Ⅰ. OBJECT

Create new useful design of sports field using systematic design methodology encompassing all design process in engineering

Ⅱ. PROBLEM DEFINITION

1. Design problem

   We think that if shuttlecocks are automatically rearrange and classified, playing and practice quality of badminton would dramatically increase. So our group try to make automatic shuttlecock classifying product called 'Damage Classifying Shuttlecock Collector'.

2. Information gathering

   a. Stake holders

      (1) Background

      By now you should have an idea of what kind of information you don't yet know and you need to find out. Make a list of how you intend to get that information. You may want to draw up a Gantt chart or a task list for each of the team members. How can you get the information that you need? Where can you look? Who can you talk to? Who can you talk to to find out whom you need to talk to?

      (2) Activity

      (a) Who will use the product?
      Various kinds of people will use this product. Starting from the people who play badminton just for fun, and even pro players can use this. Anyone who plays badminton, and uses the shuttlecock will be able to use the product.

      (b) Who will buy the product?
      Mostly, people who run the badminton club will buy the product. By buying this product, they will save lots of money by reducing the number of people who clean up the court. Also, lots of official badminton matches will need this product, therefore most of the courts where the match is held will purchase the product.

      (c) Who will sell the product?
      Sports equipment companies will sell the product. Especially badminton goods company which sells the racket or the shuttlecock will sell the product.

      (d) Who will manufacture the product?
      It can be manufactured by various factories, depending on the way the machine works. If the machine works by absorbing the air, the product can be manufactured with the vacuum cleaner. On the other hand, if the machine works by sweeping, the product can be manufactured with the sweeper.

(e) Who will transport the product?

The product will be used worldwide, so that airplanes and ships will be used in international shipping. Also, the product should be small enough to use, so transporting the product won't be a big issue. Small products will be easily transported by any kind of delivery service.

(f) Who will store the product?

Since people who run the badminton club will buy the product, these people will store the product too. By the way, this product will be kept used without stopping, so it would mainly stay at the court.

(g) Who will maintain the product?

It should be easily repaired, so that buyers would be able to fix the problems on their own. If the machine is critically damaged, then the after service can be done by the developers.

(h) Who will recycle or dispose of the product?

If the product is damaged so much that it can't be repaired, the product can be collected by the company and it would be part of the new products. So the company will recycle the product.

(i) Whom else will the product affect?

The product will affect the people who clean the badminton court. By the development of this product, lots of people would be substituted by the product and those people will lose their jobs. On the other hand, people who run the court will be able to save money.

b. User

(1) Background

The person who uses your product probably has the most to lose or gain from your design. Remember that the user is often not like you, and s/he probably does not see the product from your point of view. You need to understand your users wants and needs as well as possible. Be systematic about it. Write down everything you know about your users. This list can get you started:

(2) Activity

(a) What is the user's lifestyle and background?

Mostly users are students who took a lesson from the instructor. They practice for less than 30 minutes and sometimes with more than 2 people. A person who finishes the practice then cleans up the shuttlecock and sets up as an initial state. This process is repeated until the practice is done. Sometimes, teachers or instructors have to clean the shuttlecock, so there are sometimes over thousands of shuttlecocks randomly distributed.

(b) What are the user's expectations?

They want to clean all the shuttlecocks with less effort. Not only do they just pick up, but also they need to make the shuttlecocks well arrayed. Power source is expected to be wireless, because it is very uncomfortable to use electric wire in such a wide area.

(c) How will the product be used?

Just turn on the machine and sweep the floor to pick up all the shuttlecock, also with a sorting mechanism, unusable ones can be automatically separated. Finally, what the user has to do is just pick up the array of shuttlecocks and have a lesson.

(d) When will the product be used?
Time interval between lessons, people who finish the lesson can use this machine to quickly finish the cleanup. Or after the whole lesson finished, the instructor can use this machine to save their energy to teach.

(e) How often will the product be used?
Every day the lesson is present. Usually every 10 minutes. (mostly one lesson routine is 10 minutes per person; based on personal experience)

(f) What is the user thinking about while using the product?
Power supply: How often do users have to charge, or how to connect the power? Is it wireless or not? Does it utilize only man-power?

(g) Maintenance: Is it easy to fix when the shuttlecock is jammed in the machine? Are there any parts users have to replace frequently?

Price: If it is too expensive, then using people is the best option.

(h) Is it possible to use the product in a way that was not intended?
Not really, this product's usage is highly specified.

(i) What are the user's limitations (cognitive, physical, etc)
Someone who can only use one hand is difficult to pick up and arrange the shuttlecock easily.

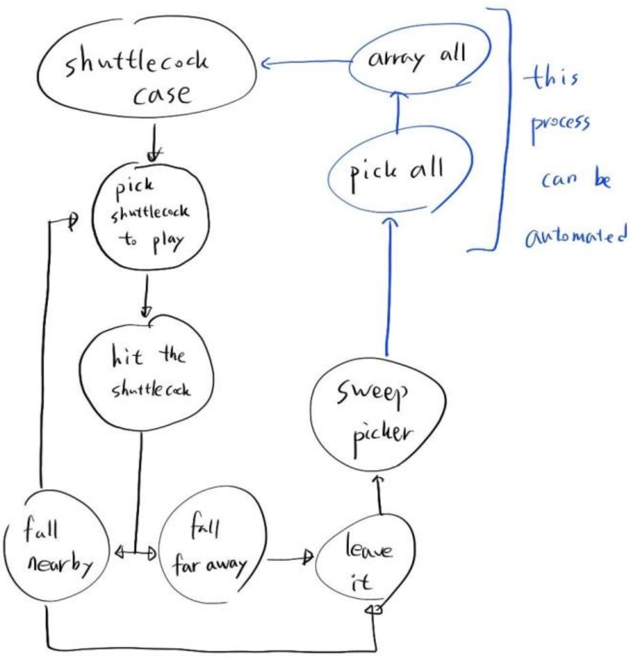
c. Environment

(1) Background

The environment that your product is used in can have a huge impact on design requirements. Often it is difficult to know a priori which aspects of the environment might affect your design. Temperature? Noise level? User distractions? You want to understand the environment as much as you can. Get some personal experience in the environment if possible. You want to be able to think like the user in the user's environment so that you can identify potential issues early in the design process. Talk to people involved, and get a sense for what the environment is like. Visit the place where the product might be used.

(2) Activity

(a) Make an outline of the activities surrounding the environment where the product might be used. An example is shown below for a product that was designed to help with managing clean laundry:



d. Product domain

(1) Background

You should understand what other products are available to people, what needs those products meet, and what needs are still unmet. Go to the store and look for other products that address your problem or similar problems. Take other products apart and see how they accomplish their functionality. What does your product need to offer to be competitive?

(2) Activity

(a) Market survey

○ List other products on the market that meet similar needs.

- Shuttlecock sweeper

○ How does the product fit in with these surrounding products?

- Features: It helps gather shuttlecocks on the ground.
- Advantage: It is helpful to clean the gym faster when a badminton lesson is finished.
- Disadvantage: the product only gathers shuttlecocks, people have to arrange the cocks themselves and put them into the box or cage. Also people sort what can be used later or throwed away.

(b) Reverse engineering

- List other products that have similar or analogous functionality.
  - Minton bot

- How do similar products accomplish functionality?
  - It has motors so that shuttlecocks automatically come into the cage.
  - While a man sweeps with the product, when a shuttlecock reaches in the middle of the sweeper, it is sucked into the cage.
  - Also, when the shuttlecock is sucked into the cage's highest part, it is arranged in one direction by falling. Because its head is heavier than the feather part.
- How do other products perform analogous functions in other domains?
  - Kinds: In some ball game sports, there are some similar products like table tennis ball collector and tennis ball collector
  - Common: Those perform the same as Shuttlecock sweeper. So, those make people easily collect the balls and put them into a cage.
  - Difference: Unlike shuttlecocks, tennis and table tennis balls are spheres, so they don't have to be arranged in a certain direction. So those products don't have an automatic arrangement process. It is more likely to be a shuttlecock sweeper than the bot.

e. Information Gathering method

(1) Background

By now you should have an idea of what kind of information you don't yet know and you need to find out. Make a list of how you intend to get that information. You may want to draw up a Gantt chart or a task list for each of the team members. How can you get the information that you need? Where can you look? Who can you talk to? Who can you talk to to find out whom you need to talk to?

(2) Activity

(a) User interviews:

This product can be used in anywhere the badminton court exists. Maybe it can be paired with tossing machine so the player can practice many type of impacts in completely automatic system during the practice. So we have to talk to both badminton trainer and trainee. Also the gym owners or the factory operator and express companies, other badminton auxiliary equipment making companies are all stakeholders. We should ask the pro and con of using this product in real life badminton to the actual players. Does it have practical advantage compared to just using their hands or using other products already there. We should ask the gym owners would you buy this product for your own profit and we should know from the factory operators and express companies about the cost.

(b) Expert interviews:

The makers for already existing shuttlecock sweepers are the best choice for asking about this domain. First we have to get the information about what they are finding to improve the past generation. And major malfunctions happen in real usage. Also need to ask how to expand the badminton playing range of not only places (outside, gym, etc) but also the age range of players. Asking how we can cooperate this business with other equipment makers for badminton is necessary.

(c) Focus groups:

Although just imagining about the discussion, I will invite not only badminton players for daily sport, but also professional players. I expect very appreciating response from them because I think this machine will make noticeable improvement in their practicing process and decrease wasting time. Maybe the discussion about cost and technical issue will be the main topic between users and stakeholders.

(d) Study users:

Anywhere that have badminton court will be the target. Especially the indoor gym that opens training classes for citizens. Actually this is not a work, it is sports which is entertaining movement so we must concentrate on not only the efficiency of training but also the 'fun' of using this product in real use. We maybe easily find what they want for the function or entertaining part of the product. The safety must be considered because the people are in dynamic movements so designing with low risk of bruising, scratching and cutting will be essential. We can check the safety in that place in real use.

(e) Personal experience:

Be a user by myself is the perfect way to know and understand what the users need for more pleasant environment for playing badminton. I must try hard to think objectively about our design compared to existing other products. Also I can check does the product drag more population of badminton players and caused expansion and new construction of badminton gym. (In long term investigation)

(f) Product domain:

By web searching and calling to many badminton court owners and managers and asking what do you use for picking up the shuttlecock on the floor. Also we can find existing products in web too. We will pick some of popular makers and can make 1:1 comparison with our product. The best is we only take the advantages of old one and remove any bad (in either function or safety) parts of them. This will push us to design more perfectly but it's essential process in engineering design.

3. Problem identification

a. HMW

(1) Background

First, assume that there is a solution out there. Second, how might we can put idea out there that may or may not work. Finally, how we are going to do it together and build on each other's ideas.

(2) Activity

(a) identify the need

Mainly, all the badminton players who are trying to improve their performance do thousands of swing in practicing. Inevitably, they use pile of shuttlecocks which are stored in the cylindrical tube. Except in the case of using the shuttlecocks only once and throw them away, they need to collect all the shuttlecocks on the ground and put them back into the tube. This process is also needed in other sports like golf, tennis, table-tennis, etc. But these examples' use 'spherical' shape, which is called the 'ball'. So it makes easy to collect them on the ground because they are easy to roll and have no 'direction'. But the shuttlecock does have direction and it does not roll freely in all directions either. So this make the work complicated compared to others and so the need for collecting machine and technology rises. Without machine or technology, the time will be wasted, and the players have to use their stamina, which should be used in their own practices, in picking up the shuttlecocks.

(b) problem definition statement

So the main HMW question is 'HMW help all of people who want to improve their badminton performance/ reduce their time and effort in collecting the shuttlecocks on the ground/ to make the quality of practicing better. And now, we need 'even if' statement to make the problem statement more accurately. First, the form of solution is narrow down to make an automatic sweeper which puts shuttlecocks into the storing tube. Now, even if the group of shuttlecocks contain defective ones or we don't have power source (which means we need to operate the machine by our own human power, but required not too much of it) or the shuttlecocks may be stuck at the intake of the machine or the dust or F.Os blend into the stream of shuttlecocks and might make dirty or cause damage on the machine, we have to gather the shuttlecocks very neatly with low cost and compact size of machine. This will be the complete problem statement, and next we now have to find corresponding 'might' ideas for these problems.

b. Persona

(1) Background

persona is a description of a character that the product will be designed for. It represents the needs of larger groups of users, in terms of their motivations, expectations and goals. Pick a name, Include a picture, Demographics, Profession, Family status and roles, Social status, Hobbies/ entertainments, Values, goals, motivations.

