Ono, a DIY Open Source Platform for Social Robotics

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Abstract
This paper describes the current status of Ono, an open source social robot that can be made using DIY tools and techniques. We believe that low-cost open source social robots provide advantages that current high-end robots do not have: they are well suited for large-scale studies and they are accessible for students and hobbyists. We describe the main parts of the current prototype: the modules, the frame, the foam and textile cover, and the control box and electronics. We also describe the planned improvements for our next prototype.

Author Keywords
Do-It-Yourself; emotions; facial expressions; human-robot interaction; maker movement; open hardware; open source; rapid prototyping; robotic user interface; social robot

ACM Classification Keywords
I.2.9 Robotics, H.5.2 User Interfaces: Input devices and strategies, Prototyping

Introduction
Human-robot interaction (HRI) researchers are often faced with the choice between using an existing robotics platform, or developing their own custom robot, and each approach has its own downsides.

Building a custom robot is time-consuming and expensive, but does offer a large degree of flexibility. Using existing robots is usually more feasable, but then experiments are mostly limited to the programming of the behavior of the robot, the embodiment of the robot is often much harder to change. Both approaches have downsides when performing large-scale HRI experiments, where cost and flexibility are of paramount importance.

To address this issue, we have created Ono, a low cost open source social robot for use with children, designed to be produced using only do-it-yourself techniques and materials. The design goals for Ono are:

Open Source
We aim to distribute Ono as open hardware and open software. We want other researchers and robotics enthusiasts to be able to easily tailor the robot to their specific needs by allowing unrestricted access to hardware and software source files. The source files of the robot can be found in a public Github repository [7], however full assembly instructions have not been created yet.

Do-It-Yourself
Our goal is that Ono can be built without the aid of paid experts or professionals, using common materials and using easy accessible production techniques.

Modular
By dividing the robot into smaller functional subunits, repairs can be made more quickly and more easily, modules can be reused in other projects, and more specialized modules can be developed.

Figure 1. Current prototype of social robot Ono.

Reproducible
Ono is constructed from standardized components and readily available materials. The custom components of the robot can be produced using standard CNC manufacturing techniques, most notably laser cutting. With this approach, we aim to make it possible to replicate this robot anywhere in the world, without the need for high-end components or manufacturing techniques.

