Feasibility Investigation of Low Cost Highly Functional Hardware Options for a Community Designed Social Robot

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Abstract

This document outlines the potential hardware options for the socially intelligent Human Robot Interaction (HRI) robot Quori. The robot design is to be driven by the community and thus these designs will serve as technically feasible options to discuss with the community and gain feedback. Three hardware design sections are discussed: Expressive head, gesturing arm, and mobile base (or table top mounted). It is important that the designs be modular, expandable and low cost.

Introduction

Hardware for social robotics can be limiting because of its cost or lack of functionality. By working with the HRI community to identify the most important hardware capabilities for a social robot some optimization can be achieved to lower cost and maximize functionality. Furthermore, by providing a platform for multiple researchers the investment in the design and manufacturing of the hardware has a greater return.

The HRI community has been and will continue to be surveyed for input in this design process. Our quorum,a diverse group of researchers in the broader HRI community, will allow us to design the hardware for Quori, a modular platform which will provide the community with a low cost platform for a variety of researchers. Quori will enable large numbers of computing researchers to enter the field and develop and test algorithms, as well as conduct statistically significant user studies by deploying systems in the real world and collecting user data to inform further computing research in HRI.

The hardware for Quori is divided into an expressive head, gesturing arms, mobile base, and overall appearance. The following sections will discuss the first three topics and the final topic will be address as more input from the community is gathered. Current technology options and preliminary performance of each are offered as a feasibility investigation.

Expressive Head Options

The look and style of facial features can impact the interactions people have with a robot. To maximize flexibility, both in the style and apparent motion of the head, we plan to exploit the recent availability of low cost portable projectors (picoprojectors, e.g., an AAXA LED Pico Projector at \$114, 0.7x2.36x4.25) in a retro-projected animated face (RAF). RAFs, implemented in such projects as Lighthead (Delaunay, De Greeff, and Belpaeme 2009), Mask-Bot (Pierce et al. 2012), Furhat (MOUBAYED, Skantze, and Beskow 2013), and Engineered Arts commercial Socibot, have proven to be highly expressive.RAFs consist mechanically of a small projector, a lens or mirror, and projection surface.

These components can fit within a compact space, about the size of a human head. This technology benefits from being expressive, customizable, and natural for human interaction (Delaunay and Belpaeme 2012). As a comparison, mechatronic faces, while effective, offer little freedom in exploring themes. For more complex android faces, such as those from Hansen Robotics, very realistic motions can be created by adding many DOF, but the complexity and cost quickly become excessive. Furthermore, as system complexity grows, robustness declines. However, in simpler, low-cost mechanical faces, such as Maki, the lack of DOF results in reduced expressiveness. RAF involves just three components with almost no limit in DOF.

The following expressive head designs are investigated: 1) spherical projected head, and 2) rotating head with projection. Other mechanical designs are not considered due to their increase in price control complexity and restriction in DOF of expression. Preliminary results with different projectors and projection surfaces are also presented here.

Spherical Projected Head

A spherical projected head is a low cost highly expressive option for a robotic head. A major challenge in this design is having the projection appear bright enough especially in ambient light. By using a projector and bending its light to fill a spherical bulb any image can be displayed and animated. Projector selection is difficult as a balance of cost, illumination and throw/focus length is required.

Two methods for bending the light to fill a sphere were investigated, fisheye lense and a domed mirror, Fig.1. The fisheye lense proved to be difficult to work with and more expensive than the domed mirror. However it does offer a low profile and no noticeable blind spot, something the domed mirror creates. Table 1 compares each technology over four categories. The mirror design is easily able to fill the sphere, Fig.2, and can even be altered to full specific portions of the sphere.

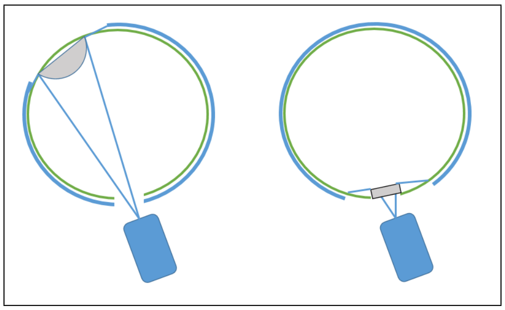

Figure 1: Comparison of mirror(left) and fisheye lense (right) designs showing "bald spots" as lack of blue.

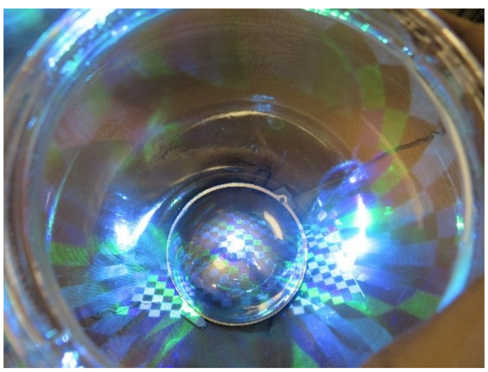

Figure 2: Mirror reflecting projected image to fill the sphere with a fabric covered surface.