(2) Activity

(a) Michael

① Picture

② Personal information

i. Age: 16

ii. Gender: Male

iii. Job: Student

iv. Marriage: No

v. Hobby: Playing badminton, Listening music

vi. Family status: Mom and Dad and Younger Brother

vii. Goal: Engineer

③ His thought about the product Michael is learning badminton as a hobby. He organized the shuttlecock after class. Each time, he collected them with a shuttlecock sweeper, distinguished by hand what was reusable from what had to be thrown away, and arranged them in a row for the next lesson. He thought it was a little annoying every time he organized it, and he thought it would be nice to have a machine that automatically reuses the shuttlecock and cleans it up at once. And he thought it was unfair to clean up only himself and adults who take classes with him don't participate.

(b) Charlie

① Picture

② Personal information

i. Age: 40

ii. Gender: Male

iii. Job: Bank Clerk

iv. Marriage: Yes

v. Hobby: Playing badminton, Riding a bike

vi. Family status: Wife and One Son and One Daughter

vii. Goal: Be a President of a Bank

③ His thought about the product

Charlie plays badminton for his health. He takes classes after work during the week, so he takes classes in the evening and goes home to spend time with his children after class. On weekends, he attends classes in the morning, and he goes on a picnic or spends time with his family in the afternoon. Charlie doesn't want to spend much time cleaning up the shuttlecock after class because he has a job and family to devote his time. So he wants a machine that automatically arranges the shuttlecock. Also, he wants to be able to clean up the trash such as shuttlecock feathers at once.

(c) David

① Picture

② Personal information

i. Age: 41

ii. Gender: Male

iii. Job: Programmer

iv. Marriage: Yes

v. Hobby: Playing badminton and Taking a walk

vi. Family status: Wife and Two Sons

vii. Goal: Achieving Diamond I Rank in BAEKJOON Online Judge

③ His thought about the product

David sits on a chair everyday so he takes care of his health by exercising regularly. He usually spent his free time walking around the company and home. Recently, he also participated in a badminton club and has been playing badminton hard. Although he lost his left hand in an accident when he was a child, there is no big problem hitting a shuttlecock with a racket. However, he feels that picking and especially arraying shuttlecocks with one hand is annoying and difficult. He wants this series of tasks to be automated.

(d) Alice

① Picture

② Personal information

i. Age: 52
ii. Gender: Female
iii. Job: badminton coach
iv. Marriage: Yes
v. Hobby: playing with a dog
vi. Family status: one daughter
vii. Goal: Making her player the best badminton player in the world

③ Her thought about the product

Alice coaches badminton minimum 20 people per day. After every lesson, she asks the badminton players to clean up the court. Even though there are some people who don't clean up the court after the lesson. When this happens, Alice cleans up the large court by herself. This makes her hurt a lot, so she wants to have a machine that cleans up the court filled with shuttlecocks.

c. Scenario

(1) Background

Write a short story of a user in the environment that your product will be used in. Describe his/her interaction with the relevant object (use scenario). Give it some thought and use details about the environment and the user. Think about feelings and emotions as well as functionality. If appropriate, describe the problem difficulty (needs) or aggravation that the user is facing (Is this the problem you are trying to solve?).

(2) Activity

Alice is a badminton instructor. She has a big problem, as she teaches 20 people a day. It's cleaning up the badminton shuttlecock. Some people ask her if she can hit the ball and the students can organize it. But students aren't the only ones who are taking lessons.

Michael is one of Alice's favorite badminton course students. He is a student, and he is a sincere student who cleans up the shuttlecock he hit on his own. He is also very agile, so it takes less than 5 minutes to organize all the shuttlecock. However, some people who take lessons at the same time take a lot of time to organize their shuttlecock and are often upset because they organize the shuttlecock that has been damaged to an extent that they cannot use it. However, except for themselves, office workers or seniors are in a situation that cannot be strangely unfair.

This is especially true of David. David is a disabled man who has lost his left arm, and he can hit the shuttlecock with his right hand without any problems and even serve with one hand, so he doesn't have much trouble playing against most people. However, once David has a lesson, he takes too long to clean the shuttlecock. It is extremely difficult for him to pick up the shuttlecock with one hand and make it stand for the lesson.

Eventually, David's next person will clean up his shuttlecock with him, and, unfortunately, Charlie is next. He has a strong desire to succeed. He manages to relieve the responsibility of feeding his family and the stress of his work by playing badminton. However, he is recently considering quitting badminton while watching a shuttlecock that is twice the amount of other people's on the floor after lessons. Under these circumstances, he hopes to have a device that can be easily organized.

David is also not comfortable. He tries his best to organize the shuttlecock, but it takes too much time to do it with one hand, which seems to be a nuisance.

Alice is also worried that if Charlie quits badminton and someone else cleans David's shuttlecock, there will be a vicious circle of students quitting again. In particular, it seems clear that Michael, who is otherwise dissatisfied, will quit if he becomes that person.

Alice was looking for a machine, but I'm worried that it would be difficult to plug in electricity in a gym without an outlet, and the price is too expensive. She thinks it would be useful if anyone could easily carry it wirelessly and find an equipment that can quickly organize a shuttlecock. If it's too expensive, she'd rather work hard to organize it herself. Of course, it's unclear whether she can continue her coaching career for a long time.

4. Engineering specification

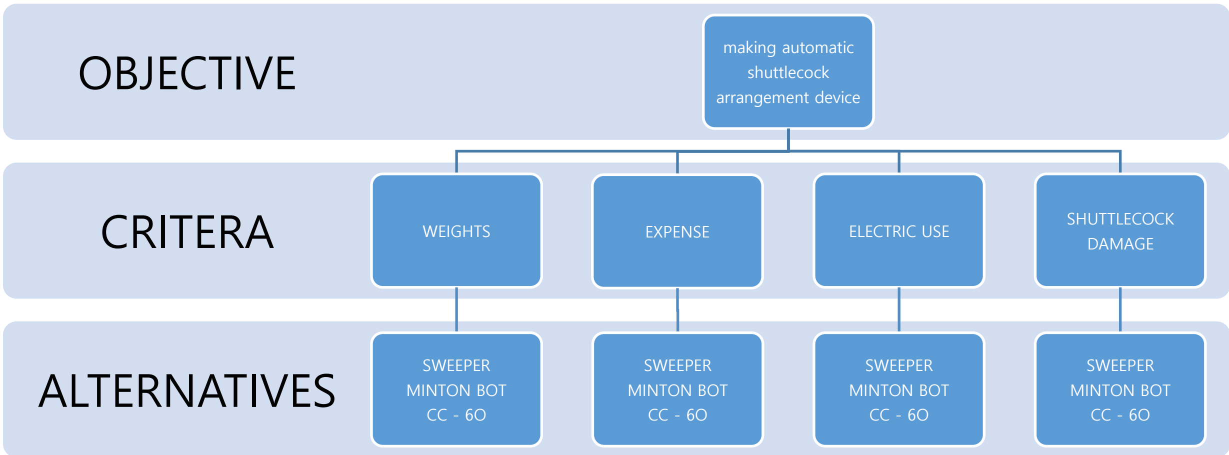
a. AHP

(1) Background

Introduced by T. Saaty (1980) in his book "Fundamentals of decision making and priority theory with the AHP". Information is decomposed into a hierarchy of alternatives and criteria. Information is synthesized to determine relative ranking of alternatives. Both qualitative and quantitative information for criterion can be compared using informed judgments to derive weights and priorities.

(2) Activity

(a) Hierarchical tree



(b) Explanations of each category

① Objective

We chose the object as making automatic shuttlecock arrangement device. This is because it is very inconvenient to organize the shuttlecock by hand when taking badminton classes. Thus we decided to develop the device to resolve the inconvenience.

② Criteria

i. WEIGHTS: The device is used by people, it should be easy to move. Thus weights is important part of consideration to buy the device.

ii. EXPENSE: The device is usually used by badminton coach or player, so price have to be reasonable to buy the customer base.

iii. ELECTRIC USE: The device is using in the whole badminton court that is in the gym, so it is better that the device is not use electricity or is rechargeable device. Only then, it is possible to clean the whole gym

iv. SHUTTLECOCK DAMAGE: While using the device, shuttlecock damage must be the minimum. If not, it will increase shuttlecock which is unjustly abandoned

③ Alternatives

1. SWEEPER

2. MINTON BOT

3. CC-6O

(c) Rankings

① Criteria

	$weights$	$expense$	$electric\ \ use$	$shuttlecock\ \ damage$	$ranking$	$critera$
$weights$	1	0.25	1	2	$1. expense$	0.6154
$expense$	4	1	4	8	$2. electric\ \ use$	0.1538
$electric\ \ use$	1	0.25	1	2	$2. weights$	0.1538
$shuttlecock\ \ damage$	0.5	0.125	0.5	1	$4. shuttlecock\ \ damage$	0.0769

② Alternatives

i. Weights

	$sweeper$	$minton\ \ bot$	$cc-6o$	$ranking$	$weights$
$sweeper$	1	32/6.4	13/6.4	$1. sweeper$	0.5909
$minton\ \ bot$	6.4/32	1	13/32	$2. cc-6o$	0.2909
$cc-6o$	6.4/13	32/13	1	$3. minton\ \ bot$	0.1182

ii. Expense

	$sweeper$	$minton\ \ bot$	$cc-6o$	$ranking$	$expense$
$sweeper$	1	368/14	356/14	$1. sweeper$	0.9282
$minton\ \ bot$	14/368	1	356/368	$2. cc-6o$	0.0365
$cc-6o$	14/356	368/356	1	$3. minton\ \ bot$	0.0353

iii. Electric use

	sweeper	minton bot	cc − 6o	ranking	electric use
sweeper	1	220/60	1	1. sweeper	0.4400
minton bot	60/220	1	60/220	1. cc − 60	0.4400
cc − 6o	1	220/60	1	3. minton bot	0.1200

iv. Shuttlecock damage

	sweeper	minton bot	cc − 6o	ranking	shuttlecock damage
sweeper	1	2	4	1. sweeper	0.5714
minton bot	0.5	1	2	2. minton bot	0.2857
cc − 6o	0.25	0.5	1	3. cc − 60	0.1429

③ Total ranking

	weights	expense	electric use	shuttlecock damage
sweeper	0.5909	0.9282	0.4400	0.5714
minton bot	0.1182	0.0353	0.1200	0.2857
cc − 6o	0.2909	0.0365	0.4400	0.1429

*

ranking	criteria
0.1538	weights
0.6154	expense
0.1538	electric use
0.0769	shuttlecock damage

=

0.7737
0.0803
0.1459

④ Conclusion

ranking	alternatives
1. sweeper	0.7737
2. cc − 6o	0.1459
3. minton bot	0.0803

Ⅲ. IDEA GENERATION

1. Brainstorming

a. Background

Effective tool for both divergent and convergent thinking. Useful for problem definition and idea generation. Brainstorming is a group or individual creativity technique by which efforts are made to find a conclusion for a specific problem by gathering a list of ideas spontaneously contributed by its member(s). Brainstorming encourages you to think expansively and without constraints. It’s often wild ideas that spark visionary thoughts. With careful preparation and a clear set of rules, a brainstorm session can yield hundreds of fresh ideas.

b. Sorting

(1) Belt

(a) Use of center of gravity

(2) Damage Prevent

(a) Wing protection

- Designed to move one by one
  - Rail

c. Weight

(1) Simple structure

(a) Sweeper shape + shuttlecock storage box

(b) Small classification device

(2) Light material

(a) Plastic

(b) Carbon

- High-priced

d. Lifting

(1) Belt

(a) Pulley lubrication

(b) Chain

- Rising in weight

(2) Robot arm

(a) Forefinger

- Hydraulic type
- Cam shift
- Grab the shuttlecock skeleton

(b) Adhesive type

- Quality of the material
  - The use of feathers' stripes
- Static electricity

(3) Vacuum

(a) Electricity required

- Minimum diameter of shuttlecock movable
- Using high performance engines

(b) Easy to get stuck

- The shuttlecock passage way should be made of smooth material

(4) Waterwheel – structure

(a) Lift with waterwheel using sweeper moving power

(5) The shape of a dustpan

(a) Sweeper travel speed utilization

(6) Roller shape

(a) Sponge material roller

e. Price

(1) Power

(a) Powered by sweeper wheel rotation

(b) Rechargeable battery utilization

(2) Cheap material

(a) Plastic

(b) Stainless

(c) Wood

- Wood dust

(d) Painting X?

