Project Mobee

ISDN 3001 Final Report

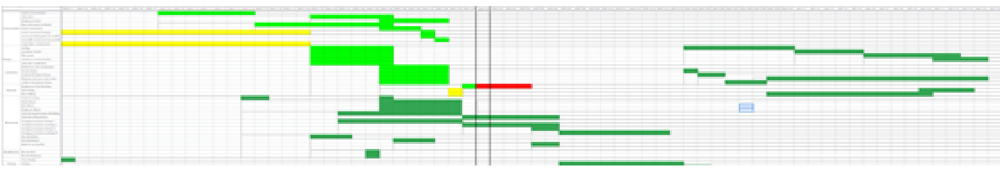
Group MEC (Marius, Eric, Cat)

CONTENT

1. Process and timelines

The project starts from the fall semester of 2020. The theme of the project is already confirmed, so we start with interviews. Then we move on to define our first HMW questions and then we do some questions iterations and decide our final HMW questions. We decide our solution in the next project and generate our specification and visual prototypes. After going through several iterations, we move on to work on our functional prototype.

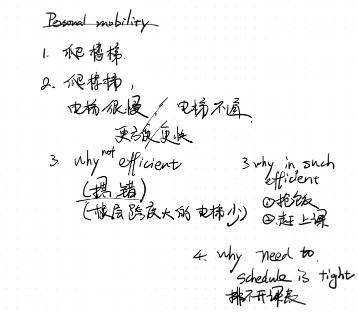
Sep, 2020	Interview, need gathering and generate problem statements
Oct, 2020	Refine problems
Nov, 2020	Concept selection
Dec, 2020	Concept review and POC, Building prototypes
Jan, 2021	Biulding Prototypes

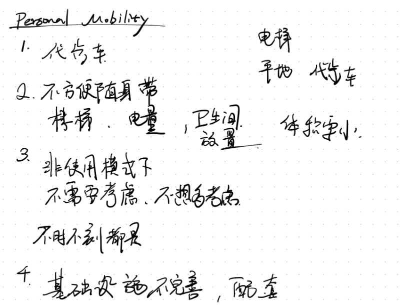


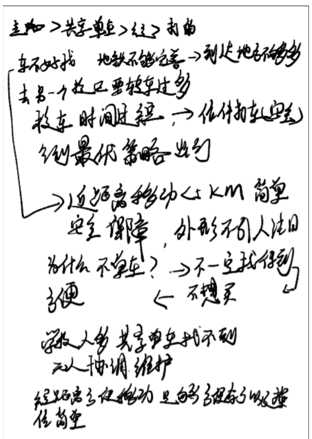
Gannet chart can be seen here: https://docs.google.com/spreadsheets/d/1gEfs-qn6VfNM5k_owu8gQQoR1pUlCxtI3GJ4g8svCk0/edit?usp=sharing

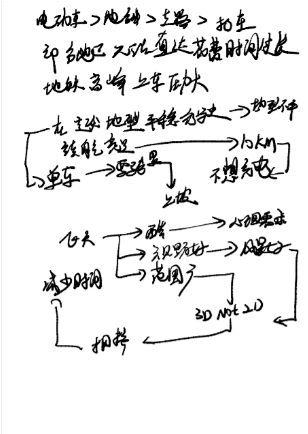
2. Needs gathering

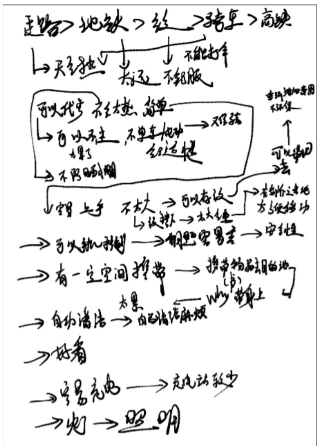
Our needs gathering mainly consist of interviews. Personal mobility is all about taking a person to their destination at the right time, so we start with finding interviewees that do a lot of commuting like students and workers. We ask them about how they usually go out and what problems are they facing during the process. Some of the interview notes can be seen here. Since most of our interviewees are Hong Kong locals or live in Mainland, most of our interviews are done in Chinese to avoid language barriers and misunderstanding.

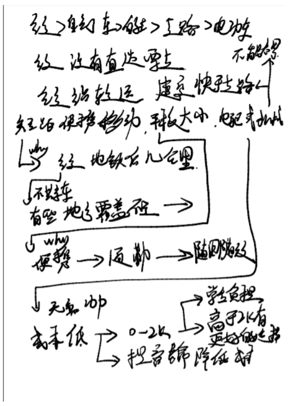


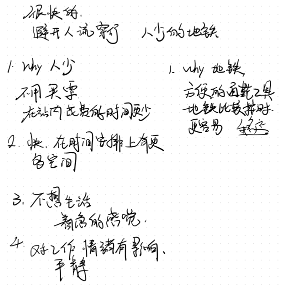












Below are the two representative interviewees:

1. An year 3 undergraduate student studying in Si Chuan China:

   One of the two most representative interviewees was a year 3 student studying in SiChuan. “I mostly travel inside campus on foot. Sharing Bike is my second choice when the distance to my destination is a bit far for walking yet too short to take a bus. I always spend a lot of time finding a sharing bike. Sometimes the nearest is too far, sometimes the bikes are broken.” When we tried to dig deeper and ask him why not buy a bike/PMD. He said that there is no place for him to store such an object in his place. *In this case, we define storage and the last 1Km problem as the need and pain point we need to focus on.*

2. A year 4 Chinese student studying abroad:

   Another representative interviewee was a year 4 Chinese student studying abroad. ”I live in a sub-area, I need to walk for a while to the bus stop when I leave home because there is no other way for me to get to the bus stop. The reason I do not want to buy a PMD is you need to take care of it, either carrying it with you or locking it somewhere, to me it is annoying.” The thing that prevents him from using the PMD is not actually the PMD itself but the trouble during maintenance and parking. *From which we summarize our second need statement: the parking and maintenance issue.*

3. Literature Research

Personal mobility is a highly developed market with all kinds of interesting products. Companies like XiaoMi, Segway and other startups have been working on this area. Therefore, there are a lot of products that can be seen on the internet. In this session we will go through some of the products we think are very interested to be mentioned.

3.1. Ground personal mobility devices

In general, ground personal mobility devices can be divided into two different types according to different thoughts. One class tries to minimize the size of the device and make it easy to carry, another class focuses on the comfort of the user more. Basically, almost all devices in this catalog are modified from some common device.

3.2. Underground personal mobility devices

This catalog only has several devices. Almost all of them focus on how to transfer objects fast. Almost all of them try to dig deep into the ground and build tubes or rails.

