CSE 176A/276D Healthcare Robotics Final Report: Therapeutic Robotic Interactive Canine Companion (TRICC)

Therapeutic Robotic Interactive Canine Companion (TRICC) is an interactive and lovable companion robotic pet dog with a customizable and detachable busy blanket that is mainly designed for people with dementia. TRICC helps provide sensory stimulation and soothing effects to people with dementia by reacting to a user's petting like a real dog (e.g., head nudging, and tail wagging) and carrying a user's personalized busy blanket.

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Sally Lei, *Software Development Lead*: Software Development for TRICC and Busy Blanket Creation

Stakeholder Partner Names:

Dr. Stacey Vieyra-Braendle

Dr. Christine Grosso

  

Executive Summary

Our project is the Therapeutic Robotic Interactive Canine Companion, or TRICC for short; it is a robot dog meant to provide sensory stimulation, interaction, and engagement to people with dementia, as these are proven to help with alleviating the symptoms. We spoke to our stakeholders, Dr. Stacey Vieyra-Braendle and Dr. Christine Grosso, who are occupational therapists who work with people with dementia, to learn more about the features TRICC should include. After an initial meeting, we analyzed the pain points highlighted by our stakeholders and decided to focus on features to make the robotic dog feel more lifelike, such as simulated heartbeats and body heat, as well as features encouraging interactivity, such as positive reinforcement when users pet the dog via head nudges and tail wags. TRICC is also "needy" and draws the user's attention when it is not being interacted with by illuminating LED lights on its neck. Finally, TRICC comes with a detachable busy blanket which can help to calm people with dementia who might be experiencing anxiety or trouble focusing. We interacted with TRICC in order to confirm the expected behavior for the features we had designed and also presented a demo to our stakeholders. We were excited to receive very positive feedback and were also able to implement all of our planned features with the exception of one– the ability for TRICC to bark– due to a hardware issue with one particular component. To summarize the lessons we learned from this project, timing is key when working on a robot like TRICC. Having sufficient time to research, listen to stakeholders' input, and work on both software and hardware is especially important to keep in mind. In the future, we hope to ask TRICC's users what other features they would like to see in TRICC and tailor its features to their specific needs.

Introduction

Dementia affects tens of millions of people worldwide (approximately 55 million) and the number is ever-growing, at about 10 million per year (World Health Organization, 2021)[1]. Those affected by dementia gradually lose their cognitive functions whilst developing a stronger sense of confusion and disconnection from the world (World Health Organization, 2021) [1]. To help alleviate such symptoms, sensory stimulation can play a major role (Mileski et al., 2018) [2]. Sensory stimuli can evoke positive emotions, memories, or thoughts that help those with dementia relate to the present. Sensory stimulation can be brought about by scents, sounds, and various forms of interactions including interactions with small pets. Our team was very interested in how we might encourage sensory stimulation for people with dementia and help alleviate some of the issues that they might encounter. We spoke to our stakeholders, Dr. Stacey Vieyra-Braendle and Dr. Christine Grosso, who are occupational therapists who work with many people including people with dementia. As occupational therapists in Oregon, they are focused on helping clients maintain and recover day-to-day skills, and reiterated the importance of sensory stimulation and engagement in effective therapy. To help provide sensory stimulation to people with dementia, we decided to build an interactive robotic pet dog that would mimic a realistic dog for our project. We decided to call it the Therapeutic Robotic Interactive Canine Companion, or TRICC for short. By imitating the behavior of an actual dog, our robotic dog is meant to allow for realistic and positive engagement that will properly stimulate those with dementia and allow them to feel a form of connection with the world. We also implemented features to make the robot feel more lifelike, such as simulated heartbeat and body heat features. Such features contribute to the realness of the pet and increase the amount of comfort the pet provides. In addition, the pet robot carries a detachable busy blanket (a blanket that can help soothe those with dementia by keeping their hands busy). The busy blanket adds an extra layer of interactivity and can aid in calming anxious and fidgety users. Overall, our robotic dog aims to soothe its user while also providing them with positive stimuli.

Methodology

3.1 Overall Design Process

Our design process began with meeting and interviewing our stakeholders to learn more about them, the areas of interest they had for our project, and the effects they hoped for our project to have on the user. Following this interview, we summarized the key takeaways we had from meeting the stakeholders and framed the ideas collected from stakeholders by categorizing them into six different categories: “Occupation, Interests, and Hobbies of stakeholders”, “Impact on Clinicians”, “Impact on Patients”, “Patient Recovery”, “Stimuli”, and “Comfort” as shown in the following figures.