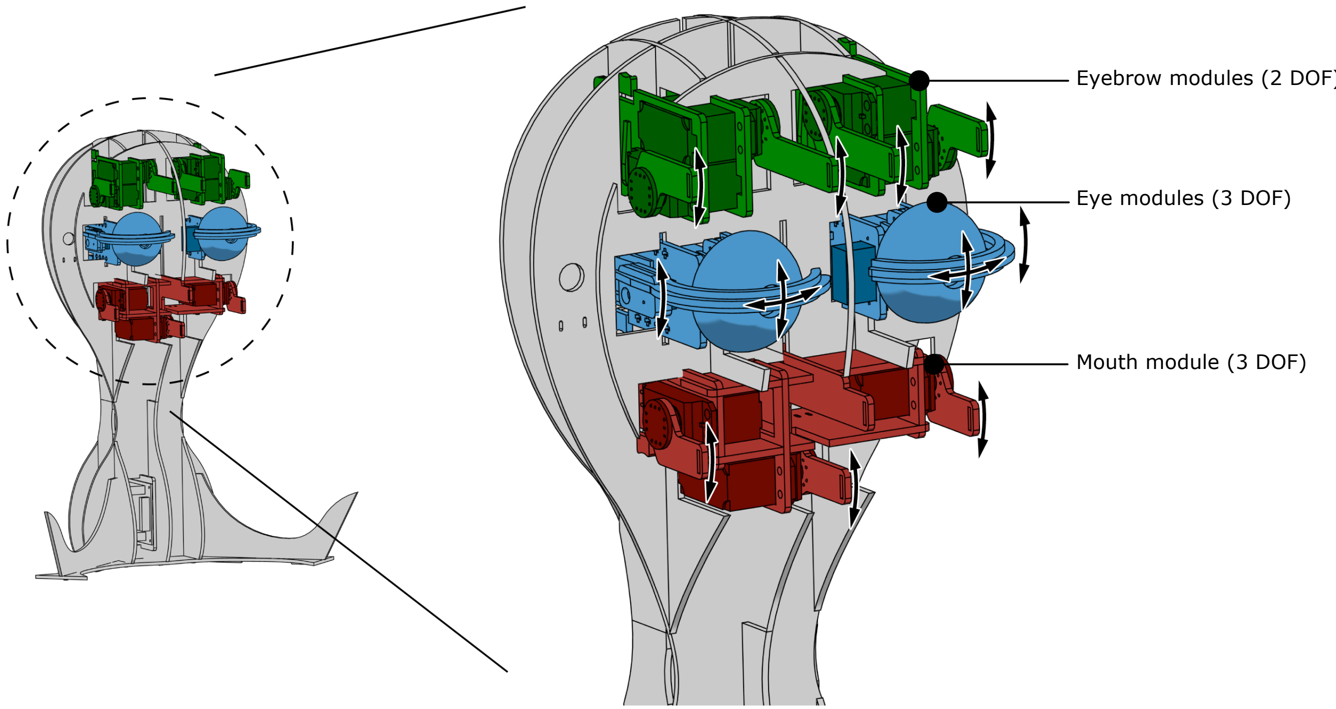

Figure 2. CAD model showing construction and DOFs of Ono. Servo actuators are shown in a darker color.

Social expressiveness

Ono's face contains 13 degrees of freedom (DOF), allowing the robot to gaze and to show facial expressions. The DOFs are based on the action units defined by the Facial Action Coding System [4], as well as our experiences with the social robot Probo [8].

Construction

Ono was developed as a social robot for children. The reason we chose this target group is twofold: 1) there is a large demand for this type of robot for treatments of developmental disorders such as autism [2] and 2) other social robots (e.g. [5][3][8][6]) exist within this segment, providing us with a reference point to compare our robot to. By narrowing our focus to this application area, we gain more specific information about the usage context of the Robot, which is helpful in the design process. However, we believe Ono's extensibility will allow it to be used within other contexts as well. Our choice of target audience had several consequences for the design of the robot. The entire robot is covered in a soft foam and textile skin to attain a soft and inviting appearance for children, as well as to protect the internal components from damage. The robot has a disproportionally large head to make its facial expressions more noticeable. Ono is posed in a sitting position to improve stability. As a consequence of its size and pose children can interact with the robot at eye height when the robot is placed on a table. The actual robot consists of 4 main parts:

Modules

The facial features of Ono are divided into modules. Each module is a group of related actuators, sensors and structural parts. The current prototype has 3 types of modules: 2 eye modules, 2 eyebrow modules, and 1 mouth module. Modules are connected to the frame using snap connectors. We chose to group components into modules because it makes it easier to repair defects, they can be reused in new robots and they enable us to improve modules without having to redesign the entire structure. With respect to modularity, we designed Ono to be somewhere in between robotics building kits (such as Lego Mindstorms or Vex robotics) and purpose-built monolithic robots. We aim to create a building system that is specifically tailored for the development of social robots, by combining the flexibility of robotic building kits with an accelerated design process.

Frame

The frame of the robot is made from laser-cut interlocking cross-sections, which together form a sturdy structure. The sections of the frame are connected to each other using slot and tab connections. The frame has openings to accommodate the different modules and has slots and holes to secure the cabling to the frame. To create the frame, we took a 3D model of the intended appearance and offset the surface of the model inward to account for the thickness of the foam layer. The 3D model was then sliced into cross sections. Finally features such as connectors, slots and holes were added to the cross-section plates. By repeating this approach and by reusing the existing modules, new robots with different appearances can be created quickly. Currently, we create these slices manually by intersecting our 3D model with datum planes in CAD software. However, for future versions we would like to automate this process. One example of software that can slice 3D models for production with a laser cutter is 123D Make [1]. Challenges of this approach are maintaining mounting points and structural strength while still offering a user-friendly way to generate new appearances.

