Disco Bot: An Interactive Gesturing and Dancing Robot for Group Dancing Inclusivity

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CHI'19 Extended Abstracts, May 4-9, 2019, Glasgow, Scotland, UK.

ACM ISBN 978-1-4503-5971-9/19/05.
ABST DOI: https://doi.org/10.1145/3290607.

KEYWORDS

Human-computer interaction; Hardware; Design; Engagement; Rapid-prototyping; Internet-of-things; Physical-Activity; Gesture-Based Interaction; Persuasive Technology

CCS CONCEPTS

H.1.2. [Information Systems Applications]: Models and Principles—User/Machine Systems; H.5.2 [Information Systems Applications]: Information Interfaces and Presentation (e.g., HCI)—User Interfaces

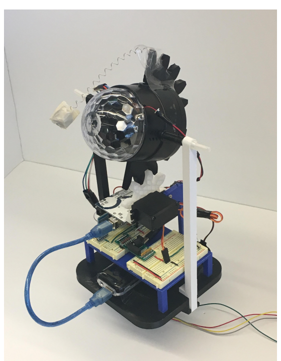

Figure 1: Disco Bot: Complete manufactured design, with disco ball head.

ABSTRACT

Disco Bot is an interactive gesturing and dancing robot designed to create dancing interactions between guests at a house party with better social inclusivity. Our robot combines gesturing with its disco ball head (affirmative nodding and a horizontal ‘no’ motion), with dancing (horizontal 360° motion to enable twirling, along with head bobbing) and colored lighting. With Wizard of Oz controls, Disco Bot was deployed in house party settings to create frictionless inclusivity on the dance floor to integrate individuals and groups into a collective and connected dance group. To achieve this, the main components of our design consisted of a deconstructed disco ball, a 180° servo, a stepper motor, two Arduino Unos, a HC-05 Bluetooth module, and a 3D-printed mount and gears.

A video of Disco Bot can be found here: https://www.youtube.com/watch?v=2Wn8Tfbi9GE

INTRODUCTION

Most house party and college dorm room party settings do not foster a socially inclusive environment for guests to start dancing, as well as to dance together. Usually, guests fear being the first person to start dancing, which results in a deadlock; no one starts dancing, so no one dances to the music playing. When groups of guests finally do dance, guests often feel uncomfortable dancing with strangers and other groups that they are not currently dancing with.

This work presents Disco Bot, an interactive tabletop robot designed to address and influence these two social situations. We used the symbolism of a disco ball (associated with dancing), and repurposed it in an anthropomorphic fashion with the ball acting as the ‘head’ of the robot. Disco Bot has both horizontal (360°) and vertical (180°) motion, in addition to RGB lighting. Different combinations of colors (red, green, and blue) can be displayed on a ceiling or nearby wall. The horizontal motion is controlled via a wired joystick, while the vertical motion and RGB lighting are controlled via an Android app through Bluetooth.

In our user study, Disco Bot was deployed and tested in two situations to make dancing more inclusive. The first situation was an individual guest entering a room with others who are already dancing; our goal was to implement frictionless inclusion of this individual into existing social structures on the dance floor. The second situation involved groups that are separated on the dancing floor (not associating with each other). In this context, our goal was to create a connection between the two groups such that they come together and begin dancing with each other, thus alleviating social frictions and pressures that result from the separation of such groups. These interactions were fostered using Disco Bot’s various coloration patterns of LED lighting as well as horizontal and vertical motion for gesturing and dancing. Key interactions included affirmative nodding (in which the disco ball head vertically bobbed up and down), horizontally rotating back and forth to “track” people on the dance floor, and dancing to the music together via horizontal and vertical motion with guests.

DESIGN INSPIRATION

In our initial brainstorming session in February, we focused on broad student-based problems, then decided to focus on a specific question. Comprised of designers, engineers, artists, and musicians, our team walked in with multidisciplinary skill sets. The brainstorming began with initial sketching of ideas and face to face conversations about problems on campus and beyond. As our ideas became more specific, they focused on group conversations in meeting settings and a physical experience regarding music. When digging deeper into the physical experience including music, we began brainstorming how to solve the problem in which musicians want to create music with others, but don't have access to other bandmates at the time (songwriting and composing is a collaborative process). This began a roadmap of ways to improve the creative process of creating music.