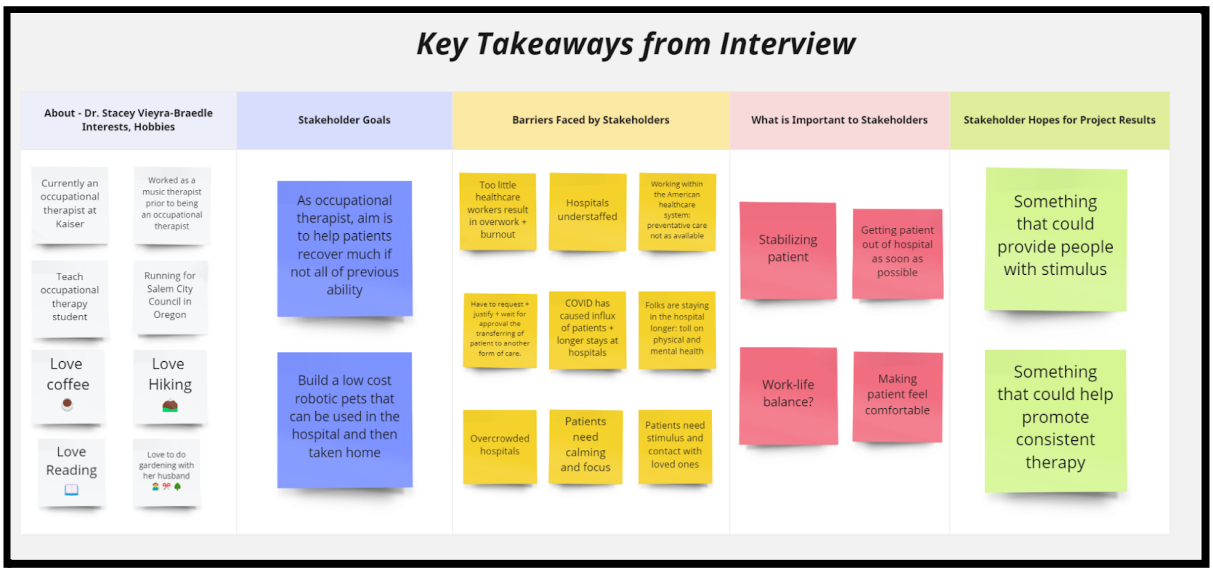

Figure 1: *First Stakeholder Meeting Key Takeaways’ Affinity Map*

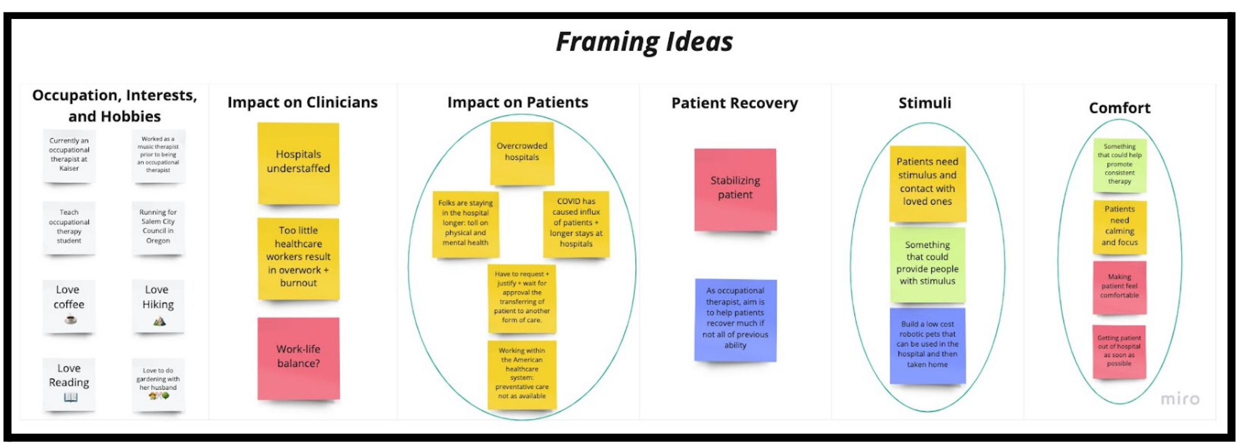

Figure 2: *Ideas Framing after the First Stakeholder Meeting*

Then, our team brainstormed 29 different ideas that revolved around the stakeholders' hopes for our resulting project which was for it to be something that will provide the user with stimulus and/or help promote consistent therapy in the user. This is presented in the ideation affinity map below.

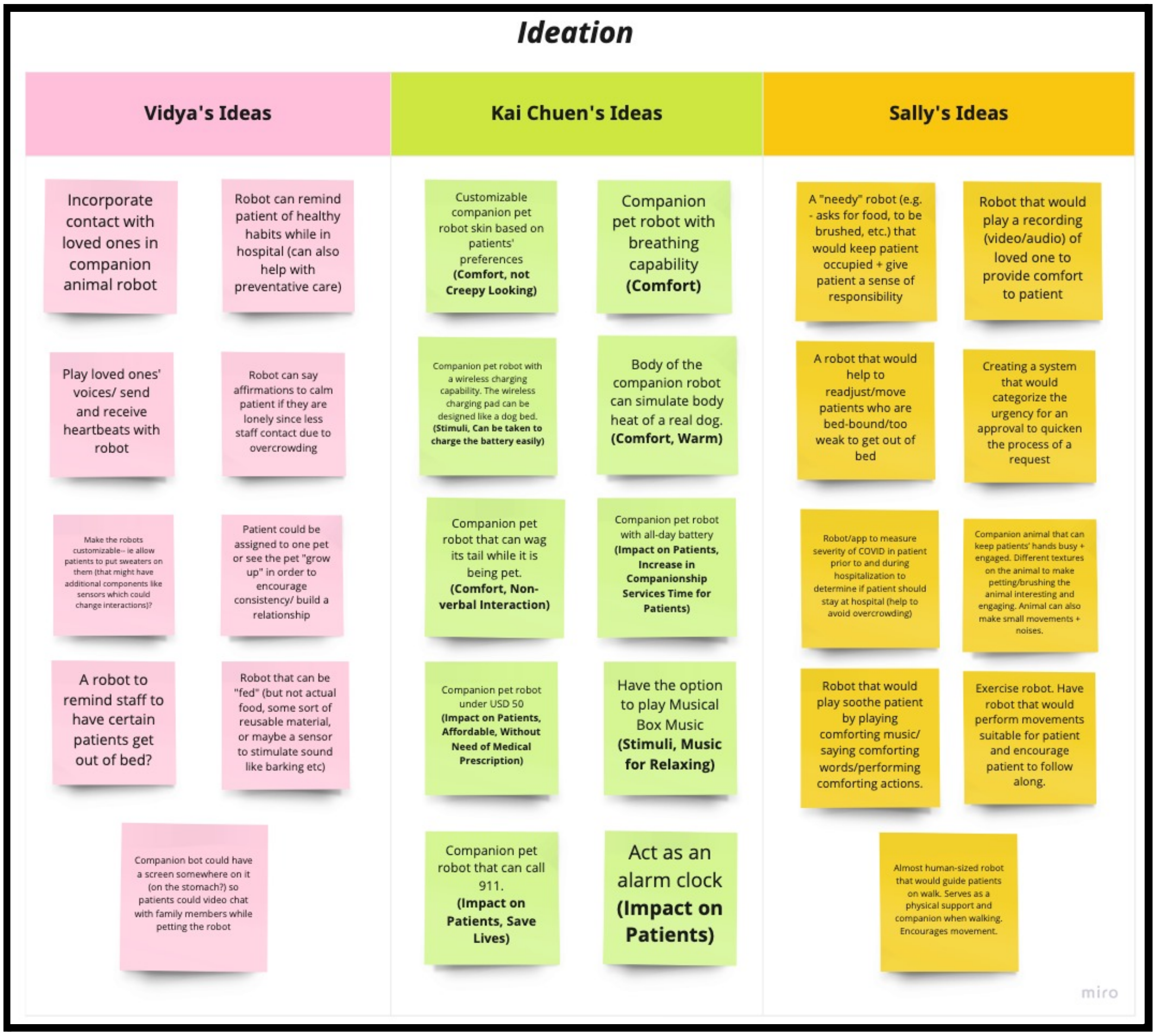

Figure 3: *Ideation Affinity Map*

After the framing and ideation brainstorming process, we found that our ideas all shared the common idea of a companion animal and so, we decided to move forward with the companion animal idea by brainstorming the ideas for features that we believed might be feasible and helpful to the user of the companion animal. The features that we brainstormed included: reacting to touch, head nudging, tail wagging, playing music, having an internal alarm clock, barking, calling the emergency line when the user asks, "busy-blanket" texture, lights to grab attention, and acting "needy" by demanding interaction from the user so the user feels a sense of responsibility towards and have more engagement with the robot as illustrated in the following figure.

