A Robotic Platform for the Social Robot Project*

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Abstract— **Social Robotics is a rapidly expanding field of research, but long-term results in real-world environments are still limited. The Social Robot project focuses on bringing together the Robotic and Computer Science fields by integrating state of the art Robotic and Virtual Social Care Community network technologies and ICT-based services to provide solutions for improved independent living and quality of life of elderly people and efficiency of care. In this paper, we present the Social Robot robotic platform to the research community. We discuss the constraints involved in the design and operation of our Social Robot, and describe in detail the platform that has been built to accommodate the project goals while satisfying some constraints. We also present some preliminary results of the navigation methodologies that are used to control the Social Robot robotic platform.**

I. Introduction

Designing robots for social purposes has been a trendy topic for the last decades. The literature in this area is huge and has yielded valuable lessons [1], [2]. In the last years there is growing attention for assistive technologies in helping the older individuals to stay active and live independently for longer in their preferred environment. However, the market of ICT and robotics for ageing well, while growing fast, is still in a pre-mature phase and does not yet fully ensure the availability of the necessary solutions. Existing imperatives are either not quite ready for commercial service or are of high cost.

The Social Robot Project[1] aims to provide an answer to the demographic change challenge, through knowledge transfer and creation of strategic synergies between the project's participating academia and industry regarding the development of an integrated Social Robotics system (SocialRobot) for "Ageing Well".

The SocialRobot target group includes people with light physical or cognitive disabilities who can find pleasure and relief in getting help or stimulation to carry out their daily routine at home.

Key scientific hypotheses underlying the Social Robot project research are that (i) current technologies enable the acceptance and confidence in robots by humans and (ii) robots can provide day-to-day support to the elderly to stay active and independent in their preferred environment.

These hypotheses are supported by extensive existing work on (i) robotic technologies, enabling sophisticated perception and autonomous navigation, and (ii) ICT-based Care & Wellness services making use of virtual Social Care Community networks. SocialRobot addresses the link between these two areas to provide affective and empathetic user-robotic interaction, taking into account the capabilities of acceptance by elderly users.

The constraints of the social environment are partially translated into physical constraints on the robot platform, such as its maximum allowable dimensions and velocities, and also behavioral constraints that can reflect on the methods that are used to control the platform, such as its navigation algorithms.

This paper presents the SocialRobot platform to the research community. The platform is well-suited to a wide range of applications that extend beyond the Social Robot case study: combining different high-level actuators and sensors, the base can be used in the office, domestic or industrial environments.

This document is organized as follows. First, in Section II, it is provided an overview of the constraints that were taken into account in the design of this robot platform. The robot hardware will then be described in Section III; and also the methods to carry out its navigation are briefly presented in Section IV.

II. Constraints on Robot Design and Control

The Social Robot project has a significant component of human-robot interaction (HRI) to be carried out within specialized use case scenarios. The nature of these scenarios implies concerns and constraints on the type of robot to be used, namely,

- The range of allowable linear and angular velocities;
- The body volume of the full robot;
- Aesthetics;
- Maximum height of the platform;
- Payload;
- Power supply autonomy;
- Self-safety features;
- Human-oriented safety features;
- Cost.

Moving naturally is an essential capability for a robot to be able to “survive” in a social environment. In a sense, if a robot moves naturally, with velocities in the same order as those used by humans moving, then other HRI interfaces can

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[1] Website: http://mrl.isr.uc.pt/projects/socialrobot/

be focused and their behavior does not need to depend on the motion of the robot. Motion in 2D (as is the case in Social Robot) is completely described by linear and angular velocities and hence the ability to combine these two velocities determines the baseline expressivity of the movement. This is a key aspect when designing a mobile platform for socially embedded HRI purposes, as in Social Robot. In terms of kinematics the SocialRobot is running over a two wheeled differential drive, where in each side of the robot one wheel is connected to a single motor and two omnidirectional wheels on the back. This type of kinematics is adequate for indoor smooth surfaces and based on the fact that it only uses two actuators with simple mechanics, this solution has lower costs of implementation.

The physical presence of the robot has a large influence in the way bystanders perceive the robot and its intentions. The physical dimensions of the robot must not be perceived by humans neither as a menace nor as a physically diminished social entity. Some previous tests with adults showed that they feel more comfortable when interacting with a robot that is relatively lower than they; based on this the SocialRobot was set to a maximum height of 125 cm. The body volume is selected in order to be socially acceptable and dynamically stable (not tilting under high accelerations or decelerations).

The ability to carry a large number of sensors and interfaces is a key feature in a social robot; this meaning that payload is an important feature. Moreover, such payload has to comply with the volume/height/aesthetics concerns above.

