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RoboParrot 2.0: A Multi-Purpose Social Robot

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***Abstract*—A large variety of social robots with various applications have been developed recently in order to improve Human-Robot Interaction (HRI) and satisfy certain social needs such as companionship. However, they cannot be deployed in Middle East due to their inability to have verbal communications in user's native language, availability issues, and high costs. This research introduces the design and development of a semi-autonomous robot called RoboParrot which can be used in various applications such as Autism Spectrum Disorder (ASD) therapy, teaching foreign languages, and elderly companionship. Previous versions of RoboParrot have been successfully deployed as a tool for ASD screening and have shown high acceptance rates among children. The new version has been used for interaction with both autistic and typical children and also elderly people. The platform is capable of adding further features to increase its autonomy so it can be widely used in homes of independent-living elderly people, nursing home, hospitals, and for home based ASD therapy. In order to expand applicable fields, various features have been added to the robot making it a multi-purpose portable social robot.**

Keywords— Social robot; Human-Robot Interaction; Robot-Assisted Therapy; Robot companion; Native voice command

I. INTRODUCTION

Human-Robot Interaction (HRI) has become a trending topic among researchers and a vast variety of socially interactive robots have been developed for a variety of applications such as companionship, edutainment, assisting people with everyday tasks and Robot-Assisted Therapy (RAT) [1-4].

In the field of RAT, there are many robots developed or used to help in the therapy of children with Autism Spectrum Disorders (ASD) [5-8]. In the case of RAT for children with ASD, due to their high interest in technological tools, robots have shown great potential for augmenting human therapists, in a way that even non-robotic researchers are contributing and have conducted studies [6, 9].

In the case of HRI for elderly two major types of robots have been developed: service robots and companion robots. The service robots are used to assist elderlies in their daily activities and the companion robots are used to provide or replace the needed social interactions for elderly. Both categories aim to improve the Quality of Life (QoL) which is shown to help for longevity [10].

Despite recent research endeavors, proper social robots for successfully deploying in other cultures, other than the origin of the robot, are not yet available. They cannot be easily used by other culture and language users due to their inability to have verbal communications with users in their native language. Furthermore, these robots have limitations in working in natural human environments, are not widely available, have lack of social acceptance, and they are very costly [11, 12]. RoboParrot is designed and developed to address a few of these issues. It is designed such that the users get used to it, so long term interaction would be possible for better impact [13].

In this paper we present RoboParrot 2.0, an intelligent socially interactive parrot-like robot which is based on the previous versions of RoboParrot [14, 15]. RoboParrot 2.0 is a portable and semi-autonomous social robot which can operate in full autonomous mode, combined autonomous with remote controlled mode, and full remote controlled mode. The robot has a Persian voice command system to verbally interact with users in Persian. It can also interact with users in English. Furthermore, it has automatic face, object, and color detection capabilities, allowing the robot to interact with users autonomously. The remote operation of the robot is done through an easy to use and cross platform GUI (Fig. 1).

Fig. 1. RoboParrot 2.0 in its cage which provides secure and safe environment for both users and the robot.

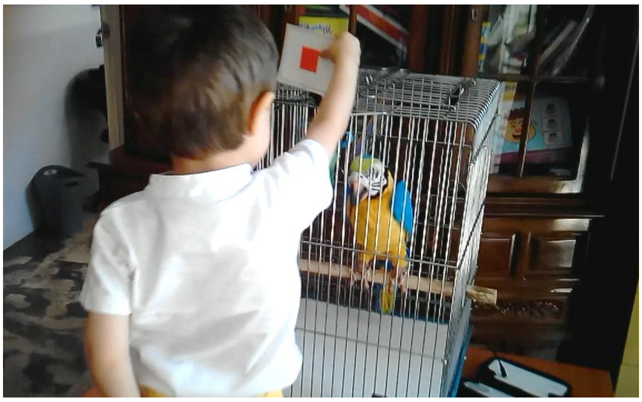

Fig. 2. A child with autism interacting with RoboParrot 2.0, showing it a card and asking about its shape and color

RoboParrot 2.0 has been oriented to the Iranian culture and language while it can be used in English speaking countries which makes this robot stand out among other social robots. The robot has been deployed for autism screening and rehabilitation and is currently under test. It is also under test with elderly people and normal children. The initial tests of RoboParrot 2.0, in Iranian Center for the Treatment of Autistic Disorders (CTAD), show better acceptance, compared to RoboParrot 1.0, among children and better interactions via various capabilities developed on the robot (Fig. 2).