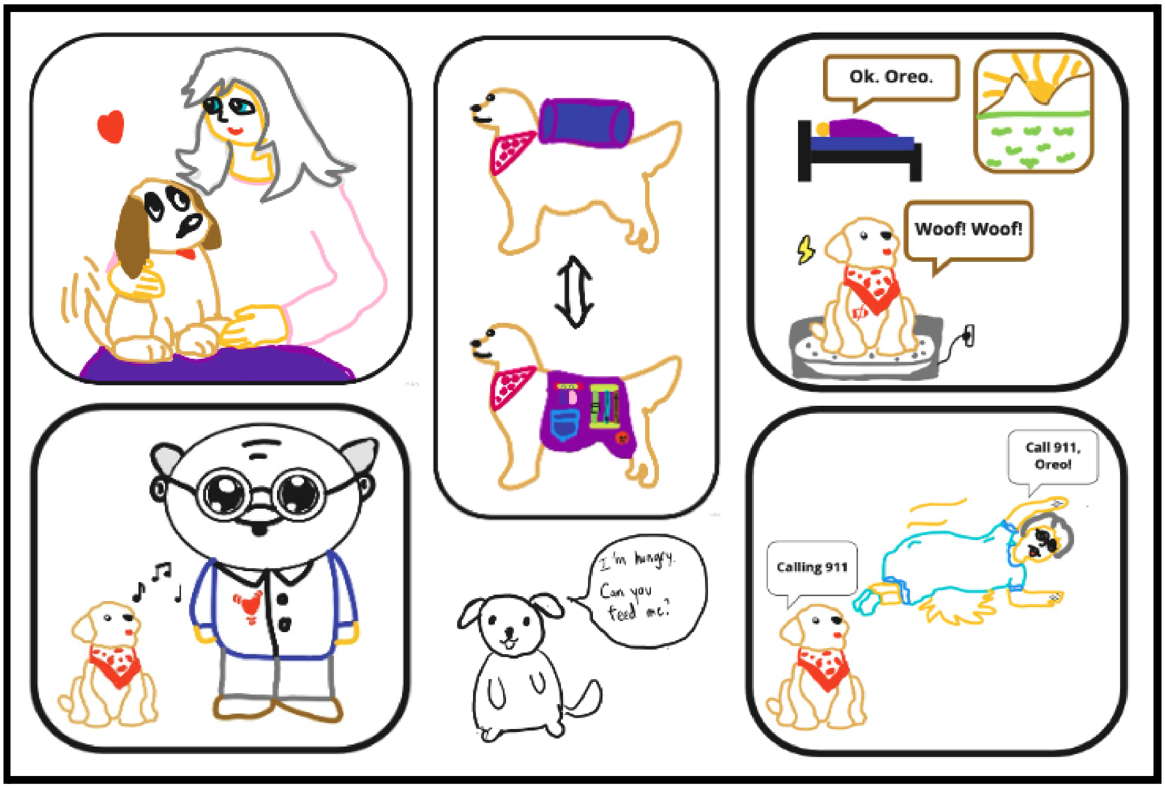

Figure 4: *TRICC Prototype Sketches*

These ideas from ***Figure 4*** were shared with our stakeholders during our second stakeholder meeting. During this meeting, our stakeholders expressed their interest in having the companion animal be as realistic as possible – that is, the companion animal we are creating should be as similar as possible to the animal we are basing the companion on. Adding features that these actual animals do not possess may be off-putting to some users and can confuse those in later stages of dementia about the actual nature of the animal.

We decided on having the companion animal be a dog as dogs are adorable and have an approachable and friendly nature. The stakeholders expressed interest in the more dog-like features we proposed such as tail-wagging, barking, and head-nudging in order to make the robot appear more realistic. They stated that for the more non-typical features of a dog such as having an alarm clock, we could make those features something that can be toggled on and off. Our stakeholders also expressed interest in the busy blanket as being an add-on item to the dog. Following this meeting, we had an in-class discussion where we continued to narrow down the features we wanted the dog to include based on feasibility. The final features we settled on include the pet having a heartbeat, reacting to pets by wagging its tail and nudging its head, barking, having led lights to draw attention, having body warmth, and having a carry-on busy blanket. After settling on these features, we began to approach the development process of the hardware, software, and busy blanket of TRICC.

Figure 5: *Flopsie Plush Goldie Labrador Dog by Aurora World Inc.*

After finalizing the features of the companion robotic pet dog, it was crucial to meet one of the stakeholders' design requirements, which is the size constraint of TRICC. Based on stakeholders' experience with other companion robotic pets, stakeholders shared that the body size of the companion robotic pets they have for people with dementia at the Kaiser Permanente hospital is about 6 to 7 inches long. Therefore, our team selected and bought an adorable and friendly-looking stuffed golden retriever puppy that has about a body size of 6 inches long from Amazon (Aurora Plush Store, 2019) [3] as shown in ***Figure 5***. Based on our measurements using a meter rule, the dimensions of the TRICC body are approximately 18 cm (length) × 8 cm (width) × 5 cm (height); hence, all of the components need to be fit into the limited size of TRICC's body.

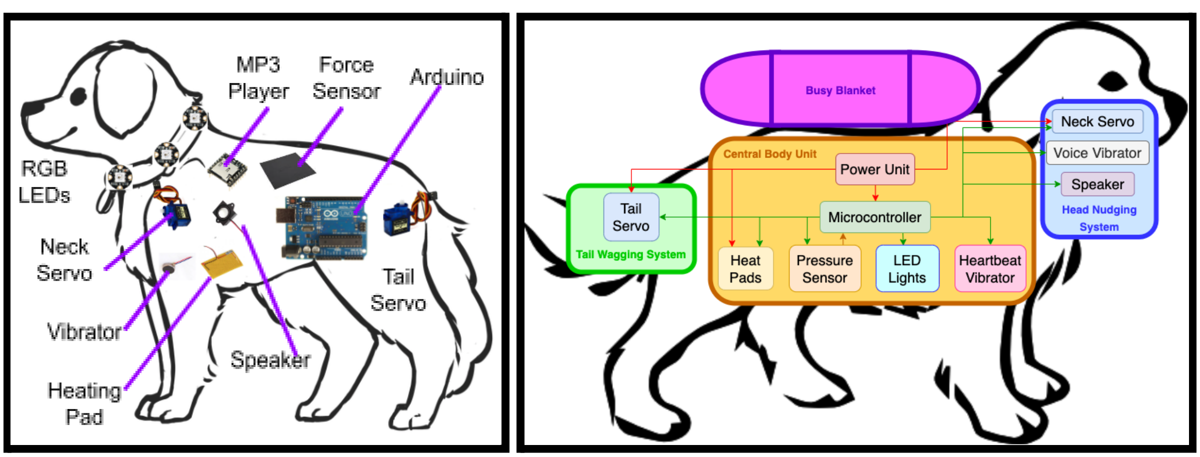

Figure 6: *TRICC's Electrical Hardware Components and System Diagram*

In order to make TRICC come to life, several electrical components are needed including a neck positional servo, a tail positional servo, a pressure sensor, RGB LEDs, a vibrating motor disc, a heating pad, a 3W 4 Ohms speaker, an MP3 player, an Arduino Uno microcontroller, a 9V battery, and a breadboard as presented in ***Figure 6*** *(left)*. TRICC's body is separated into three different sections, which are the main body, tail section, and head section. The main body contains the power unit, microcontroller, heating pad, pressure sensor, heartbeat vibrator, and RGB LEDs. The tail section contains a tail positional servo only, and the head section contains a neck positional servo, and a speaker with a built-in vibrator as illustrated in ***Figure 6*** *(right)*. Since our companion robot, TRICC, is designed to be interactive, it can sense the petting sensation from the user with the pressure sensor, and react to it happily by wagging its tail and nudging its head using positional servos. In addition, to create a more life-like companion robotic pet dog and to enhance users' petting experience, TRICC is built with a vibrating motor disc and a heating pad to simulate the heartbeat and the body heat of a real dog, respectively. Furthermore, if TRICC is not being petted for a certain period, the RGB LEDs that are attached around the neck of the robot will light up to catch the attention of the user. All of these electrical components are controlled by an Arduino microcontroller, and TRICC is powered by a 9V battery.