Foam and textile cover

The frame of Ono is covered in a polyurethane foam shell to create a soft exterior for children to interact with. This foam layer also protects the inner components from potential damage. An outer layer of elastic fabric, which gives the robot an attractive appearance, covers the foam layer. In earlier prototypes, we experimented with molding techniques to produce this flexible foam cover. This proved to be difficult: creating large molds is labor-intensive and the PU resins we used are very sensitive to temperature and humidity conditions. Our solution was to create the foam cover from flat laser-cut pieces of foam. We took a 3D model of the intended appearance, and divided it into regions. These regions were then flattened in software in a manner that minimizes total amount of expansion and compression. The resulting shapes are laser-cut out of foam and are then sewn onto the frame, resulting in a 3D foam shape. The same process is used to create the patterns for the textile skin. The resulting pieces of textile are stitched together using a sewing machine. While our approach is much faster than molding and casting the outer layers (especially when building just one robot), it is still a time-consuming part of the fabrication process of the robot.

Control unit and electronics

The robot is currently controlled from a separate control box with joystick interface. This control unit also contains the power supply and the microcontroller

Figure 3. Children interacting with Ono through the control box.

controlling the robot. The microcontroller reads the joystick position, maps this position to an emotion using Russel's circumplex model of affect [4], translates this emotion to actuator positions and sends these values to the servo controller inside the robot. While this is a quick method for changing the robot's emotions, it does not offer precise control. Additionally, during a pilot study with autistic children, we found out that the control box can be very distracting.

Next Steps

Currently, we have built several working prototypes of Ono and have done preliminary testing with them. However, the project is not yet mature enough for the intended use scenarios. The current prototype has no sensors and can only be controlled through the joystick interface. Up until now, the design focus of the prototypes was the embodiment of the robot, and only basic electronics were developed as a result. The focus of our next prototype is to turn Ono into a basic, yet functional platform that can be used in HRI studies. We hope to encourage other researchers and hobbyists to use and improve Ono through open source collaboration. To achieve this, we propose the following steps of improvement:

Electronics

The external control unit proved to be problematic during testing, as mentioned earlier. For our next prototype, we wish to address this by integrating all the electronics inside the robot, instead of doing most of the processing in an external box. Improvements to the electronics include support for batteries, wireless communication, circuitry for basic sensors, and new types of output, such as audio.

Sensors

Our current prototype contains no sensors, and as a result, usage is limited to Wizard of Oz experiments. For our next prototype, we wish to integrate sensors into the robot to make semi-autonomous and autonomous behavior possible. We want to include touch sensors (in the arms, the face and the top of the head), a microphone and a camera.

Mechanics

During testing we discovered that the eye module is not quite as robust as the other modules: the cover of the eye is prone to loosening and eye movement is not as smooth as we would like. As a result, we intend to completely redesign the eye module in our next prototype. In addition to this, we want to add 2 degrees of freedom to the neck of the robot to improve the emotional expressiveness and to enable the robot to look around.

Documentation

We want Ono to be reproducible, and part of this requirement is good documentation. While we have made some assembly instructions of old versions of Ono, this was done mainly to see how inexperienced users handle the assembly process. We intend to write more extensive documentation once the next prototype is completed. This will allow us to re-evaluate the assembly process with users and will hopefully encourage hobbyists and other researchers to copy and transform the Ono robot.

Conclusion

We have presented the current state of social robot Ono, as well as the planned steps for the next prototype. We believe that low cost open source social robots offer several advantages over existing high-end robots: they can be used in large scale studies and they can be used by users that previously did not have access to social robots, such as students, hobbyists and social scientists. The focus of the current prototype is on the embodiment of the robot. For our next prototype, we want to address the issues we discovered during testing, as well as give the robot new electronics and sensors, to enable the implementation of autonomous and semi-autonomous behavior in addition to current Wizard of Oz-style control.

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