Testing

Three projectors were tested; Acer K132, UO Smart Beam Laser, and AAXA LED Pico Projector. The AAXA does not emit enough light to be seen in ambient light and with the required projected area, 314 square inches (10 inch sphere). The UO Smart Beam projector was chosen for its laser technology which can focus without adjusting any lenses. Furthermore, laser technology appears brighter than LED as the UO 60 lumen projector performed similarly to the Asus 600 Lumen projector. General information for each projector is provided in Table 2.

After testing, the Asus projector provided the best project image for our expected image size of 314 square inches, Fig.3. However, the projector was still too dim. We expect a projector with twice as many lumens to be ideal, however, projectors with larger lumens and images that are in focus at our image size are difficult to find and this specification is not something manufacturers advertise, which leads to an expensive technology search.

Table 1: Robot head design matrix for fisheye lense and mirror technologies.

Topic	Winner	Notes
Cost	Mirror	A good fish eye lense can cost more than 50$ and a domed mirror can be less than 10$
Profile	Fisheye Lense	Depending on the lense and projector a fisheye lense can fit sleekly in front of the projector
Ease of instillation	Mirror	While both require mounting, the mirror only require fixing it in the sphere and has smaller tolerances in adjusting.
Area of projection	Fisheye Lense	The mirror leads to a bald spot in projection where the mirror is mounted in the sphere Fig. 1

Table 2: Specifications for three projectors used in testing.

Specification	Asus	UO	AAXA
Price(USD)	284	380	114
Lumens	600	60	25
Technology	LED/DLP	Laser	LED/LCoS
Resolution	1280x800	720p HD	960x540
Minimum Focus Length and Size (inches)	10 and 8x5	12 and 9x5	4.3 and 3x1.7
Size (inches)	5.5x4.6x1.6	2.2x2.2x2.2	0.7x2.36x4.25

The projector surface has two components, the structure and the finish. The structure is a spherical clear acrylic light bulb with a small neck. The sphere is 10 inches in diameter and was chosen as it is close to human proportions for Quori which expected to be about 4 feet tall. Furthermore, if the head were any larger, it would be very difficult to project an image bright enough to be seen in ambient light.

The surface finish can be optimized to reject ambient light and maximize both contrast and brightness. Our goal is to have a face be easily viewed in a typical indoor environment, lights on but no direct sun light. Below we compare multiple surface finished on flat surfaces, Fig.4 and 5. It should be noted that the shutter, aperture, and ISO were selected to best capture what is seen by eye for each figure.It can be seen that some finishes are too transparent, some have warm spots where the projector source is easily identified, and some reduce the brightness. Surprisingly, a simple white latex painted surface on 1/8 inch clear acrylic performed as well as a company rear projector screen.

Figure 3: The output of a Asus 600 lumen project and mirror to fill a 10” sphere in ambient light filled room.

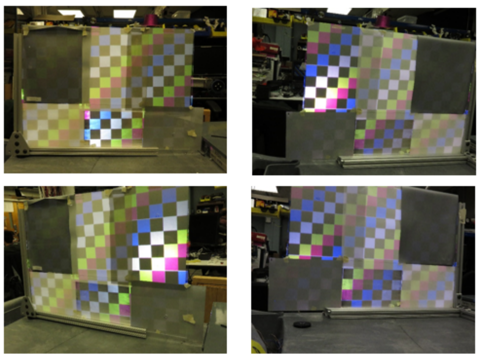

Figure 4: Asus projector filling a 24x16 sheet with multiple surface finishes.

Rotating Projector and Head

Some potential issues in using RAFs include getting enough contrast in the images (typically limited by the picoprojector brightness). Another impact of having a spherical head and a fixed neck is that added RGB-D sensors will not have panning capability. It will then be important that the field of view incorporates the full range of projected directional gaze to minimize inconsistencies when the robot actively interacts with users - including sensing the location of the users.

By focusing the projected image to a fraction of the sphere more brightness and higher contrast are observed. The image presented by the projector only needs to cover the face. The design would include the eyes, noise, and mouth, although the ears may be included. The face only needs to cover at most 180 degrees to even as low as 80 degrees across the horizontal of the head.

If it is desired that the head appear to rotate the projected image can be modified to achieve this within some margin, depending on the latitudinal coverage and desired rotation. In order to increase rotational potential the head and or projector can be rotated via a motor. While this mechanism adds cost and design and manufacturing complexity it is presented here for comparison, Table 3.