3.2 Technical Approach

The main objectives of the Therapeutic Robotic Interactive Canine Companion (TRICC) project are not only to ensure all the electrical components that are mentioned in ***Section 3.1.1*** fit inside the main body of the companion robot and keep them together, but also to ensure each subsystem including the heartbeat subsystem, heating subsystem, lighting subsystem, tail wagging subsystem, head nudging subsystem, and the audio system works as intended with a sufficient power supply from a 9V battery, to develop a software that allows TRICC to perform several interactive tricks that mimic a dog behavior while being petted, and to create a busy blanket that is specifically tailored for people with dementia. To accomplish the objectives, our team divided the project into three major tasks, which are the hardware mechanical and electrical tasks, the software development task, and the add-on busy blanket task.

Before building the real hardware of the robot, CAD software, Solidworks, is used to design the skeleton part of the companion robotic pet dog that helps contain most of the electrical components together by mounting them on the part. The CAD software not only helps our team to plan how each electrical component should be arranged and placed to ensure the size of the assembled parts does not violate the constraint of TRICC's body size. After the part was carefully designed, the part was 3D-printed using the 3D printer at the Electrical and Computer Engineering (ECE) Makerspace. Moreover, an open-source electronic hardware design software, Fritzing, is used to design the electrical circuit system of the robot and to plan how each subsystem should be wired appropriately to prevent any short circuits that will damage the

Arduino board. The technical approach to the mechanical and electrical hardware tasks is discussed in detail in ***Section 3.2.1***.

For the software, we focused on the logic we wanted our pet to incorporate. At all times, we wanted the TRICC to emit heat while always having a steady heartbeat. If the dog is petted, then the pet would wag its tail and nod its head. Finally, when the dog hasn't been petted for a while, we would have the lights on the collar turn on as well as have the dog bark in order to grab the attention of the user.

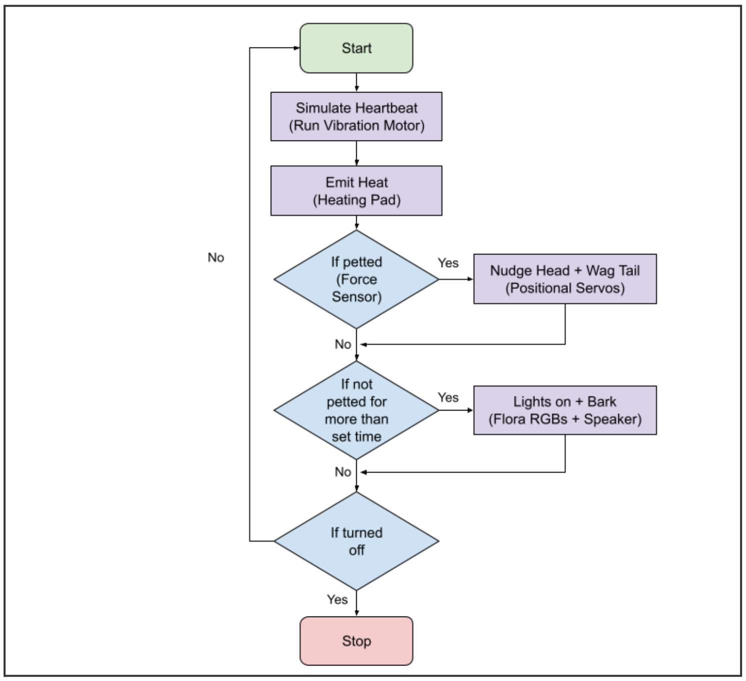

Figure 7: *Logic diagram for TRICC*

For the busy blanket, we began the process by researching examples of busy blankets online and some of the activities they have. We noted that a lot of the busy blankets have small trinkets such as buttons to engage the user. After researching, we decided on creating a busy blanket with six different tiles, with each tile having its own activity. The activities on the six tiles we decided on were "yarn tying", "buttoning and unbuttoning buttons", "poms-poms to remove and place back in an envelope", "ribbon hooks", "beads on strings", and "photograph of something significant to the user."

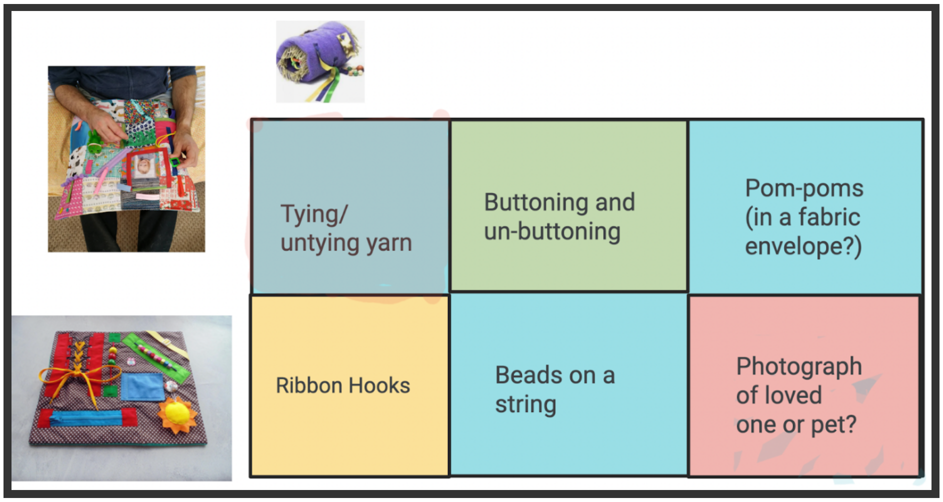

Figure 8: *Image shows examples of busy blankets found online (pictures on the left) as well as a layout of our idea of having different activities for each tile.*