Power supply autonomy severely constraints HRI capabilities if the robot requires too much time to recharge batteries or recharging occurs at an inadequate time. An HRI aware battery management system limits the situations in which users may perceive the robot as a flawed social entity. Moreover the robot should be able to autonomously charge itself. For this purpose a charger docking station has been developed to be installed in a service area, where the robot can enter and plug itself in.

Of extreme importance are the safety features in the platform. In addition to basic physical safety of the people handling the robots, safety concerns are directly related to Ethics issues and of paramount importance when in social environments such as the one of Social Robot. Safety measures are embedded at both hardware and software levels. Unexpected collisions trigger can be detected at hardware level and bypass all decisions levels to stop the robot. Each of the software layers has their own safety measures.

One important issue that should be addressed is the price of on-board equipment. The project is pursuing an optimal solution, fulfilling the project requirements and at the same time minimizing the cost of the final technological solution. This should ease the process of the future commercial exploitation of the project achievements.

III. ROBOT DESCRIPTION

The kinematics of a robotic platform can greatly impact the type of social interactions that it can be expected to perform. As the use case scenarios for the Social Robot were being defined and the constraints posed by the environment of operation were being discussed, it became evident that the sensing and mobility capabilities of the robot could be a critical issue to the achievement of project goals. Moreover, the project is pursuing an optimal solution, fulfilling the project requirements and at the same time minimizing the costs of the final technological solution.

The mechanics of the robot platform are being designed in SolidWorks, paying attention to the chosen kinematics and the final placement of the actuators and sensors. All the sensors that will be included have been already tested in previous activities from the partners. In terms of kinematics the SocialRobot is running over a two wheeled differential drive, where in each side of the robot one wheel is connected to a single motor complemented by two omnidirectional mecanum wheels in the back. This type of kinematics is well known and it is adequate for the defined use case scenarios.

The development and assembly of the SocialRobot platform has been divided in two phases. The first phase included the platform base mechanics with the motors, batteries and low-level electronics. The resulting platform can be adapted to serve different applications. A second phase, which specifically targets the Social Robot use case scenarios, includes the installation of high-level devices mounted over an upper structure and the design of an outer shell. At this time, the construction of the inner body of the robot and installation of all devices is concluded. The outer shell is currently being manufactured.

A. *Social Robot Platform Base Main Features*

An assembled platform base is shown in Figure 1 and it can be described through the following design features:

- Body: Polyacetal - POM (PolyOxyMethylene) 10 mm thick plates; rigid PVC 4 and 6 mm; transparent polycarbonate 2mm; and aluminum 3mm plate.
- Platform kinematics: differential
- Platform weight: 24 Kg (with batteries)
- Payload capacity: 30 Kg

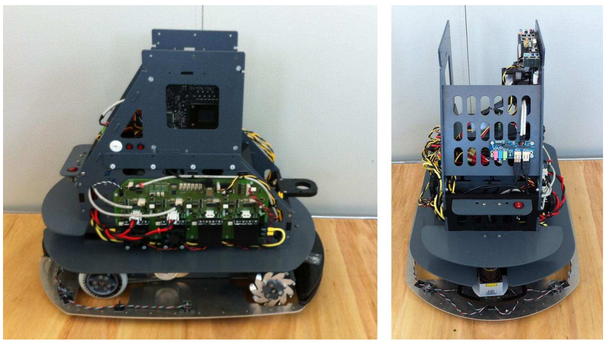

Figure 1. Assembled SocialRobot platform base

- Maximum Linear Velocity: 2.0 m/s
- Acceleration: 1 m/s2 (low-level programmed)
- Emergency Stop Acceleration: -3.3 m/s2 (low-level programmed)
- Batteries:
  - Supports up to 4 batteries at the same time;
  - Capacity: (12v) 17-20 Ah 5.5 kg each;
  - Chemistry: Lead Acid or LiFePO4 block 12V batteries with PCM;
  - Autonomy: 4 to 6 hours.
- Actuators: 2 DC motors for locomotion
- Sensors:
  - Battery level;
  - Motor encoders;
  - IMU
  - Omnidirectional bumper;
  - 4 ground sensors;
  - 12 sonars;
  - Laser Range Finder (5m range);
  - Temperature sensors to measure the motors and drivers temperature;
  - Temperature and humidity sensor to measure the environment conditions.
- Installed Electronics Boards:
  - Mini-ITX computer Board with i7 CPU, RAM and SSD;
  - Sensor & Management Board;
  - Motor Control Board;
  - Sonars Board;
  - Ground Sensor Board;
  - IMU Board;

B. *Social Robot Upper Body*

The upper body of the platform is depicted in Figure 2 and includes different high level devices:

- One RGBD camera (Asus Xtion Pro Live);
- One webcam;
- One 10” touch-screen;
- One RFID reader;
- Audio amplifier with speakers;
- LEDs on the robot body.