3.3. On & Underwater personal mobility devices

There are two kinds of devices in this catalog. One try to add power, another try to make different devices working in the water.

3.4. On-Air personal mobility devices

Except flyboard-like devices, this catalog only contain some fix-wings or rotor-wings drone that take
some person.

3.5. Important product examples and factor analysis

In this session several products are listed out and analysed based on the factor listed in the chart. This allows us to compare all the products and see what is common or why the product succeeds or fails.

factor	Gyroshoes 	AMX Ebike 	Mini Falcon 	The ONE 	skatebolt 	WHILL Model CI 
cost	**	***	***	***	***	*****
Environ ment	***	*****	****	****	****	****
weather	*	**	***	***	***	****
sustain ability	****	****	****	****	****	****
conveni ence	*****	**	****	****	*****	*
comfort	**	*****	****	***	***	*****
safety	**	*****	****	****	**	*****
persona l space	**	***	**	***	***	*****
simplicit y	*****	*****	*****	***	*****	**
maneuv erability	**	*****	****	****	***	*****
fun	*****	****	****	***	*****	**
Endurance	8km		10km 25km/h 8kg	40-60km 12.5kg	15miles	

Below is the products summary that is highly related to our later on project.

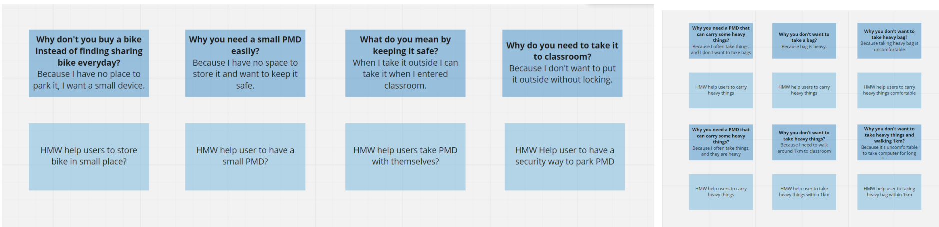
Product Name	Summary of the product
e-Scooter and Self-Balance device 	Expensive for individual user Take certain amount of place to store Hard to carry when not in use
OFO sharing bike 	Fast Easy to use Hard to manage,maintain and control distribution Sometimes hard to find or too far to get one
Segway loomo 	An open platform for engineers and designers that has: 1.SDK 2.Intel's RealSense camera and IMU 3.Hardware Extension Bay 4.Robot Base can be used to create personal product by building robot applications and accessories

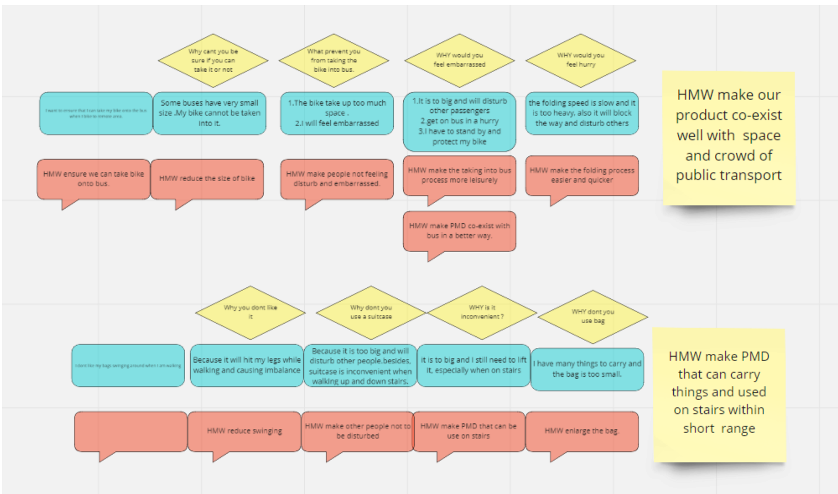
4. Problems formation and re-defining

The three team members of this project went through different problem formulation processes. The interview related to PMD is done separately. During our interview, Abstract Ladder is used to drive us to ask deeper to find the real need of the interviewers. By keep asking why to the user, we can deep down mean while we can generate the HMW problems taking reference of interviewees answer. Below is some of the Abstract Ladder we did during the process.

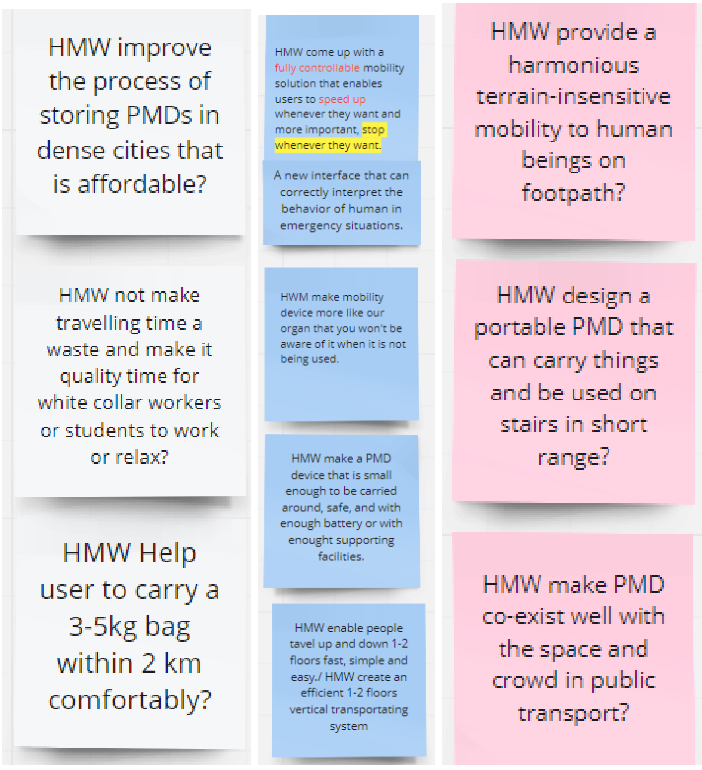
Based on the different interviewees and different Abstract Ladders, we selected and developed our 9 HMW problem statement.

These 9 questions are the very first question we got from our interview. After this we repeat the process again by doing an interview using Abstract Ladder and generating HMW problems statements based on what we have in our version one problem statement again and finish an iteration of our problem statement.





At last, by partnering with other people, we get several refined problem statements.



