A Four-Legged Social Robot Based on a Smartphone

David A. Diano and David Claveau

CSU Channel Islands, Camarillo, CA USA
david.diano751@myci.csuci.edu, david.claveau@csuci.edu

Abstract. This paper presents a simple four-legged robot platform that can transform a smartphone or tablet into an autonomous walking social robot. Smartphones are already designed to be easy to interact with and to assist humans in everyday activities. They are also equipped with impressive computational resources and powerful sensors. As such they can serve as a powerful controller for a robot. By giving them four legs they have the added abilities to walk about our environments and express themselves using posture and body language. An example of such a four-legged robot is described in this paper along with a preliminary exploration of its capabilities as a social robot. Simple walking and posturing are demonstrated in ways that show how such a robot can better play the role of companion or assistant in the office or home. The platform is designed and built using inexpensive off-the-shelf components and can serve as an affordable development system for students and practitioners who wish to study social robotics.

Keywords: social intelligence, human-robot interaction, education.

1 Introduction

Powerful mobile devices such as smartphones and tablets have become commonplace items. These devices have been designed to allow humans to interact with them in rich ways using visual display, touch and voice. However, they remain devices that must be carried around, locked in a body without mobility. This despite the fact that they contain the computational resources and the sensors needed to control an articulated robot body. Even the least expensive of these devices contain cameras, accelerometers and GPS. An internet search for "smartphone robot" is likely to find some interesting examples such as Romo [1], a programmable robot companion that uses an iPhone as a controller and that can respond to humans and roam around a desktop using tracked wheel locomotion. Another example is the SmartBot [2] which is a small robot that can use Android or iOS-based smartphones to control its behavior. Both are shown in Figure 1. While these robots add mobility to a smartphone they are limited in their ability to move; they cannot move in ways that dogs, cats and other four-legged creatures do. We have become very familiar and comfortable with four-legged creatures and we easily understand their body language. If we could plug our smartphone into a four-legged body it would allow the device to more closely embody an assistant or perhaps a robot 'familiar' such as a magician's black cat.

J.-H. Kim et al. (eds.), *Robot Intelligence Technology and Applications 3*,
Advances in Intelligent Systems and Computing 345, DOI: 10.1007/978-3-319-16841-8_12

Your smartphone could now climb onto your shoulder and alert you by whispering in your ear, perhaps helping you to cross a street if you have a visual impairment. It could also use a form of body language to express itself more clearly.

Fig. 1. Commercially available smartphone robots include (a) Romo [1] and (b) SmartBot [2]

Here we present a simple four-legged robot platform that can transform a smartphone or tablet into an autonomous walking robot. A smartphone can be simply ‘plugged into’ the body and then control its own motion. An important aspect of our design is that only inexpensive off-the-shelf components are needed along with open source software. This makes it a convenient platform for students who want to explore social robotics. Just about every university student has a smartphone or tablet and soon even young children will have such devices. This opens some exciting possibilities in education since students can simply plug their device into the robot platform and program new behaviors. In this paper we give some simple examples of walking and posturing behaviors. An informal survey was performed to explore their effectiveness and their reception by an average smartphone user. In the rest of this paper, section 2 discusses some related work and following that the smartphone robot platform is described in section 3 with implementation and preliminary results in sections 4 and 5.

2 Background and Related Work

The personal nature of our relationship with smartphones and tablets is a topic of current exploration [3]. These devices contain everything from our memories of happy and sad experiences to our preferences in music and film. Our physical relationship with these devices is rather limited however. Since visual interaction is confined to the display we can think of these devices as ‘virtually embodied’. Studies have shown that a ‘physically embodied’ robot that can move its own body is more engaging [4][5][6]. These studies have also shown that physical embodiment leads to more feelings of enjoyment, trust and respect toward the robot. An example of a socially expressive robot based on a smartphone is MeBot [7]. This is a telepresence robot that allows an operator to express nonverbal behavior such as hand and head gestures. It combines video and audio of the remote operator’s face with mechanical arms and wheeled desktop mobility.

There are several examples of mobile robots based on smartphones that bear some similarity to our work but they have generally been wheeled robots and have not addressed the social interaction issues. A popular option is to use an Android-based smartphone directly connected to an IOIO (or the newer IOIO-OTG) circuit board that controls servos and other sensors [8]. The IOIO board can be connected to the smartphone via Bluetooth or USB and can read values from digital/analog sensors using the Java API provided. For example, an Android smartphone can be programmed to send commands through an IOIO board that is connected to an inexpensive remote controlled car [8][9]. The smartphone can read sensors, such as the built-in GPS or an infrared sensor connected to the IOIO, and send commands to the servos and electronic speed controller to navigate the car. Other options for building smartphone robots include using the LEGO Mindstorms system [10] which is used in schools and universities because of its affordable yet flexible building options.

