Master's Thesis

Wired Drone and Suggestions for its Applications

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Wired Drone and Suggestions for its Applications

A thesis submitted to the Graduate School of Creative Design Engineering, UNIST in partial fulfillment of the requirements for the degree of Professional Master of Design-Engineering

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Executive Summary

UAV(unmanned aerial vehicle), which is commonly known as a drone is enlarging its applications in the many different fields. The drone was originally developed for military use, but it is now used for various purposes such as photography, traffic control, leisure, and delivery (Kim, S.-H., 2016).

Drone delivery not only reduces the cost of maintenance than using traditional delivery transportation such as trucks or scooters but also reduces the labor cost by saving manpower for driving. Since the drones are less limited by obstacles such as traffics, buildings and infrastructures, it also saves time than delivering on the ground (K. Dorling, J. Heinrichs, G. G. Messier, and S. Magierowski, 2016).

Thus, major shipping companies like Amazon, UPS, DHL are increasing investment in the drone industry to innovate their current delivery methods into the new delivery system. Also, transportation companies like Uber, Ehang, Audi, Hyundai aim to commercialize PAV(personal air vehicle)to shorten the travel time at the city roads in traffic hours.

Although drones are developing as a means of transportation, it has a major technical issue. Most of them is the battery issue. Commercial drones have short flight time of about 5~20min, and it cannot deliver heavy objects weighting over 2~3kg for a long distance. This issue greatly reduces the potential of drone use by restricting the flight time range and limiting the weight of the objects to be transported.

To solve this, first, this study aims to find a practical battery solution which can be applied in the current market. Focusing on the loadable drones, various fields such as agriculture, photography & inspection, light, and heavy weight delivery have been analyzed in terms of usage and its limitation by battery issue. Researching various battery solutions, it compares the pros and cons of each solution. Through this, it defines suitable solution for the current market available within 3~5 years. Second, utilizing flight time solution, it aims to suggest new drone applications. It aims to find various use contexts of wired battery solution. Through the ideation, it makes a context tree and defines design requirements for 3 selected contexts. By presenting a range of use contexts and scenarios, it aims to deliver new user value through the long-term flight and sufficient loads, which has not been possible with previous drone technology. Third, selecting 3 use contexts, it describes ideation, testing & refinement, development process and the output of 3D modeling and prototypes of a final concept.

Keywords: Drone, Delivery, Transportation, Wired battery, Flight time, Payload

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Introduction

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1.1 Background

In the early days, drones, which were used for photography or leisure, are now expanding its field to delivery. A major shipping company, DHL (Figure 1), has worked on a project called ‘Deliver Future’ with Parcelcopter, to deliver a medication flying over 37 miles away autonomously (Dronedj Oct 6, 2019). Large shipping companies, such as Amazon (Figure 2) are also working on new delivery systems with drones. Besides, drones with larger propellers and powerful batteries can also transport passengers. Chinese autonomous 'flying car' maker EHang is planning to commercialize the 'Drone taxi' (Figure 3), to reduce the travel time for heavy traffic in the city. Major transportation companies such as Uber, Rolls-Royce, Audi, and Hyundai are also developing an ‘Air taxi’ to commercialize it.

Figure 1. DHL Parcelcopter(left), Amazon Prime Air(right)

Figure 2. EHang AAV (Autonomous Aerial Vehicle)

Particularly, transporting through the drone has the following benefits:

- *It significantly reduces the time than moving through the ground. They are less limited by obstacles like traffics, buildings, or infrastructures.*
- *Delivery through drones saves costs than using traditional transportation such as trucks, scooters, cart, carrier etc. It can also save labor costs through an autonomous flight.*

Also, drone has broader applicability by following features:

- *Vertical takeoff or landing is possible in confined spaces. Drone can take off & land in narrower space or even private lands.*
- *Various sizes of a drone are possible depending on the number, length, layout of each propeller. By*

modifying it, the form and structure of the drone can be changed to be suitable for any environment, for example, forested mountains or narrow indoor hallway.

- A drone has simpler and safer flight than the helicopter. It has one motor for each propeller, so it can be stable even if one of them is broken.

Thus, the drone has many possibilities to be used for the variety of applications of transportation, but it has limited usage because of the battery capacity. This study aims to study how the battery effects on the variety of drone usage and find a solution which can be applied for the drone and can be used practically in the current market.

1.2 Project aim and scope

There are two goals on this study.

- The first goal of this project is to research the battery issue which limits the application of the current drone. By analyzing current usage of the drones in the market, it presents in terms of function, impacts on the application of drones.

- The second goal is to find an appropriate battery solution to suggest its application ideas. By comparing with other solutions, it validates how it could be practical in the market. Also, by proposing 3 different application ideas, it presents how they can be applied in a specific context of the real life.

Currently, there are variety of applications of the commercial drones. However, there are still many opportunities of applications which have not been discovered yet. By suggesting appropriate battery solution through comparison, this study aims to increase the scope of its utilization in the current drone market. These applications focus on the drone that can be produced with the current technology level, which is commercially available within 3-5 years than the future technologies which requires much time for commercialization.

1.2.1 Main research question

The main research question to achieve this project aim is:
Firstly, “How does the battery issue effects and limits the current drone application in the market?”

Secondly, “Which battery solution can be suitable to suggest applications of the current market and how it can be applied in the real context?”

1.3 Report structure

In this chapter, the research background, purpose and scope, and the Main research question have been defined.

In Chapter 2, it describes the definition of the drone and conducts research on commercialized delivery drones in the market and concepts through the desktop research. By analyzing this, it defines how the flight time problem limits the usage of the drone.