With this initial idea, the team thought about how we could test this with our target population at Cornell University. So, we took parts of this idea and started brainstorming a new idea that focused on creating a physical space that was interactive and allowed people to share their emotions. Focusing on lighting design, scent, and a confined space, we believed this in a new robot that could be on all four sides of a wall, encompassing the space. Taking aspects of the creative musical processes and the idea of transforming a physical space, the team developed the initial idea of the disco robot.

The brainstorming process for the disco robot began with an idea to allow anyone to dance. We believe that anyone should be able to join in a dance party, even if they don't feel they have the proper dance moves or social skills to join a group. We wanted to focus on group interactions that allow people to meet each other, and join in on the experience in this inviting and exciting physical space. With these goals in mind, we designed Disco Bot to have the power to make someone comfortable and have fun through dance.

RELATED WORK

Similar research addressing dancing robots has been created, although many of them focus more on the autonomous aspect of robots being able to dance to different music, genres, etc. In Grunberg et al.'s autonomous dancing robot, the researchers identified an algorithm to match the tempo of songs for the autonomous robot to match; the applications of such research would be more related to robot choreography and simulating human dance moves [1]. Although this research is adjacent to what we displayed, ultimately this research differs greatly from our methods of analyzing whether or not the robot was successful in encouraging groups to dance or interact with each other because the focus of the paper is on the algorithms itself.

One paper that uses methods most similar to what our dancing robot aims to achieve discusses how the researchers studied the effect of a small creature-like robot, Keepon, on the social interactions between children and their interactive involvement with the robot [2]. Keepon, similar to our robot, has nodding control and panning control which can be operated remotely. The observations from this paper concluded that the robot's responsiveness to people's behaviors did indeed positively influence the children's behavior with the robot. These research methods focused more on the rhythmic interaction between the robot and the children by honing in on the modality and quality of the children's movements, which varied from our method of evaluating whether or not the robot facilitated social interactions and led to an increase in movement between participants at a party. However, measuring the degree of the robot's responsiveness to the children was similar to the interaction methods we used in which our disco ball robot responded to our participants' behavior, such as meeting their gaze or following their movement.

Another related robot is Travis, an expressive robotic speaker dock that dances and "bobs" its head to the music played on it [3]. We were inspired by the natural motion of the robot's head movement, as the research paper studied the effects of the robot companion on people's enjoyment of the music as well as how users rated the human-like traits of the robot. Although this work also measured the robot's effect on humans, it focused more on the individual interaction between the human and the robot rather than the effect on interpersonal relationships in social groups. In comparison, we focus on group interactions; however, Travis's interactions with a single person inspired us to focus on and gesture at one person in a group at a time when inviting people to dance.

PHYSICAL PROTOTYPE

Initial Design

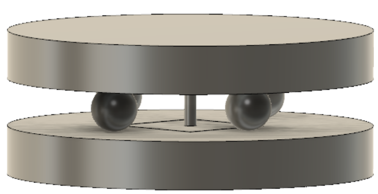

Figure 2: CAD model of lazy susan platform for U-mount.

For our initial design, we considered using a lazy susan as we wanted the disco ball to be able to rotate completely 360° horizontally without balance issues (Figure 2). The lazy susan would consist of two circular laser cut wooden or 3D printed panels with ball bearings sitting between them. The stepper would rotate the lazy susan on its side and as a result, there would be no issues with the mount balancing on the stepper. The servo that controls the second degree of freedom, rotating the disco ball 180° vertically, would be mounted on a U-shaped mount holding the disco ball that sits on top of the lazy susan. After receiving feedback, we chose to redesign the U-mount such that it sits directly on the stepper, bypassing the lazy susan idea completely. This design decision came with its own tradeoffs, which we will later address, although it ultimately worked for our final prototype.

Another design consideration that we had to take into account is where to mount the servo that handles the 180° "nodding" motion of the disco ball. Our initial idea was to mount the servo to the outside of the U-mount, and have one axle going through the U-mount that attached to the servo head. However, this posed potential balance issues. As such, we contemplated moving the servo onto the bottom center of the U-mount and moving the disco ball head using other methods. One such method was a cam and rod which ended up not working via cardboard prototype testing, as it did not provide complete 180° motion. Another method we considered was a timing belt, which we decided against due to lack of available parts. Ultimately, we came to the decision to use two 3D-printed gears. One larger gear would be edited to fit tightly around the disco ball, and a smaller gear would be attached to and controlled by the servo. With this design, we found that we

Figure 3: Initial Design of Physical Prototype. Disco ball LED and 180° vertical servo motion are used with wires to an external breadboard, which prevent the freedom of horizontal 360° motion.