3.2.1 Technical Subtask 1: TRICC's Structural, Biomimetic, and Electrical Circuit Design (Lead: Kai Chuen Tan)

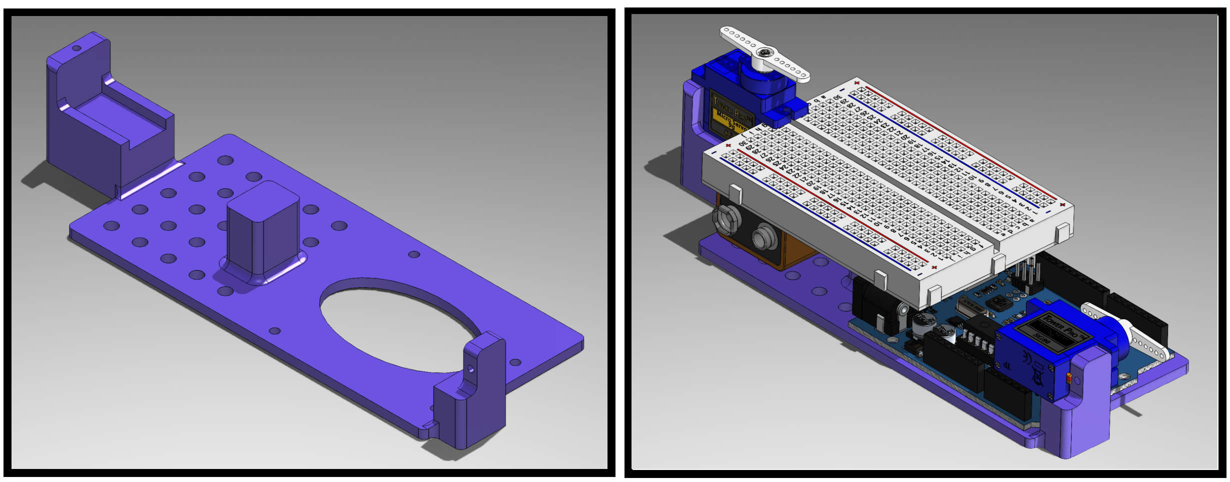

Figure 9: *Skeleton Part (left) and Skeleton Assembly (right)*

Before the skeleton part was designed using the SolidWorks, the arrangement and placement of several major electrical components, which are the 400-points solderless breadboard, neck positional servo, tail positional servo, Arduino UNO microcontroller, and 9V alkaline battery must be planned to ensure the overall size of the assembly does not exceed the size of the TRICC's body. Furthermore, the placement of the solderless breadboard must not block the Arduino pinouts that would be in use. Besides that, the placement of the tail positional servo must be placed horizontally to allow the servo to wag TRICC's tail left and right, and the placement of the head positional servo needs to be placed vertically so that the servo can nudge TRICC's head up and down as illustrated in ***Figure 9*** *(right)*. After confirming the placement of the 400-points solderless breadboard, neck positional servo, tail positional servo, Arduino UNO microcontroller, and 9V alkaline battery, the skeleton part as shown in ***Figure 9*** *(left)* is designed to combine the tail section and the head section with the main body by mounting them onto the same unibody. CAD files of the electrical components including the 400-points solderless breadboard (MRMS - WORKSHOP, 2020) [6], positional servos (Matheus, 2017) [5], Arduino UNO microcontroller (Whitham, 2014) [7], and 9V alkaline battery (Cancilier, 2011) [4] were downloaded from GRABCAD Community website to visualize how the electrical components can be assembled with the designed skeleton part accurate with all the given fairly accurate dimensions of all of the electrical components. The overall dimensions of the assembly are 165.78 mm (length) 56.05 mm (width) 46.65 mm (height) as shown in the image below, which would fit into TRICC's body.

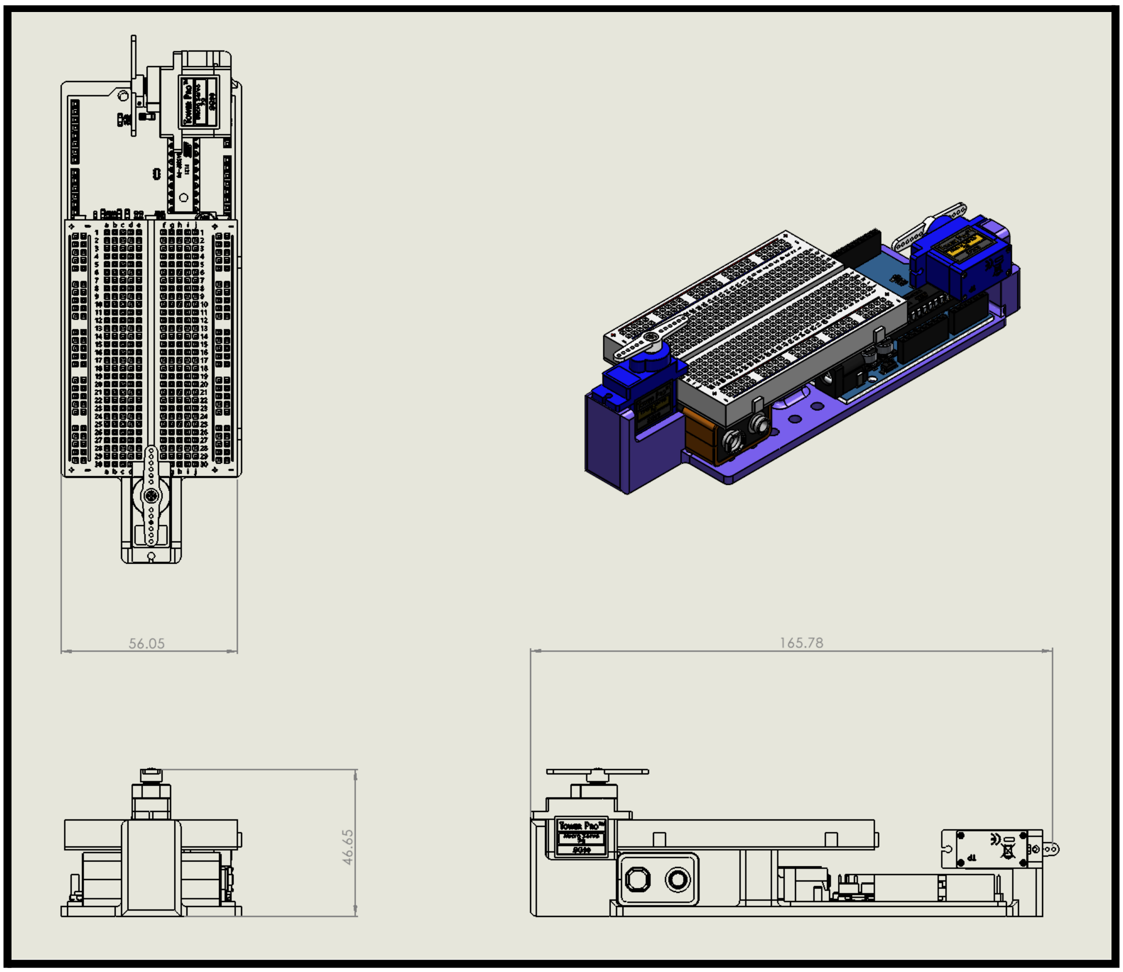

Figure 10: *Skeleton Assembly Engineering Drawing*

After the skeleton part was carefully designed, the skeleton's SolidWorks part file was exported to an STL file, which is a fairly standard file format for 3D printing, and saved to the thumb drive. The thumb drive was passed to the ECE Makerspace worker to help our team 3D-print the skeleton part for free as shown in the image below.

Figure 11: *3D-printing Skeleton Part at ECE Makerspace*

The skeleton part took approximately two and a half hours to complete the 3D-printing process. The material used for the skeleton part is the polylactic acid (PLA) material, which is lightweight and biodegradable.

