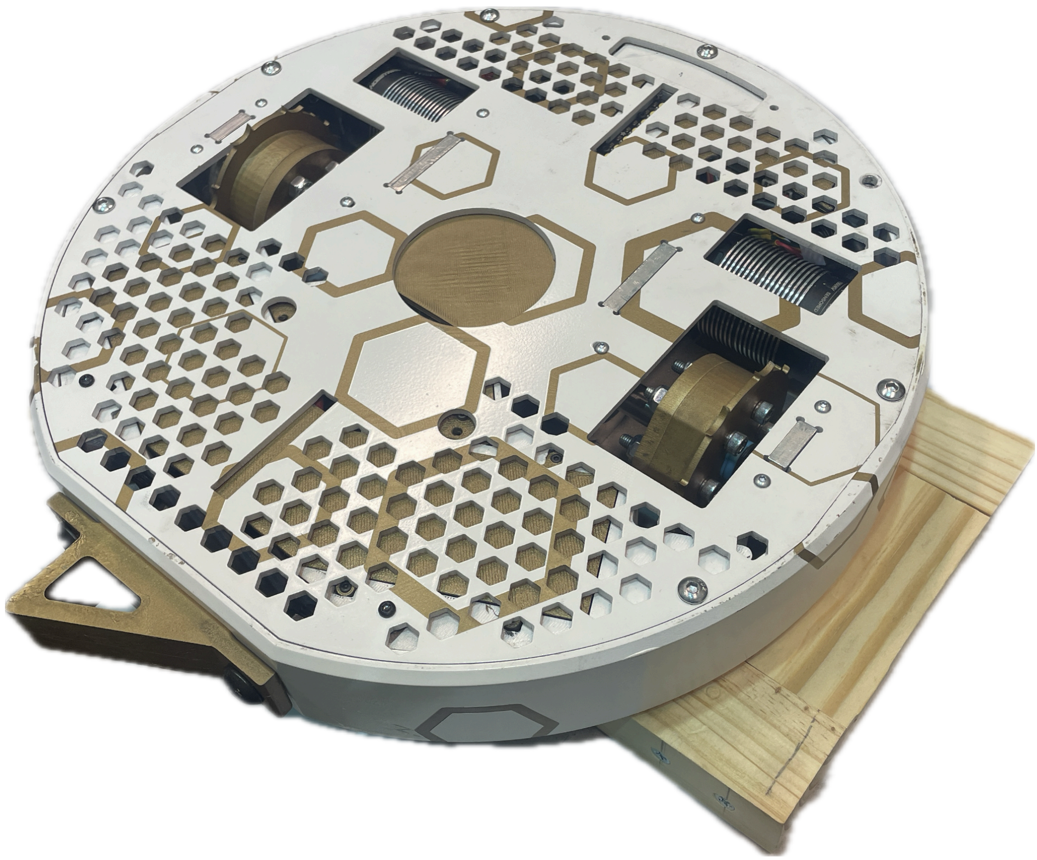
Hockii

2022-2025



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Section 1: Overview

1.1. Introduction

Hockii is the second version of Hocki, Robojackets' initial attempt at a meltybrain robot that competed at Motorama 2022 and defeated Bucki in valiant combat. As a meltybrain, it lacks a separate weapon and instead makes use of its entire mass to strike its opponents, modulating motor speeds to translate while still rotating at high speeds. To create this robot, inspiration was taken from the original Hocki, along with other meltybrains such as Project Liftoff and Halo, melding the lessons learned from the past and concepts that have found success at competition to create a new, cohesive design. This report shall discuss the various factors that have been considered in this latest iteration and justify the choices made, giving the reader a full understanding of the robot's lifecycle from concept to combat.

Figure 1. Hocki v. Bucki, a fight for the ages.

1.2. Concept Motivation

Meltybrain robots are known for the high angular velocities obtained by the entirety of their bodies, resulting in both high amounts of energy imparted to struck opponents and high accelerational forces applied to its internals, creating an interesting design problem that attempts to maximize energy transfer while also minimizing damage to one's self. This style of robots has the greatest potential for damage amongst those of its weight class due to their ability to put every ounce of its mass into a hit, making it attractive to bring to competition. However, the aforementioned self-destructive tendencies make this easier said than done, as seen with the original Hocki. This particular robot aims to look at the successes and failures of its predecessor and the other robots currently leading the field to create an equally powerful contender.

