. They are also equipped with RGBD cameras, which empower them to increase their perception in 3D space. The RGBD sensors are used to create 3D maps of the environment, as demonstrated in Fig. 3, but more importantly allow us to distinguish moving obstacles (i.e. people) from the "background" map.

Fig. 1. A photo of inventorying robots "Frida" and "Loci" [23].

The robot is able to navigate autonomously and dynamically, based on the perception of the environment. Navigation is based on the perception of the 2d map of the environment. The robot's own pose (location and orientation) is estimated accurately (less than cm error) in real-time, thanks to the embedded Kalman and Particle filter algorithms that exploit the rich measurements provided by the lidar sensor.

The same sensory-equipment will be embedded in the museum's robot; thus ensuring, as a minimum, at least the same

Fig. 2. A 2D map created by the robot.

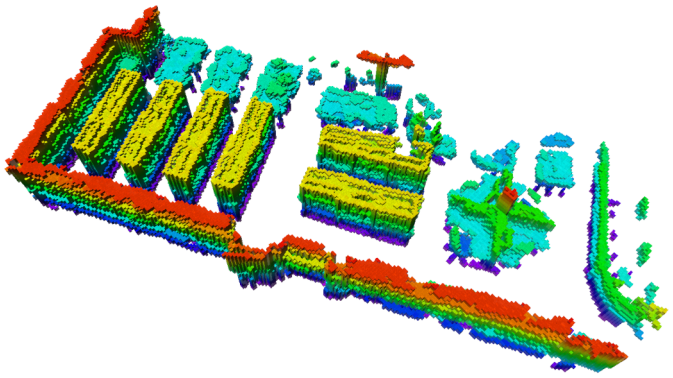

Fig. 3. The 3D map created by the robot.

functionality. In contrast to the robots of Fig. 1, which were designed to be tall, to ensure inventorying at greater heights, the social robot is much shorter, with a maximum height in the order 1m, to support friendly interaction with groups of younger visitors. The UHF RFID reader, along with at least two small-form-factor, closely spaced, microstrip antennas will be hidden inside the "chest" of the robot, allowing for interaction, localization and 2d-direction-finding capabilities with the surrounding RFID-tagged items. The robot will host a touch screen reproducing its facial expressions and allowing for interactions by means of touch in the context of the games presented next. Furthermore, the robot is equipped with Speech To Text and Text to Speech capabilities, in order to support verbal interaction with the visitors. The group has developed prototype algorithms based on artificial intelligence to perceive the context of the "talks" with the visitors and respond accordingly. Finally, the robot will include a camera, able to "identify" objects/people in the surrounding environment and then interact "personally".

Summarizing, the robot includes the following technical properties:

- 2D and 3D map creation.
- SLAM.
- Accurate real-time localization of its own pose.
- Obstacle avoidance.
- Dynamic path planning.
- Interaction with RFID tagged items.
- Localization of RFID tagged items.

- Direction finding of RFID tagged items.
- Speech To Text.
- Text to Speech.
- AI to perform verbal interactions (conversations).
- Camera for visual identification.

In the following section, we present some representative scenarios, focusing on the exploitation of RFID technology.

IV. Representative Scenarios

A major task of the project CultureID concerns the design and development of Museo-Pedagogical activities for visitors (mainly students), using the RFID-enabled social robot and the portable RFID reader with localization-capabilities, developed by the group. The social robot will play the role of a facilitator, aiming to motivate, guide, and support the visitors (students). At the same time, the RFID reader (with the RFID tags installation at each cultural artifact of interest and also on the activity tangible material and also on each tangible material of the activity) will offer the possibility of a) identification of the artifact from the robot, b) identification and localisation of the artifact by the users (students), and c) presentation of the artifacts' information to the users. The two Museo-Pedagogical activities and their implementation scenarios that have been developed offer different educational contexts for familiarisation with the artifacts, knowledge acquisition through serious gaming, and skills and attitudes concerning museum exploration and its exhibition approach. In this way, the project aims at the soul of the museum visiting action, the museum experience, and specifically to support the development of a dialectic dynamic between visitors and the artifacts [22].

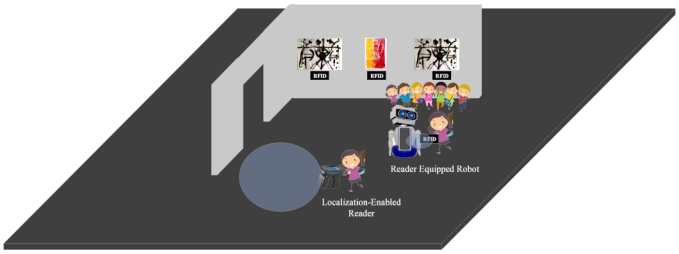

Fig. 4. Abstract representation of the equipment involved in the scenarios.