(e) Made in Korea

f. Maintenance and Repair

(1) Prevent shuttlecocks from getting stuck

(a) Using a belt to move

(b) Using a rail to move

(2) Minimize shuttlecock damage

(a) Roller made of sponge

(b) Waterwheel type that minimizes shuttlecock contact

(3) Sturdy material

(a) Aluminum

- CNC
- Casting processing
- Bending
- Aluminum profile
- Lathe

(b) Plastic

- 3D printing
  - Difficulty in manufacturing large parts
- Casting processing
- Lathe

(4) Troubleshooting breakdowns in classification devices

(a) Intuitive design

- CAD
  - SOLIDWORKS
  - INVENTOR

g. Power

(1) Electricity

(a) Turn sweeper wheel to generate electricity

(2) Solar power

(a) Use rechargeable batteries

(3) Manpower

(a) Push to move

h. Broken ball classification

(1) Separation

  (a) Active separation

    ■ Servo motor

    ■ Blower

  (b) Hydrodynamic difference

    ■ Whether it falls straight or not

  (c) Weight difference

    ■ The time it takes to fall off

    ■ Bouncing speed

(2) Sortation

  (a) Camera

    ■ Neural Network

      ○ CNN

        ◆ Learning data?

          ✧ Create ourselves

          ✧ Shuttlecock image dataset

    ■ Image Processing

      ○ At least we need Raspberry Pi

      ○ Color filtering

  (b) Light sensor

    ■ Infrared sensor

      ○ Cannot use a black shuttlecock

    ■ Color sensor

      ○ It can respond to a variety of color shuttlecocks

    ■ Illuminance sensor

  (c) Ultrasonic sensor

    ■ Difficulty measuring near distance

(d) Weight sensor

- How to measure?

i. Prevention of foreign substances inhalation

(1) Selective inhalation

(a) Filter

(b) Shape recognition

(2) Picking up to ball ourselves

(3) Inhale together

(a) A filter that does not pass through a ball

2. Scamper

a. Background

(1) Substitute something

(2) Combine it with something else

(3) Adapt something to it

(4) Magnify or Modify it

(5) Put it to other use

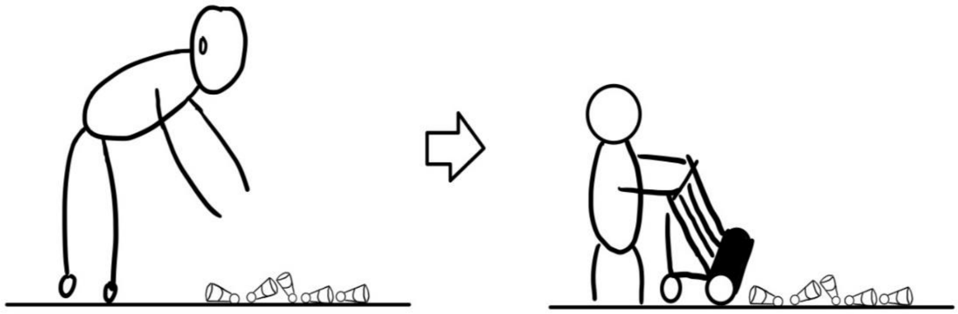
(6) Eliminate something

(7) Rearrange or Reverse it

b. Activity

(1) SUBSTITUTE

(a) We could manually change the way a person moves a device to move automatically



(b) Manually picking up and sorting shuttlecocks

- Bend our back and hold them with our hands
- Pick them using long tongs

(c) Cheap and moderately sturdy material

- Plastic
  - PVC
  - PETE

(d) Readily available ingredients

- Pringles case
- Paper box

(e) A non-sharp roller

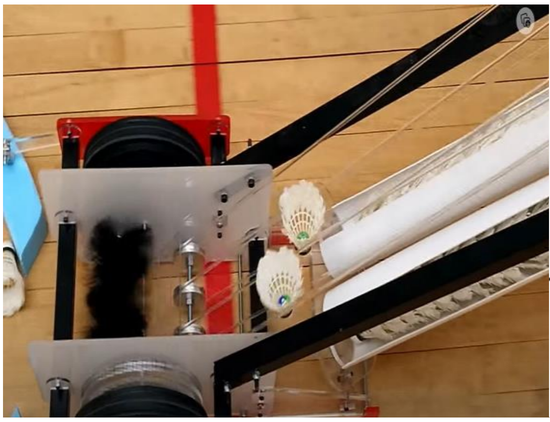
- Sponge material
- Rubber or PVC

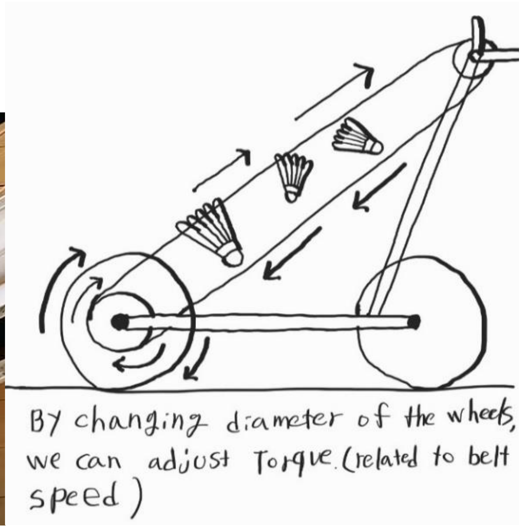
(f) Cart with wheels

(2) COMBINE

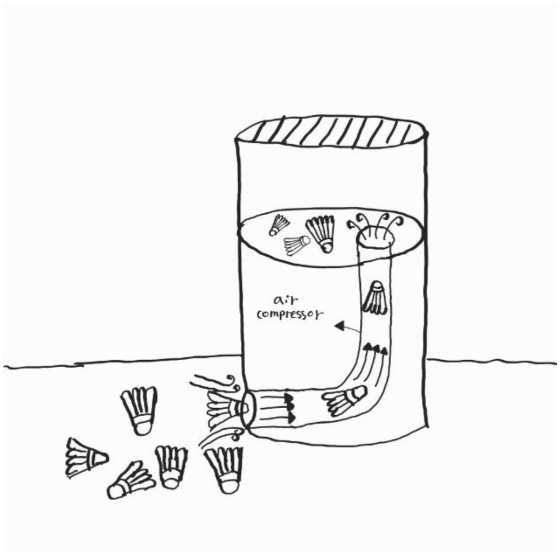
(a) Lifting process

- The conveyor belt is operated with power using wheel rotation of SWEEPER to move shuttlecocks to the sorting device

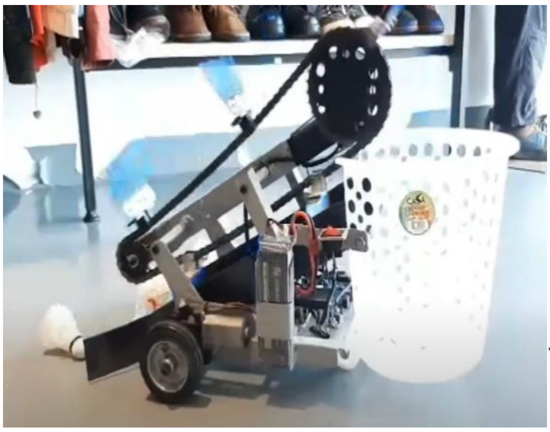


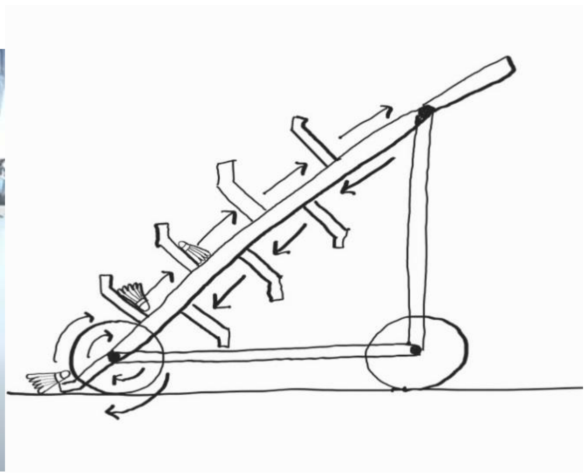


- Inhale the shuttlecock in a vacuum and move it to the sorting device

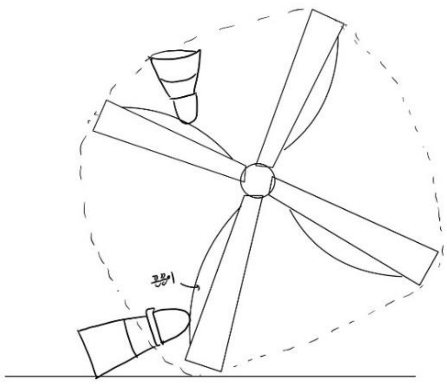


- Push the shuttlecock like a watermill-structure to move it to the sorting device

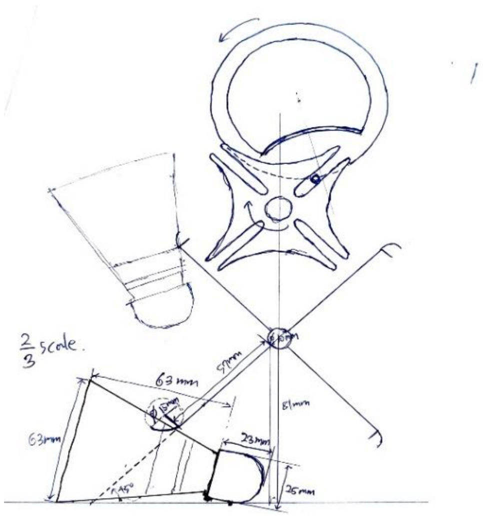




- Use glue to stick a shuttlecock to rotate and pick it



- Push up shuttlecock from top to bottom
  - ○ Soft material
  - ○ Styrofoam, a fruit net that wraps around apples or pears
- Lift the shuttlecock from bottom to top

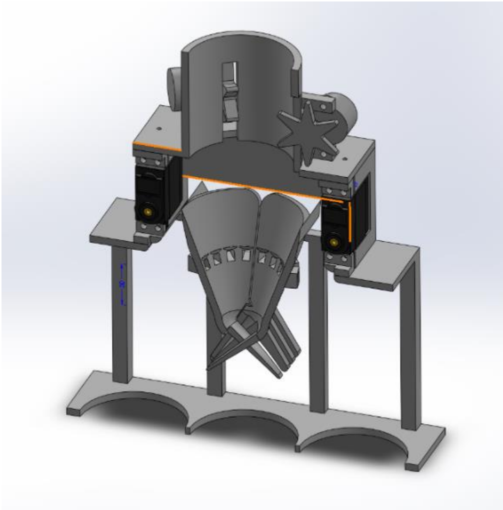


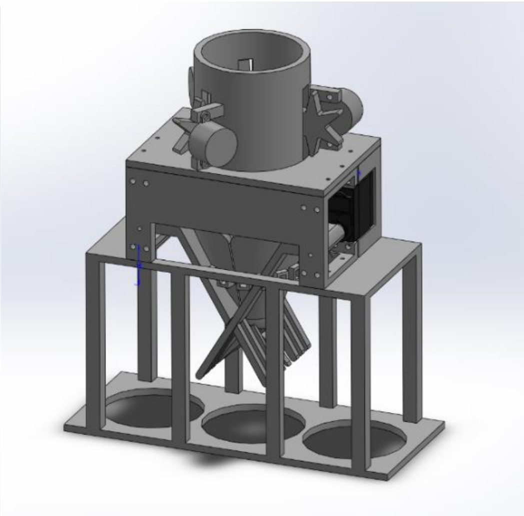
- Pick shuttlecock using small plunger

(b) arrangement

- Use light sensors to determine the wings' conditions of the shuttlecock and separate the available shuttlecock and the disposable shuttlecock
  - ○ The shuttlecock enters the uppermost cylinder of the design drawing, and one shuttlecock falls down every certain period of time by a gear connected to the servo motor.

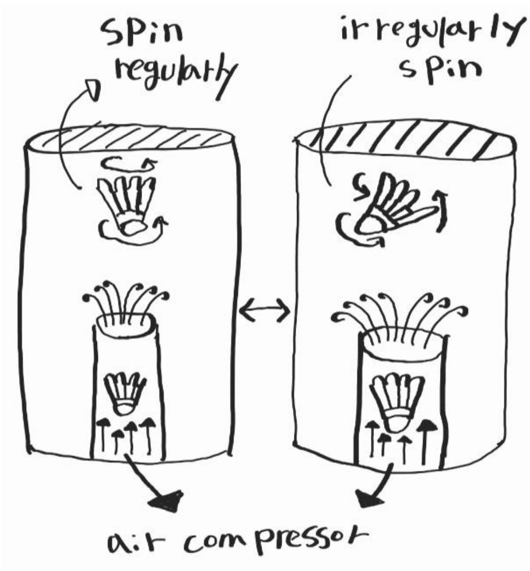
- ○ When the shuttlecock enters the classification device of the cone model, a light sensor located in 16 holes determines whether the shuttlecock is damaged.
- ○ If the threshold is exceeded, the entrance is opened to the left and to the right if it is within the threshold, to classify the damaged shuttlecock and the untouched shuttlecock.