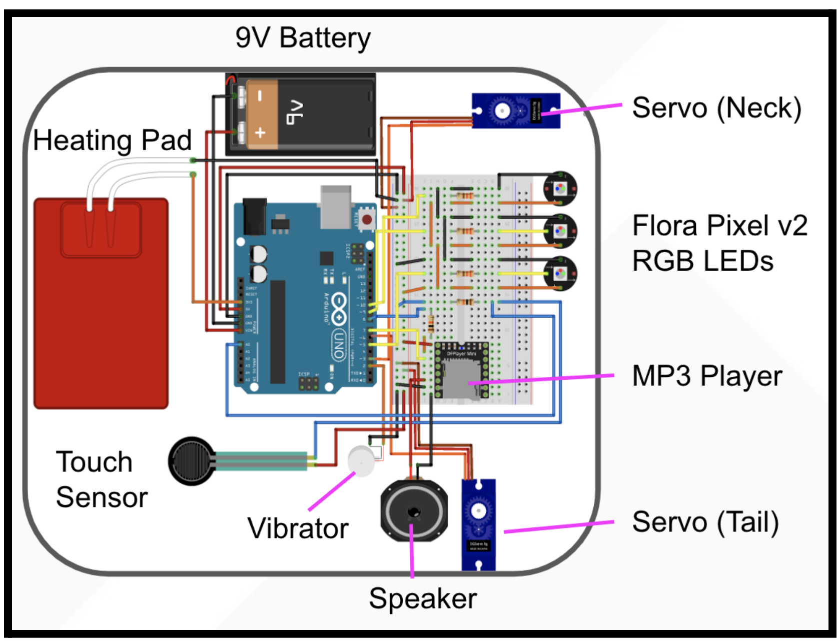

Figure 12: *Electrical Circuit System Design*

Based on ***Figure 12***, TRICC's entire ecosystem is powered by a 9V alkaline battery, and it is controlled by an Arduino UNO microcontroller board. The entire electrical circuit system consists of multiple subsystems which are the heating subsystem, heartbeat subsystem, lighting subsystem, tail wagging subsystem, head nudging subsystem, and the audio subsystem. The heating subsystem was constructed with a heating pad that was connected directly to the 5V pin and the ground pin to simulate the body heat of a real dog. Besides that, the heartbeat subsystem was integrated into the system to simulate the heartbeat of a real dog using the vibrating motor disc, which was connected to Pin 2 and the ground pin. Furthermore, to enable TRICC to wag its tail and nudge its head at a certain angle, the tail servo and neck servo were attached to the Pulse Width Modulation (PWM) Pin 3 and PWM Pin 6, respectively. TRICC is also built with a touch sensor that was connected to an analog read pin, A0, with a pull-down resistor of 330 Ohms to read the force input sensor value while TRICC was being petted. Moreover, the lighting subsystem consists of three Flore Pixel v2 RGB LEDs that were attached to PWM Pin 5, 9, and 10 to control the color output of the RGB LEDs. Finally, the audio subsystem has a DFPlayer that communicates with the Arduino microcontroller, reads 32 GB micro SD card files, and plays music using a 3W 4 Ohms speaker. In order to communicate with the microcontroller, DFPlayer's RX pin and TX pin were connected to the Arduino's TX Pin 8 with a 1 kOhms resistor and RX Pin 7, respectively.

3.2.2 Technical Subtask 2: TRICC's Software Development (Lead: Sally Lei)

The components of TRICC are controlled by an Arduino board and so, the code for TRICC was written on the Arduino IDE. The code for TRICC was written as each component of TRICC was added to the skeleton. Implementing each component at a time ensures that each component is working correctly and that we have an easier time troubleshooting if we need to.

As the positional servos for the neck and tail were the first items to be added to the skeleton of TRICC, we began by coding the logic of the neck and tail movements of TRICC. Movement for both the neck and tail is controlled by positional servos. As positional servos rotate the number of degrees written to it, we started off by determining the degree that would move the head as well as the tail to its central position relative to the dog's body. We found that 100 degrees centered the neck servo and 88 degrees centered the tail servo. Thus, within the setup function of our code, we centered the head by writing 100 degrees to the neck servo and centered the tail by writing 88 degrees to the tail servo.

After centering the servo in the setup function, we moved on to adding the head nudging and tail wagging movements in the loop function. We added a direction variable which is initiated with the value of 1 and then is multiplied by -1 in every loop of the loop function. The purpose of the direction variable was to help control back and forth movement. The head nudging was achieved by adding the direction variables times 30 degrees to move the head 30 degrees from the center back and forth. A delay of 500 milliseconds was added after writing to the neck servo to ensure that the head movement can be seen. The tail wagging was achieved by adding the direction variables times 30 degrees to move the tail 30 degrees from the center back and forth. A delay of

250 milliseconds was added after writing to the tail servo to ensure that the tail movement can be seen.

Following the implementation of the movement of the head and the tail, we moved on to adding the touch detection to TRICC and correlated it to the tail and neck movement. For touch detection in TRICC, we used a force sensor. The force sensor outputs the detected force value based on the force applied to it. We observed the value of the force sensor when we applied force to it to decide the threshold to set before movement is invoked in the dog. After testing (process described in Section 3.3, Testing Approach), the final threshold value we settled on was 200. If the force sensor detects a force value that is greater than 200, then the tail and head movement will occur. Otherwise, if the force sensor detects a value less than or equal to 200, the servos will return to their respective center positions. To account for touches that may not be detected after an initial touch that was accounted for, a counter that accounts for consecutive "no touches" was added. If the counter increments to 2 which indicates that no touch was detected for two consecutive loops, then the movements would stop and the servos would reset to the center position. Otherwise, if touch was detected prior to the counter reaching 2, the counter resets to a value of 0, and movement of head and tail would continue.

The next component implemented in the code was the Flora RGB Smart NeoPixels lights. These lights are also dependent on force detection. For these lights, a timer and a boolean called "untouched," initially set to true, were used. The boolean untouched is used to detect whether or not TRICC has been touched. If the untouched boolean is true for five or more seconds, then the lights would have the RGB values defined to be non-(0,0,0) values, and thus be turned on. When a force greater than 200 is detected, untouched gets set to false, and thus, the lights would be set to the RGB value of (0,0,0) to indicate no light. When the servos are stopped after no touch has been detected, the untouched boolean is set to true again and the timer for five seconds restarts from that instance.

Following this, we implemented the components that are independent of the force sensor – that is, the vibration motor and the heating pad. For the vibration motor which was meant to mimic heartbeat, we had it vibrate rapidly for 250 milliseconds, stop for 100 milliseconds, vibrate for another 250 milliseconds, before stopping for another 250 milliseconds. We had it repeat this pattern every loop to create a somewhat realistic heartbeat. As for the heating pad, no code was needed.

In addition, we also tried to implement a barking noise using the DFPlayer Mini which was meant to read an mp3 file from an SD card and play it through a connected speaker. The logic was that the DFPlayer would play an mp3 file of a bark when the Flora RGB NeoPixels initially turned on to help in grabbing the user's attention. However, after trying out several Arduino libraries, multiple DFPlayers, and two different speakers, we were unable to get the DFPlayer to work properly and so, the barking feature that we had initially wanted did not get implemented.

3.2.3 Technical Subtask 3: TRICC's Busy Blanket Creation (Lead: Vidya Raghvendra)

The first step in creating the busy blanket was to create the 6 tiles for the blanket. We sewed on 3 cloth tiles and super glued two cloth tiles onto a blanket base. The sixth space on the blanket was left empty as it is to contain a photograph of a loved one or something the user finds to be important. We then organized activities into each tile.