Here we got our first generation HMW problem related to our later project, which is state as below:

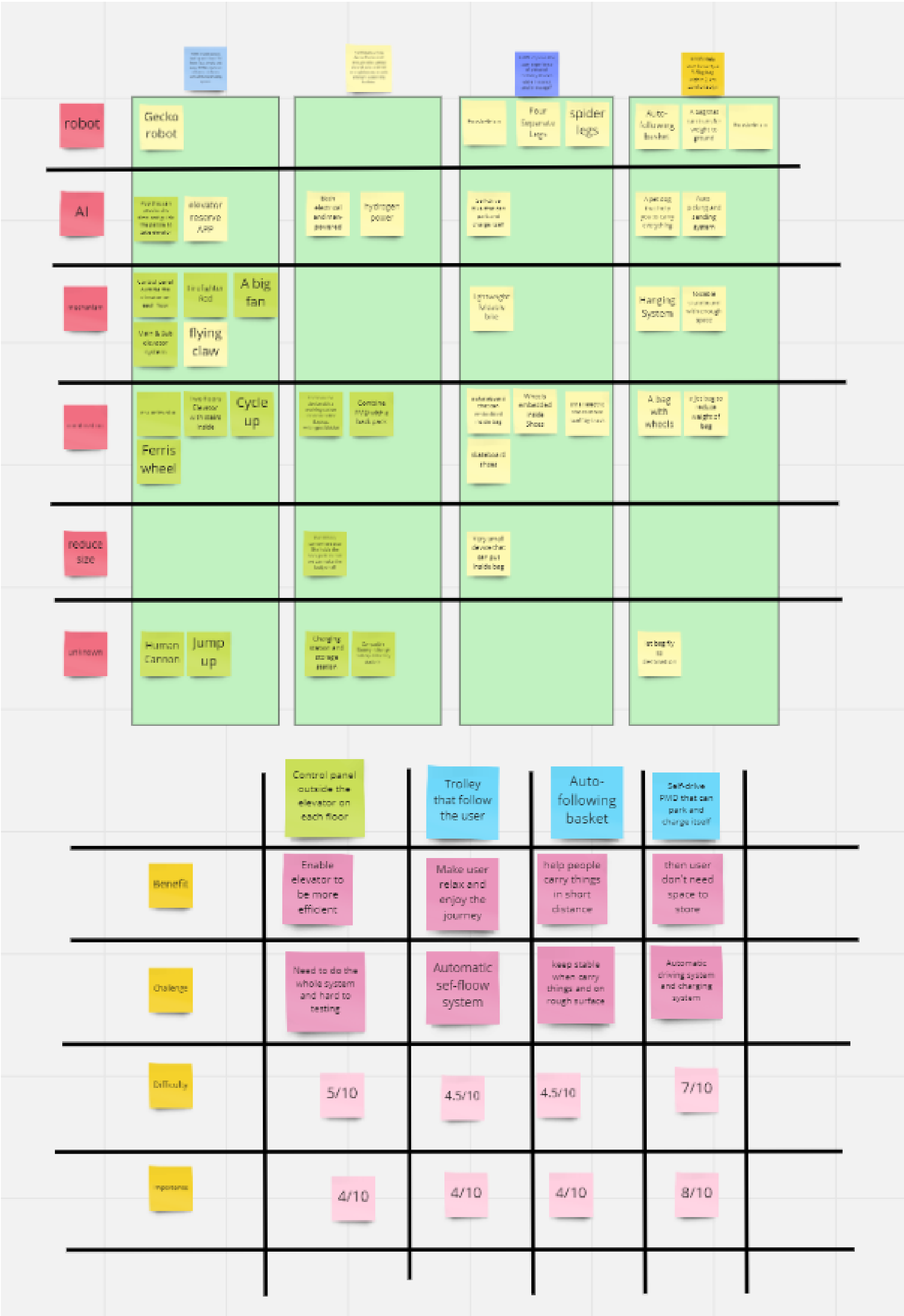
1. *HMW enables people to spend their last mile's journey more conveniently?*
2. *HMW helps users to store their personal mobility device?*

We did several more interviews and several round discussions, we discovered that what ofo is trying to solve is exactly what we have stated above and we know that ofo has a lot of problems that are worth solving. So we refined our problem further more into the following statement:

1. *HMW create a SHARING Personal Mobility Device that can enable people to spend their last mile's journey more conveniently?*
2. *HMW make changes to sharing PMD devices to make them easy to be managed*

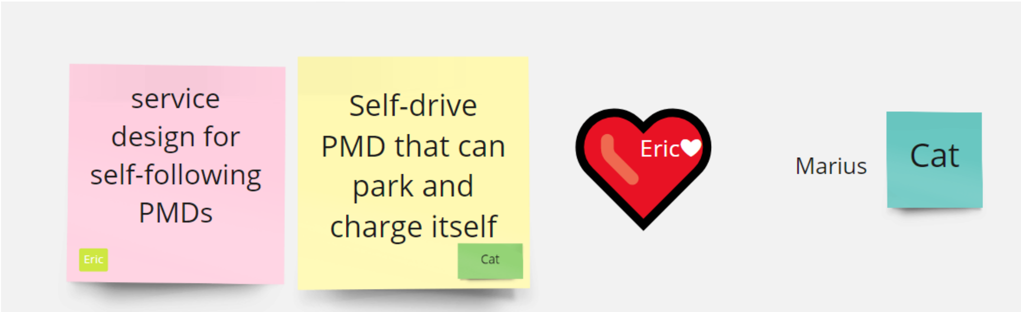
5. Ideation and idea selection

In the previous step we diverged to a lot of problem statements and converged back into one to two problem statements. After refining our problem and confirming our problem statement, we need to converge to all sorts of solutions based on our statement. We use the creative matrix to perform the task.