In Chapter 3, it describes the types of flight time solutions being studied, such as hydrogen battery or wireless charger like PowerPad. By comparing pros and cons of each solution, it judges whether each battery solution is technically feasible within 3 to 5 years, and whether it provides practical benefits to the user in their real life. Through this process, it decides the one flight time solution that can be utilized for various contexts.

In Chapter 4, it conducts context research where drones can be used by defining the design problems and design requirements. Through making context tree, it selects 3 cases to be developed.

In Chapter 5, it describes process of an ideation & develop of each case, based on the design requirements derived from the previous chapter and output of each ideas.

Chapter 6 describes development and user test with final design of a 3D data and details with prototype.

Chapter 7 summarizes the limitations and conclusions of the final design, in terms of technical or safety aspects presenting further improvement plans.

2

Desktop Studies

2.1 Definition of Drone

2.2 Market research

2.3 Summary

In this chapter, it examines the definition, types and usages of the drone. By analyzing commercial drones of the market, it describes how the battery impacts on the current usage of the drone.

2.1 Definition of drone

Drones are called by various names, such as unmanned aerial vehicles (UAVs) or unmanned aerial systems (UAS). Although drones have many definitions, the most recent definitions from the UAV roadmap, published by the US Secretary of Defense (OSD) is as the following:

"Powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload" (TheFreeDictionary Oct 1, 2019)

2.1.1 Type

There are several classifications of the drone based on packaging, technology type, ability, size, and range. Among them, the most representative classification is technology types, which can be classified as follows. (Skilled Flyer Oct 1, 2019)

A. Multirotor

Figure 3. Multirotor drone (Fox4)

Multi-rotor is a drone with two or more rotors, and is used in various fields such as photography and filming, racing, agriculture, and architecture. Since it has multiple rotors, they are easy to control than other types.

B. Fixed wing

Figure 4. Fixed wing drone (eBee Plus)

Fixed-wing drones have the same structure as airplanes and cannot take off vertically because their wings are fixed to the aircraft. Instead, they can fly at high altitudes.

C. Single rotor helicopter

The single rotor helicopter has the same structure and design as the normal helicopter. One main rotor can be used to take off vertically, and a small rotor near the tail can be used to adjust the direction and balance the flight.

D. Fixed wing hybrids

Fixed-wing hybrid drones have fixed wings, but it is also able to takeoff vertically and landing like a single rotor helicopter.

2.1.2 Usage

Drones can be used in a variety of fields, such as aerial photography, agriculture & farming, leisure, aerial delivery & shipping, filming, inspection, advertising, Air taxi etc.

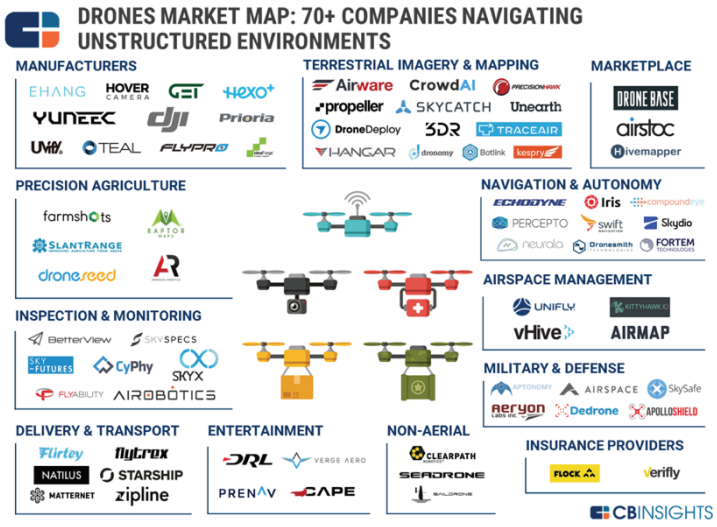


Figure 5. Current drone usages & companies in the market (CDINSIGHTS, 2017)

Drone mapped by size and flight range

The usages of the drone can be mapped by its size and flight range. Most of the commercialized drones were the Small(51cm~2m) size and its flight range was mostly less than Close(~50km) range. This also shows that as the flight range gets wider, the size of the drone gets bigger. This shows that why the drone needs to get bigger is generally because it needs to carry enough batteries for the longer flight.

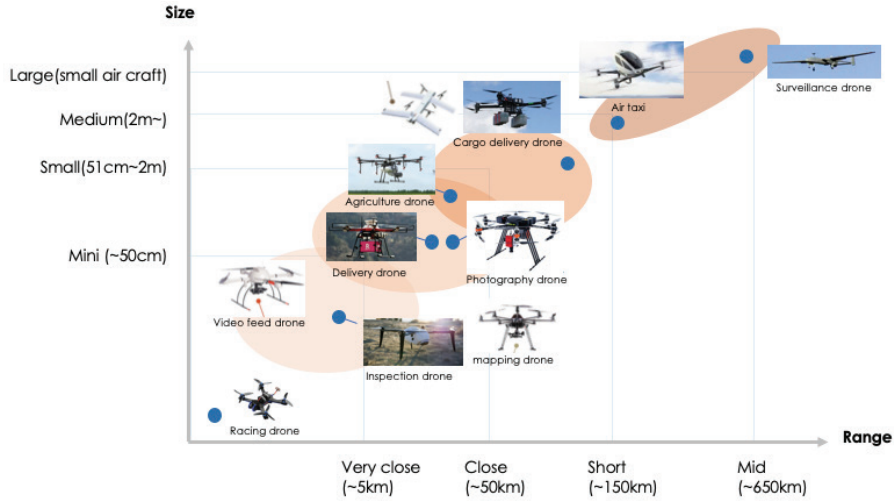


Figure 6. Usage of drones by drone size, flight range

2.2 Market research

In this chapter, it conducts market research of the drones which are designed to hold some payloads to perform its tasks such as delivery, farming or inspection etc.