While wheels are fine for the desktop, legs are needed for unstructured surfaces such as cluttered desktops and lumpy beds. They are also needed to allow the robot to assume expressive postures and poses. Legged robots are a very active research topic. A visible example is the BigDog robot [11] which can achieve animal-like mobility on uneven terrain with a focus on search-and-rescue applications. The robot is very impressive but is very sophisticated and expensive. The robot platform in this paper is an attempt to combine the mobility and expressiveness of legs in an open and affordable platform that can be used by students and researchers to explore physically embodied social robotics.

3 The Robot Platform

This section describes the design and implementation of the robot platform. The design had to meet the following basic requirements:

1. The platform should have four legs similar to a dog or cat.
2. The platform should be comparable in size and weight to a smartphone.
3. The platform should have an interface that allows a smartphone to be easily plugged into it.
4. The platform should allow for easy programming of behaviors.

3.1 Design

The design of the platform is a tradeoff between simplicity and naturalistic embodiment. It should be simple and inexpensive to build but still able to perform natural cues and exhibit personality and character. The main body of the platform, as shown in Fig. 2, is designed as a simple rectangular base made of a stiff material such as lightweight wood or plastic. Four legs are attached to the bottom of this base and a smartphone can be placed face-up on top of it. The legs were designed to each have two revolute joints of 1-DOF. This is sufficient for simple walking gaits and simple postures and makes the legs very easy to design. In fact, each leg only used one 'femur' and used the servo-motor's body as the end-effector that touches the ground.

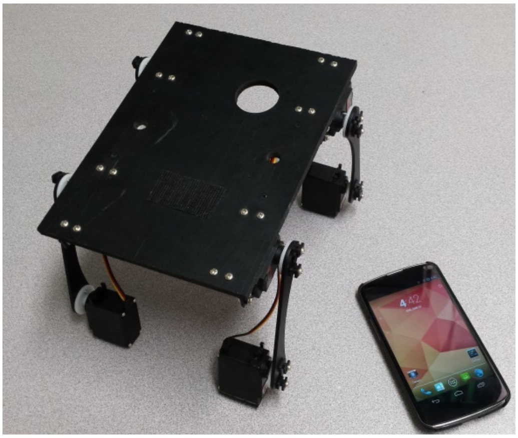


Fig. 2. The base and legs of the robot platform

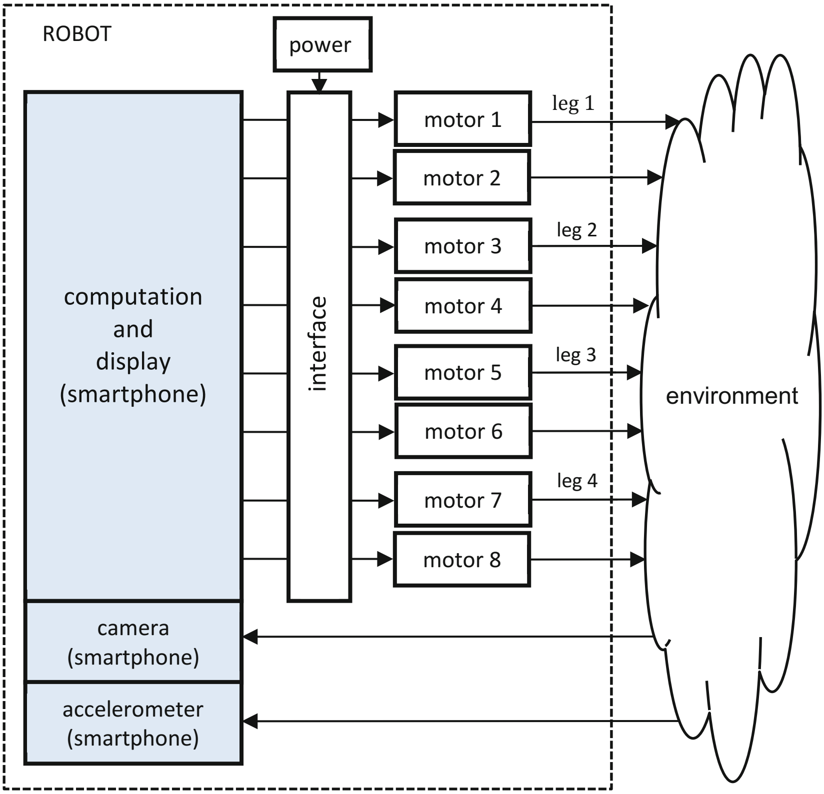


Fig. 3. System block diagram for the robot platform

Standard off-the-shelf servo-motors and brackets can easily be used for these legs. A hole is made in the base for the camera on the back of the phone; a small periscope can be mounted over the hole so that the camera can be used for navigation.