Figure 13: *Finalized Layout of Busy Blanket*

Traveling horizontally from the top left of the image of the finalized layout for the busy blanket: For the first tile, the tile with the "Tying/Untying Yarn" activity, we sowed several pieces of yarn onto different locations of the tile so that the user can freely tie the yarns in a variety of ways as well as untie the yarn afterward. The second tile contains various buttons as well as loops and a cloth with holes so that the user can play with unbuttoning and buttoning. The third tile is left empty so the user can customize it with a photograph of their loved ones. The fourth tile has fabric hooks sewn onto it, with each hook formed by folding a small piece of cloth and sewing together the long open end. These hooks were then looped through with a piece of yarn to add a lacing activity to the tile. The fifth tile is the pom-pom envelope activity. To create an "envelope", the top of this tile was left unsewn. Poms-poms were then attached to one end of several pieces of yarn. The other end of those yarns were glued to the blanket in the area below this fifth tile. Attaching the pom-poms to one end of a piece of yarn while securing the other to the blanket ensures that the pom-poms won't be lost and reduces any mess. Finally, the last tile contains the activity "Buttons on a string". This tile contained two strings with buttons on them. The user can move the buttons around the string to stimulate themselves.

Figure 14: *Resulting Busy Blanket*

All these various activities engage the tactile senses of the user while also providing sensory stimulation.

Figure 15: *Attaching Busy Blanket to TRICC*

To make the blanket a carry-on item for the TRICC, we rolled up the blanket and attached a string with velcro at its ends to the rolled-up blanket. This allowed for the blanket to be securely fastened to TRICC while also ensuring that the blanket won't be easily lost. In addition, this makes it possible for TRICC and the blanket to come as a compact unit users can conveniently access.

3.3 Testing Approach

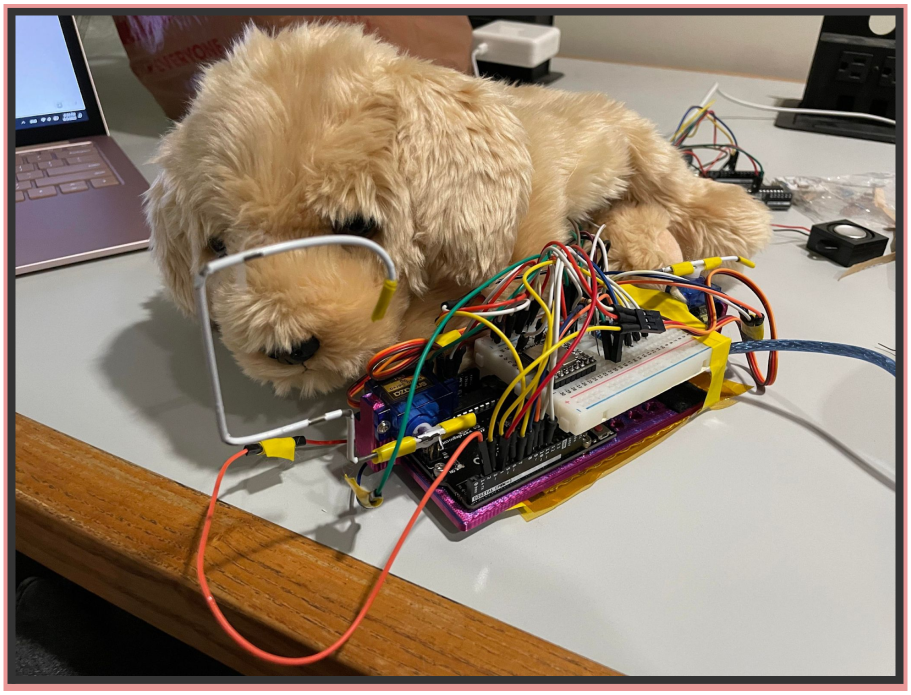

Figure 16: *Skeleton Part and Electronics Hardware Assembly*

After the skeleton part was 3D-printed, the Arduino UNO microcontroller, the neck positional servo, and the tail positional servo were mounted to the skeleton part tightly using four #4-40 screws and nuts, and two M2 screws without any fitting and dimension tolerance issues. Besides that, the solderless breadboard can be perfectly placed on top of the Arduino with the support of the skeleton part without blocking the Arduino pinouts that were in use. Next, ***Figure 16*** shows that all of the electrical components including the heating pad and the vibrator that were taped at the bottom of the skeleton part, DFPlayer, RGB LEDs, servos, and force sensor were connected to the Arduino microcontroller to build the entire electrical system of TRICC as shown in ***Figure 12***. Then, each functionality of the subsystem was tested and ran with a test sketch to ensure the wiring connections were good and worked as intended. For example, the heating pad that was directly connected to the 5V pin was able to generate about 38 °C of heat, the RGB LEDs were able to turn on and off, and the head and tail servos were able to move 30° up and down, and 30° left and right, respectively, from their neutral axis, the Arduino microcontroller was able to read the input value from the force sensor, and the vibrator was able to simulate a normal heartbeat of a real dog. The only subsystem that did not work is the audio subsystem; due to different DFPlayer hardware with a different chipset, the Arduino microcontroller failed to communicate with the DFPlayer to play recorded mp3 files. After the parts were assembled and all of the subsystems' functionality were tested, the entire skeleton part and the internal electronics hardware successfully fit into TRICC's body as presented in the following figure.

Figure 17: *TRICC's Internal Hardware*

Then, the 9V alkaline battery was plugged into the Arduino microcontroller to power up TRICC. Finally, TRICC would be ready to interact and play with the user. Besides that, TRICC only has about 2 hours of battery life, and if the battery voltage falls below 8V, the Arduino microcontroller would keep resetting due to insufficient power supply and huge current drawn from the electrical components.

Testing for the software occurred as we coded each component. After adding a component, we coded it and ensured that it functioned as intended. Anything that didn't appear to operate correctly was fixed on the spot. Determining the threshold for the force sensor in the code, however, was required for testing after the robot was built. This was because we were unable to account for the force detected after the skeleton is inserted into the dog's body and the busy blanket is placed atop the dog. We did not want the dog moving when the force sensor detected the weight of the dog's fabric along with the weight of the busy blanket. Thus, after the dog was completed and the busy blanket was secured on the dog, we measured the value the force sensor detected and established that measured value plus a value of five to be the minimum threshold value. Following the determination of the minimum threshold, we petted the dog to determine the value of the threshold. We found that the value detected when we placed a sufficient amount of pressure on the backside of the dog where the force sensor was located was 200. The value of 200 is greater than the established minimum threshold value and so, after this testing process, we set 200 to be the threshold value for our force sensor.

Figure 17: *TRICC and its Busy Blanket*

To test the busy blanket, we fiddled with the various tile activities to ensure that all parts were secure.

Results

TRICC is built with several electrical components including actuators, sensors, LEDs, and a heating pad, and sensed petting via a force sensor. TRICC is also powered with a 9V battery. We interacted with TRICC in order to confirm our expected behavior– that when a user pets TRICC, it responds positively by wagging its tail and nudging its head up and down. If TRICC hasn't been pet in a little while, it will grab the user's attention when colorful lights on its collar around its neck illuminate.