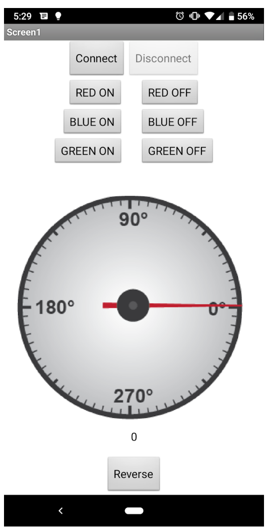

Figure 4: Android app to control red, green, and blue disco ball LEDs and 180° vertical servo angle via Bluetooth HC-05 module.

were able to achieve the 180° "nodding" that we desired. We encountered a few issues with teeth and gear ratio but with a few iterations, we were able to achieve the functionality that we needed.
After achieving the gear redesign, we moved on to redesigning the mount as to fit and balance all of the mechanical and electrical components on the stepper. The U-mount consisted of two holes at each side of the mount. Axles went through this hole and the hole of each side of the disco ball, held in place with spacers on each side such that the disco stays in place and the gears stay interlocked. Furthermore, in initial iterations of our U-mount, it was quite thin and fragile, so we made it thicker and added more support where the U-mount attaches to the stepper to better balance the load of the entire robot on the stepper. With all of these parts working in tandem, our initial design worked in the sense that the disco ball moved in two degrees of freedom: one being the entire robot moving horizontally 360° as well as the disco ball nodding back and forth 180°.

To control the Disco Bot, we used a potentiometer (changed to a joystick) to control the horizontal speed and direction generated by the stepper motor. See attached schematic for a wiring diagram. We also used a potentiometer to control the angle of the mounted servo, and thus the vertical angle of the disco ball head. Finally, we used three push buttons to turn the red, green, and blue LEDs on and off.

Now that our initial prototype achieved the goal of motion in two directions, we aimed to redesign it such that it was more balanced and more modular as we noticed that wires were wrapping around our Disco Bot (Figure 3). Ultimately, these wires were preventing the robot from achieving both horizontal 360° and truly smooth motion.

Wireless Iteration, with Bluetooth

The main problem we faced with our initial design was that the wires connecting the LEDs and the servo to the Arduino wrapped around the disco ball whenever it spun horizontally. Thus, we decided to use an HC-05 Bluetooth module to remove the wiring issue. We created an Android app using MIT App Inventor that includes connecting and disconnecting with the Bluetooth module, buttons to turn each colored LED on and off, and a rotating gauge that determined the degree of head tilt for the disco ball.

By changing the wiring to include a Bluetooth module, we also needed to restructure the placement of our breadboards to fit the Arduino for the LEDs and servo motor onto the disco mount itself. In addition, we needed to create an additional level to mount these breadboards, as we also needed space for the batteries powering this electrical system. We designed and 3D printed screw mounts attached to an upper platform level to mount the Arduino upside down above the breadboards, then cut wires to size to minimize the horizontal and vertical height needed, as well as to ensure that wires would not fall out and create faulty connections. See attached schematics at the end for a comprehensive wiring diagram. The breadboards rested on the top of this platform table; we used the breadboards' sticky back side to secure them to the platform. In addition, we redesigned the servo mount similarly to the screw mount such that the servo would hang over the breadboards to minimize the additional vertical height needed with this

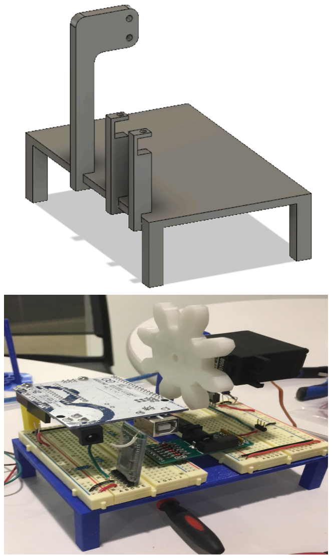

Figure 5: CAD model of platform, servo mount, and screw mounts (above). Manufactured mounted electrical system onto platform (below). Main components include Arduino Uno, servo, and HC-05 Bluetooth module.