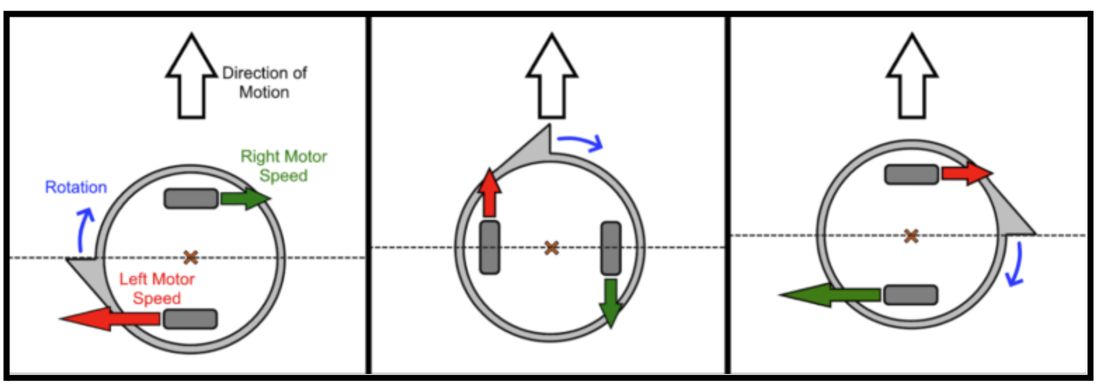

Figure 2. This image of unknown origin describes the translation strategy of a meltybrain, using the sizes of the arrows to show the relative speeds at which each motor rotates to create forward motion throughout a single revolution.

1.3. High-Level Design Overview

From the outset, Hockii was intended to be a mechanical overhaul of the original, reusing much of the original's electrical and software design with improvements using the experience from Motorama 2022. However, to facilitate a design using sensored motors that had the potential to aid in some of the issues seen at competition, many subsystems intended to be left alone were reviewed and revised. Even so, both robots follow the same core design schema, with a thick aluminum ring enclosing the electronics, constrained by two metal plates. Hockii deviates from its precursor by shrinking vertically while expanding radially, maximizing its moment of inertia. It also moves away from the intrinsic aluminum tooth mount to a bolted-on steel design following unexpected damage seen at competition. It makes use of cleated titanium wheels to better grip the wooden arena floors, and it encloses the wires and electronics in a clamshell to avoid wire strain and electronics damage from the high accelerations.

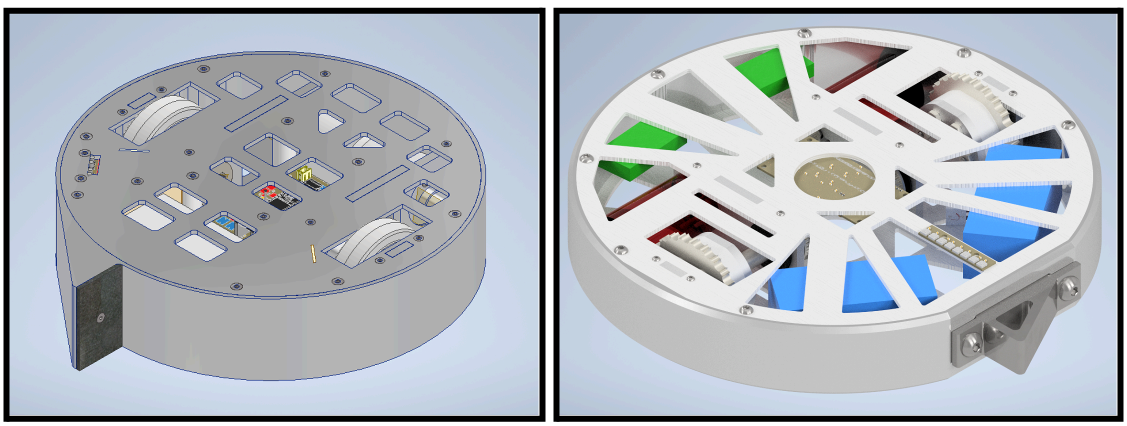

Figure 3. This figure shows the design of the original Hocki (left) and Hockii (right).

This cleated wheel design was inspired by Project Liftoff, which has used a similar system to great effect at NHRL in the past. Additionally, a decision was made to focus weight on the edges of the bot, much like Halo, despite not being a "ring-style" meltybrain.