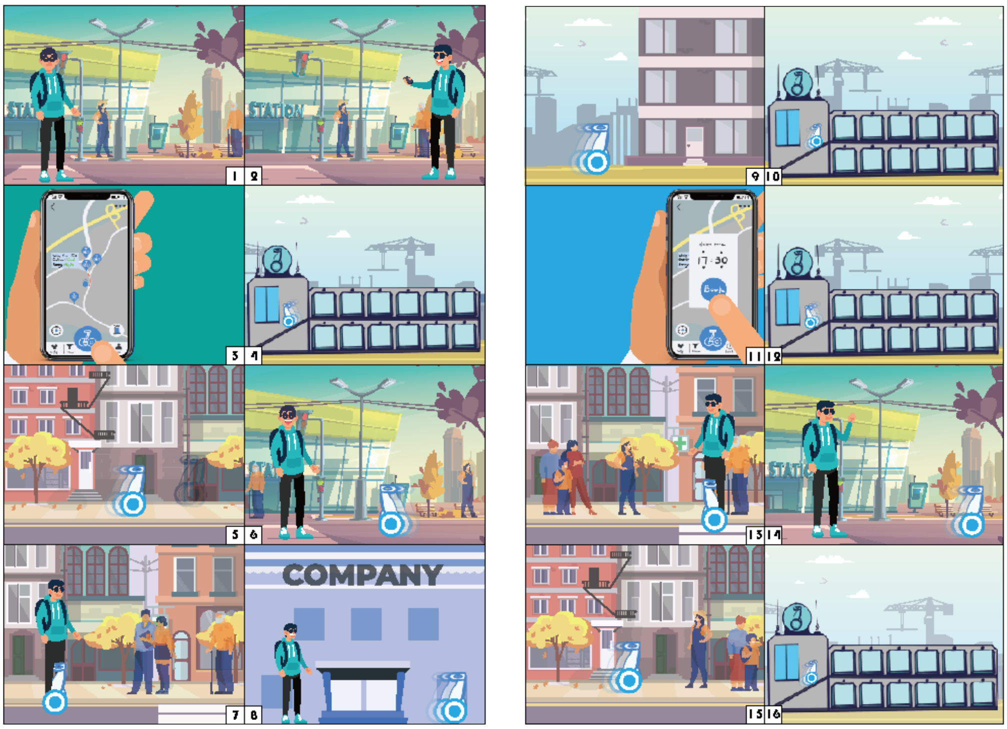


For each of the columns, designate a customer segment. For each of the rows, designate a particular technology, enabling solution, or value proposition. By doing this we can get lots of solutions. And then we evaluate the solutions based on benefits, difficulties, challenges and importance. At last we select the best one as our potential solution.

We select the concept in the team formation period by voting. Each Ideation concept was placed out and each one voted for the idea that he thinks is feasible, desirable ,innovative, and viable. After this process the concept was selected and a team was formed.



6. Storyboard



The storyboard tells a story of a boy named Jack getting out of a subway station where he cannot find any sharing bike. So, he takes out his phone and calls for our product. The PMD gets out of a charging station and moves to Jack's position automatically. After it gets to Jack, Jack hopes up and goes. After arriving at his destination, Jack went into the building directly and the PMD Leave for the nearest station by itself. It went at the nearest station, went in and charged itself waiting for the next service. When Jack is about to leave the building, he appoints the PMD to come and wait for him downstairs. When Jack gets down the building he just gets on the PMD and heads to the station. Upon arrival, Jack gets into the station directly while PMD leaves for the nearest station to charge itself.

7. Proof of concept

Our proof of concept mainly lies on the software side. By looking at the previous research and figuring out the latest technology, we found that some of the technology has already been done by universities. Things like using SLAM for scanning the surrounding environment and route planning have papers describing how it can work. The main job will be understanding the basic principle and applying it on the loomo platform.

In the following link video, the demo shows that simultaneous localization and mapping on robots is feasible.

http://www.youtube.com/watch?v=mQQL8pmztb4

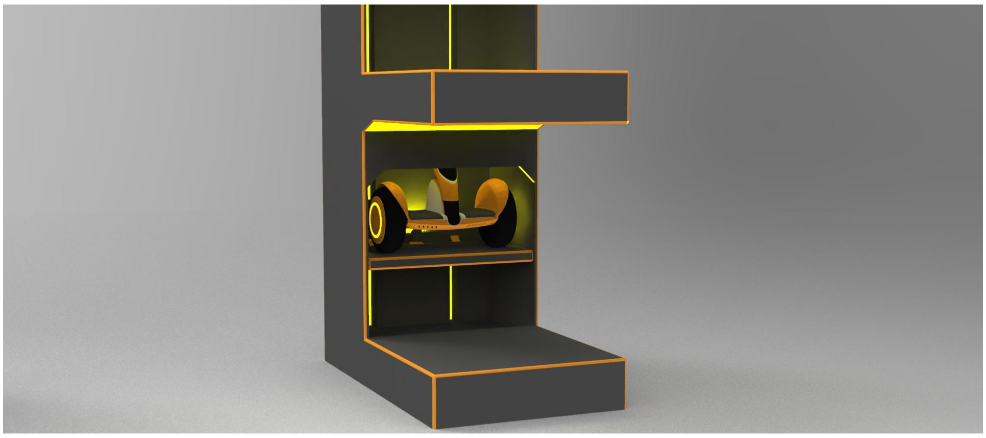
8. Visual prototypes

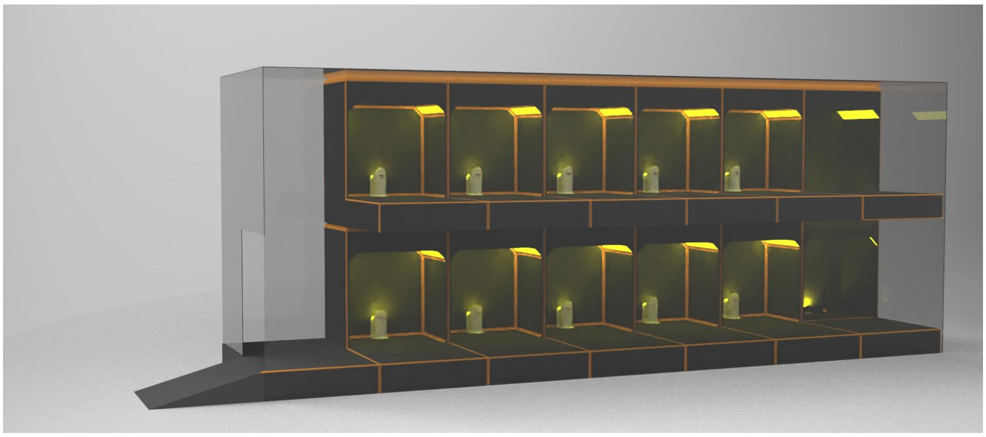
Our visual prototype goes through two generations. The first generation station is using boxy design with white yellow light orange adding with yellow light. The boxy design has no problem. While some professors suggest boxy design is too simple and is not intriguing when put on the street, some professors suggest boxy is good enough. Considering we want it to be beautiful on the street to attract people to use our product, we make the second generation visual prototype.

The second generation visual prototype station consists of several modularized hexagon parking cells. These cells can be fixed together both horizontally or vertically which allows the station to expand.

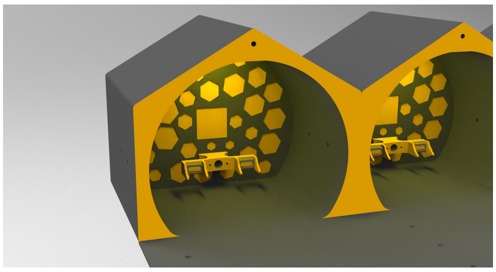
Elevator module is introduced in the visual prototype to enable the PMD to travel between different floors to park and charge itself.