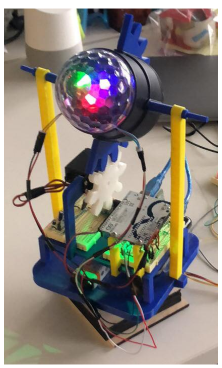

Figure 6: Manufactured wireless iteration, with Bluetooth. Used in first round of user testing.

redesign. The bottom platform held the batteries (the 9V battery for the isolator, as well as the external battery pack to power the Arduino).

After successfully assembling the mounts and 3D printed structure to house the breadboard, Arduino and batteries, we filed holes in the disco ball shell for the disco ball inner motor wires and LED wires to go to the breadboards via jumpers that were taped together. Upon further testing, we also came to the realization that the inner disco ball motor could be powered by connecting this to 5V and ground. This meant that the second external battery was not actually required in our design and thus the multi- level table structure was not necessary for our configuration since we only needed one external battery and the 9V battery. We then dismantled the original wiring for the inner disco ball motor that spun the LEDs, connecting the motor to 5V and ground on the breadboard that controls the LEDs instead. This saved both extra room and weight by removing one of the external batteries needed to stick onto the mount.

In addition to enabling a greater degree of horizontal motion, we also considered improvements to the gear mechanism for the redesign of this prototype. For this iteration, we took more measurements to get the right cutout for the gear. To get a better motion using the gear mechanism, we aligned the center of the gear to match the horizontal plane of the center of the axle holes.

Since this redesign increased the vertical height of the disco robot by a significant amount, we needed to reprint the mount in separate pieces because it could not fit fully onto the 3D printers. We decided to separate the beams from the bottom part of the mount that fits into the stepper motor, and superglue the pieces back together. Overall, this base and beam structure managed to hold together during shorter periods of testing; however, the choice to use glue instead of printing the full structure resulted in reduced stability. The structure turned out to be more susceptible to breaking down after extended periods of vibration and motion due to the vertical stands and horizontal levels being glued together.

The complete CAD design of the mounts and horizontal level can be seen in Figure 5 (above), with this part of the manufactured system in Figure 5 (below). The complete manufactured wireless Disco Bot design can be seen in Figure 6.

USER TESTING

In order to test the interactions created, we designed a user testing session that involved people outside of our class with no knowledge about the project. This initial testing procedure was very important to eliminate bias within the project. We primarily tested the emotions and actions attached with Disco Bot's interactions and movements.

The first user testing session was created with a house party environment that hid the wired joystick control to create a Wizard of Oz testing procedure. In a small apartment in Collegetown in Ithaca, New York, the environment was designed with a DJ booth controlling the music and horizontal movement through the joystick. Disco Bot was placed on the DJ booth tabletop surface at the back of the room. Another group member controlled the vertical movement and lighting through the app created on an Android device in the back of the room. We had 7 participants comprised of five men and two women who were all undergraduate students at Cornell University. We played three songs, according to guests' song requests.

Our initial insights for the first user testing session began with visible discomfort when walking in the room. The unfamiliarity with the space and the dark room created initial discomfort among the guests. We realized that the transformation from discomfort to comfort had to be quick and intentional, as the robot could potentially make people uncomfortable. In the first testing session, we focused on a welcoming interaction. When a group walked in, the disco ball displayed a blue pattern, and followed the subjects as they walked into the room through horizontal movement.

Focusing on gestures (e.g., affirmative head bobs) and creating new movements that caused people to recognize Disco Bot as a friendly fellow dancing figure was successful in this stage of testing. We increased its amount of bobs (vertical movement) according to the rhythm of the music during the testing session. Users thought the robot was bobbing with the music and dancing with them. Several users got closer to the robot as they wanted to further investigate how this robot worked. This impressed them, and made them more interested in trying to discover the robot's interaction patterns.

At the end of this round of user testing, we gathered feedback through questions that explored the interactions, emotions, and experience tied with this user testing procedure. After the testing procedure, we debriefed the subjects to explain the intentions behind the experiment. The group of subjects were very interested in following the robot's progress further and consented to being asked further questions in the future. Overall, most users enjoyed the experience, with many noting how Disco Bot seemed "like a friend." Several users commented on how human-like our Disco Robot seemed, with one user noting how the beams seemed like arms and how the disco ball seemed like a head with a mohawk.