By examining commercial drones, it presents how the battery effects on the usage of the drones and shows the possible opportunities in the market by solving the battery issues.

2.2.1 Commercial drones

The commercial drones which hold payloads can be divided into light lift drones and heavy lift drones. These drones were mainly applied to agriculture, photography, inspection, cargo delivery, mapping purposes.

A. Agriculture

Figure 7. DJI AGRAS MG-1

- The agriculture drones are used for pesticide spraying equipped with advanced technologies such as obstruction sensing and flight recording. By increasing the efficiency of farm caring, it is possible to operate a wide farm with minimal manpower. They can be also used for scaring away the birds, planting seeds, and impregnating fruit trees, although these applications require much more precision than is currently possible from a technological perspective.

- The payload for pesticide spraying varies from 10kg to 40kg.

- Drones for agriculture has a relatively short flight time than the general ones. For AGRAS MG-1, it has only 10 min of flight time with full takeoff weight, and 24min with half of take off weight (DJI AGRAS MG-1, June 15, 2020).

- Although it has a limited capacity and short flight time, approximately 17% of the maximum takeoff weight is used for battery weight.

Battery issues on the usage of drone

- Increasing load capacity, it can be utilized more efficiently. Since the amount of rice and fertilizer that can be loaded on the drone is small, its usage has been limited to pest control. For the sowing and fertilization, 50 kg of rice seed and 200 kg of fertilizer are required, but the maximum load of agricultural drones distributed in Korea is only 15 to 48 kg. If the maximum loading capacity is increased to 50kg-200kg, it can be used for sowing and fertilization, further improving utilization (농민신문, 2019).

Also, since it has short term flight, drone has to turn back and charge at the charging station. It does not only take longer time, but also requires autonomous flight technology. To perform various tasks such as spraying pesticides and monitoring crops, long-term flight technology would be more efficient (Sunghwan Kim, Gunhee Lee, Kiho Yoo, 2016).

B. Photography & Inspection

Figure 8. Tarot T-18 Ready To Fly Drone

- This photography drones have cameras for industrial, scientific, research or agricultural purposes (Tarot T-18 V2.1 Ready To Fly Drone, June 15, 2020).

- Small photography drone does not carry loads, but the professional one carries about 8kg to 30kg of camera and has approximately 20 min of flight time.

Figure 9. Vulcan Airlift (left), HYDRA-12 (right)

- Vulcan Airlift is drone used for inspection such as for industrial inspection or patrol, fire control, shipping or construction purposes. (Aircraft-VulcanUAV, June 15, 2020)

- Its payload is about 30kg and Maximum takeoff weight is 40kg. The flight time is 30min loaded with 20kg. However, weight of the drone with battery is about 10kg.

Battery issues on the usage of drone

- For inspecting or filming at a large area, the limited flight time makes it stop inspection and requires more time to finish the inspection. When inspecting for construction, some unexpected conditions can affect the quality of the visual data, such as shadows and glare from reflective surface which impacts on the result of the 3D process. Also, the bad weather condition such as rainy weather makes its flight time even shorter. Enough battery capacity in preparation is needed to improve its work performance.

C. Delivery

There are various purposes of delivery drone such as food, flower, parcel, medicine, cargo etc. For the light-weight delivery, it could be food, flower, parcel, medicine or even Wi-fi hotspots. For heavy-weight delivery, it could be cargo, fire extinguisher or munitions.

Light lift delivery drone

Figure 10. Rakuten drone

- This is an automatic drone used by Japan's major shipping company ‘Rakuten’, for aerial delivery. The drone is served by shopping App that indicates weight of the product. It delivers by auto controlled flight, which does not require any kinds of controllers. It also lands safely by its newly developed parachute (Rakuten Drone, June 16, 2020). Its payload is up to 5kg, and the flight time is maximum 40 minutes.

Battery issues on the usage of drone

- Drone delivery has a limited flight distance due to the battery capacity. The heavier it is, the more electricity is needed to deliver. Also, charging 1~2 hours for each delivery significantly reduce time efficiency of delivery. Also, as the charging and discharging is repeated, the battery is consumed more quickly (Hee-Wan Kim, 2017). In terms of management, changing the quickly consumed batteries costs a lot in the delivery system.

Heavy lift drone

Figure 11. GRIFF 300

- GRIFF 300 is a heavy lift drone which is used for industrial, military or search & rescue applications.
- It carries around 226kg of payload weight. It can sustain 30-45 minutes of airtime depending on the payload (GRIFF Aviation: Fly with a legend, 2020).

Battery issues on the usage of drone

- GRIFF 300 has relatively longer flight time than the general heavy lift drones which has 15~25min of flight time. This drone is used for various purposes. However, for some cases, it needs to be prepared for the unexpected situation. For example, in emergency rescue, the average rescue time consumed was more than 2 hours according to Korean rescuers in the mountain(한국일보, 2006). The mission time is unpredictable according to the situation and also for the delay from the environmental factors such as wind, snow, rain for searching the patient. Also, the time needed for coming back to the original point can be varied according to where the patient was found in the mountains.

2.2.2 Analysis

From the research, it was found that the limited battery capacity had significantly restricted the usage of the drone in the various fields. The longer flight time with increase of load capacity was needed for some reasons in each industry. In case of emergency, to find missing person and transport the patient safely to the ambulance, at least 2 hours of flight time was needed for the rescue drone per each charge carrying the patient. Also, in agriculture, increase of load capacity was needed for the broader usage. The battery solution needs to be flexibly adaptable for the needs of each case. The time efficiency of battery charging or cost efficiency were also the important factors for the current market for the delivery drones. For the faster charging, automatic battery replacement is used currently, but the cost of the production is expensive by using autonomous flight system. Also, the battery life cycle by the frequent charge of the battery can be the cost factor of the delivery.