II. Potential Deployable Applications

This level of autonomy elicits so many deployable applications for RoboParrot from which a few are listed and elaborated here.

A. *Home-Based Autism Therapy*

Using social robots in RAT is an ongoing research trend, specifically for helping children with ASD. Autism is a neurodevelopmental disorder resulting to impaired social interaction, communication difficulties, and stereotyped repetitive behaviors [16]. Recent research has shown that children with ASD interact better with technological tools like social robots than their playmates, family members, and therapists [3, 17].

The previous version of RoboParrot, i.e. RoboParrot 1.0, was successfully used as an ASD screening tool in the past [15]. It was also used for turn-taking therapy in which a child learns how to correctly decide whether it is his/her turn to speak or act. In this study, it was seen that the presence of such social robot in therapy sessions and clinical environments is beneficial in therapeutic interventions for children with ASD [14, 15]. The ease of handling and the autonomy of the newly developed RoboParrot makes it possible to continue therapy sessions at home without the supervision of a therapist. Furthermore, it is expected to make current robot-assisted autism therapy more efficient and easier. The capability of deploying a robot at home would open up daylong interaction which potentially helps children to better learn the needed skills. Furthermore, it would allow interaction between children and parents through the robot [4, 17].

RoboParrot 2.0 can be used in therapies such as turn-taking, joint attention, and self-initiated behavior [3]. Also interactive social games with RoboParrot can be defined to help children with ASD make better social decisions in everyday activities.

It should be noted that the families with children with ASD are under huge pressure since they do not know how to interact with their children or they do not have the patience to work with them. Using a social robot, such as RoboParrot, would ease up this process and empowers the parents of children with ASD to work with their children.

B. *Robot-Assisted Language Learning*

Despite limitations of RoboParrot 1.0, it showed great potential for deploying RoboParrot in the field of edutainment. The newly added features and the ability to interact with users in their native language, makes this robot suitable to be used as an interactive teaching tool. For instance, shape and color detection features could be used in order to answer queries about objects for teaching basic geometric shapes and different colors to children and help them to learn better social interactions.

Case studies prove the effectiveness of HRI in foreign language education and recent research conducted on normally-developing language learners [2, 18, 19] suggests Robot-Assisted Language Learning (RALL) will lower children anxiety levels and increase interest in learning a second/foreign language. Appealing design and attractiveness of RoboParrot yields very high acceptance rate among Iranian children. Its appearance is so appealing that even young adults were attracted to its communication skills. With adding a second language, such as English, it could be used as an assistive teaching tool for children to learn a second language.

C. *Companionship for Elderly People*

Social studies and demographic analysis show that the distribution of human population is intensely changing where the proportion of older adults will increase eventually [20, 21]. Elderly people form a fragile part of a society that, alongside having to go through the aging process, have trouble fulfilling their social needs and tend to seek companions. Addressing their social needs can help cope with the challenges of aging and overcome its difficulties resulting an improved QoL [22].

Developments of technological tools such as social robots can be useful for adapting to the future changes in population [1]. For instance, many older adults do not need help in their daily life activities and live independently thus have to face aging challenges alone. Consequently, deploying a companion robot, for even the slightest social interactions, can address certain social needs and promote successful aging, a decent way to ensure maintenance of QoL [22]. At the same time social robots can be used in nursing homes for socially interacting with elders and entertaining them, reducing their caregivers' work load.