C. *Sensors*

The robot is equipped with perception, navigation, interaction, environment and low-level safety sensors. For locomotion the robot uses encoders to control the velocity of the motors, and for navigation it uses an inertial sensor to determine the angular speed and a laser range finder to detect obstacles and the geometry of the environment. For perception and interaction, the robot is using a RGBD camera and a webcam for people tracking, face analysis and body

Figure 2. Mechanical drawing (left) and assembled platform (right).

gesture recognition. For environmental sensing the robot will be equipped with temperature and humidity sensors. Finally, the bumpers and sonar sensors provide low-level safety sensing. To increase the robustness of localization, some other sensors/solutions are also being evaluated, e.g., RFID, IR and UWB.

The list of onboard sensors is now presented.

Navigation Sensors: The robot will navigate in the environment while making a fusion of measures provided by different sensors. The robot will be able to use a depth camera, a laser range finder, encoders’ odometry and the IMU sensor to estimate its position and orientation. For obstacle avoidance, mapping and localization it can use the laser and sonar sensors.

- Inertial Sensor IMU: MPU6050
  - Function: Orientation estimation
  - Position: in the robot’s kinematic centre
- Laser range-finder: Hokuyo URG-04LX-UG01
  - Function: Mapping, localization and obstacle avoidance
  - Position: frontal and horizontal
- Sonar Sensors: Maxbotix EZ4
  - Function: obstacle detection (e.g.: glass wall or objects)
  - Position: ring of 12 sonars around the robot
- Depth camera: Asus Xtion
  - Function: obstacle detection and space geometry analysis
  - Position: Top and looking ahead;
- Other sensors still being evaluated: RFID, IR and UWB.

Perception and Interaction Sensors: The robot will make use of a depth camera for people detection and sense visual user feedback for natural user interaction. It can also be used to detect changes in the surrounding environment. The webcam will be used for analysis of facial expressions and gestures.

- Depth camera: Asus Xtion
  - Function: Interaction, people and gesture recognition
  - Position: Top and looking ahead
- Webcam: Microsoft LifeCam Studio
  - Function: face analysis
  - Position: top and looking ahead
- Microphone array: Asus Xtion
  - Function: sound feedback for natural user interaction
  - Position: top and looking ahead
- 10" Touchscreen
  - Function: user feedback on specific contents
  - Position: turned to the user
- Other sensors still being evaluated: RFID and UWB

Environment Sensors: The environment sensors are used to detect environment variations that can affect the normal operation of the robot. These sensors are: temperature and humidity sensors.

Low-level Safety Sensors: The fundamental sensors for low-level safety are the sonar sensors, internal temperature sensors, motor current sensing and the omnidirectional bumper switch.

D. *Actuators*

The robot is equipped with locomotion and interaction actuators.

Locomotion Actuators: for locomotion, this differential platform uses two motors to drive its wheels.

- Two Maxon RE 35 90W 15V motor with a Maxon GP 32 HP 14:1 Gearbox and encoder HEDS 5540 with 500 pulses;
  - Function: provide a differential locomotion system;
  - Position: In the platform base, connected to the drive system.

Interaction Actuators: here follows the list of interaction devices. The robot is able to display the contents on the interaction monitor.

- 10" Monitor with Touchscreen
  - Function: Interaction with displayed contents;
  - Position: Front of the robot;
- Body LED lights
  - Function: show robot expressions or states;
  - Position: mounted on the robot body;
- Stereo Speakers
  - Function: content playback and robot communication;
  - Position: turned to the user.

E. *Electronic Power Architecture*

The robot can be powered by several 12V 17-20AH batteries. It uses one 12V battery to deliver power to the motor drivers. Up to 3 other batteries to provide energy to the computer and all other electronic components. An individual charging unit is used inside the robot to charge each battery. The batteries and the power in the robot is managed by the Sensor&Managment Board that measures the battery levels, battery charge, and also controls the units (motors, sensors and actuators) powered by the batteries. All onboard electronic systems can be powered by the battery system. The ATX computer power supply provides regulated voltages (from 5V to 12V). Figure 3 depicts the onboard power architecture. Several DC-DC converters are also used to provide the necessary regulated power for other DC-DC powered devices.