2.3 Summary

The solution is required to give benefit to the user by having long-term flight time with heavy load capacity to broaden the application of the drone for the various usages. Also, to be utilized for the current market with the existing technology level, saving the time that needs for the charging is also required and the cost efficiency & productivity needs to be suitable for the market.

3

Proposal

3.1 Current solutions

3.2 Battery pack solution

This chapter aims to find an appropriate solution for the battery issues described in the previous chapter. Corresponding to the second main question, “Which battery solution can be suitable by suggesting application ideas of the current market and how it can be practically applied in the real life?”, it compares each of battery solutions that already exists or developing now and finds a practical solution to apply for the further applications at the current drone market.

3.1 Current solutions

3.1.1 Studies on battery issue

There are several battery solutions being studied currently to develop the battery charging method or to increase the flight time efficiency.

A. Inductive charging system

Figure12. Inductive charging drone

The system comprises a ground-based power station with a frame of wires positioned in a roughly circular shape. When turned on, this creates an electromagnetic field in the air near the station. A drone equipped with a special antennae charges by flying into the range of the power cloud. Eight minutes of charge time translates to 30 minutes of flight*(Futurism, Oct 6, 2019)*.

B. Hydrogen fuel cell

Figure13. Hydrogen fuel cell drone

Hydrogen fuel is about 4 times higher energy density than lithium batteries, possible to fly for a longer time. Manufacturing company such as Doosan sells the hydrogen fuel pack in individual item,

so that users can easily replace it.

3.1.2 Comparison of the current solutions

These are 5 battery solutions which are currently available or developing for the commercialization. To find the suitable solution in the market, they are mapped by its flight efficiency and cost & productivity level.

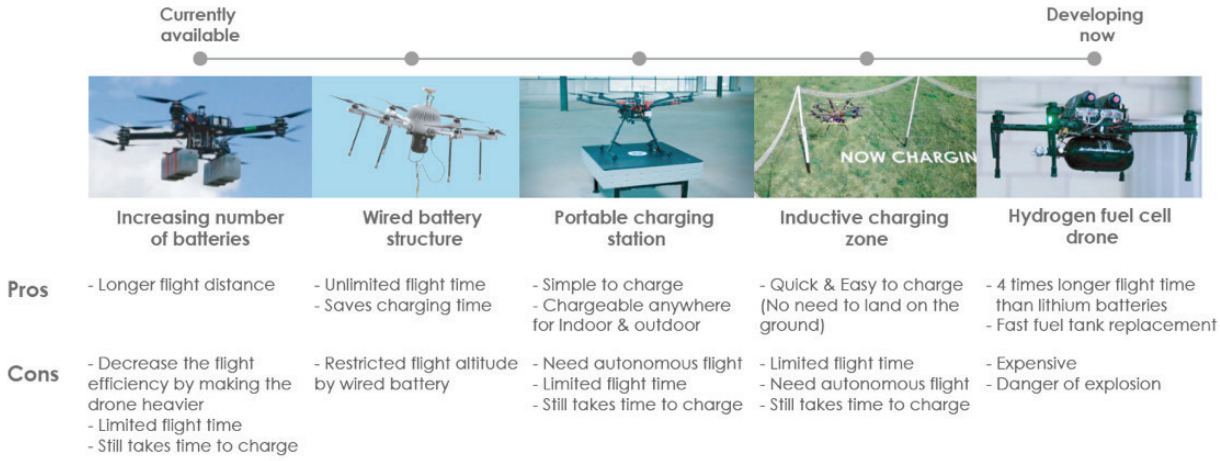


Figure14. Comparison of battery solution examples

Those 5 battery solutions can be divided into two broad categories – innovating charging solution or maximizing the power supply. Each has advantages and disadvantages, but the innovating the charging system – such as portable charging station and inductive charging zone have several limitations for the usage. Firstly, due to the limitation of the flight time per a single charge, it still requires about 10 min to 30 min of time to be fully charged. The drone requires additional energy to fly back to the charging zone, which is inefficient in terms of power usage. Secondly, the location of the charging spots can be limited since it also requires the external power supply. Since it requires infrastructure or power generator, there is a limitation of the maximum flight distance of the drone.

On the other hand, maximizing power supply – solutions such as increasing number of batteries or using hydrogen fuel cells, or using wired battery structure are appropriate to increase the flight time or load capacity per each flight.

Increasing the number of batteries can secure the flight time for short-term flight. However, for the long-term flight, the increase of battery weight makes the drone heavier and leads to the drastic decrease of the flight efficiency. To supplement that, light-weighted materials such as carbon fiber can be used, but still its weight increase is much heavier.

Hydrogen fuel cell drone has 4 times longer flight time than the lithium battery and can extend the

flight time by simply replacing the battery power pack. However, it still has barriers to widespread adoption. The hydrogen fueling infrastructure is limited, the cost of producing and delivering hydrogen fuel to service stations is currently expensive at low volumes. Also, only drones that are specifically designed to be compatible with the hydrogen fuel cells can fly using the power packs. For such issues, it is still difficult to be distributed for diverse applications. For fuel cell to reach the mainstream market, consumer understanding of the technology and its benefits needs to improve (Seong-an Hong, 2005).

The wired battery drone is differentiated in terms of manufacturing. Since it uses existing components such as lithium batteries and compatible with any type of drones, it is simpler to manufacture than the hydrogen fuel drone. It also has better usability, since the user only needs to replace the batteries without stopping the flight. Thus, it can be produced in a variety of forms and types of applications with a reasonable price.