The advantage of using a parrot like robot is that parrots are naturally used as companion pets and are highly acceptable among elders. However, real companion parrots require constant care and attention and require complicated nutrition. Also the cost of parrot keeping is higher than regular pets and isn't easily affordable. Thus RoboParrot brings the joy of parrot keeping without all the work and bite marks. Due to its safe, robust, and autonomous design no supervision is

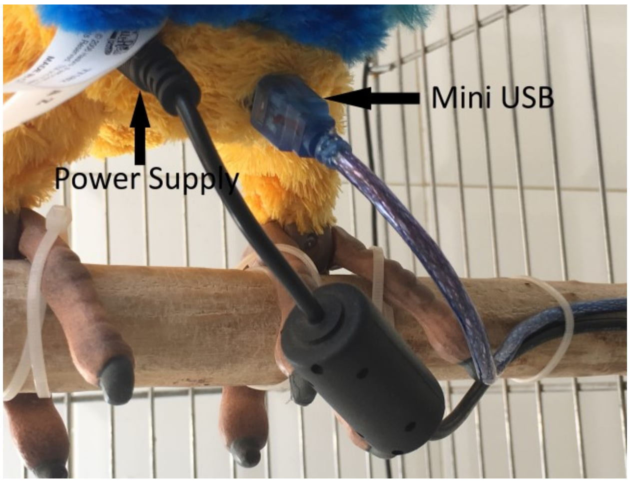

Fig. 3. DC jack and mini USB ports

required which makes it suitable to be used in homes of independent-living elderlies, nursing homes, and hospitals.

III. RoboParrot Design and Development

A. Exterior Design

RoboParrot initial design was based upon a Hasbro Company's[1] toy which is inspired from Macaw parrots. It has such a realistic design that could be mistaken for a real Macaw parrot at first. We decided to develop a parrot like robot due to its intelligence and natural verbal interaction ability. These features in addition to its social appeal and charming appearance make it highly attractive and acceptable. It has been placed inside a cage, a natural environment for parrot pets, as a mean to ensure both users and robot's safety meanwhile giving younger children a safe distant to approach the robot without administration and restriction unlike similar studies in HRI [2, 4, 7] (Fig. 1).

Although the mechanical structure of RoboParrot 2.0 is basically the same as RoboParrot 1.0 [14], the robot's controller has been integrated into the robot. Thus, there are only two jacks, one is a mini USB port for communicating with a mini computer and a DC barrel jack for connecting to power supply (Fig. 3), which are sewed inside the tail thus are not easily visible. The cage has been replaced with a more spacious and durable one and a custom designed tray is hidden at the bottom leaving enough room for extra hardware components (Fig. 4) such as mini computer, the voice command hardware, and speakers. A small package is designed and developed using a 3D printer to house a microphone for voice command interaction. A dimmed blue LED is also placed on the package to indicate when to speak (Fig. 5) to the robot. The package fits between front bars of the cage for easy access. Finally, a camera is placed at the top front of the cage for maximal field of view.

B. Hardware Description

Robots mechanical properties haven't been changed, degree of freedom is the same and still two motors are being used [14]. However, the controlling hardware has changed significantly and a few new hardware have been added to the system, giving it more capabilities.


Fig. 4. Mini computer and other necessary hardware components, which are fixed firmly upon the surface of the bottom tray

All the hardware components are fixed in place upon the surface of the bottom tray and have been thoroughly tested. Only one power supply wire comes out of the robot to be connected directly to a power supply, therefore it's constantly ready to operate. It should be noted that the robot can operate on battery too.

The RoboParrot's hardware consists of four main parts. Fig. 6 shows a block diagram of all the main hardware components and how they interact with each other.

1) Mini Computer: A mini computer with Intel Core i3 processor, running Windows OS has been used to receive and process video stream from the camera, respond upon incoming data from voice recognition module, retrieve and process sensors data from the board inside robots body, send required commands related to movement of the body, connect wirelessly to third party devices for remote control and observation. Mini computer is basically the main platform for running all the software which will be elaborated thoroughly in the next section. It should be noted that a mini computer was used for ease of design and development. The new very