The smartphone connects to the robot platform via a simple interface. The complete system diagram is shown in Fig. 3. The smartphone is on the left and contributes computation, display and sensing. There are eight motors (two for each leg) connected to the smartphone through the interface. A second power supply is needed for the motors. The interface needs to drive the eight motors independently and receive commands from the phone. Smartphones typically have a micro-usb or similar port that can be used for this. The implementation section describes how we were able to use an off-the-shelf interface to meet all of these needs.

3.2 Implementation

The smartphone used in this project is the Android-based LG Google Nexus 4. It has a 1.512 GHz quad-core Krait CPU, 2 GB of RAM, a 3-axis accelerometer, an 8-megapixel camera and several other sensors. These are typical features for many smartphones and they are well-suited for robotics applications. The smartphone is connected to the other components via USB as shown in the hardware block diagram of Fig. 4. Most smartphones at least support the USB 2.0 standard that can read/write on an average speed greater than 30MBps. Some Android-based devices do not provide the correct voltage required to power USB devices such as a keyboard or mouse. This seems to be a rare case and unfortunately a 'hack' to the Android kernel and a three-way Y cable connecting a USB power pack is usually required to enable USB support.

The Phidgets Advanced Servo Controller 1061[12] is a motor controller that uses a mini-USB cable connection to control the position, acceleration, and velocity of up to 8 servo motors in a compact module that requires 6-15 volts to power. The circuit board can be purchased individually or in a kit that comes with 4 Hitec HS-422 Deluxe servo motors and a power supply. Specifications state that each servo is powered at up to 3.4 amps using a switching regulator that protects the motors from overvoltage and maintains a high resolution of 125 steps per degree The position of each servo is controlled by the smartphone using an Android application and a library of functions provided by Phidgets. Also included with the installation of the drivers and libraries is the Phidget Control Panel which can help test your Phidget board to make sure it is working properly, calibrate servos, and update the firmware.

The software stack for the robot is shown in Fig. 5. At the bottom is the Android operating system which is open source, making it possible for developers to modify the kernel as mentioned above to enable USB support on the Nexus 4. It provides all of the tools needed to create applications that take full advantage of the hardware capabilities for each device. Using Android Studio we developed a small Java application that can run on any device with Android Honeycomb 3.1 or higher. The application has a user interface on the phone that displays simple controls to move the servos and show accelerometer readings for testing purposes. In addition to this we used the OpenCV computer vision library to test the camera and use some simple machine vision algorithms for navigation. For the final implementation the total cost of materials turned out to be around $250 (USD) without the cost of the smartphone (See Table 1).