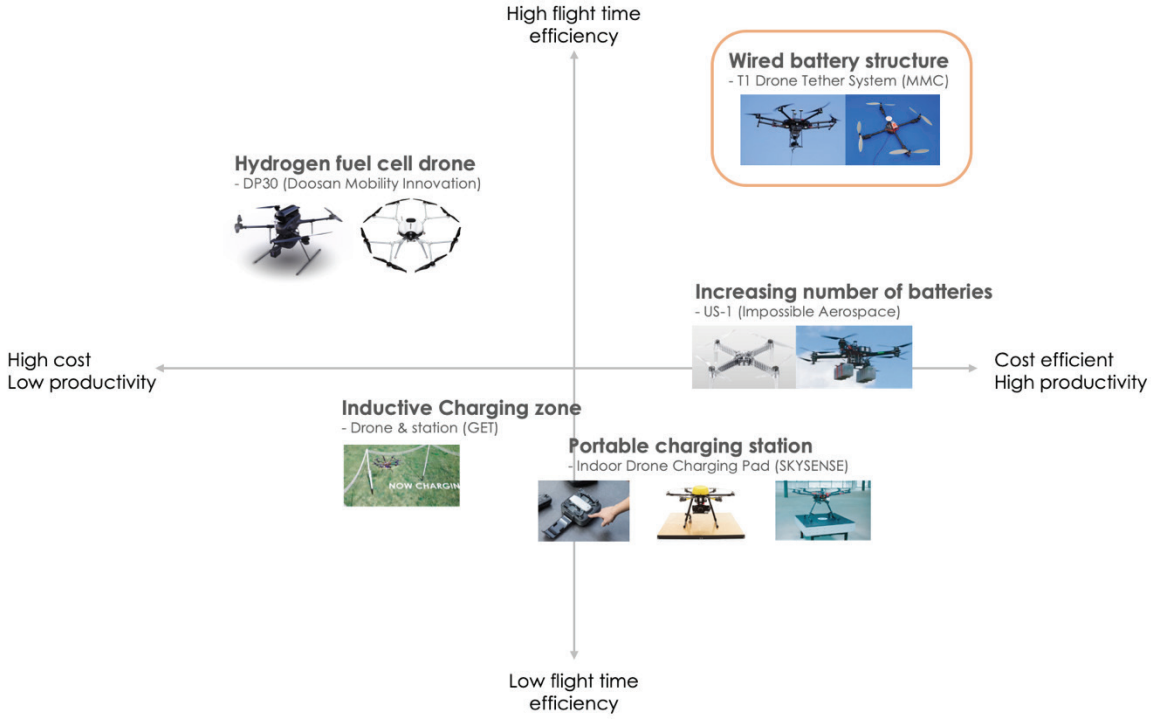


Figure15. Mapping of the Battery solutions

It also has higher flight efficiency than normal lithium drones since it lightens the weight of the drone body by separating the batteries. Most of all, it benefits to the user by supplying unlimited electricity when holding the heavy weight loads for a long-term flight. Although it has a limited altitude that can fly, but the benefit it provides is much more significant for using the drone for various applications.

Type	Example	Power supply	Full charging time	Max flight time	Max payload	Price
Wired battery structure	 Wired power drone	Lithium Ion batteries	No need to charge	24 hours	Customizable	$275.20 (Expected price of only batteries needed for 24h flight with 1.3kg load)
Increasing number of batteries	 US-1 (Impossible Aerospace)	Lithium Ion battery	45 min	2 hours	1.3kg	$7,500~$9,500 (Drone only)
Portable charging station	 Indoor Drone Charging Pad (SKYSENSE)	Electricity through wire	31 min (for Mavic 2)	31 min (for Mavic2)	1.1kg	$649~$4,365 (without drone)
Inductive charging zone	 Inductive Charging drone & station (GET)	Not needed	8 min	30 min	7kg	$120,000 (Power station +2 drones)
Hydrogen fuel cell drone	 DP30 (Doosan Mobility Innovation)	Hydrogen fuel	No need to charge (Power pack replacement)	Minimum 2 hours	5kg	Approximately $30,807+$7.33 /per a single flight (Drone + Power pack price)

Figure16. Battery solution drone examples

3.2 Wired battery solution

The wired battery drones have following advantages:

- *Using wired structure with lithium batteries, it is applicable with current technology level*
- *Less production costs compared to hydrogen fuel drone*
- *Efficient electricity use by reducing the weight of the drone*
- *Replacing the battery cells, flight time is adjustable even with the heavy loads.*

Also, the form of the batteries can be varied by its use purposes. The battery could be loaded in a mobility such as truck, but also can be a type of backpack for the delivery drone, or the wearable types such as armband or wristband also can be used. As an example among various battery types, the Battery Pack can be used as below.

Battery Pack structure

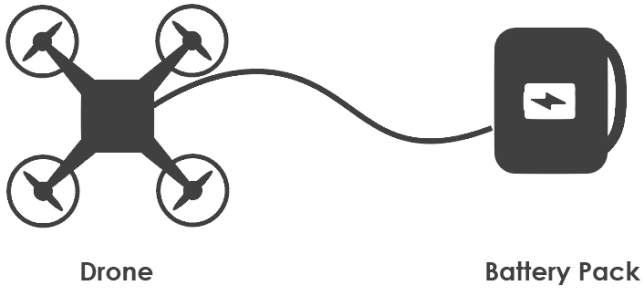


Figure17. Wired drone with Battery Pack

Features

A. *Adjustable flight time*

The Battery Pack is a backpack type of batteries which users can wear. Containing 4 to 6 lithium batteries inside, it expands the flight time by reducing the weight of the drone. By supplying full charged batteries, it lifts heavy load drones for a longer time and make it successful to finish the tasks such as searching a survivor.