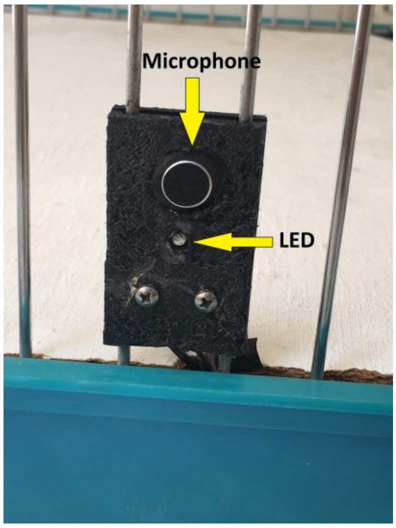

Fig. 5. 3D printed case for the microphone and the indicator LED

[1] www.hasbro.com

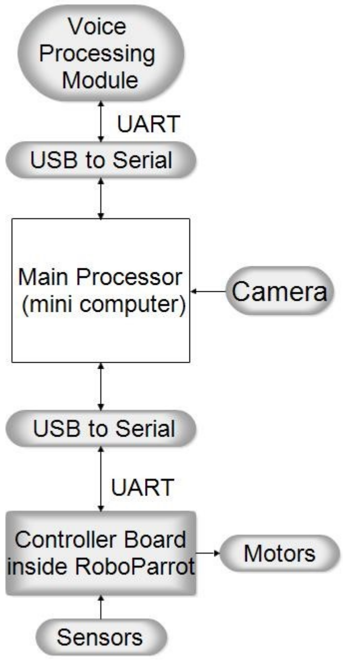

Fig. 6. Hardware schematics

small scale mini computers such as Rasberry PI can be used instead of the current mini computer.

2) Controller: The RoboParrot 1.0's controller hardware [14], which consisted of two boards, were redesigned from the ground up to turn it into only one board. It collects and sends sensor data to mini computer, controls movements of the body via driving the motors and sends general feedback to mini computer. The controller includes micro-controller, USB to Serial converter for communicating with mini computer, drivers for sensors, and motor drivers (Fig. 7).

3) Voice Recognition Module: EasyVR 3, a cost effective multi-purpose speech recognition module manufactured by Veear, was used for voice recognition and developing a Persian voice command system. Since this module communicates with other devices through UART protocol, a USB to Serial converter was used for connecting EasyVR to mini computer. six general purpose I/O lines are available on the module that can be controlled via UART commands, one of them was used to drive the blue LED for informing the user when to speak. A 3D printed case was designed for its microphone and the LED, to be safely attached in front of the cage between the front bars, in a way that minimum noise is being picked up by the microphone.


Fig. 7. The PCB layout, which was designed in a way to fit in the limited space in RoboParrot's body

4) Camera Module: A Logitech C615 Webcam, with 8 megapixels resolution, a wide lens, and built-in autofocus (up to 10 cm from the camera lens), that can stream video in HD is used to send video feed to mini computer via USB for processing.

C. Software Modules Structre

RoboParrot 2.0 has been advanced in a way that can operate autonomously. The back-end software development was done using free open source and cross platform tools to keep costs down. For instance, OpenCV for processing the incoming video stream and Qt 5.3.2 as a tool for creating GUI and developing multithreading are used. It is worth mentioning that the whole system were tested on a Raspberry Pi 2 Model B, running Ubuntu Mate as OS, and it functioned flawlessly.

The software is written in modular form consisting of the following modules: the initialization module, the voice recognition module, the vision module, the command module, and the remote control module. At start-up, the initialization module is called to establish communication with the vision module, the voice recognition module, and command module. It also checks potential connection errors. After start-up, the robot goes to its default mode which is verbal interaction and acts according to user commands. The software modules and functionalities are elaborated in the following.

1) Remote Control module: RoboParrot can be operated remotely with any mobile or desktop device independent of the OS, courtesy of TeamViewer application and an easy to use cross platform GUI. Mini computer runs a script at start-up which creates an access point for wirelessly connecting remote clients to it while a host TeamViewer local server is running in the background, it gives users the ability to remotely observe/control the robot's behaviors. Fig. 8 and Fig. 9 show different elements used in the GUI.