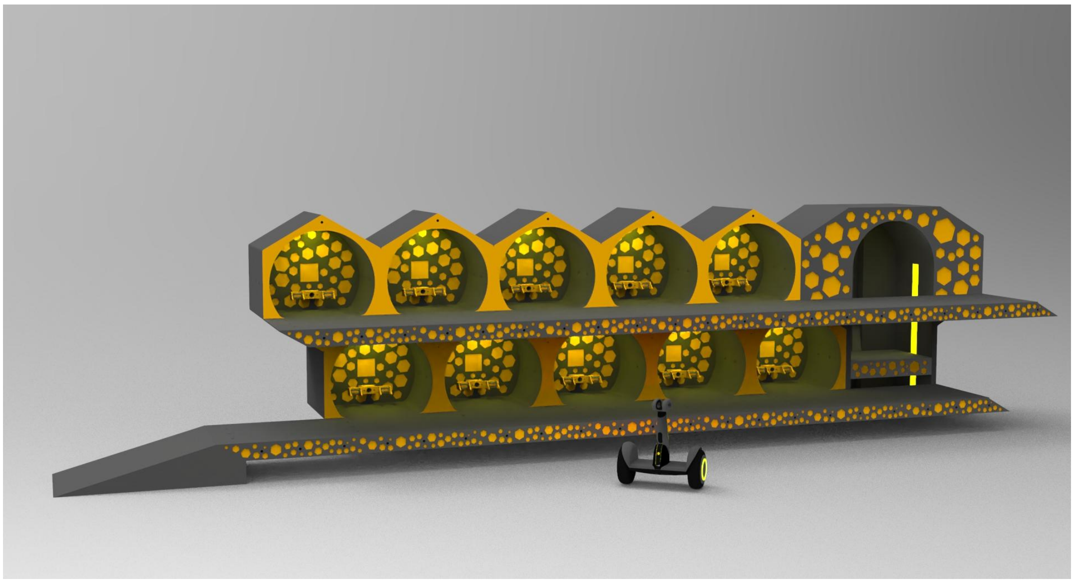
8.1. First Generation Visual Prototype

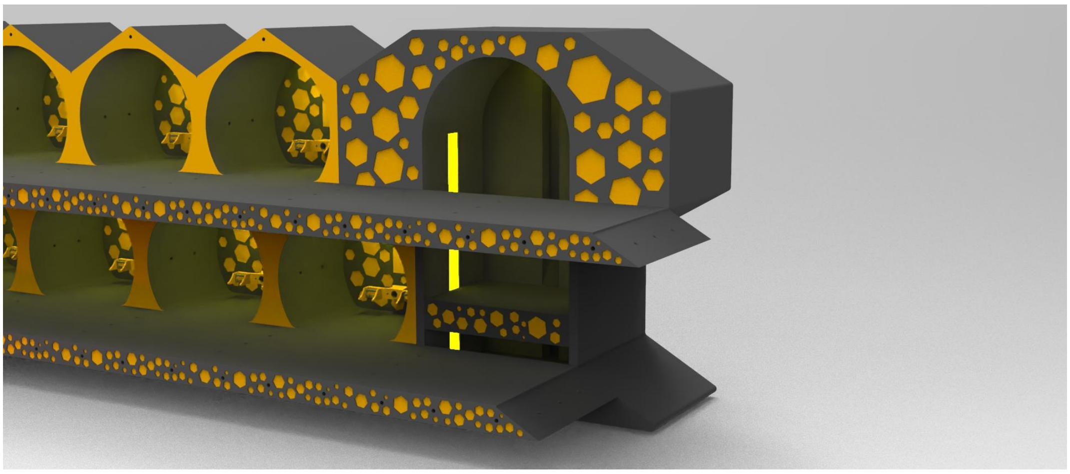




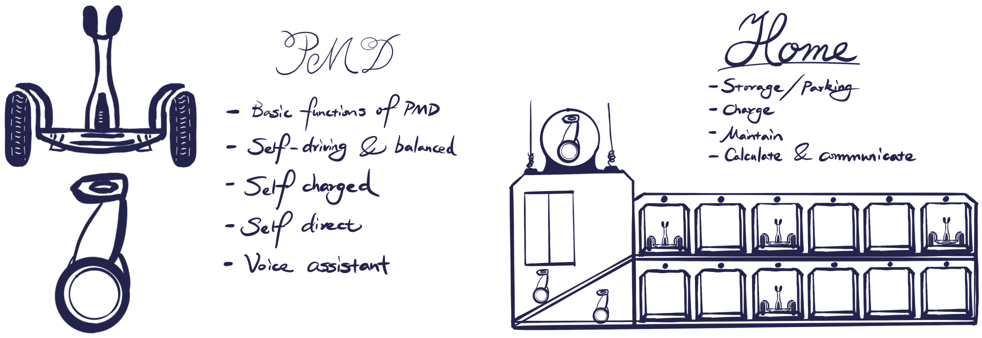
8.2. Second Generation Visual Prototype







9. Target specifications

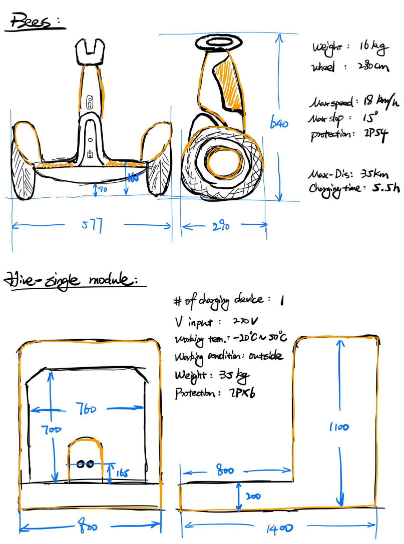


9.1. HIVE(station):

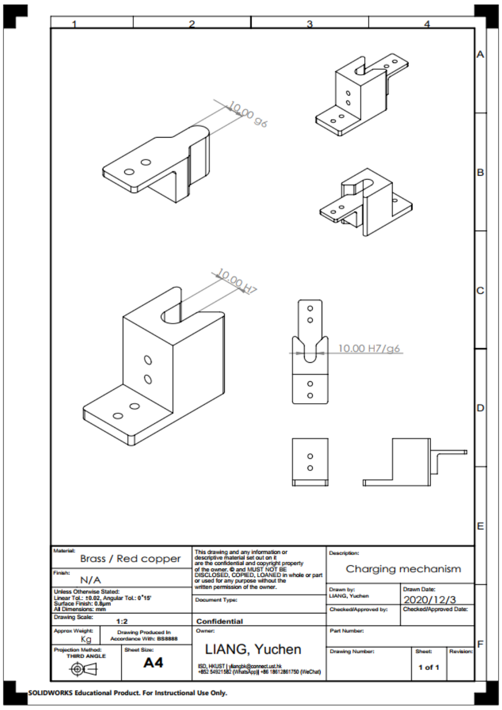
Being able to store the bee safely and provide charging installation to the bees.