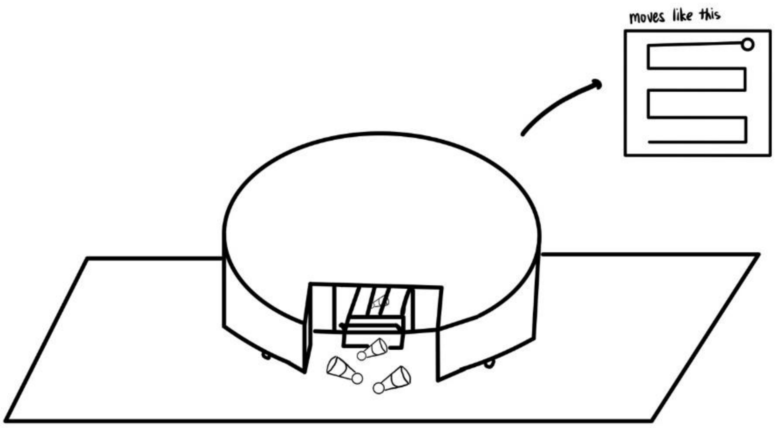


- ■ To measure the weight of the shuttlecock to classify the damaged winged shuttlecock - the weight of the shuttlecock is 4.75 to 5.5g, requiring an ultra-precise device.

- ■ Using the wind to float the shuttlecock in the air, determine the rotation and shaking of the shuttlecock, and separate it.



- ■ By introducing a robot vacuum cleaner, it would be possible to create a device that moves around on its own, picks up and classifies shuttlecocks.



(3) ADAPT

(a) Light sensor - Identifying if the shuttlecock is damaged using the functions of an object detection device or security device using an infrared sensor

(b) Device that can prevents shuttlecocks or conveyor belt from getting stuck

(c) The same process can be used for the collection and classification of ping-pong balls

(d) Attach velcro to the surface of the waterwheel structure to prevent it from spinning in vain

(e) Like a forklift, sweep it all at once and tilt to sort it

(f) A bag for a defective shuttlecock (a vacuum cleaner dust bag)

(g) A method of identifying shuttlecock damage using rotation pattern analysis using wind used in the method of inspecting defective products in the shuttlecock production process

(h) Recall by aligning the shuttlecock with the fan wind (prevent damage and getting stuck)

(4) MAGNIFY&MODIFY

(a) Conveyor Belt

- The Number
  - Increase the speed of shuttlecock arrangement by increasing the number of lifting belts for raising shuttlecocks
  - Reduce product size by reducing the number of lifting belts
- Length
  - Reduce product size by reducing the length of lifting belts – more portable

- Increase belt length to increase shuttlecock travel time to secure shuttlecock classification time

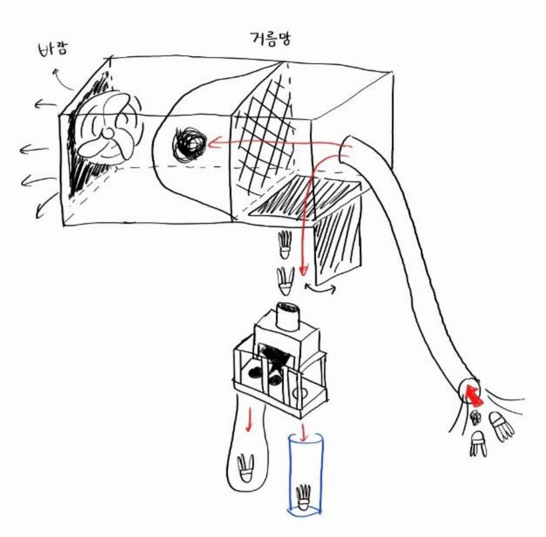
- Angle of Inclination
- If the angle of inclination is too gentle, the size of the product increases unnecessarily
- It should be easy to store, and the size of the body will also be important for convenience of use
- Reduce the number of shuttlecock storage boxes to ensure maneuverability through volume reduction
- Organize many shuttlecocks at once by increasing the number of shuttlecocks

(b) wheel

- The number(2,4,etc)
- size
  - Fast shuttlecock transportation by making the diameter of the wheel larger and increasing the power acting on the conveyor belt
  - Making the diameter of the wheel small to ensure the mobility of the sweeper under turning
- Changing of direction
  - If we put a lot of things in a shopping cart, it becomes difficult to change the direction of the cart quickly. The new equipment we will make makes it easier to change direction by eliminating disadvantages like shopping carts.
- Add Auxiliary Wheels

(5) PUT IT TO OTHER USE

(a) How to collect and discard the trash collected in the process of collecting shuttlecocks together with shuttlecocks



(b) Sweepers are also combined coat-cleaning push bar function

(c) Blades are attached to the head and used as a weeding machine

(d) It can be used to find things that have been dropped on the lawn

(6) ELIMINATE

(a) Reduce prices by removing excessive power from shuttlecock collecting devices and using minimal power, such as rechargeable batteries, in classifying devices

(b) If there are too many shuttlecock storage boxes, such as the shuttlecock storage container of MINTON-BOT, the volume increases and is inconvenient, so reduce the number of shuttlecock storage boxes to about 3

(c) Remove existing cc-60 pedestal

(7) REARRANGE & REVERSE

(a) Classify first and then collect

(b) Design a coat with a moving floor with a shuttlecock

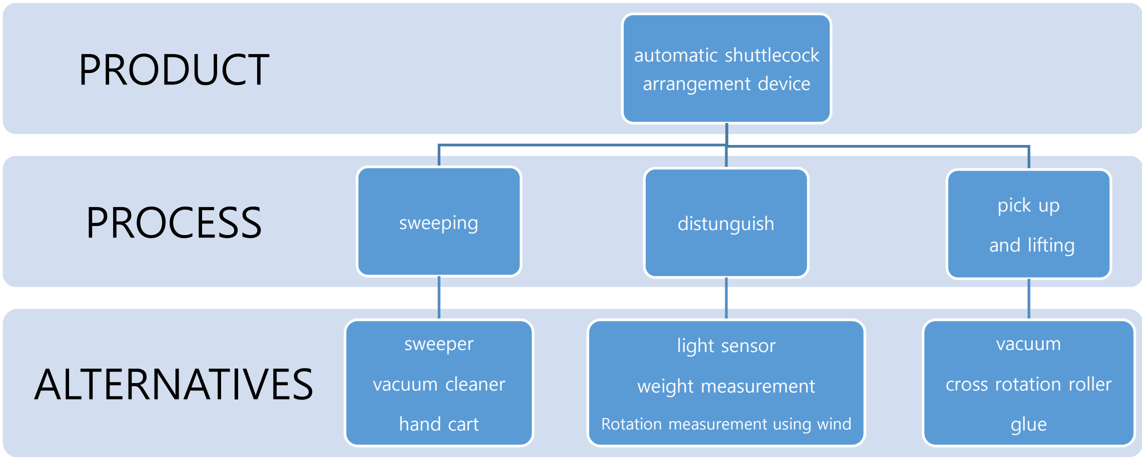
3. Decision matrix

a. Background

(1) Decision matrix

An iterative evaluation method that tests the completeness and understanding of requirements, rapidly identifies the strongest alternatives and help foster new alternatives.

(2) Basic structure



b. Activity

(1) Junho Kim

(a) Sweeping process

Criteria	Importance	Hand cart	Sweeper	Vacuum cleaner
Sweeping process	2	1	D	1
Convenience	5	1	A	-1
Safety	7	0	T	-1
Stuck	7	0	U	-2
Electricity	10	0	M	-2
Sweeping velocity	12	2		1
Cost	15	-1		-2
Weight	7	-1		-2
Volume	10	-1		-1
Debris filtering	5	2		-1
Shuttlecock damage	10	2		0
Durability	7	0		1
Grip feeling	3	2		1
Sum	100	35	0	-81

(b) Distinguish process

Criteria	Importance	Light sensor	Rotation measurement using wind	Weight measurement
Safety	5	1	D	1
Electricity	12	1	A	1
Distinguish velocity	15	1	T	-2
Cost	17	0	U	1
Accuracy	15	2	M	-1
Volume	8	0		1

Weight	5	1		1
Debris filtering	5	-1		-1
Shuttlecock damage	13	1		1
Durability	5	1		1
Sum	100	80	0	15

(c) Pick up and lifting process

Criteria	Importance	Glue	Cross rotation roller	Vacuum
Stuck	12	-1	2	D
Electricity	14	2	2	A
Pick up velocity	18	-1	-2	T
Cost	19	2	1	U
Debris filtering	11	0	2	M
Shuttlecock damage	12	1	2	
Weight	7	2	1	
Volume	7	2	1	
Sum	100	76	95	0

(2) Jaehoon Nam

(a) Sweeping process

Criteria	Importance	Hand cart	Sweeper	Vacuum cleaner
Sweeping process	10	0	D	2
Convenience	8	0	A	1
Safety	5	0	T	-2
Stuck	8	0	U	-2
Electricity	8	0	M	-2
Sweeping velocity	10	-1		2
Cost	15	0		-2
Weight	5	0		-2
Volume	5	0		-2
Debris filtering	5	0		-1
Shuttlecock damage	8	0		-1
Durability	10	0		-2
Grip feeling	3	-1		-1
Sum	100	-13	0	-80

(b) Distinguish process

Criteria	Importance	Light sensor	Rotation measurement using wind	Weight measurement
Safety	7	2	D	2
Electricity	8	1	A	1
Distinguish velocity	12	1	T	1
Cost	15	-1	U	-1
Accuracy	20	2	M	-1
Volume	6	2		2
Weight	6	2		2

Debris filtering	6	2		2
Shuttlecock damage	8	2		2
Durability	12	1		2
Sum	100	123	0	75

(c) Pick up and lifting process

Criteria	Importance	Glue	Cross rotation roller	Vacuum
Stuck	13	-1	2	D
Electricity	10	2	2	A
Pick up velocity	13	2	-2	T
Cost	18	2	2	U
Debris filtering	14	2	2	M
Shuttlecock damage	12	2	2	
Weight	10	-2	1	
Volume	10	-2	1	
Sum	100	81	128	0

(3) Daeyong Kim

(a) Sweeping process

Criteria	Importance	Hand cart	Sweeper	Vacuum cleaner
Sweeping process	8	1	D	-1
Convenience	7	1	A	-1
Safety	10	1	T	-1
Stuck	6	-1	U	-1
Electricity	7	1	M	-1
Sweeping velocity	8	0		1
Cost	10	0		-1
Weight	9	0		-1
Volume	9	0		0
Debris filtering	9	1		-1
Shuttlecock damage	6	0		-1
Durability	6	0		0
Grip feeling	5	0		0
Sum	100	35	0	-29

(b) Distinguish process

Criteria	Importance	Light sensor	Rotation measurement using wind	Weight measurement
Safety	14	0	D	0
Electricity	9	0	A	0
Distinguish velocity	9	1	T	0
Cost	14	0	U	0
Accuracy	13	1	M	-1
Volume	8	1		0
Weight	7	1		0
Debris filtering	11	0		0

Shuttlecock damage	8	0		0
Durability	7	0		0
Sum	100	37	0	-13

(c) Pick up and lifting process

Criteria	Importance	Glue	Cross rotation roller	Vacuum
Stuck	10	-1	1	D
Electricity	12	1	1	A
Pick up velocity	13	-1	-1	T
Cost	17	1	1	U
Debris filtering	15	1	1	M
Shuttlecock damage	11	0	0	
Weight	10	1	0	
Volume	12	-1	-1	
Sum	100	19	29	0

(4) Sungbin Park

(a) Sweeping process

Criteria	Importance	Hand cart	Sweeper	Vacuum cleaner
Sweeping process	7	0	D	1
Convenience	10	0	A	1
Safety	4	0	T	-1
Stuck	5	0	U	-1
Electricity	11	0	M	-2
Sweeping velocity	8	1		-1
Cost	23	0		-2
Weight	3	0		-1
Volume	4	0		0
Debris filtering	5	0		-2
Shuttlecock damage	9	0		-1
Durability	6	0		0
Grip feeling	5	0		0
Sum	100	8	0	-90

(b) Distinguish process

Criteria	Importance	Light sensor	Rotation measurement using wind	Weight measurement
Safety	7	0	D	0
Electricity	12	2	A	-1
Distinguish velocity	13	1	T	0
Cost	20	2	U	-1
Accuracy	10	1	M	-1
Volume	8	1		-1
Weight	8	1		0
Debris filtering	7	1		0
Shuttlecock damage	7	0		0