2) The Voice Recognition Module: after evoking verbal interaction mode, the main voice command recognition module is called which sends recognition interrupts to EasyVR and retrieves the recognition results in five second intervals. Then, recognition results are passed to the command module, which handles all incoming sensor data as well as voice commands. This module will call other required modules for properly responding to the recognized voice command through a variety of static responses that are available for verbal interaction, e.g. pre-recorded phrases, musics, or real Macaw parrot sounds. A vast database of static responses have been created to give the robot more spontaneity. All the sounds are synthesized in order to get RoboParrot's voice pitch close to a real parrot. . Sixteen Persian voice commands have been statically trained using the previously mentioned voice recognition module i.e. EasyVR. Implemented voice commands have been correlated to the associated modules in order to answer user queries about objects geometric properties such as their shapes and colors.

It should be noted that EasyVR recognition hit rate is not ideal, but it is fairly acceptable for now. We are considering

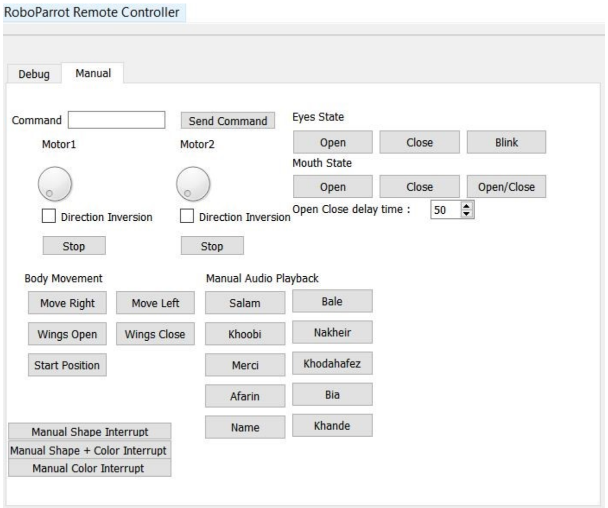

Fig. 8. RoboParrot Remote Controller Interface: including a textbox for sending commands directly to the controller board inside robot's body, different types of button for controlling motors and robot's body movements such as its wings, eyes and beak, some of the most used pre-recorded messages for manual playback, buttons for manually sending interrupts to vision module.

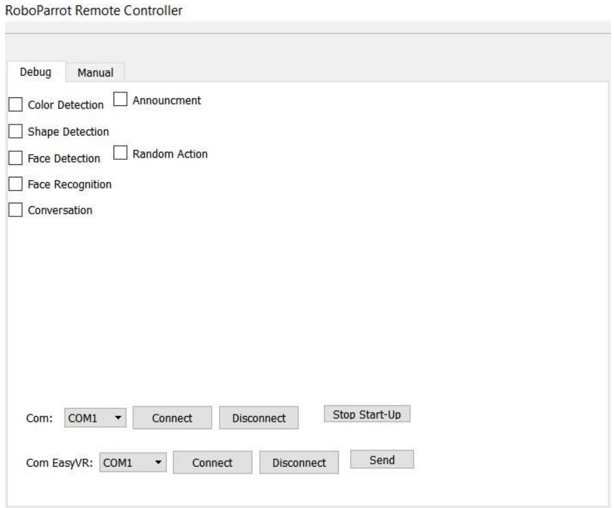

Fig. 9. The debug tab which brings functionalities such as stopping start-up module, changing communication ports and observing the behavior of computer vision modules for monitoring and debugging.

other voice recognition methods to replace EasyVR in order to achieve minimum recognition failure.

3) The Vision module: The vision module is always being executed in the background which handles various tasks such as a greeting function, developed to greet the forthcoming user upon face detection [23] and initiate conversation. It resets when hears goodbye from a user or when nobody has not intracted with the robot for a while. Face detection module is also used to check whether a face is being detected to know if someone is using the robot.

A color detection module is developed which currently can detect nine different colors. It works in RGB color space and checks the ranges with embedded static ranges in the code, which are gathered from different lighting situations and were optimized for the specific camera used in RoboParrot 2.0.

Another implemented module is the shape detection module which can detect circles, squares, and triangles. At first, color space is converted to grayscale for decreasing the CPU load and increasing efficiency. Then Canny Edge detector algorithm [24] is applied and objects' corners are detected from line intersections, using corners and angle degrees. Then shapes of objects are detected. Also a modified version of Hough Circle Transform is used for efficient detection of circles (Fig. 10).