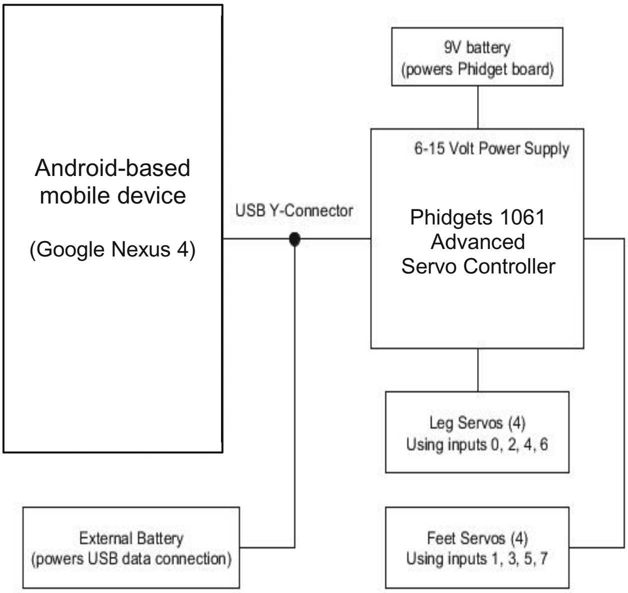


Fig. 4. Hardware block diagram for the robot platform

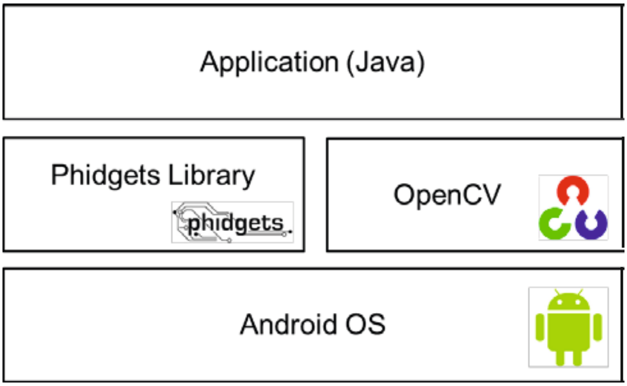


Fig. 5. Software stack for the robot platform

Table 1. Prices paid (USD) for robot platform components

Google Nexus 4	$200
PhidgetsAdvanceServo Kit (4-motors)	$140
Hitec HS-422 Deluxe Servo (4)	$50
Lynxmotion Femur for legs (4)	$25
Photojojo Smartphone Spy Lens	$25
Stiff board for base	$10
TOTAL COST(USD)	$450

4 Experiments and Results

So far we have created two demonstrations of the robot's social capabilities as described in the following two subsections. The first is a simple demonstration of the robot's ability to move about our environment and physically interact with us. The second is an exposition of a sequence of body postures designed to enhance conversations with humans.

4.1 Good Morning Robot!

The first demonstration involves the smartphone robot playing the role of a personal assistant. The robot is 'sleeping' on the bed and awakens when the smartphone's alarm rings. It proceeds to walk over the bed to tap the arm of its boss and announce any schedule commitments. This gives us a hint at the possibilities of having a robot assistant that has all of the information of a smartphone coupled with a familiar and capable four-legged body. The video for this demonstration is available at:

https://www.youtube.com/watch?v=ErMmKLlDkp4&feature=youtu.be

We have presented this video at seminars and talks and it has been well received without any mention of the creepy feelings that accompany some artificial moving creatures as in the so-called uncanny valley effect. As an example of how easy it is to program, the walking was accomplished through observation and trial-and-error. Our first attempt at walking was having the robot push off its hind legs like a frog but the movement would jostle the smartphone and circuit board, and then eventually offset the balance of the robot causing it to falling over. Walking needed to either have one leg move at a time so that there are three contact points to keep the robot stable or alternate a pair of legs similar to the movement of a dog.

4.2 Robot Body Postures for Conversation

The second demonstration consisted of having the robot assume some set postures that would be intended to communicate something conversational to a human.

This type of body language would enhance typical verbal or visual messages, making the robot seem more lifelike. Fig. 6 shows an example of two such postures with the accompanying facial expressions. A video sequence of four such postures was created in order to survey a typical user's interpretation of each posture without the accompanying face. The video is available here:

https://www.youtube.com/watch?v=PtCIbGjJV4c&feature=youtu.be

The survey question was as follows:

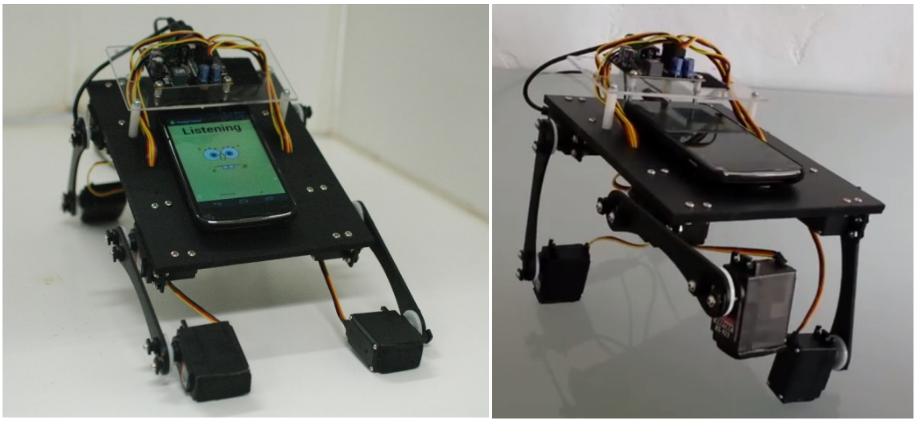
You are interacting with the robot from the video. What do you think it is trying to convey after each posture?
Please put the posture number with the interaction that you think matches:

a) It is confused
b) It is ready to listen
c) It understands what you said
d) It is about to leave

We did a small, informal study of ten participants gathered from faculty and staff close to our offices. The results of the survey are shown in Fig. 7. The first two postures were accurately interpreted by most people in the survey. The last two had some problems but this was attributable to their ambiguous nature when not combined with verbal and facial cues. A full video with facial expressions is here:

https://www.youtube.com/watch?v=B43FYX4GtXs&feature=youtu.be

The survey participants also viewed the robot postures with the facial expressions and all agreed that the combination was clear and added to the feeling of having a real conversation.