Durability	8	0		0
Sum	100	110	0	-50

(c) Pick up and lifting process

Criteria	Importance	Glue	Cross rotation roller	Vacuum
Stuck	12	-1	1	D
Electricity	10	1	1	A
Pick up velocity	13	2	-1	T
Cost	17	1	2	U
Debris filtering	14	1	1	M
Shuttlecock damage	12	2	1	
Weight	10	-1	0	
Volume	12	-1	1	
Sum	100	57	81	0

(5) Joonseo Kim

(a) Sweeping process

Criteria	Importance	Hand cart	Sweeper	Vacuum cleaner
Sweeping process	5	0	D	1
Convenience	10	0	A	1
Safety	5	0	T	-1
Stuck	5	0	U	-1
Electricity	8	0	M	-2
Sweeping velocity	10	1		0
Cost	15	0		-2
Weight	10	0		-1
Volume	10	0		0
Debris filtering	5	0		-1
Shuttlecock damage	8	-1		-1
Durability	5	0		0
Grip feeling	4	0		0
Sum	100	2	0	-64

(b) Distinguish process

Criteria	Importance	Light sensor	Rotation measurement using wind	Weight measurement
Safety	8	0	D	0
Electricity	8	0	A	-1
Distinguish velocity	10	1	T	-1
Cost	17	2	U	-1
Accuracy	14	1	M	-2
Volume	10	1		-1
Weight	11	1		-1
Debris filtering	7	0		0
Shuttlecock damage	8	1		0
Durability	7	0		0

Sum	100	87	0	-84

(c) Pick up and lifting process

Criteria	Importance	Glue	Cross rotation roller	Vacuum
Stuck	8	-1	1	D
Electricity	10	1	1	A
Pick up velocity	15	1	1	T
Cost	20	0	1	U
Debris filtering	7	1	0	M
Shuttlecock damage	10	0	1	
Weight	15	-1	-1	
Volume	15	0	0	
Sum	100	9	48	0

c. Discussion

First of all, it is judged that most of the individual activity results show the same ranking. Therefore, we decided to derive the average of the results of the individual activity matrix as the final results. This is because it is judged that even if so, the trap of the average will not occur.

d. Conclusion

(1) Sweeping process

Criteria	Importance	Alternatives		
		Sweeper(datum)	Vacuum cleaner	Hand cart
Sweeping process	6.4	S	+0.8	0.4
Convenience	8	S	+0.2	0.4
Safety	6.2	S	-1.2	0.2
Stuck	6.2	S	-1.4	-0.2
Electricity	8.8	S	-1.8	0.2
Sweeping velocity	9.6	S	+0.6	0.6
Cost	15.6	S	-1.8	-0.2
Weight	6.8	S	-1.4	-0.2
Volume	7.6	S	-0.6	-0.2
Debris filtering	5.8	S	-1.2	0.6
Shuttlecock damage	8.2	S	-0.8	+0.2
Durability	6.8	S	-0.2	S
Grip feeling	4	S	S	+0.2
	Total +	0	1.6	2.8
	Total -	0	10.4	0.8

sum	Overall total	0	-8.8	2
	Weighted total	0	-76.52	13.2

(2) Distinguish process

criteria	importance	alternatives		
		Light sensor	Weight measurement	Rotation measurement using wind(datum)
Safety	8.2	+0.6	+0.6	S
Electricity	9.8	+0.8	S	S
distinguish velocity	11.8	+1	-0.4	S
Cost	16.6	+0.6	-0.4	S
Accuracy	14.4	+1.4	-1.2	S
Volume	8	+1	+0.2	S
Weight	7.4	+1.2	+0.4	S
Debris filtering	7.2	+0.4	+0.2	S
Shuttlecock damage	8.8	+0.8	+0.6	S
Durability	7.8	+0.4	+0.6	S
sum	Total +	8.2	2.6	0
	Total -	0	2	0
	Overall total	8.2	0.6	0
	Weighted total	84.6	-7.76	0

(3) Pick up and lifting process

criteria	importance	Alternatives		
		Vacuum(datum)	Cross rotation roller	Glue
Stuck	11	S	+1.4	-1
Electricity	11.2	S	+1.4	+1.4
Pick up velocity	14.4	S	-1	+0.6
Cost	18.2	S	+1.4	+1.2
Debris filtering	12.2	S	+1.2	+1
Shuttlecock damage	11.4	S	+1.2	+1
Weight	10.4	S	+0.2	-0.2
Volume	11.2	S	+0.4	-0.4
sum	Total +	0	7.2	5.2
	Total -	0	1	1.6
	Overall total	0	6.2	3.2
	Weighted total	0	77.04	52.2

(4) Final choices

Process	Sweeping	Distinguish	Pick up and lifting
Final alternatives	Hand cart	Light sensor	Cross rotation roller

IV. SOLUTION FINDING

1. Engineering feasibility

a. Background

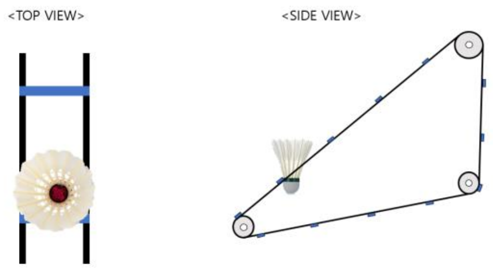
Engineering Feasibility means an engineering study that is completed by a qualified consulting engineer, who has worked in consultation with and is acceptable to the Employment Land User, at the Development Proponent's expense, which includes in its terms of reference:

b. Introduction

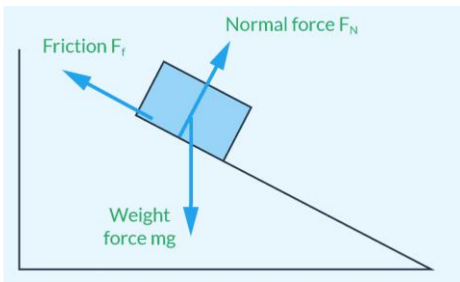
The shuttlecock is very light so the loads that subjected to the parts are negligible. So, stress and strain analysis are not necessary. The first part expected to fail is the belt. But in real product, which is about 2 to 3 times larger than our prototype, will have more thicker belt but still the load is very small. So, the expected lifetime is long and the replacement cost is also low.

c. Conveying mechanism

If we only use friction force to convey the shuttlecock, the possibility of sliding increases. In our product, required friction coefficient is $\tan\theta=1.2$ so it must slide on the belt. And if we set low slope of belt, then the total length of the body will be too long in order to convey enough height. So, we put narrow EVA foam pieces across the belts so that will support shuttlecocks while conveying them up.



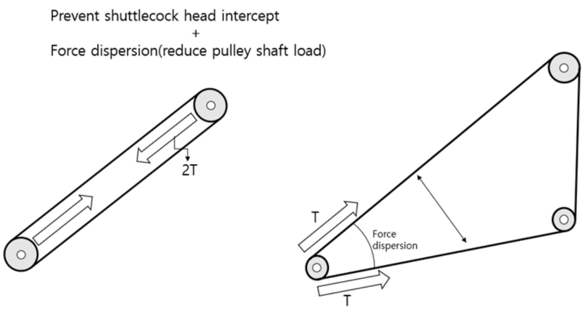
<conveying mechanism>



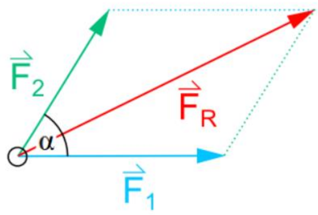
<Friction force FBD>

d. 3-pulleys mechanism

In this figure instead of using two pulleys we used three pulleys so that we can disperse the tension force (reduces total force in factor of $\sqrt{\frac{1+\cos\alpha}{2}}$). that subjected to the shaft and also prevent the intercept of shuttlecock head while conveying up.



<advantage of 3 pulleys>

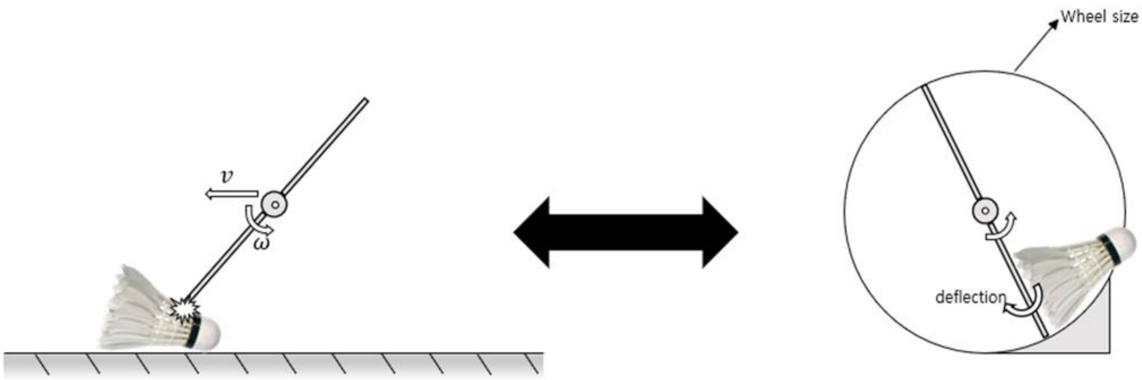


$$F_R = \sqrt{F_1^2 + F_2^2 + 2 \cdot F_1 \cdot F_2 \cdot \cos\alpha}$$

<force vector addition>

e. Design of propeller

Another problem is in the sweeping up phase. If we use solid materials in sweeper, situation like figure below happens, the propeller or shuttlecock will be damaged and the shuttlecock will bounce from the ground and fall somewhere. But if we use too weak materials, then in the sweeping up phase, the propeller has not enough stiffness to sweep it up to the conveying belts and will be deflected largely. In solution, the brush type of material is considered the best because it can penetrate through the frame of shuttlecock so the first situation not happens and also have enough stiffness to sweep up. In our prototype, we use wood board and multi-layered Eva foam to make proper stiffness of propeller.



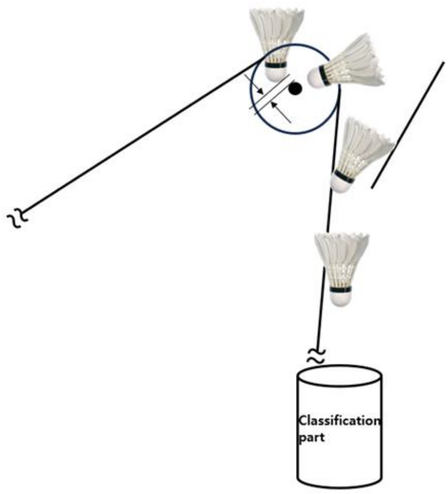
<Problem in sweeping phase>

<brush can penetrate through shuttlecock frame>

<woodboard+multi-layered eva foam>

f. Top pulley part design

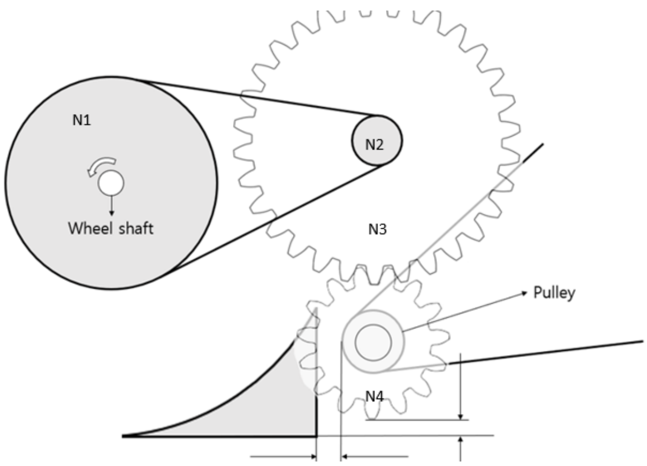
In the top pulley part, to avoid shuttlecock get disturbed by the top shaft, we needed large size pulley and in the drop phase, to make shuttlecock head faces downward, we needed additional part to get right direction of falling into the classification part.



<design of top pulley part>

g. Gear-pulley mechanism design

Due to the nature of sweeping up from the floor, the body frame's position is very low. So we needed to design the pulley or gear parts have higher position than the wheel or body. Otherwise, they will hit the ground and eventually that product will fail to move. By only using two gears, the possibility of hitting ground increases so gear train made up of even numbers of gears(because of the rotating direction) or mechanism like figure below is look proper to apply. In addition to get enough conveying speed of shuttlecock, we have to increase gear ratios, and the first pulley must be larger considering the gap between first pulley and arc shaped slope.