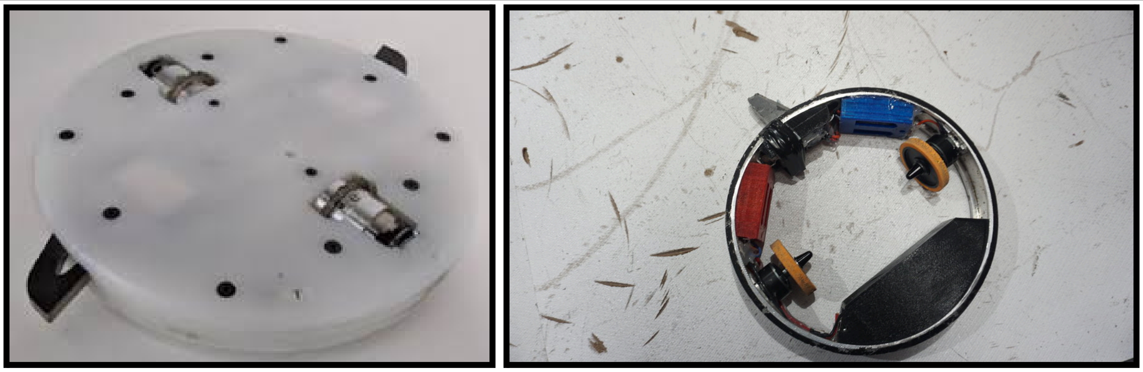

Figure 4. The images above depict two successful beetleweight meltybrains, Project Liftoff (left) and Halo (right). These robots and the design choices they have made over their many iterations provided some guidance on the direction Hockii eventually took.

1.4. Hocki Review

Hocki, due to being an experimental robot for Robojackets, had some compromises made mechanically due to the lack of a base to build on, and, as such, left over a pound unutilized. Despite this, the design proved to be relatively robust in most respects, as seen in Figure 5, in which the only damage to the outer circular surface of the shell was a few gouges taken out. This gave a strong starting point for the chassis thickness, informing future design decisions.

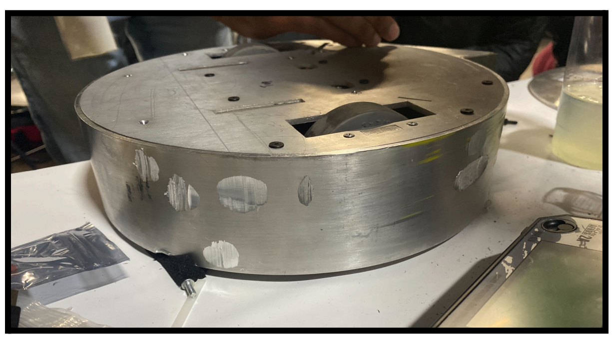

Figure 5. This shows Hocki following a few fights, in which the outer shell remained mostly intact.

However, despite the robustness of the primary chassis walls, the tooth mount failed to hold under the experienced loads. The steel tooth, directly affixed to the outer shell, caused the mounting location to cave inwards while also shearing the mounting bolt, damaging the shell and preventing its removal. Similar issues arose with the top and bottom plates, which also became locked in place due to the sheared mounting bolts. This makes it clear that the method of attachment for these subsystems requires further analysis and development.

Figure 6. This depicts the caved-in tooth mount

The bot also suffered from imprecise movement at a low-speed tank drive, which was likely an effect of the low torque and confusion inherent in BLDC motors when insufficient back voltage isn't built up. The high rotational speeds of meltybrains prevent highly geared BLDC motors from being used to overcome this low-speed-low-torque weakness, so sensored motors are a necessity. Sensored motors utilize hall effect sensors to locate the orientation of the motor and immediately apply the full current to the appropriate poles, allowing it to use its maximum torque even at low speeds.

With these factors in mind, large changes must be made to the chassis, teeth, drive, and electronics, which will be further detailed in later sections.

1.5. Hockii V2

Section 2: Chassis

2.1. Overview

The chassis was the primary point of change between Hocki and Hockii, with a near-total redesign occurring. The chassis is made of 4 major unique systems: the ring, the top and bottom plates, the electronics clamshell, and the weapon teeth, which may all be seen in the figure below. Its primary purpose is both protecting the internals and striking the opponent while sustaining several hundred g's of acceleration, requiring close attention to the balance of mass and the location of each component.