Features such as a built-in heating pad to imitate the warmth of a real dog, as well as a simulated vibrating heartbeat proved to help TRICC feel realistic when we interacted with it after building it. Lastly, we found that the detachable busy blanket was both warm and provided interesting activities to complete. The velcro attachment also ensured that the busy blanket would be less likely to be misplaced, and would be convenient for a user to access.

Figure 16: *TRICC Laying on Top of the Busy Blanket we Created*

Figure 17: *TRICC's Collar Lights Illuminate when it has not been Petted*

While it would have been interesting to test out TRICC with the users that we had designed for (people with dementia) if time permitted, based on our own interactions with TRICC we were glad to see that our original goals for the robot (providing stimulation, engagement, and calm) could be accomplished.

Overall, our project was successful in terms of the goals we had outlined in our proposal– with the exception of the speaker functionality, which did not work due to an issue with a hardware component (the DFPlayer), we accomplished all of the tasks we had planned and were able to ensure that these planned features worked within the timeframe we set.

We also had the chance to demo our robot to our main stakeholders, Dr. Stacey Vieyra-Braendle and Dr. Christine Grosso, and were happy to receive positive feedback from them. We did receive a few follow-up questions from our stakeholders during the development, including whether the robot's neck would be able to move in additional directions, as well as whether we planned to add more padding to the robot so that it would be soft. We did add more cotton padding into the robot to ensure that it would be soft and comfortable for users, and decided to explore additional head movements (side-to-side in addition to up and down) as a next step in the future.

Discussion and Future Work

The applications of TRICC are many– in addition to potentially helping people with dementia, TRICC could help any groups of people who might benefit from the calm, focus, engagement, and interactivity that TRICC is meant to provide. These groups could include people living in nursing homes or other care facilities, patients who might have extended stays in hospitals, and perhaps even young children who might benefit from TRICC's features.

We are excited about the features we have implemented thus far and think it would be helpful to tailor the robot's features to specific clients as potential next steps. For instance, if one client might find the collar lights distracting rather than helpful, we could configure them to glow with less frequency. We could also ask clients about their preferences for TRICC's head and tail movement and incorporate the ability for it to play calming music. Because we have included a zipper in the underbelly of the dog, internal technical components can easily be accessed and therefore easily moved or modified.

To summarize our lessons learned, timing is key when working on a robot. Having sufficient time to research, listen to stakeholders' input, and work on both software and hardware is key, and we saw this in the main roadblock that we encountered in the building process. The DFPlayer, which is responsible for playing the barking audio, was not working properly (despite trying out multiple pieces of the hardware and trying to debug the issue)-- more time would have allowed us to order components earlier, and try to solve the problem earlier. Future groups working on extensions to this project or similar projects could keep this in mind and decide on their supply lists as soon as possible after determining which features they will implement.

In the future, we hope to ask TRICC's users what other features they would like to see in TRICC and customize features to their specific needs. We also think that implementing the barking feature with a speaker would be very helpful for enhancing the interactivity and engagement provided by TRICC, so would suggest that as a possible first next step

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Appendix

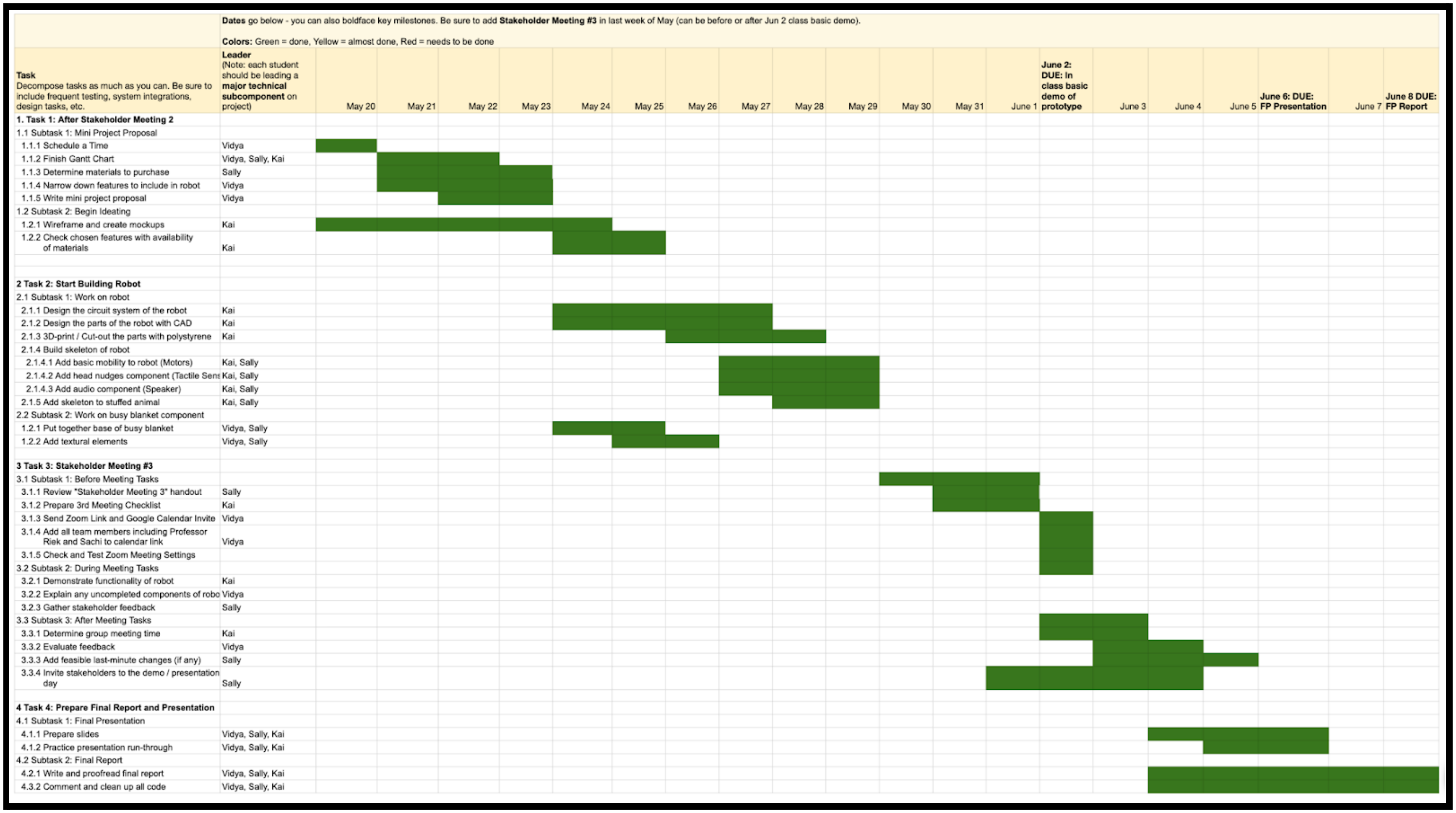

Figure A1: [*TRICC Project Gantt Chart*]