<suggested gear-pulley mechanism>

$$\uparrow \boldsymbol{gear\ \omega\ ratio}$$

$$\frac{\boldsymbol{N_1}}{\boldsymbol{N_2}}\times\left(-\frac{\boldsymbol{N_3}}{\boldsymbol{N_4}}\right)$$

In our prototype, total velocity ratio of conveying velocity to pushing velocity is

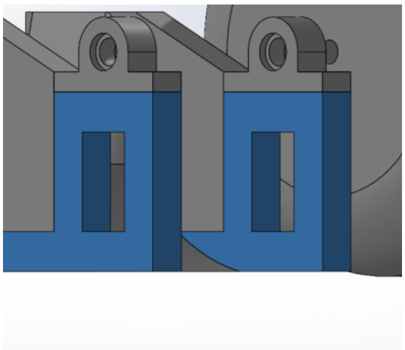
$$\omega\, ratio = \frac{57}{33}$$

$$r\, ratio = \frac{12}{225}$$

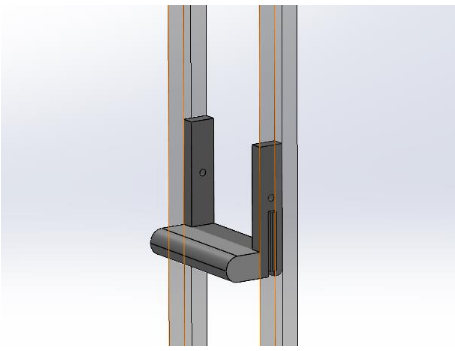
V ratio=0.092 which means 1 shuttlecock moves from bottom to top when we move ~3.5m

h. Reinforce rigidity

The parallel and vertical relationship between parts must be solid because the alignment of pulley shaft and parallel belt positions and same conveying velocity of two belts is very important. So we printed additional support parts in the front which fit perfectly in the profile frame. Plus, make top pulley part able to slide through the profile so fix the position precisely in order to adjust the tension of belts. By the pushing force to drive the product, the vertical frame will tilt to the front so the belt can be loosen. So we put two more profiles to support between the front and vertical bodies.



<right part perfectly fits into the left aluminum profile body>



<top pulley part slides vertically>

<additional two profiles>

i. Miscellaneous designs

-The wheel is not fixed to the shaft so we fixed the gear at the shaft first and used 3d printed parts to fix wheel to the gear. Only one wheel will supply power to mechanism so we can steer in any direction.

-In order to move shuttlecocks, move to the middle line of belts, we used narrowing design of front parts

-In actual prototype test, 2 propellers are enough and in case of 4 propellers it throws the shuttlecock far away back and two shuttlecocks can stick between the propellers. So, we used 2.

2. Product evaluation

a. Classifying sensor value

Criteria	Shuttlecock existence classification	Available shuttlecock classification average	Available shuttlecock classification average limit	Available shuttlecock classification standard deviation of limit average
value	200	850	800	150

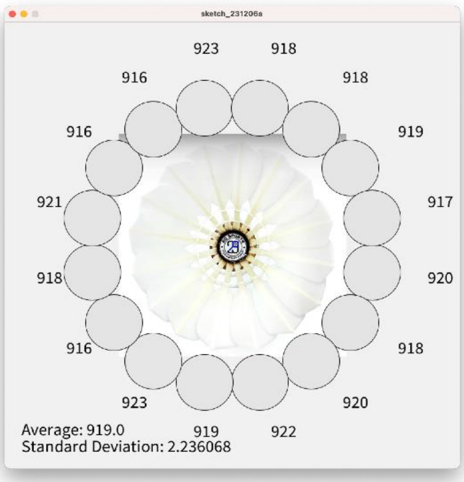
(1) If the shuttlecock does not exist in the measuring device, the result value is 200, and at this time, the step motor is operated to move the shuttlecock to the measuring device. And if the result value exceeds 200, the step motor is stopped to prevent the shuttlecock from moving, allowing only one shuttlecock to be determined at a time.

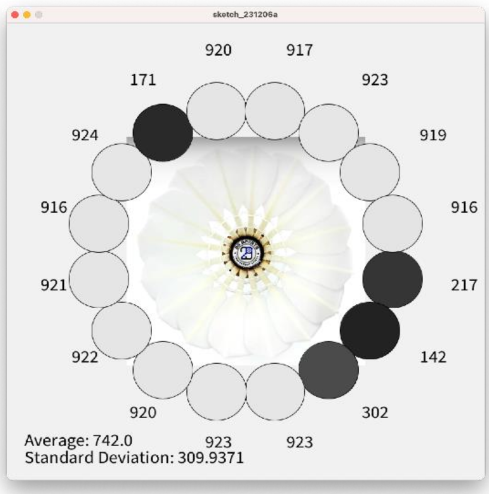
(2) Average is average light sensor value when product classify new shuttlecocks. And average limit is limiting value that makes product to decide the shuttlecock is available one. Thus, we design when sensor value is higher than 850, we classify that the shuttlecock is available.

(3) The standard deviation was used to distinguish between when one of the shuttlecock's wings was completely broken and when several wings were slightly broken, and when two or more wings were completely broken, the shuttlecock was used to distinguish it as unusable.

b. Classifying program visualization

<new shuttlecock value>	<damaged shuttlecock value>





(1) When a new shuttlecock enters, it yields a result value of about 900, and if there is a slight damage, it yields a result value of about 850. So, as we saw in part a, the numbers for classification are quite reliable.

(2) If the wings of the shuttlecock are completely broken, the result value will be very low, as shown in the picture on the right. And in this case, use the standard deviation to determine the number of wings of the broken shuttlecock and classify it as a shuttlecock that should be discarded if two or more wings are completely broken.

3. User test

a. Background

(1) user test

Ideally, usability testing should happen throughout the design process. At the end of the design process, user tests help you to refine what you've built. Goal is to gather as much feedback as you possibility can as early as you possibly can. The earlier you identify problems, the less expensive they are to fix. User tests will help you to identify if users are able to complete specific tasks successfully, establish how efficiently users can undertake predetermined tasks, pin point changes to the design that might need to be made to address any shortcomings to improve performance. Representative methods of user test include A/B testing and competitive testing.

(2) A/B Test

A/B testing is used to compare two versions of the same design to see which one performs statistically better against a predetermined goal. The tests are run by randomly assigning different people down two paths – the "A" test and the "B" test until a statistically relevant sample size is reached. Even though there is a benefit to being able to measure which design generates better results, A/B testing won't help you understand why the design was preferred over the alternate.

(3) Competitive test

Competitive testing is the process of conducting research to evaluate the usability and learnability of your competitors' products. Competitive testing provides design teams with an opportunity to assess a competitor's products from the end user's point of view. Researchers must be aware of the potential for introducing bias into competitive testing. A best practice should be to not reveal your company name to participants when recruiting for the event. Results from competitive tests should be tracked and compared over time.

b. Activity

(1) Focus group

Age	10~19	20~29	30~39	40~49	50~59
number	10	33	3	4	7

Job	Student	Office worker	Coach/player
number	33	23	1

Badminton experience	Less than 1	1~5	5~10	More than 10
number	24	23	6	4

Regular experience	No	Less than 1	1~5	More than 5
number	19	25	9	4

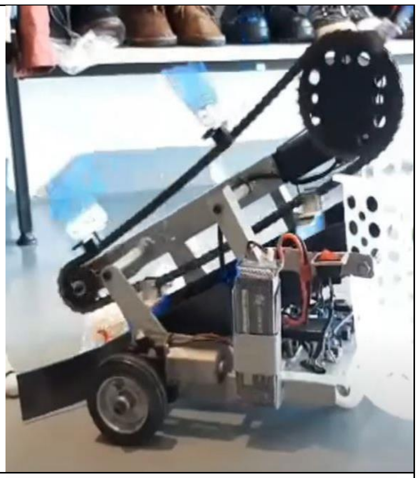
(2) A/B test

(a) Design type

- Type A: prototype
- Type B: another model we design in SCAMPER

(b) Design specification

Criteria	Type A	Type B

Picture		
Explanation	As the cross roller below rotates, it moves the shuttlecock by lifting it on the conveyor belt	A broom-shaped part attached to the conveyor belt sweeps the shuttlecock and moves it up.
Sweeping ability	Same	Same
De-escalation	Less than 10%	Less than 10%
Consumables number	2belts, 4 EVA foams	6~8 vroom shaped part, 2 belts
Consumables cost (won)	20000~30000	20000~30000
Size (cm^3)	20*50*10	20*50*40
Shuttlecock damage	Nearly zero	Nearly zero

(c) Evaluation criteria

- ability to sweep shuttlecock
  - Which design is more efficiently collect sporadic dropped shuttlecocks?
- De-escalation probability
  - Which design is more frequently occur de-escalation of shuttlecock during lifting process?
- Cost
  - Which design costs less to maintain, such as the number of parts used and the replacement of consumables due to the use of the product?
- Aesthetic
  - Which design is more aesthetic and damages the aesthetics if stored and placed in the gym?
- Convenience
  - Which design is more inconvenient because it has problems with storage, movement, and product use hitting or catching the surroundings?

- Importance
  - When evaluating the design, which section do you think is the most important? (Choose 2)

(d) Scoring criteria

Criteria	A is much better	A is better	Both are same	B is much better	B is better
Point	+2 to A	+1 to A	Both 0	+2 to B	+2 to B

(3) Competitive test

(a) Product specification

Criteria	Prototype	Minton bot	Sweeper
Picture			
Price (won)	200000	3680000	140000
Weight (kg)	5	30	6.4
Electric use (kW)	0.45	160	0
Auto classification	O	X	X
Durability (years)	5~10	5~10	More than 10
Arrangement	O	O	X

(b) Evaluation criteria

- Cost
  - If you play badminton as a hobby, are you willing to buy it?
  - Are you willing to purchase it when conducting school and various sports classes (for students and office workers who take classes, do you think it would be good to have the product even if you pay for each product)?
- Durability
  - Do you think the power usage is too high?
  - Do you think the price and accessibility of product parts and consumables are appropriate?
- Volume

- Is it the right size to keep in the gym?
- Is the product suitable for use (do you think it's inconvenient because it's too big)?

■ Convenience

- Is it convenient to automatically organize the shuttlecock in a specific direction?
- Is it convenient because it automatically classifies the available shuttlecock?

■ Shuttlecock damage

- Do you think the use of the product causes a lot of damage to the shuttlecock?

■ Importance

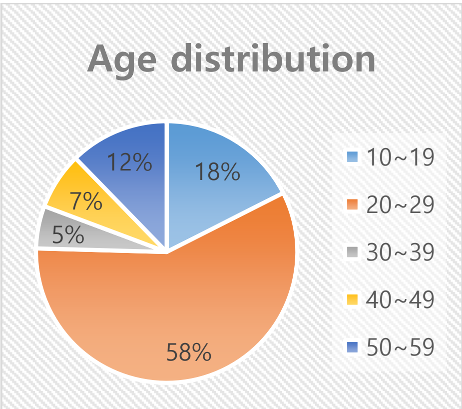
- When evaluating the design, which section do you think is the most important? (Choose 2)

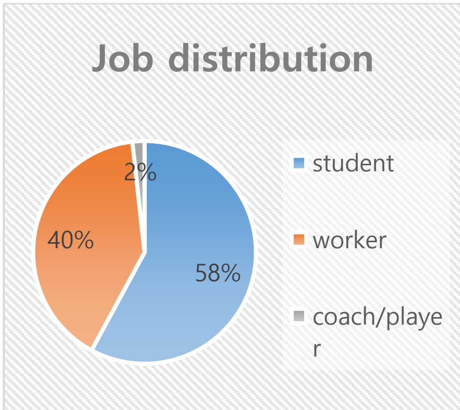
(c) Scoring criteria

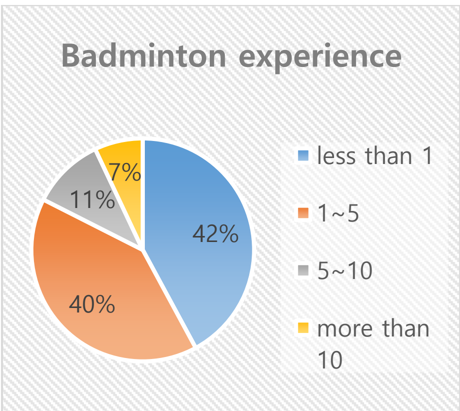
criteria	A is much better	A is better	B is much better	B is better	C is much better	C is better	All same
Point	+2 to A	+1 to A	+2 to B	+1 to B	+2 to C	+1 to C	All 0