Figure 7. Chassis

2.2. Frame

2.2.1. Ring

The Hockii ring is a highly complex, 3D CNC'd part that encapsulates many subfunctions into one.

2.2.2. Plates

2.3. Electronics Clamshell

2.3.1. Hockii V1

2.3.2. Hockii V2

2.4. Weapon Teeth

2.4.1. Overall

Like Hocki, Hockii was designed to have one weapon tooth with relatively low bite to maximize the opportunity to spin up after impact. During the original design phase, a triangular tooth shape was selected over concave and convex teeth using comparative FEA because it was the best combination of mass and strength. The tooth sits in a pocket on a flat in the outer ring; because the pocket is not a slot going all the way through the material, the stiffness and strength of the ring are not highly affected. The teeth were manufactured in both steel and titanium; the titanium teeth are more experimental, but weigh less than the steel.

2.4.2. Steel

The steel teeth are made of CNC-milled S7 tool steel, chosen because of its high strength, impact toughness, and hardness. The teeth were hardened after machining to an approximate hardness of Rockwell 54C to increase their effectiveness as weapon teeth. The triangle design was modified with a large internal cutout for weight savings and rounded internal and external corners to reduce the risk of cracking.

2.4.3. Titanium

The titanium teeth are made of Ti6Al4V ELI, which is Grade 23, printed on an EOS M 290 laser powder bed fusion 3D printer (flex). To leverage additive manufacturing technology effectively, two different designs were created using the Generative Design feature in Fusion 360, one through generative design and the other through topology optimization using the steel tooth design as starting geometry, with the intention of optimizing the tooth geometry for the assumed loading conditions. The teeth were annealed after printing to increase toughness, and the surface was smoothed significantly on thin sections to reduce the risk of cracking.

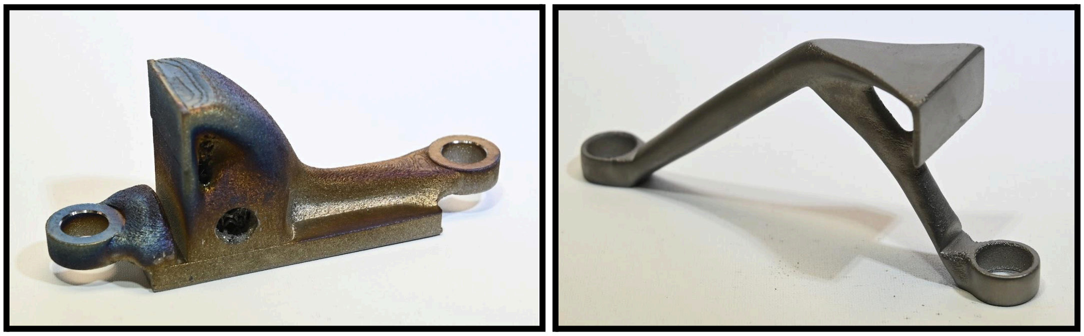

Figure 7: The images above show the two titanium tooth designs. The generative design option, left, slots into the outer ring like the steel tooth. It is multicolored due to discoloration that occurred during the annealing process. The topology optimization option, right, is lighter but does not slot into the outer ring.

Section 3: Drivetrain

3.1. Hockii V1

3.1.1. Hockii V1 Overview

Like all meltybrains, Hockii's weapon is itself, so the drivetrain needs to be robust and easy to control. Hockii's drivetrain is composed of two mirrored systems, each with a motor (described in 4.3.1), a live shaft, a wheel assembly, two pulleys, and a belt. Each drive system is aligned and attached to the chassis with two aluminum 6061 plates, both with press-fit ball bearings and one with a motor mount.

3.1.2. Shaft Design

The shaft for each drive system is made of Grade 5 chemically pure titanium for rigidity. Retaining rings and keys are used to hold the wheel pulley, wheel assembly, and plates in the correct orientation and position.