B. Wired direction control

Since the drone is wired with the Battery Pack, it follows the user through the wire without complicated controls. It does not need any safety sensors or high-tech components for the direction control inside of the drone. Using gyroscope sensor only, the drone maintains parallel and keeps the flight safely. This simple structure allows it to be more economical and efficient to produce.

4

Application Studies

4.1 Context tree

4.2 Design requirement

In this chapter, it suggests various applications of wired battery structure. Organized by a ‘Context tree’, it shows how the context tree is structured and where it can be used. Among various use contexts, 3 use contexts are selected to be described at the further ideation process.

4.1 Context tree

Various use contexts of ‘transportation’ in the Context tree can be classified as the following criteria.

1) Classification based on what it carries: Person / Object

2) Classification based on the purpose or usage of drone: assistant / transportation

- As an assistant: In this context, it focuses on performing specific ‘tasks’ flying beside of the user, such as giving guidance for the elderly or helping inspection etc.

- As a transportation: In this context, it simply focuses on carrying loads on behalf of the user, such as parcel or furniture delivery.

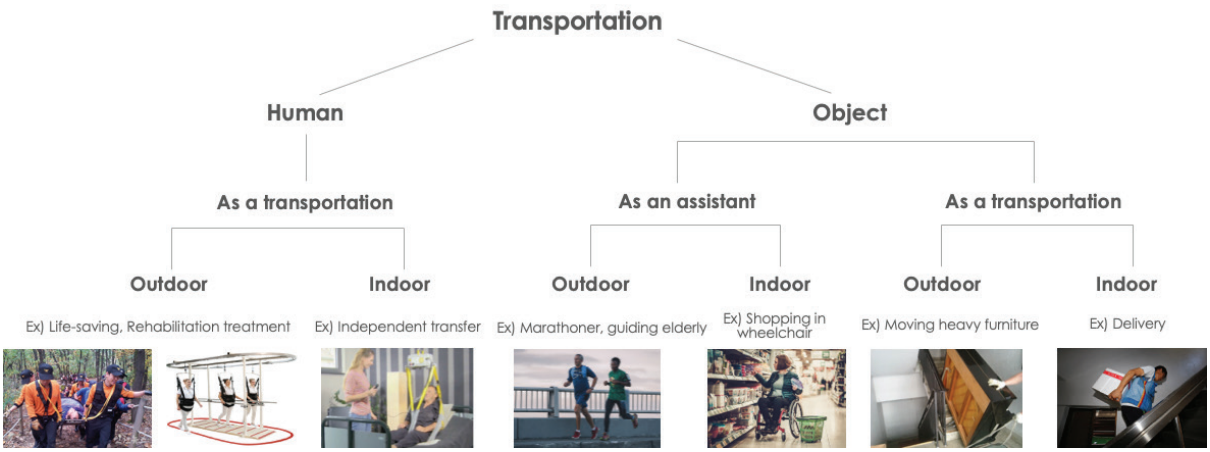


Figure18. Context tree with various applications classified by criteria

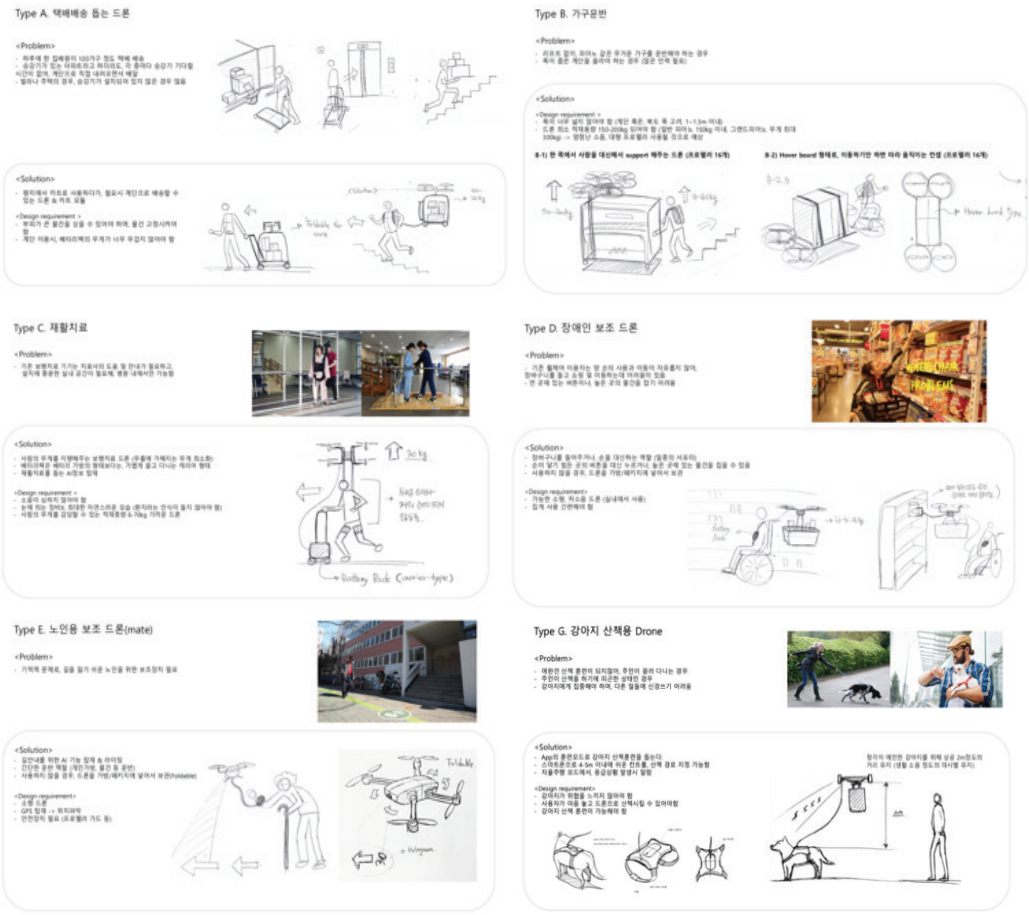


Figure19. Various idea sketches of wired battery drone

First, in case of transporting ‘human’, rehabilitation treatment can be an example. It can be used for walking aid device, helping patients to walk for a medical treatment. By holding the patient, it helps them to walk comfortably with reduced pain on their legs and helps them to be recovered. Another example is a rescue stretcher, which simply transfers the patient who weighs about 8-90 kg on behalf of the rescuer in emergency.