Also to increase robustness, a visual trigger system was developed, to initiate shape and color recognition upon seeing a card, to improve the performance and reduce errors. When an object query is received from a user, RoboParrot 2.0 prompts the user to show the desired card, then a motion detection algorithm with optimized threshold detects whether the card has been put up in front of the camera or not. It also applies the detection algorithms in a period of time after triggering and takes all the frames into account, in attempt to minimize detection errors, then properly responds or lets the user know that it could not detect any cards or understand the object's shape/color.

The mentioned computer vision algorithms are all typical algorithms with tweaks to run more efficently, resulting a fairly good recognition rate.

4) Random Behavior: Another module that is always running in the background is the random behavior module. It creates random body movements, random phrases, and random parrot sounds, which is an imitation of real Macaw parrots. This feature is developed to attract users and create a sense of reality for the robot.

5) Debugging and Future Development: Also an easy-to-use debugging system is provided for making future developments simpler. It can show the region of interest, draw detected shapes and faces, and print RGB and detected colors which can be selected in the GUI via checkboxes in the manual tab. Also an exception system is provided for easily debugging any issue that may come up such as capturing empty frames and communication problems (Fig. 9).

It should be mentioned that the software system was developed in a way that has a modular structure which makes future developments and adding extra modules easier. All kinds of modules can be added to the current system in order to improve RoboParrot's capabilities, for instance addition of continuous speech recognition will make RoboParrot more intelligent, expand its means of interaction and make it more

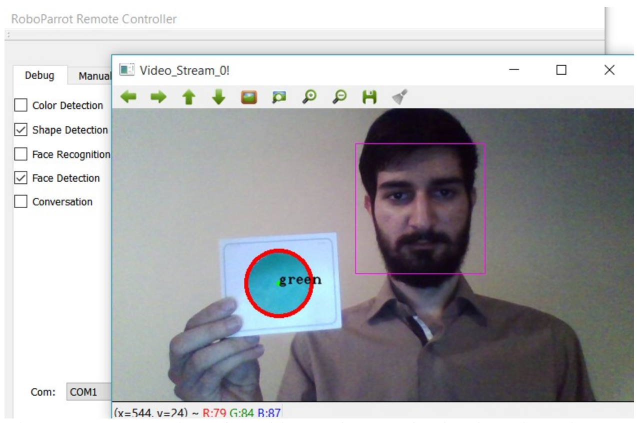

Fig. 10. Demonstration of an object's shape and color detection, along with the face detection feature.

suitable for providing companionship. It can specially be beneficial in RALL and can make it possible to use the robot in more advanced language learning classes.

As it was mentioned earlier, the software system is cross platform and it was tested on a Raspberry Pi 2 and gave an acceptable performance. Therefore, the main platform may be changed to the new Raspberry Pi 3, or other similar small scale mini computers, in order to save more space, reduce energy consumption and improve portability.

IV. CONCLUSION AND FUTURE WORK

This paper presented the development of RoboParrot 2.0 and discussed the potential values of deploying RoboParrot in different fields. The results of initial tests aimed to explore different applications of this robotic platform, such as companionship, education, and Robot Assisted Therapy (RAT). The current prototype of RoboParrot 2.0 is ready to be utilized in clinical centers for assisted ASD therapy, nursing homes, and in homes of independent-living older adults for companionship and entertainment. Further evaluation studies are in progress to validate its effectiveness in the mentioned fields.

Only the groundwork for deploying RoboParrot in the field of education have been done, with slight modifications and upgrades in the voice command system, it can be used for Robot-Assisted Language Learning (RALL), for both autistic and typical children [25].

RoboParrot applications can also be extended in the field of autonomous health care for assisting elderly people in everyday tasks, reminding them to take medications and monitor their physical and emotional well-being to help older adults successfully age in place [26, 27].

Another module that is currently under development and will be added to the system in the near future is face recognition with online learning, which means the robot will be able to learn a user's face during runtime, correlate it with his/her name and store it in the database. This makes RoboParrot able to interact better with users, gives each user a more personal experience and inspires intimacy.

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