3.1.3. Wheel Design

Each wheel assembly is three parts: the wheel, the plastic spacer, and the keyed plate. The three parts are connected by 6 button head bolts with nuts. The wheel is made of titanium for rigidity and strength. The shape has teeth similar to a saw blade to maximize the traction on soft arena floors (i.e, wood). The plastic spacer is 3D-printed PLA for lightness and design control. Its purpose is to make the footprint of the wheel the same as the backup Colson wheels, so no major modifications would be necessary if the titanium wheels had to be ditched. The keyed plate is made of aluminum 6061 because it needs to hold up to torsional loads. It constrains the wheel assembly to the drive shaft axially.

3.1.4. Pulley Design

The wheel and motor pulleys are made of Ti6Al4V ELI and were printed on an EOS M 290 laser powder bed fusion 3D printer (flex 2.0) to ensure accurate tooth geometry. The motor-to-wheel ratio is 1:3 to increase torque without drastically decreasing speed. The belt is a 6 mm timing belt with GT2 teeth made of neoprene with fiberglass cords for strength. The wheel pulley is keyed to the drive shaft, while the motor pulley is pressed onto the motor's D shaft. The wheel pulley has internal lattice structures for funsies and weight reduction.

Figure 8: This is an artistically staged image of the drive pulleys.

3.2. Hockii V2

3.2.1. Hockii V1 Results & Hockii V2 Overview

The drive subsystem was the main failure point for Hockii V1. During the first match at March 2023 NHRL, the retaining rings on the end of one of the drive shafts slipped off, allowing the wheel to slide into the chassis and lock in place. This issue was temporarily rectified after the match by copious amounts of hot glue. Despite promising testing before the second match, the robot was unable to move in the box before the second match had even begun due to the teeth on the belts having been completely worn down due to friction with the pulleys.

The Hockii V2 drive redesign addressed the issues faced by V1 while increasing the overall robustness of the drive subsystem. The main components and layout are the same, and the wheel assembly is effectively identical, other than a switch to TPU for the 3D-printed spacer.

3.2.2. Shafts & Bearings

The most obvious difference between Hockii V1 and V2 drive subsystems is the switch to tapered roller bearings. This swap was made to increase bearing robustness after a few too many crunchy bearings and to allow the system to withstand larger axial loads. Tapered roller bearings must be axially preloaded to function correctly; conventionally, this is done with stiff springs. This method, while simple, is relatively imprecise, so we decided to pretension the bearings by squeezing them into the mounting plates using a retaining feature on either end of the shaft (a retaining ring on the inner end, and an end-tapped bolt and washer on the outer end). The end-tapped bolt required the mounting plates to be held in place while it was tightened to ensure effective tuning of the compressive force, which was annoying, but the bolt did not loosen (once Loctite was applied), so it (theoretically) only needed to happen once.

3.2.3. Pulleys

After some experimentation, we determined that the issues with the Ti pulleys used in Hockii V1 were the surface roughness and the pitch. Somehow, the pulleys ended up with a pitch of 2.5 mm, but the V1 drive system used 3 mm-pitch GT2 belts. To address both of these issues, the V2 drive system uses off-the-shelf 2 mm aluminum pulleys, which required some machining but removed all naturally occurring risks to the belts. The decision to move to 2 mm GT2 was due to belt availability.

Section 4: Electronics

4.1. Hockii V1

4.1.1. Overview

The overall design of the robot electronics has been simplified. The IR subsystem has been removed because the other sensors should provide sufficient data for accurate driving and weight considerations.

4.1.2. Control PCB

The control PCB is the only board that has been changed since the first iteration of the robot. It still interfaces with the LED board the same way that the V2 Hocki board does.

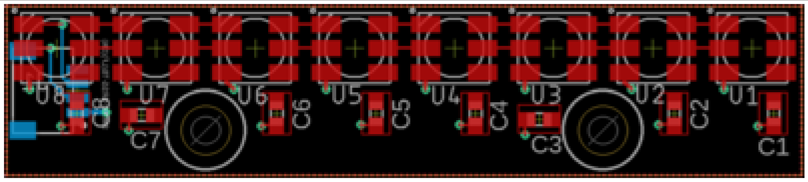

Figure 7. 8 RGB LED board

Due to the failure modes suffered by Hocki during competition, we have opted for a simpler design focused on more robust connections and retaining only necessary sensors that we are confident in.