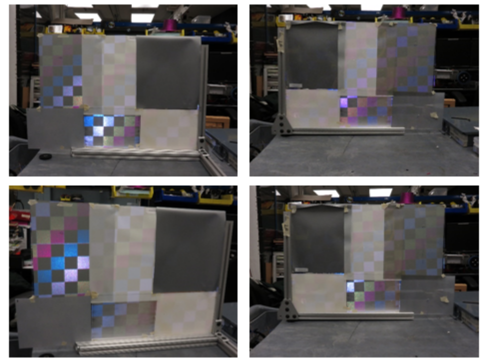

Figure 5: Laser projector filling a 24x16 sheet with multiple surface finishes.

Table 3: Cost comparison estimate for mechanical rotating head versus full projected head.

Item	Spec	Cost(+)/ Saving(-) (USD)
Servo	5kg-cm>, 180deg,	+30
Projector	Potentially a lower cost model as less lumens are required	-50
Bearing	Promote smooth motion	+10
Additional Electronics	For driving electronics	+10
	Total Difference	+0

Gesturing Arm

A gesturing arm allows for social interaction. The arm design presented is safe, low cost, and modular and expandable. Leveraging a gravity compensated design (Whitney and Hodgins 2014) for the shoulder joint, low powered and thus lower cost motors can be used. These motors which usually suffer poor position control are enhanced with an anti-cogging motor controller (Piccoli and Yim 2014). This technology coupled with lightweight design allow for a low mass, inertial and stiffness arm mechanism, Fig.6, which is safer robot as described by the Head Injury Criterion (Zinn et al. 2004). Our current prototype, Fig.6 can be 3D printed and assembled with simple hardware.

Multiple options for the arm are planned to be offered. These include 3, 4, and possibly greater DOF arm options. This is offered for cost reasons. Our current understanding of which DOF in the arm are most important are shown in the following list, however, community feedback will be considered in the final decision. Letters A, B, C, D, and E correspond to Fig.7.

- 1 and 2 DOF: the shoulder joint, A and B
- 3: rotation about the elbow, D
- 4: rotation along the forearm, C
- Multiple: wrist and hand control

The joint labeled E can be added to replace C and offer a different workspace.

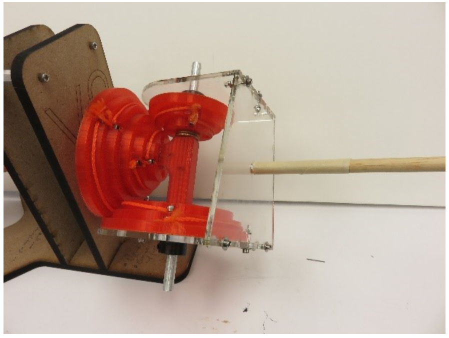

Figure 6: Cable driven should joint prototype.

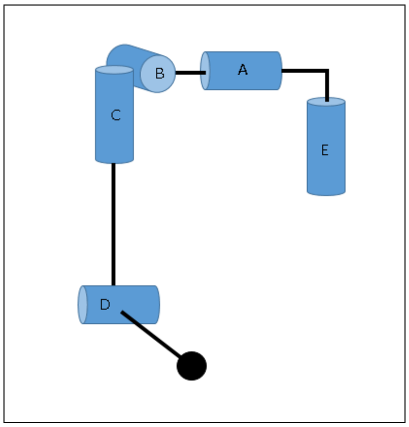

Figure 7: Expected arm joint configuration for Quori.

Mobile Base

The options for a mobile base are to be holonomic, non-holonomic, or table mounted. From our current surveys Quori is expected to be mobile and holonomic, although a table top version can easily be offered for a potentially lower price. Our current base design involves using the Persona[Yim] wheeled base for Quori. It is a fully holonomic base utilizing a differential drive with an offset turret mount as established with the Ramsis II holonomic base (El-Shenawy et al. 2007). The base is capable of traversing all ADA compliant flooring (e.g., floor thresholds and gaps of 0.5, 1:12 ramps etc.) and has a quantity one bill of materials cost of $916.

Conclusion

Preliminary investigation of design options for Quori, a community design low cost social robot for HRI research, is presented. Three hardware categories are discussed: the expressive head, gesturing arm, and mobile base. The feasibility of the rear projected head is tested and results are presented for different projection systems and surface finishes. Continued interaction and feedback from the community will drive further design decisions for Quori.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. CNS-1513275 and CNS-1513108.
We also thank the following students for their assistance in prototyping and testing: Alex Hsu, Miranda Cravetz, Thulani Tsabedze, and Brian Zhang.

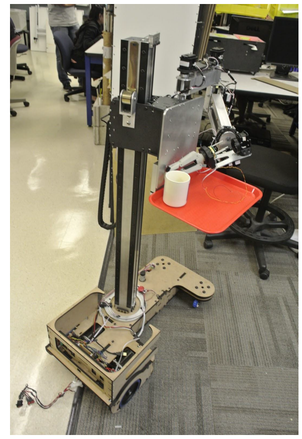

Figure 8: Persona robot with a low cost holonomic mast.

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