Secondly, example of ‘transporting an object’ as an ‘assistant’ of a user's work, a ‘shopping cart’ for the elderly or a wheelchair user could be an example. It carries personal possessions or shopping baskets instead of the users, to simply assist them. Also, in case of the elderly get lost in direction, it could have navigation function to guide the direction. An ‘assistant’ drone usually lifts light-weight objects, whereas ‘transport’ drone lifts heavy-weight things.

Thirdly, as an example of ‘transporting an object’ simply to transport, furniture-lifting drone could be an example, which lifts heavy loads such as pianos. In this context, the drone carries heavy objects instead of human.

4.2 Design requirement

Three chosen contexts

Among various contexts, three contexts were selected as follows.

A. Rescue in rugged or mountainous areas

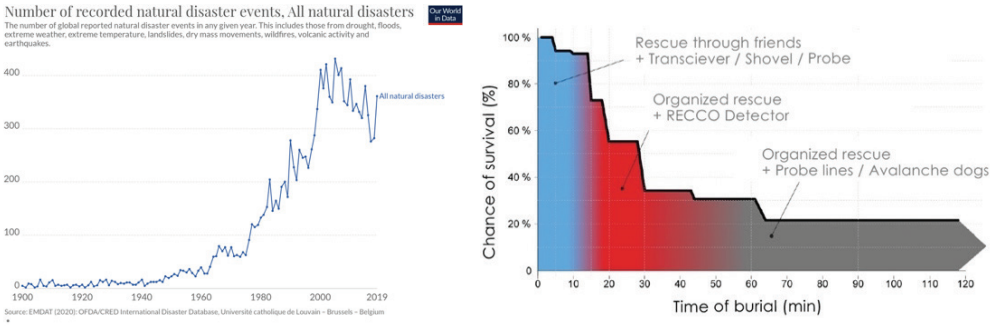


Figure20. Number of natural disaster events (left), Chance of survival for avalanche (right)

Natural disasters have been increasing through world-wide(Figure20). Not only for the natural disasters, the current rescue system effects on various accidents. Especially, keeping the golden time is directly related to the life of the patient. In the fatal circumstances such as an avalanche, the chance of survival is drastically reduced if it takes more than 30 minutes after burial (Figure20).

Figure21. Rescue working process

However, the current rescue system is very inefficient especially for mountainous or rugged areas. The rescuer need to reach at the accident point and the patient must be transported quick & safely through the stretcher. However, current system requires at least four rescue workers and need to carry heavy auxiliary equipment weighting almost 25kg in total(Figure21), which delays the time and decreases the possibility of survival. However, using the drone, it can transport the patient more quickly and safely.

B. Walking dog with a busy lifestyle

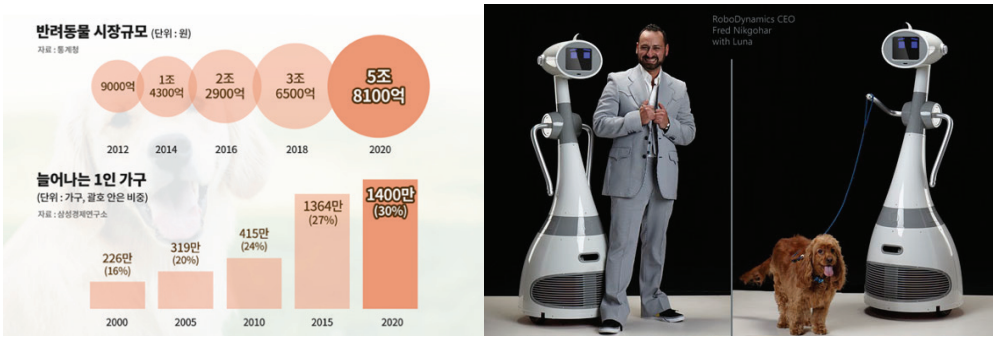


Figure22. Increase of single households (left), Dog walking robot 'Luna' (right)

Based on the National Statistical Office in Korea, about 30% are single household in 2020(Figure22). With the increase of the single households, the loneliness of living alone also effects on the increase of the pet market, which is about 5 trillion won.


Figure23. Walking the dog

However, since most of the single households are workers with a busy lifestyle, raising pet alone has many issues. Especially, walking the dog is the most significant problem. Walking the dog must be done steady and requires at least 30 min per each day (Hayley.C, Billie. G & Matthew K., 2008), which requires a lot of effort and energy for the busy owners. The dog is left in home for a long time has higher danger of the separation anxiety and it greatly effects on both of psychological & physical health of the pet. However, using the drone can help them to walk the dog more easily with less burden of caring the dog.