(a) (b)

Fig. 6. Example postures (a) "ready to listen" and (b) "waving goodbye, leaving"

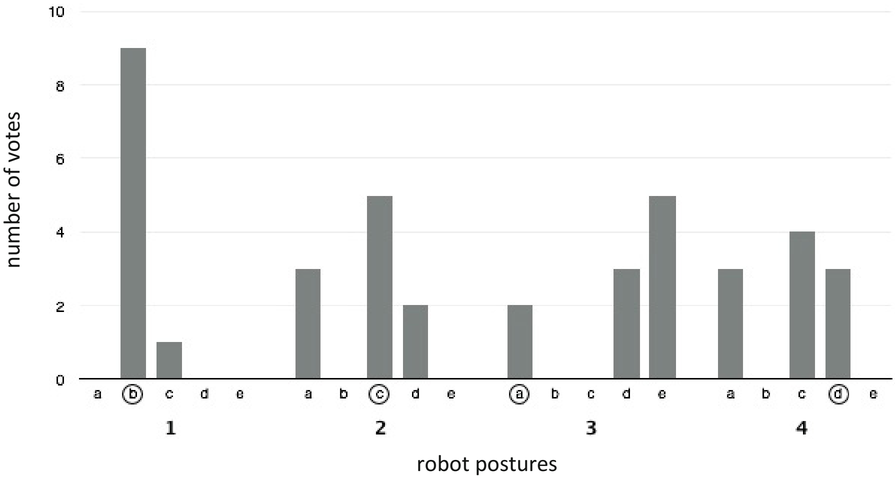


Fig. 7. Survey results for robot postures (intended response is circled for each posture)

5 Conclusion and Future Work

We have presented a simple four-legged robot platform that can transform a smartphone or tablet into an autonomous, walking social robot. Simple walking and posturing have been demonstrated to show how such a robot can better play the role of companion or assistant in the office or home. The platform offers students and researchers an inexpensive development system to explore social robotics. Our preliminary tests have shown that the system is easy to program and is well received by those interacting with it. The open nature of the software makes it possible to develop low-cost, downloadable apps by anyone who wishes to add to the system and customize it. In the future, we hope to develop a better vision system which can help to achieve richer interactions in which the robot can interpret human gestures. This type of software is also openly available and should only have to be ported and adjusted to fit the platform. There are many similar possibilities and we look forward to experimenting with the robot and working with others who are also interested.

References

1. http://www.romotive.com/
2. http://www.overdriverobotics.com/
3. Vincent, J.: Is the mobile phone a personalized social robot? In: Intervalla, vol. 1 (2013), http://www.fc.edu/intervalla/images/pdf/6_vincent.pdf
4. Wainer, J., Feil-Seifer, D.J., Shell, D.A., Mataric, M.J.: The role of physical embodiment in human-robot interaction. In: IEEE Proceedings of the International Workshop on Robot and Human Interactive Communication, Hatfield, UK, pp. 117–122 (2006)

5. Wainer, J., Feil-Seifer, D., Shell, D., Mataric, M.: Embodiment and human-robot interaction: A task-based perspective, pp. 872–877 (2007)
6. Jung, Y., Lee, K.M.: Effects of physical embodiment on social presence of social robots. In: Presence 2004, Spain, pp. 80–87 (2004)
7. Adalgeirsson, S., Breazeal, C.: MeBot: A robotic platform for socially embodied telepresence. In: Proc. HRI 2010, pp. 15–22. ACM Press (2010)
8. Oros, N., Krichmar, J.: Smartphone Based Robotics: Powerful, Flexible and Inexpensive Robots for Hobbyist, Educators, Students and Researchers. CECS Technical Report 13-16 (2013)
9. Herget, N., Keyes, W., Wang, C.: Smartphone-based Mobile Robot Navigation (2012)
10. Gobel, S., Jubeh, R., Raesch, S., Zundorf, A.: Using the Android Platform to control Robots. In: Proc. of the Robotics in Education Conference (2011)
11. Raibert, M., et al.: Bigdog, the rough-terrain quadruped robot. In: Proceedings of the 17th World Congress The International Federation of Automatic Control, IFAC (2008)
12. http://www.phidgets.com