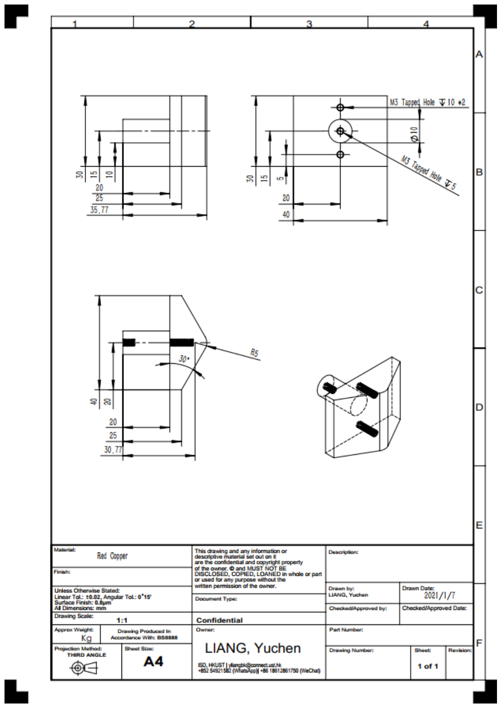
Meanwhile allow bees to enter or leave using its own mobility.It should feel and look suitable to place on the street.

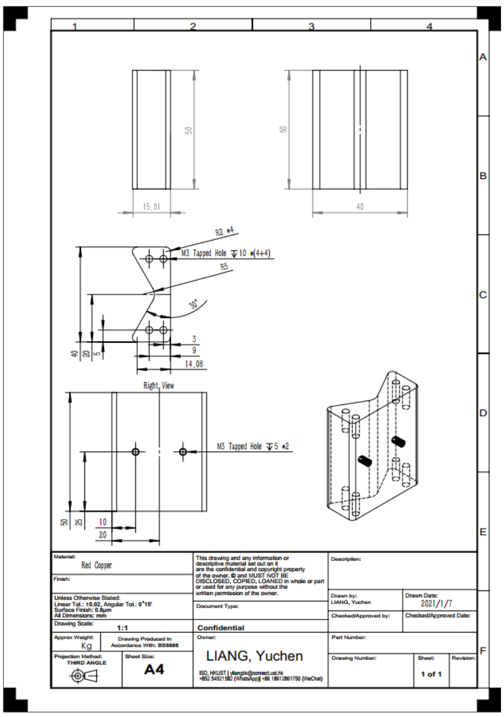
Some of the spec of the station and the charging mechanism are shown in the following pictures.

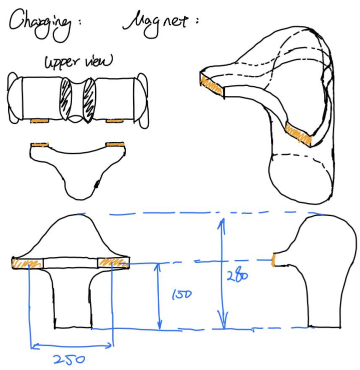


	Colour	Typical Applications	Benefits
Copper	Orange-tinted red	• Pipes & pipe fittings • Wiring	• High electrical & thermal conductivity • Easily soldered and very ductile • Impressive antibacterial properties
Brass	Can range from red to gold in colour depending on the level of zinc added to the alloy	• Decorative items • Musical instruments	• Attractive, gold-like colour • Good workability & durability • Excellent strength, with over 39% zinc levels
Bronze	Dull gold	• Medals & awards • Sculptures • Industrial bushings & bearings	• Corrosion resistant • Higher heat and electrical conductivity than most steels.









- Charging spec: 120W 58.8V

  Input: 100–240V ∼ 50/60 Hz

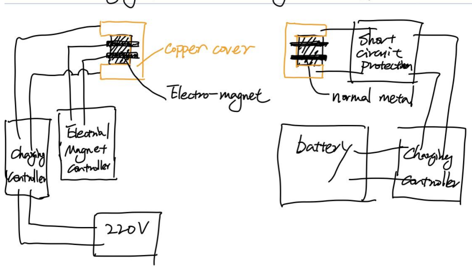
  2.0A MAX

  output: 58.8V ⎓ 2A

- Short circuit protection

- Charging port spec:

  Charging-side charged-side



9.2. BEE(PMD):

Modified Loomo.Should be able to go to a specific place by itself in simple environments.Which is realized through Simultaneous localization and mapping , and route planning.What's more it should be able to enter the station and park by itself.

Some of the specs of the electric component we use are shown as follows.

Intel® RealSense™ Depth Camera D435/D435i Features

- Intel® RealSense™ Vision Processor D4
- Up to 1280x720 active stereo depth resolution
- Up to 1920x1080 RGB resolution
- Depth Diagonal Field of View over 90°
- Dual global shutter sensors for up to 90 FPS depth streaming
- Range 0.2m to over 10m (Varies with lighting conditions)
- Intel® RealSense™ Depth Camera D435i includes Inertial Measurement Unit (IMU) for 6 degrees of freedom (6DoF) data

Core i3 Model

Built with a 4th generation Intel Core i3 processor, integrated Intel HD Graphics 4400, and 8-channel audio, the Intel NUC gives you the power to create a media centre PC that lets you fully experience iTunes, Netflix and other online entertainment content — and enjoy it all in crisp HD. The D34010WYK is equipped with Intel Rapid Start Technology, ensuring you are quickly up and running, and Intel Smart Connect Technology to keep you up to date at all times.

This new generation Intel NUC packs more features into an even slimmer form factor. What's more, the sleek, small Intel NUC has a stereo/microphone jack and USB 3.0 for easy home theatre connections and gaming requirements. Or, use it as a home office PC. The Intel NUC is small enough to unclutter your office, yet powerful enough to run the most demanding applications. The Intel NUC: as small as a desktop speaker, as powerful as a sonic boom.

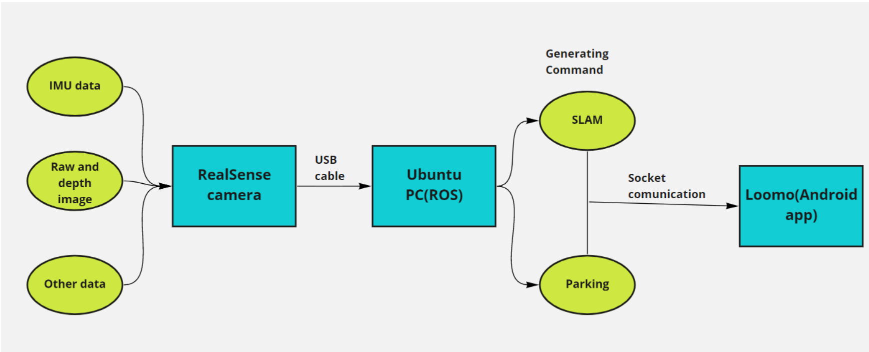
Product Differences

Apart from the differences between the i3 and i5 models mentioned above there is also one other major difference. Two of the available NUCs have an "H" suffix at the end of their model number. This means that they are able to accommodate a single 2.5" hard drive or SSD as well as a mSATA drive. The benefits of this are being able to have an mSATA as the boot drive and a 2.5" drive for storage. This increases the height to 49.5mm compared to the NUC that only supports mSATA which is 34.5mm tall.