F. *Low-level Communication Architecture*

The onboard computer communicates with the two boards (Sensor& Management Board and the Motor Controller Board) using 2 USB ports. In each board there are USB-to-RS232 converters that convert the USB data packages to serial RS232 packages for the board controllers. Each board controller communicates with the other allowing the exchange of information between them. This communication channel allows the execution of low-level behaviors, for example, react against an imminent collision, enter into charging mode with motors shut down, reduce the motors' velocities when the batteries are low, or react to changes that can affect the robot's operation, which is fundamental to the improvement of the overall system dependability. The main controller from the Sensor&Management Board communicates with other microcontrollers using Inter-Integrated Circuit (I2C) communication ports. The main controller acts as the master and the other microcontrollers behave like slaves. The Sensor&Management Board controls the battery management and charge, sensor acquisition, devices' actuators and sonar acquisition boards. The Motor Controller Board connects to the PI Motor controllers and also to temperature sensors. Each controller has a low-level fault diagnosis that will check the operation state of each microcontroller and also monitor all the communication

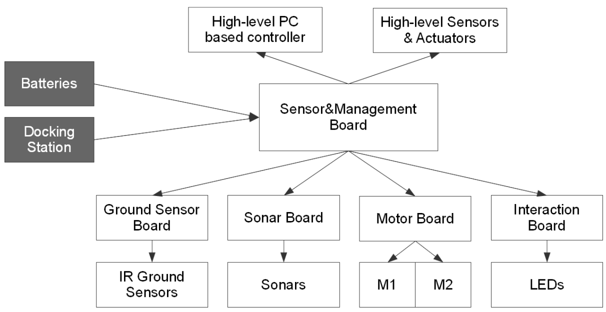

Figure 3. Onboard power architecture.

between the devices. The low-level communication architecture is depicted in Figure 4.

G. *High-level Communication Architecture*

The Social Robot can connect to a local network through WiFi. The onboard computer is connected to the high-level devices and to the platform low-level board controllers using USB ports. The computer connects to the touch-screen monitor using a DVI output and a USB for the touch inputs. For the speakers it uses the audio line out. The high-level communication architecture is depicted in Figure 5.

H. *Robot Outer-Shell Design*

The design of the shell is now concluded. The design took in consideration ongoing specification of onboard equipment, the inner body structure, envisioned user interaction and the expected visual impact on the users. Figure 6 0depicts the conceptual design proposed for the shell and that is going now to be manufactured.

IV. Brief Notes on Navigation

The development of the navigation solution is based on existing off-shelf open-source software. For navigation we are using a standard occupancy grid map [3], obtained from off-the-shelf SLAM software[1]. This map is used both for motion planning and localization. The motion planner is implemented through off-the-shelf software[2], which provides implementations of the Trajectory Rollout [4] and Dynamic Window [5] approaches to local robot navigation on a plane. In SocialRobot we opted for the Dynamic Window approach. For the localization we are also making use of off-the-shelf software[3].

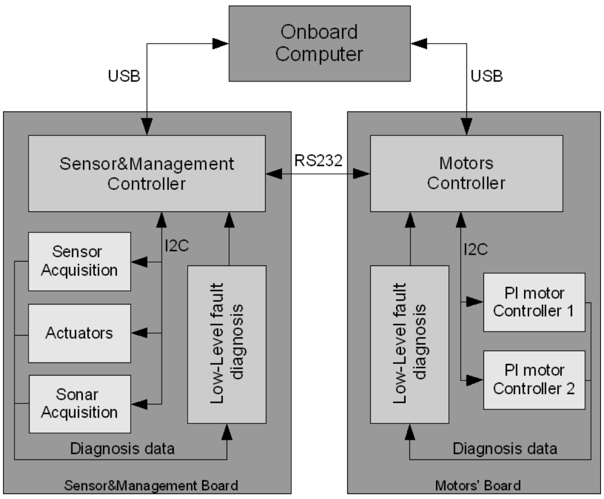

Figure 6. Low-level communication architecture.

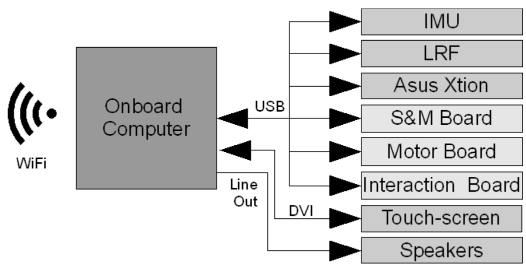

Figure 5. High-level communication architecture

Figure 4. Outer shell design.

V. Conclusions and Future Work

This paper introduces the robotic platform that was developed in the context of the Social Robot project. This development explicitly took into account a set of constraints that are induced by the social nature of the project's use case scenarios. We described these constraints; detailed the hardware that is being included in the robotic platform; and presented the methods that being used for reliable robot navigation. We believe that the qualities of the Social Robot platform make it a good choice for other applications beyond the project's case-study.

As immediate future work, we will integrate the high-level robotic and ICT services. This will endow the robot platform with HRI capabilities, establishing a basis for the future development of the socially-aware interaction methods that are crucial to the outcome of the project.

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