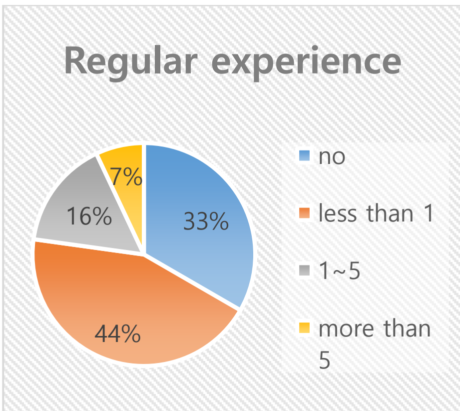
c. Analysis

(1) Focus group









(2) A/B test

■ Importance

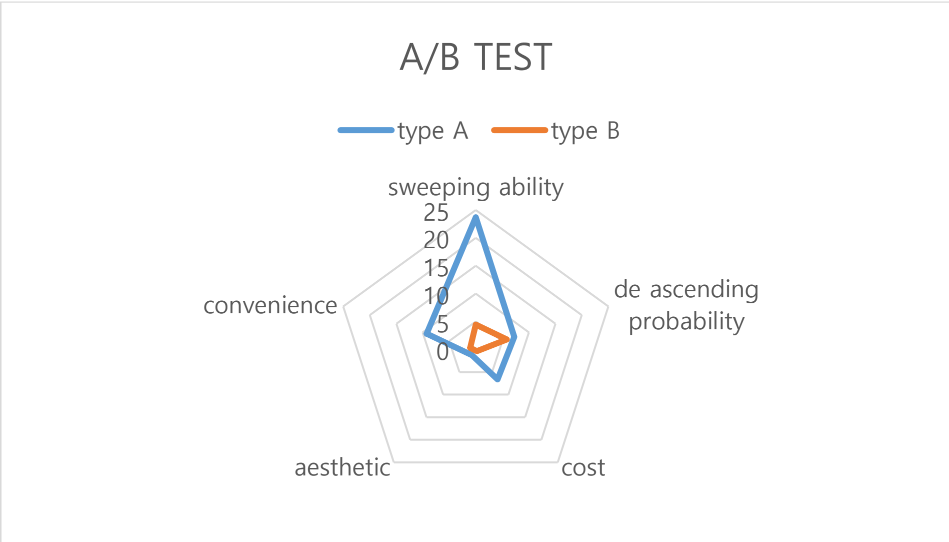
Criteria	Sweeping ability	De-escalation probability	Cost	Aesthetic	convenience
Number	51	23	13	3	24
Importance	0.447368	0.201754	0.114035	0.026316	0.210526

■ Results table

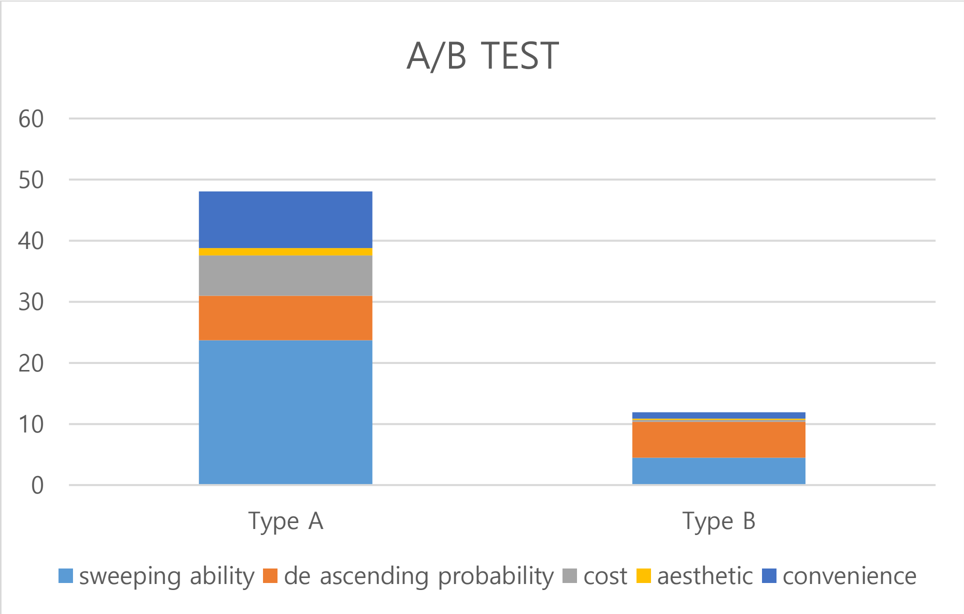
Criteria	Type A			Type B		
Sub section	Results	importance	Sub total	Results	Importance	Sub total
Sweeping ability	53	0.447368	23.71053	10	0.447368	4.473684
De-escalation probability	36	0.201754	7.263158	29	0.201754	5.850877
Cost	58	0.114035	6.614035	3	0.114035	0.342105
Aesthetic	46	0.026316	1.210526	8	0.026316	0.210526
convenience	44	0.210526	9.263158	5	0.210526	1.052632
Total	48.0614			11.92982		

■ Graph

○ Results per section



○ Total results



(3) Competitive test

■ Importance

Criteria	Cost	Durability	Volume	Convenience	Shuttlecock damage
Number	41	11	4	41	17
Importance	0.359649	0.096491	0.035088	0.359649	0.149123

■ Results table

○ Prototype

Criteria	Cost		Durability		Volume		convenience		Shuttlecock damage
Sub section	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1
Results	39	40	49	39	38	55	61	65	48
Importance	0.7	0.3	0.7	0.3	0.4	0.6	0.3	0.7	1
Sub total	27.3	12	34.3	11.7	15.2	33	18.3	45.5	48
Total	39.3		46		48.2		63.8		48

○ Minton bot

Criteria	Cost		Durability		Volume		convenience		Shuttlecock damage
Sub section	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1
Results	1	11	6	8	9	5	8	2	6
Importance	0.7	0.3	0.7	0.3	0.4	0.6	0.3	0.7	1
Sub total	0.7	3.3	4.2	2.4	3.6	3	2.4	1,4	6
Total	4		6.6		6.6		3.8		6

○ sweeper

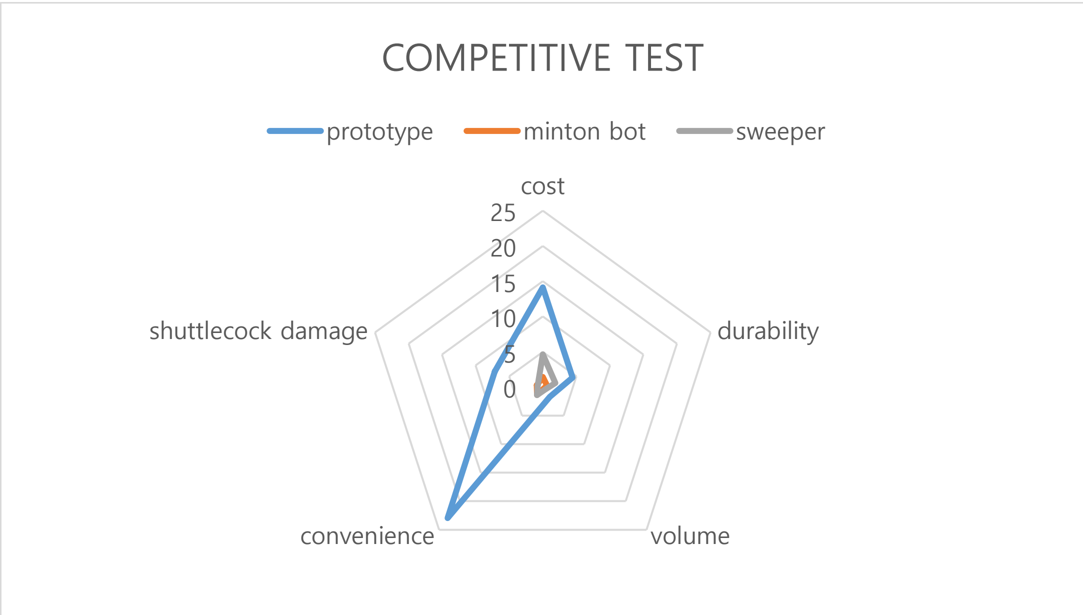
Criteria	Cost		Durability		Volume		convenience		Shuttlecock damage
Sub section	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1
Results	12	15	17	25	19	9	6	3	5
Importance	0.7	0.3	0.7	0.3	0.4	0.6	0.3	0.7	1
Sub total	8.4	4.5	11.9	7.5	7.6	5.4	1.8	2.1	5
Total	12.9		19.4		13		3.9		5

○ total results

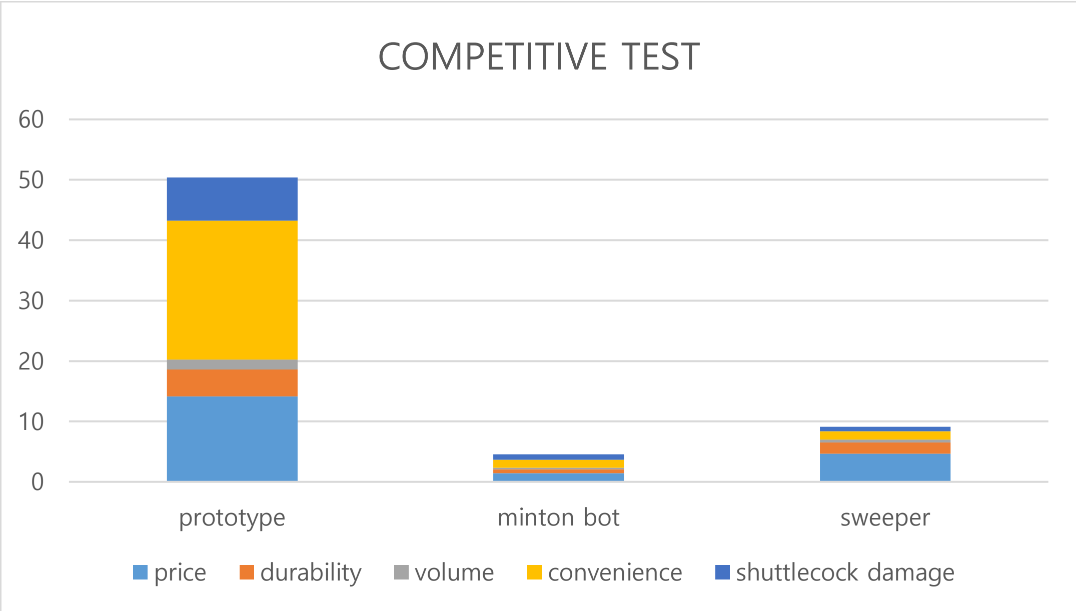
Criteria	Prototype			Minton bot			Sweeper		
Sub section	Results	importance	Sub total	Results	importance	Sub total	Results	importance	Sub total
Cost	39.3	0.359649	14.13421	4	0.359649	1.438596	12.9	0.359649	4.639474
Durability	46	0.096491	4.438596	6.6	0.096491	0.636842	19.4	0.096491	1.87193
Volume	48.2	0.035088	1.691228	6.6	0.035088	0.231578	13	0.035088	0.45614
Convenience	63.8	0.359649	22.94561	3.8	0.359649	1.366666	3.9	0.359649	1.402632
Shuttlecock damage	48	0.149123	7.157895	6	0.149123	0.894736	5	0.149123	0.745614
Total	50.36754			4.5684211			9.115789		

■ graph

○ results per section



○ total competitive graph



d. Discussion

(1) Focus group

Badminton is a relatively intense sport, so the age of the survey participants was from teenagers to 50s. Jobs were mainly conducted by students and office workers who enjoyed badminton as a hobby, and by people who played badminton as a profession, such as badminton coaches and players. We surveyed a total of 57 people. The distribution is relatively evenly distributed and are not dependent on any one group, so they are considered reliable surveys. In addition, the survey's job includes not only students but also office workers and badminton coaches. And many people who consistently played badminton, such as badminton lessons, classes, and competitions, participated in the survey, so the survey results are considered reliable.

(2) A/B test

First of all, I would like to talk about the reason why we conducted A/B test only the design for the sweeping and lifting process among the parts we set as the three stages of the prototype in SCAMPER activity. The A/B test is a test comparing the advantages and disadvantages of designs. The automatic classifier part is excluded because there is no known existing device, and other ideas from SCAMPER activities are very difficult to realize. The importance of each section was determined by requiring the user to select the section that they thought was important in the survey. All the results in each section have higher results in the prototypes compared to other designs. It seems that users have decided that the TYPE B is inferior to our prototype because it uses an electric motor and there are many broomsticks which take up a lot of volume.