Image highlighting the differences between the available NUCs

9.3. Communication:

Enable communication between PMD and server to receive command and send status.



10. Functional prototype

After finishing defining all the specs we move on to finish all the functional prototypes. In this session, prototyping consideration and process will be explained separately.

10.1. HIVE(Station)

In the first generation HIVE design, it consists of wooden board and aluminum profile, after consideration, we decide that using acrylic board could be a better solution for the outer board.

10.2. BEES(PMD)

Modified Loomo with realsense connected to NUC with usb cable . The raw and depth data is first collected by realsense and sent to the NUC for calculation .Then the command is sent to loomo through socket and loomo will execute it.

The design target for all the attachment is to hide all the components in plain sight as much as possible. Battery and converter are hidden under the Bees. The converter is hidden in the middle part but side way towards the wheel to maximum avoid the collision of the chassis with the ground. All the boards are using black acrylic to blend in with the original design of loomo.

The side board of original loomo design is replaced by an acrylic MiniPC holder also to fulfil the design purpose.

10.3. Coding

Coding for functional prototypes mainly works on combining all codes and enabling communication.

11. problems encountered and remediation

problems encountered	**remediation**
image transportation	shared pointer + multi-thread
Position estimation	ukf
Image feature detection	ORB
Path planning	move_base
ROS Android communication	socket and rosbridge
Gradle version problem	upgrade the android studio
PID Control	rospid
Apriltag (QRcode) (Coordinate transform)	ros apriltags and rostf
Loomo modeling and installation holes measuring	
Loomo disassembling	N /A
Blend in design with loomo	
Manufacture of outer acrylic board, it is too big	Divide in to half to cut it

12. Product Performance.

12.1. Expectations met

1. SLAM
   - Image transportation
   - Image feature detection
   - Map construct
   - Path planning
   - Position estimation

2. ROS -Loomo comunication
   - Send command via socket
   - Subscribe topics and receive command through ROSbridge

3. Parking
   - Position tracking
   - PID control

4. HIVE
   - Charging mechanism charging and gripping
   - Control of open and close of electricity (sensor)

12.2. Expectations unmet

1. Loomo cannot execute the command correctly

2. Thus the algorithm fail to apply on a physical robot

13. Development cost

Product Name	Bought Time	Price		Payer	Reimbursement (0/1)	Comment		
		HKD	RMB				Total(HKD)	Left(HKD)
Segway Loomo			9988	Eric	1		18477.54	6522.46
Electrical Magnet	2020/11/25		161	Eric	0			
Logistic	2020/11/25	28		Eric	1			
Laser Measurer	2020/11/06		208.46	Eric	0			
Loomo Extender	2020/11/05		199	Eric	0			
Wooden Boards	2020/12/5	/		ISD	/			
Card boards	2020/12/5	/		ISD	/			
Charger	2020/12/5		386	Cat	1			
Regulator	2020/12/5		396	Cat	0			
Aluminum Profile (A set) + logistic	2020/12/7		420	Eric	1			
Screw and Nuts	2020/12/24		287.5	Eric	1			
Logistic	2020/12/24	47		Eric	1			
Battery	2020/12/24		181	Eric	1			
Shock absorber	2021/1/6		74	Eric	1			
CNC Manufacture I	2021/1/7		1650	Cat	1			
CNC Manufacture II	2021/1/7		1435	Eric	1			
Bearing	2021/1/7		75	Eric	1			
Wall Paper	2021/1/11		181.2	Eric	0			

14. Reflection

We do believe that MoBee is a really great product but as a whole big system there are a lot of drawbacks for us to do as a semester long project.

Loomo is not an ideal platform and we should discover that immediately before we bought it. Though using angular velocity is not what a big company like Segway should do, we should see that coming and doubt everything before deciding.

The topic is too big for a three person small team. As a course project, we should expect small stuff instead of big systems. We should not choose a topic that is beyond our ability.

On the software side, we should test others' solutions before deciding to do the same thing, like using loomo. We should also confirm each detail on things that are not built by ourselves.

15. Potential improvements

We believe that our product has a lot of potential to become a real product which can change the sharing transport industry.

In terms of functional prototype, we should and can achieve more accuracy and higher speed. Loomo is a robot that runs on roads, moving slow may cause lots of trouble.

The station should be done more properly. The LED light should be powered properly and the inside should be wired properly also.

The communication now is through WIFI, we can consider using 4G or 5G as communication tools to achieve much flexible yet faster communication.

Instead of using the environment to get its position, GPS or indoor UWB should be applied to make sure loomo gets where it is.

16. Conclusions

During the first stage interview and follow up interview our group member find out there several pain point exist in the current PMD and sharing mobility product listed below:

user side:	Company side	Government side
user side: 1.Storage 2.Affordable 3.The last 1km	1.Usage rate 2.security 3.Preparation(Charging, Seeking storage places)	1.Parking disorderly 2.Government Supervision

Based on the result. We propose "HMW create a SHARING Personal Mobility Device that can enable people to spend their last mile's journey more conveniently?"and "HMW makes changes to sharing PMD devices to make them easy to be managed" two HMW problems after the process of problem formulation and refining.And we have done the literature review regarding related PMD products and sharing mobility devices. Based on the review our team proposed and chose the "sharing PMD" concept as we think this idea is viable and innovative.

After proof of concept we begin with the physical prototype's construction and finish the SLAM, ROS -Loomo communication, Parking and HIVE construction part.

Unfortunately, in the last testing stage we found that Loomo cannot execute the command correctly. Thus the algorithm fails to apply on Loomo. However , we proved that theoretically the idea is feasible when applying on a precise robot platform.