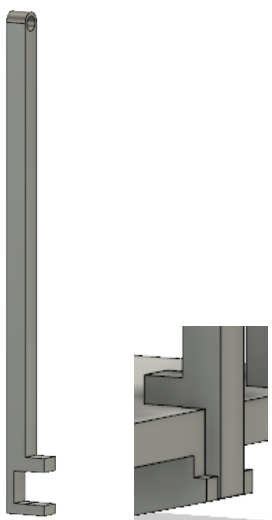

Figure 7: CAD models of redesigned beam (left), with interlocking base design (right).

REFINING PHYSICAL PROTOTYPE

After finishing the assembly and wiring the new redesigned prototype, we held the first round of user testing in a small party setting. During this first round of testing with the functioning prototype, we encountered a few problems with the mechanism and design of the robot parts. The solder on the green LED in the disco ball head broke off and one of the beams for the mount fell off while transporting the robot from the user testing site back to campus. As a temporary fix, we stripped the wire to green LED solder and reinforce it with tape and a spacer. Finally, the biggest challenge that we faced during our initial round of user testing was that the stepper heats up significantly when powered for a long time, resulting in the high temperature of the stepper motor burns through the base of the robot.

We considered fixing the green LED by soldering the wires back together; however, as we had another disco ball for backup, we decided to use that one instead. In addition, we redesigned the beams with interlocking slots in the base so that the beams holding the disco ball head would not fall off as easily (Figure 7). The redesign of the beams was ultimately successful, as the beams fit so snugly into the base that no superglue was needed to attach the system together.

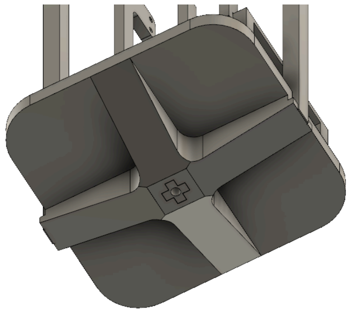

Figure 8: CAD model of redesigned base with interlocking cross-shaped stepper motor mount.

We also chose to redesign the base because in our previous design, the U-mount sat directly onto the stepper. This ended up causing issues such as the stepper burning through the superglue that was securing it to the U-mount and melting the PLA, leading to uneven and stuttering movement. The base mount was redesigned to be more modular such that there was one small cross-shaped piece that sat on the stepper; this piece interlocked tightly into the U-mount, which was reprinted to have a slot for this small piece (Figure 8). If the stepper were to heat up and burn through any more PLA, we could much more easily replace the small piece rather than needing to replace the U-mount every time. Having this interlocked piece removed the need to use superglue to form a secure attachment between the mount and the stepper.

In this final redesign, we were able to re-use the previously superglued table that held the external batteries and mounted electrical system in place. Rei assisted us in slicing off the table from the previous prototype, and we superglued it to the new mount. In addition, Professor Jung helpfully provided a spring and weight to test more anthropomorphic interactions through an antenna, based on our initial participants' reactions from our first round of user testing. We drew an eyeball on the tape holding the small weight to the spring, and taped the other end of the spring to the gear to create a more anthropomorphized version of our Disco Bot (Figure 1).

ADDITIONAL USER TESTING

The second round of user testing was in a more controlled environment. The subjects included three men and one woman who are undergraduates at Cornell University. The set up of the study was similarly designed to the prior user testing with a DJ booth, the integration of the app, and the first interaction being with a group; however, we tested more interactions with the robot in this testing session.

The session began with a welcoming design with blue lighting and horizontal movement that tracked people entering the room. We focused on tracking the person we thought would be most likely to dance (someone who was already bobbing their head to the beat of the music), occasionally bobbing the disco ball head at them to gesture them to dance. Then, we added a green spotlight and head bobbing when this person began dancing. This provided an affirmative incentive for people to dance, and it proved to be successful. This green spotlight moved horizontally with the person who was dancing, with vertical movement to make the disco ball head bob up and down with the dancer. We would then focus on tracking a different non-dancing guest. When someone was not dancing later in the testing session, the robot would turn red and bob toward the person to dance similarly to the earlier spotlight interaction design.