A. Scenario 01. TITLE: "Solve the riddle"

Roles: Thanks to its localization capabilities, the robot moves at a specific point inside the museum and rests. Then it uses its screen to present a video with a sequence of events, concerning a certain historical period, exhibits of which are currently located in the specific room of the museum (thus related to the robot's knowledge of the map). A group of children engages in interaction with the robot with a number of RFID-tagged cards. Each group of children is given the localization-enabled prototype RFID reader. The robot is the tour-guide and the portable reader is the children's assistant. The robot also interacts with the RFID reader and with the cards with the tag. The children are also given a board to place the cards of the events in the correct chronological order. A child's communication with the robot is fulfilled through:

1) the robot's screen (touch screen and facial expressions),
2) the mobile device,
3) the cards with the built in RFID tags,
4) voice

Activity Description: Children are shown how to operate the mobile RFID reader device, and how to interact with the robot. The robot is located close to the exhibits that will participate in the game. The robot presents a video at its screen about a sequence of events of a certain historical era, focusing on five important chronological events. Children are given to operate the mobile RFID device and the cards with the RFID tags. Each card is the answer to a riddle concerning the chronological order of the presented video.

As soon as the children see the video, the robot asks them to show the first card of the time sequence. When the children select the card, they approach it to the robot and from its screen they select "read". The robot reads the information and it informs them if the card is correct or not. If the card is wrong the robot urges the children to think again.

As soon as they show their correct card, the robot sets a new riddle related to the exhibit to which the card relates and is located in the surrounding. It informs the children that in order to collect the information needed to solve the riddle, they have to take the portable reader to collect the necessary answer from an artifact in the exhibition, which will allow them to answer the puzzle and urges them to show the card to the mobile device and choose "read".

The mobile device reads the RFID card and guides the children with sounds and arrows (directions) to the exhibit that solves the riddle. When finding the correct exhibit, assisted by the portable RFID reader, the children look for the information that, in their opinion, answers the riddle (it may be related to the caption or maybe they have to measure something, notice the colours, the shape or even the material of the exhibit, etc.). When they are ready, they return to the robot, they choose the correct answer from a multiple-choice list, that is shown on the robot's screen.

If the answer is correct, they place the card on the first box of a board, and they proceed with the next card until they solve all five riddles following the previous steps. In the end, the children are informed about the time they managed to solve the riddles in relation to the other schools (as in popular top-gear board).

Activity Model: The robot has five behaviors functions/postures:

- It has a face and performs voice commands to guide the children throughout the game
- Its face performs facial expressions in order to promote immediacy to the interaction
- It has a screen that presents the video that it narrates
- It interacts with the children through its touchscreen
- It communicates with the RFID reader

B. Scenario 02. Title: "Quiz"

Roles: The robot is the tour guide of a certain exhibition of the museum and a cheerful presenter of the game that gives prompts and motivates the two teams to find the correct answer. The portable reader in this scenario is used, when the children need an assistant.

Two groups of children are the opposite teams playing the quiz game, that need to interact with robot through RFID tagged cards. Also, children use the portable localisation-capable RFID reader to guide them through the exhibits when they need assistance to answer a question. A child's communication with the robot is fulfilled through the:

1) the mobile device
2) the cards with the built in RFID tags
3) the robot's screen (touch screen and facial expressions)

Activity Description: The robot is touring a specific exhibition of the museum, describing its most important exhibits and demonstrating them at its screen. Then it conducts 5 quizzes with multiple choice questions to the children, each question has 3 possible answers. The children are divided into two groups, and are given cards with RFID tags. Every card of a group is unique and corresponds to an answer of a question. So, every group of children takes three sets of cards for every question that the robot asks. Every group of children decides which is the correct answer and reaches the corresponding card to the robot; each team cannot know what the other team answered, since the answer is not visual (it is programmed in the RFID card). The robot automatically recognizes from the RFID tag of the card which team brought which answer. The robot reads the card, waits for the answer of the other team and then calculates the score – one point for every correct answer.

Whenever a team needs assistance to answer a question, it is assisted by the mobile device, which is already informed by the robot which is the question that the two teams need to answer. Through sounds and arrows it guides children close to the exhibit that matches the correct answer. In this case this team is awarded half point. The team that is the first to answer five of the questions correctly is the winner.

Activity Model: The robot has five behaviors functions/postures:

- It has a face and performs voice commands to guide the children throughout the game
- Its face performs facial expressions in order to promote immediacy to the interaction and be a cheerful presenter of the quizzes.
- It has a screen that presents images of exhibits.
- It interacts with the children through the cards with the built in RFID cards.
- It communicates with the RFID reader.

V. Conclusions

This paper presents a set of newly developed Museum-Pedagogical scenarios assisting children–visitors of the museum to engage in activities with the guidance of a social robot and utilizing a mobile RFID reader. Two different representative scenarios are outlined for supporting synchronous interaction with the robot and with the localization-enabled portable RFID reader. The utilization of a robot with a joyful character is expected to motivate children to participate in the activities and help them assimilate the new knowledge. The mobile RFID reader device, which basically plays the role of an assistant tool, is expected to encourage all children to more consciously participate in the activities and solve the requisite riddles with enthusiasm and joy. The whole design aims to support the development of a dialectic dynamic between visitors and the artifacts and also to help them adopt proper skills and attitudes for museum explorative and inquiring visiting.

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