17. Percentage contribution of each team member

Name	Responsibility	Estimate persentage
Marius	Loomo-Ros comunication; Loomo's position esitimate during parking; Loomo's parking process	33.3
Eric	Visual prototype; Mechanical design and manufacture; Loomo attachment method design; Station mechanical design, manufacture and electronics.	33.3
Cat	Image transportation between realsense and NUC; Position estimation; Image feature detection; map construct; Path planning;	33.3

18. References

Segway robotics:
https://developer.segwayrobotics.com/developer/documents/segway-robots-sdk.html

Segway Robotics: https://www.segwayrobotics.com/#/

ROS:https://github.com/ros/ros

Orb-SLAM Series:
https://github.com/raulmur/ORB_SLAM
https://github.com/raulmur/ORB_SLAM2
https://github.com/UZ-SLAMLab/ORB_SLAM3
https://github.com/electech6/ORB_SLAM2_detailed_comments
https://github.com/appliedAI-Initiative/orb_slam_2_ros

VINS Series:
https://github.com/HKUST-Aerial-Robotics/VINS-Mono
https://github.com/HKUST-Aerial-Robotics/VINS-Fusion

OpenCV:https://github.com/opencv/opencv

Turtlebot3:https://github.com/ROBOTIS-GIT/turtlebot3

Rtabmap:https://github.com/introlab/rtabmap

ROSJAVA:https://github.com/rosjava/rosjava

Move_Base:https://github.com/ros-planning/navigation

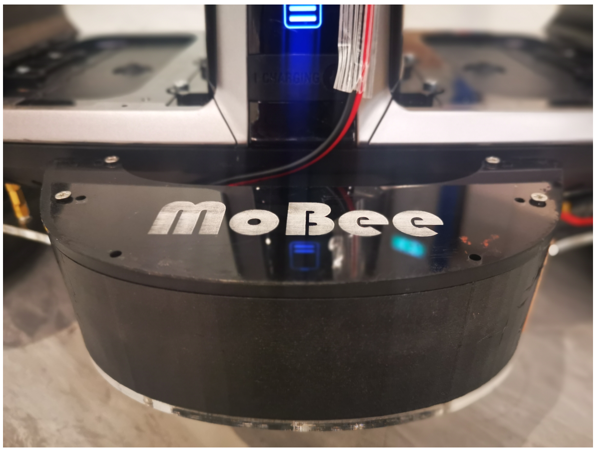
Octomap:https://github.com/OctoMap/octomap

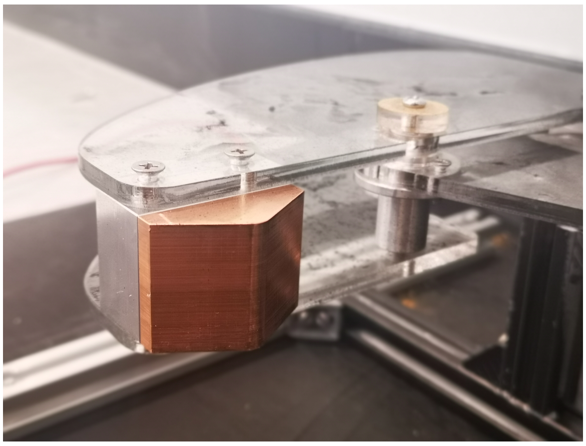
EKF:https://github.com/ros-planning/robot_pose_ekf

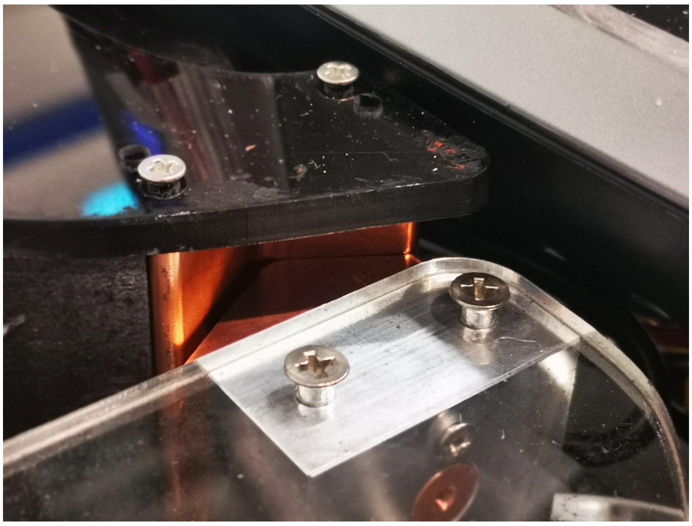
UKF:https://github.com/cra-ros-pkg/robot_localization

ROS_TF:https://github.com/ros/geometry

19. Product Photographs





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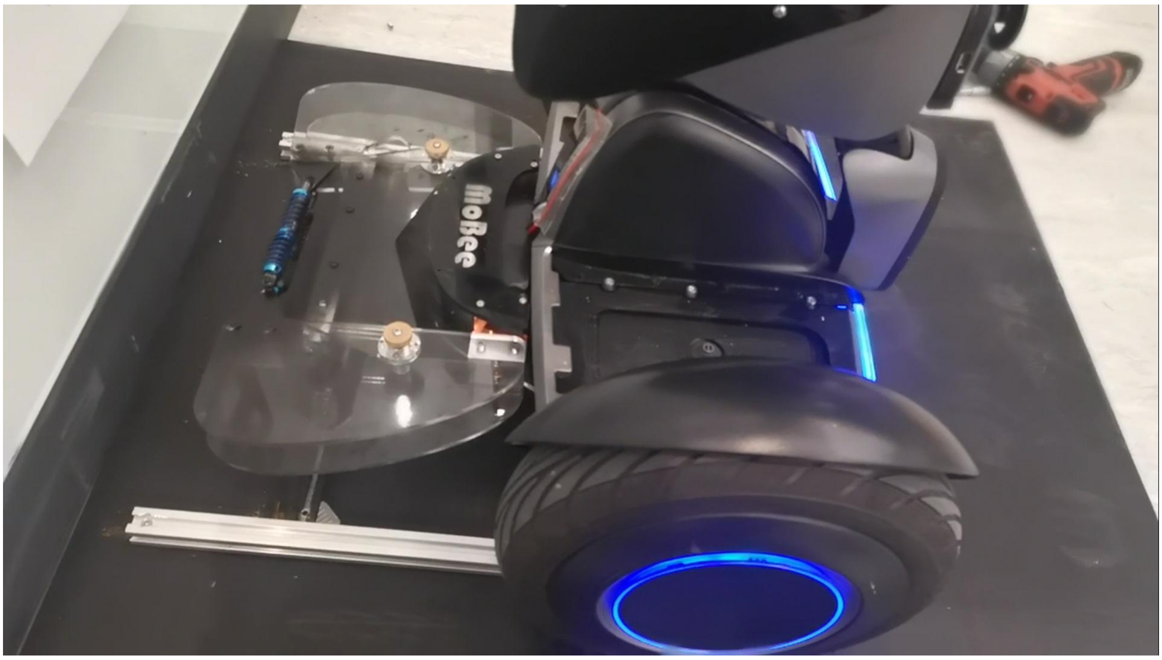
MoBee

SEGWAY
ROBOTICS

MoBee