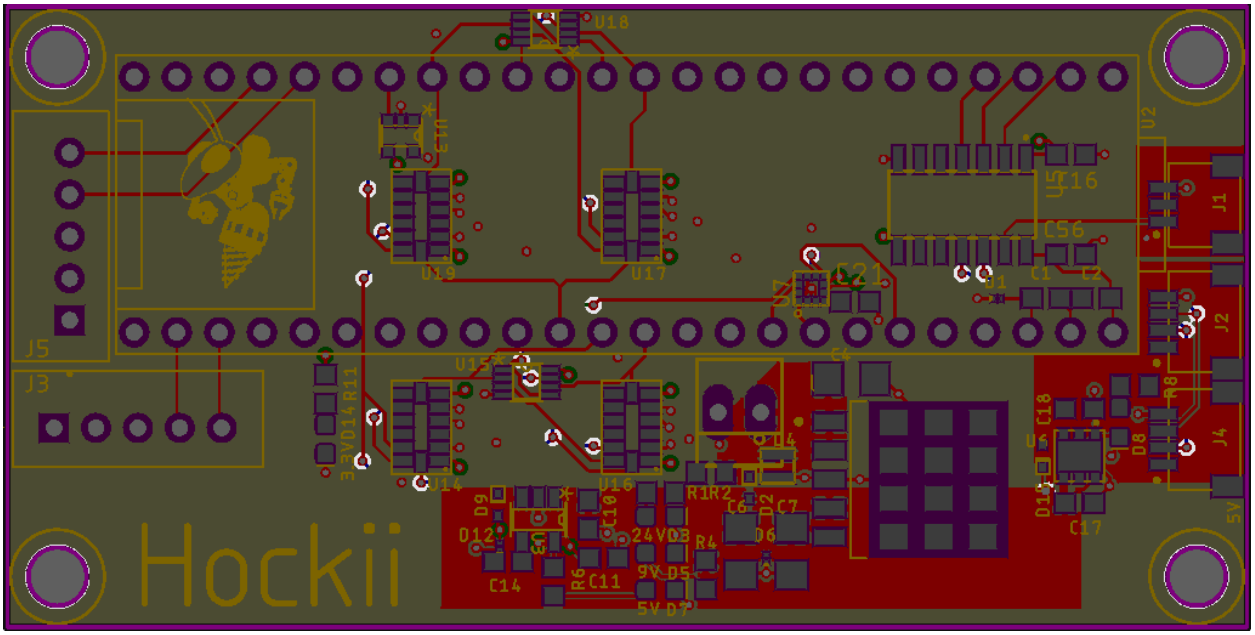

Figure 8. Hockii control board

Although the LED and receiver connections are the same, the board now interfaces with the ESCs and LiPos using robust thru-hole connections without the drawbacks of the IDC system. The board is smaller than both versions of the Hocki control board due to the removal of the IR subsystem. The magnetometer is now digital, which removes peripheral analog circuitry. Other minor changes include the voltage regulators, but those were only swapped out due to chip availability.

4.1.3. Weapon Motor

Due to low-speed driving accuracy experienced by Hocki, Hockii uses a sensored motor.

4.1.4. Weapon ESC

There are 2 locations for potential ESC connections from the control board, but ideal operation utilizes a CAN bus between the ESCs.

4.2. Hockii V1

4.2.1. Overview

Section 5. Performance

5.1. Hockii V1

5.1.1 Hockii V1 Matches

Match 1: Kilajoule (undercutter horizontal)

- Result: L (KO)
- Their gears exploded immediately, then our retaining ring came off like 20 seconds later

Match 2: who even remembers

- Result: forfeit
- Belts

5.1.2. Hockii V1 Strengths and Failure-Points

Bad robot

5.2. Hockii V2

5.2.1. Hockii V2 Matches

Match 1: Budget Boi (lifter)

- Result: L (tap out)
- Mesum got bored

Match 2: don't remember

- Result: W (forfeit)

Match 3: Sievert (midcutter horizontal)

- Result: L (tap out)
- The robot exploded because Mesum got bored and full sent into the weapon

5.2.2. Hockii V2 Strengths and Failure-Points

Sploded.

Section 6. Final Thoughts

Uh

Don’t do it

Section 7. Appendix

7.1. Contributors

- Hockii V1
  - Steven Zhao (Lead)
  - Madeline Belew
  - Valentin Richter
  - Divyam Kumar
  - Martha Leach
  - Mesum Zaidi
- Hockii V2
  - Martha Leach
  - Mihir Nagaraj
  - Mesum Zaidi

7.2. Peep the outdated GT logo lmao