Additionally, we tested the antenna in this stage of user testing. We added a spring antenna to the robot to make it seem more personalized and like a robot. When given this suggestion, we decided to test it to see if something that looked like it didn't belong in the design played a role in how people interacted with it. There were positive results within this test that made people think it was more of a friend and increase the distance they would go to get closer to it. Some people even tried gesturing at the robot to get its attention, and one participant even started talking to it.

When surveyed, they said that they felt more curious and comfortable when the antenna was on the robot. They said that the antenna did not really seem to make the robot catch their attention with the extra degree of motion any more than without it; however, we observed that the extra visual stimulation increased participants' gaze towards Disco Bot.

FUTURE WORK

If we had more time and money for this project, there are multiple reconsiderations that we would incorporate into our disco robot. First, utilizing metal rods and spacers would be stronger and more secure than the 3D printed axles and spacers using PLA, which often snapped due to the fragile material. Besides that, the table structure that we used could also be laser cut on acrylic sheets instead of 3D printing horizontal plates for the mounts, which would be much more time efficient. Furthermore, the platform table structure that we used in our prototype was very inefficient in terms of vertical space usage. As a future design consideration, we would like to keep the height of the robot to the minimum since the multi-level table structure is not actually necessary for our hardware needs; a smaller system would be faster to prototype and less susceptible to breakage. Moreover, we would like to redesign our robot such that it consists of smaller, more modular pieces and have secure attachments with the use of screws; this would lead to both a more secure robot and in case any parts break, replacement and reprinting would be much more efficient.

We would also purchase a stronger stepper motor that is less likely to heat up, as this was one of our biggest challenges that resulted in a second redesign. The entire U-mount sitting on the stepper motor caused load balancing issues that prevent the stepper motor from operating at its full capacity--we would reconsider implementing our initial idea of the lazy susan to prevent any weight from stifling the stepper's motion.

Another design consideration would be to use a continuous and more reliable servo, as our current servo only rotates the disco ball head 180°. While this is enough to facilitate Disco Bot's bobbing head motion, having a more versatile degree of vertical motion would result in greater functionality for possible interactions.

We would also perform additional user testing with and without the use of a 3D printed shell, perhaps using more flexible material, to create an outer shell that encapsulates our robot. As our robot and its inside mechanics were completely exposed, leading to a more anthropomorphic experience, this lent itself to an intriguing outcome in our user testing in which users were especially drawn to the robot and suspected that it may have been part of an experiment. Hiding all the robots' internal workings and testing its placement in various positions at a party, a casual gathering, etc. would provide us with more insight on what the most appropriate setting for our disco robot would be. Additionally, having more quantitative measures to evaluate our robots' effects on bringing people closer together (both in terms of physical proximity and familiarity) and to support our hypotheses would be a great improvement.

CONCLUSION

Disco Bot is an interactive gesturing and dancing tabletop robot designed to improve dancing inclusivity in group settings, particularly collegiate house party situations.

We have successfully implemented our Disco Bot design, which enables both 360° horizontal and 180° vertical motion of the disco ball head as well as moving RGB patterned lighting. The 360° horizontal motion is controlled via a wired joystick to the stepper motor attached to the base of the robot. The 180° vertical disco ball head motion via the servo and the RGB disco ball head lighting is controlled via an Android app over Bluetooth.

Our two rounds of user testing provided effective user feedback towards improving our design. We tested with participants at a controlled house party environment which fit our target audience. Designed to include Wizard of Oz techniques in order to provide an authentic observation of the Disco Bot interactions rather than the person who was controlling it, our testing procedure at a small house party setting provided the controlled environment which allowed the robot to be tested with different gestures and interactions. Overall, users found our anthropomorphic exposed gear design quite charming and friendly, engaging them in a more welcoming, pleasant group dance experience.

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SCHEMATICS

See following pages for (1) Schematic of Disco Ball LED & Servo, and (2) Schematic of Joystick and Stepper Motor.

ACKNOWLEDGMENTS

We would like to extend a special thanks to Rei Lee, our incredible Teaching Assistant who was always there to help and support us throughout the entire design and manufacturing process. We would like to thank YoYo Tsung-Yu for his endless positivity and incredible encouragement. Furthermore, we are grateful for the direction and guidance from Professor Malte Jung. Finally, we would like to thank Guy Hoffman and his robot Shimon for design inspiration.