(3) Competitive test

In the case of competitive tests, prototypes show superior results in all areas compared to competing products. At the time of the survey, the specifications of the products were prepared and provided without disclosing the name of each product, so it was not intentionally induced to give excellent results to specific products. However, even when the prototype was inferior to other products, such as in terms of price, the prototype obtained relatively better results. In the process of determining the question, all the questions were designed to be independent of each other, but it is judged that the users put their thoughts on most of the questions after viewing the test video and determining that the specific product was better. Looking at the importance of each section, we can see that the price and convenience of the product (automatic classification device, automatic organization device) are the most important for users. And these users' thoughts are exactly the same as the factors we considered the most important at the start of the project. Therefore, we can see that we have successfully come up with ideas by properly grasping the psychology of users, and have succeeded in commercializing them.

Ⅴ. CONCLUSION

1. Achievement

   a. Classifying & rearranging ability

   We realized both how to organize the shuttlecock scattered on the floor in a specific direction and how to classify the available shuttlecock and the shuttlecock that needs to be discarded.

   b. price competitiveness

   It also succeeded in making it a reality at a relatively low price compared to the existing automatic organizer. (minton bot)

2. Need to be improved

   a. Cost

   There is a disadvantage in that the price competitiveness is low because the price is higher than the commonly used sweeper.

   b. Accuracy

   There is a problem that it is difficult to ensure high accuracy because there is an error in the process of classifying available shuttlecocks.

c. Sweeping ability.

There is a disadvantage in that it cannot effectively collect many shuttlecocks that have fallen on the floor.

d. Speed

Since the time for arranging and classifying shuttlecocks is relatively long, it is difficult to collect shuttlecocks effectively.

3. Refine

a. Cost

(1) We can cut cost by to reducing trials and errors

(2) We can also cut cost by Mass production

b. Accuracy

(1) We can get higher accuracy by Using more sophisticated optical sensors

(2) We can get higher accuracy using More detailed classification process code

c. Speed

(1) We can increase speed by adding the number of lifting belts.

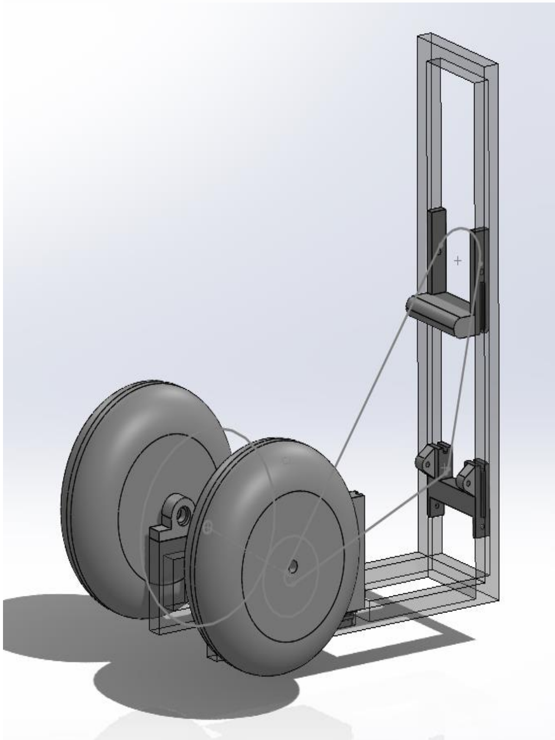
(2) We can increase speed by increasing the speed of classification

d. Sweeping ability

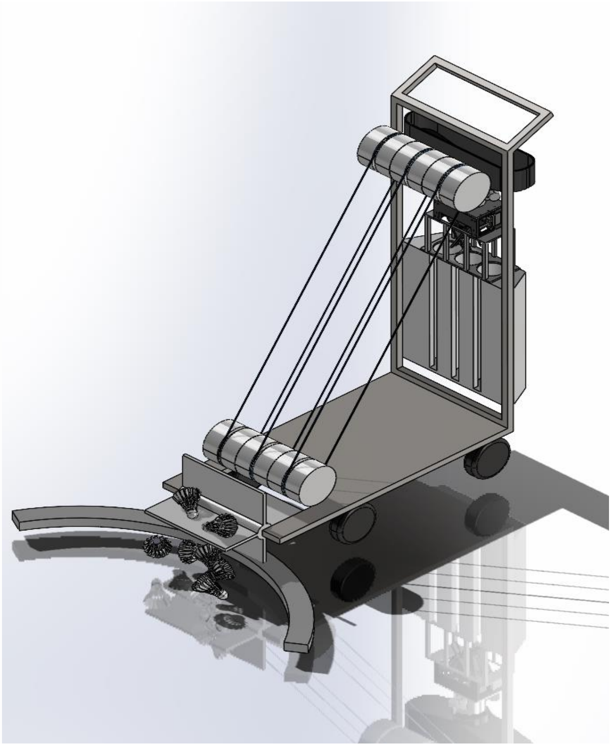
(1) We can increase efficiency of sweeping ability by Combining between Sweeper and Prototype

4. Redefine

Based on the above improvements, we were able to design a new product. Our new design is as follows through ① combining sweeper, ② increasing belt count, ③ excellent sorting device, ④ mass production, and ⑤ trial and error reduction.



prototype design



redefine design

We conclude the engineering design project for the shuttlecock automatic classification device with the above design.

VI. APPENDIX

1. Classifying code

```
#include <Stepper.h>

#include <Servo.h>


// #define IR_INPUT_PIN1 A0

// #define IR_LED_PIN1 52


// change this to the number of steps on your motor

#define STEPS 2048
```

```
// create an instance of the stepper class, specifying
// the number of steps of the motor and the pins it's
// attached to

Stepper stepper(STEPS, 8, 10, 9, 11);
int direction_ = 1, speed_ = 0;

Servo name_servo_1;
int servo_position_1 = 10;

Servo name_servo_2;
int servo_position_2 = 95;

char PinList[]={A10,A9,A8,A11,A12,A13,A14,A15,A6,A7,A4,A3,A2,A5,A1,A0};
char DigList[]={31,33,35,37,39,41,43,45,30,32,34,36,38,40,42,44};
int value_array[20] = {};
int avg_val;
int sd_val;

int existence = 200; // some_value
int avg_ref = 850; // some_value
int sd_ref = 150; // some_value

int stepper_stack = 0; // when it becomes 3, "-1 deg" and reduce to 0 for 2048

void setup() {
```

```
  // put your setup code here, to run once:
  Serial.begin(9600);
  for(int i = 0; i < 16; i++){ // total 16 LEDs and INPUTs
    pinMode(A0 + i, INPUT);
    pinMode(30 + i, OUTPUT);
  }

  for(int i = 0; i < 16; i++){
    digitalWrite(30 + i, LOW); // LOW: 0V, turn off
  }
  delay(5);

  stepper.setSpeed(10);
  name_servo_1.attach(4);
  name_servo_2.attach(5);

  name_servo_1.write(servo_position_1);
  name_servo_2.write(servo_position_2);
  delay(10);
}

void loop() {
  Serial.println("////////////////////////////////");
  int sum = 0;
  for(int i = 0; i < 16; i++){
    check_LED(DigList[i], PinList[i]);
    Serial.print(value_array[i]);
```

```
    Serial.print(",");
    sum += value_array[i];
  }
  avg_val = sum / 16; // average
  Serial.println();

  sum = 0;
  for(int i = 0; i < 16; i++){
    int d = 0;
    d = (avg_val - value_array[i]);
    sum += d*d;
  }
  sum = sum / 16;
  sd_val = sqrt(sum); // standard deviation

  // begin check
  if(avg_val < existence){
    stepper.step(-341);
    delay(2000);
    stepper_stack++;
    if(stepper_stack == 3){
      stepper.step(-1);
      delay(50);
      stepper_stack = 0;
    }
  }
  else if(avg_ref < avg_val && sd_val < sd_ref){ // normal shuttlecock -> to basket
```

```
    for(int po = 0; po <= 20; po++){
      name_servo_1.write(servo_position_1 + po);
      name_servo_2.write(servo_position_2 - po);
      delay(10);
    }
    delay(1000);
    for(int po = 0; po <= 20; po++){
      name_servo_1.write(servo_position_1 + 20 - po);
      name_servo_2.write(servo_position_2 - 20 - 2*po);
      delay(10);
    }
    delay(2000);
    for(int po = 0; po <= 30; po++){
      name_servo_2.write(servo_position_2 - 60 + 2*po);
      delay(10);
    }
  }
  else{ // the other cases -> to trash
    for(int po = 0; po <= 20; po++){
      name_servo_1.write(servo_position_1 + po);
      name_servo_2.write(servo_position_2 - po);
      delay(10);
    }
    delay(1000);
    for(int po = 0; po <= 20; po++){
      name_servo_1.write(servo_position_1 + 20 + 2*po);
      name_servo_2.write(servo_position_2 - 20 + po);
```

```
      delay(10);
    }
    delay(2000);
    for(int po = 0; po <= 30; po++){
      name_servo_1.write(servo_position_1 + 60 - 2*po);
      delay(10);
    }
  }
}

void check_LED(int IR_LED_PIN, int IR_INPUT_PIN){
  int ambient1, ambient2, ambient3, ambient4, ambient5, amb_avg;
  int lit1, lit2, lit3, lit4, lit5, lit_avg;
  int value;

  digitalWrite(IR_LED_PIN, LOW); // LOW: 0V, turn off
  delay(5);   // = 5ms, to give ADC and LED transition time
  ambient1 = analogRead(IR_INPUT_PIN); // brightness of surroundings
  delay(0.5);
  ambient2 = analogRead(IR_INPUT_PIN);
  delay(0.5);
  ambient3 = analogRead(IR_INPUT_PIN);
  delay(0.5);
  ambient4 = analogRead(IR_INPUT_PIN);
  delay(0.5);
  ambient5 = analogRead(IR_INPUT_PIN);
  amb_avg = (ambient1 + ambient2 + ambient3 + ambient4 + ambient5)/5;
```

```
  /*analogRead -> 0 ~ 1023 (between 0V and 5V)
   ambient/1023*5 = V_adc, ambient*5/1023/R = I_adc < 0.8mA -> R = 68k ohm*/

  digitalWrite(IR_LED_PIN, HIGH); // HIGH: 5V, turn on
  delay(5);
  lit1 = analogRead(IR_INPUT_PIN); // brightness of reflected LED + surroundings
  delay(0.5);
  lit2 = analogRead(IR_INPUT_PIN);
  delay(0.5);
  lit3 = analogRead(IR_INPUT_PIN);
  delay(0.5);
  lit4 = analogRead(IR_INPUT_PIN);
  delay(0.5);
  lit5 = analogRead(IR_INPUT_PIN);
  lit_avg = (lit1 + lit2 + lit3 + lit4 + lit5)/5;

  value = lit_avg - amb_avg; // brightness of reflected LED
  value_array[IR_LED_PIN - 30] = value; // 0 ~ 15

  digitalWrite(IR_LED_PIN, LOW); // LOW: 0V, turn off
  delay(5);

  Serial.println(value);
  return;
}
```

2. Visualization code

```
import processing.serial.*;


Serial myPort;
PImage img;
int[] analogValues = new int[16];



void setup(){
  size(800,800);
  String portName = Serial.list()[1];
  myPort = new Serial(this, portName, 9600);
  img=loadImage("Shuttlecock.png");
}

void draw(){
  background(240,240,240);
  image(img,200,200,400,400);
  if (myPort.available() > 0) {
    String inputString=myPort.readStringUntil('₩n');
    if(inputString!=null){
      println(inputString);
      String[] values = inputString.trim().split(",");
      if (values.length == 16) {
        for (int i = 0; i < 16; i++) {
```

```
            analogValues[i] = Integer.parseInt(values[i]);
            if(analogValues[i]<0){
              analogValues[i]=0;
            }
          }
        }
    }
}
ellipseMode(CENTER);
float UnitAngle=radians(360/16.0);
for(int i=0;i<16;i++){
   float X=400+250*cos(UnitAngle*(i+0.5));
   float Y=400+250*sin(UnitAngle*(i+0.5));
   float brightness=map(analogValues[i],0,1023,0,255);
   fill(brightness,brightness,brightness);
   ellipse(X,Y,100,100);
   float X2=400+350*cos(UnitAngle*(i+0.5));
   float Y2=400+350*sin(UnitAngle*(i+0.5));
   fill(0,0,0);
   textSize(30);
   text(analogValues[i],X2,Y2);
}
int sum=0;
for(int i=0;i<16;i++){
   sum+=analogValues[i];
}
float avg=sum/16;
```

```
  String text="Average: ";

  text(text+str(avg),30,740);

  sum = 0;

  for(int i = 0; i < 16; i++){

    int d = 0;

    d = int(avg - analogValues[i]);

    sum += d*d;

  }

  sum = sum / 16;

  text="Standard Deviation: ";

  text(text+str(sqrt(sum)),30,770);


}
```