C. *Last mile delivery service*

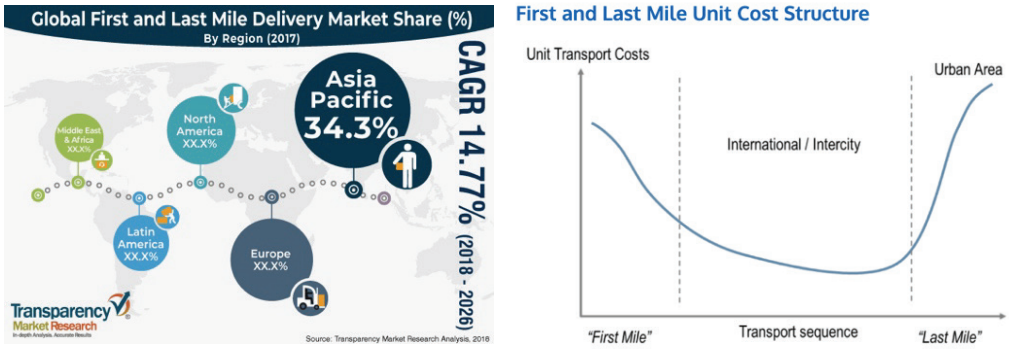


Figure24. Last mile delivery service unit cost(left), Size of last mile delivery market (right)

The last mile delivery market has a large portion in Asia(Figure24). Currently, various types of autonomous vehicles, robots, drones are developing to increase the efficiency of the delivery. However, there is still limitation of the drones or robots to deliver for individuals, because of the restricted battery capacity, and needs for extra infrastructure of the drone for landing. Thus, still labor is used to deliver inside of the building which is inefficient in terms of the time for delivery.

Figure25. Usage of cart for delivery in Korea

Korean mailman delivers almost about 100 packages to homes per each day. However, it takes a lot of time & energy since they need to carry the heavy loads through the cart. To save the time, they sometimes run the stairs instead of using elevator, which causes frequent injuries on the lower back and knees. However, using the drones they do not need to carry heavy loads and helps them to deliver in a shorter time.

Design requirements

Design requirements that can be derived from each context can be summarized as follows.

A. Rescue in rugged or mountainous areas

- *It needs to be efficient & safe to move through mountainous areas*
- *It needs to be compact size to be carried in the ambulance*
- *It needs to have enough load capacity & flight time to carry the patient*

B. Walking dog with a busy lifestyle

- *It needs to teach the dog to follow when walking*
- *It needs to prevent the threat or anxiety of the dog*
- *It needs to be sensitive at dog accidents or any risk factors*

C. Last mile delivery service

- *It needs to carry heavy boxes weighting about 7kg*
- *It needs to be compact size to move in the buildings*
- *It needs to be easy to handle when moving rapidly*

5

Ideation & Develop

5.1 Use scenario

5.2 Ideation

5.3 Testing & Refinement

5.4 Develop

This chapter aims to describe ideation & develop process through the sketches for each context by proposing 3 use scenarios from the 3 chosen concepts.

5.1 Use scenario

A. Rescue Drone

Rescue Drone is emergency stretcher for rescue in mountainous areas. To keep the golden time, it is designed to be safe and efficient to move in forested and narrow area. The wired Battery Pack structure provides flight time unlimitedly through the wire and gives sufficient power to hold the body weight. It requires only 1 person, saving 75% of manpower compared to existing stretcher, which requires 4 rescuers at least.

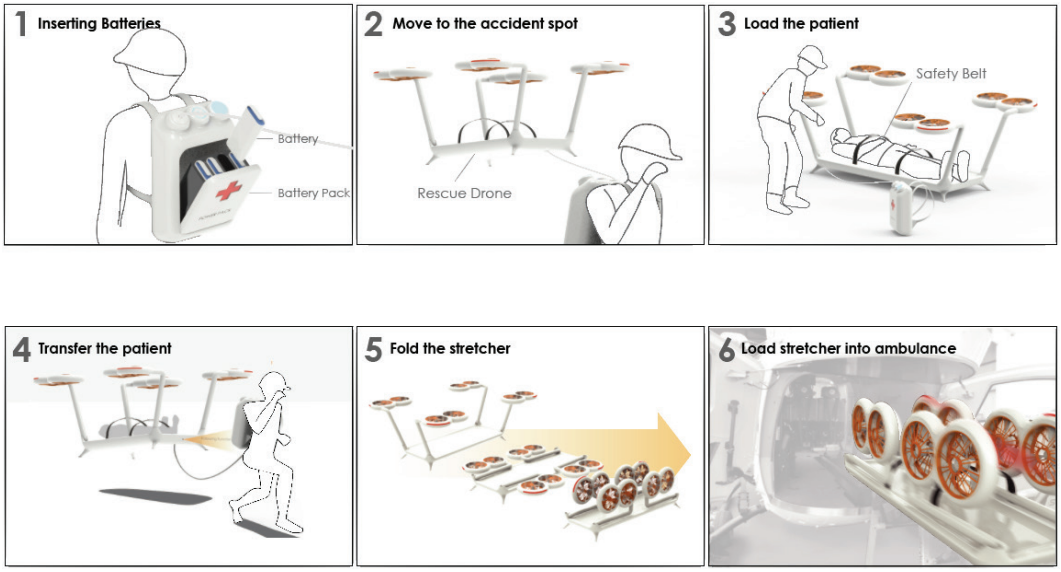


Figure26. Use scenario of rescue drone

B. Dog Walking Drone

Dog Walking Drone is a smart drone concept to help the busy owners. The dog wears a harness, which has a battery cell to supply power to the drone through the wire. Using the wire, the drone leads the dog to walk along with, just like the owner. User can train the dog to follow the drone using the App. Dropping food, it helps the dog to follow the direction. User can also control the direction of the drone or can choose autonomous flight within 4-5m range around the user. Using sound sensors &

GPS, it also gives alarms in case of an emergency.

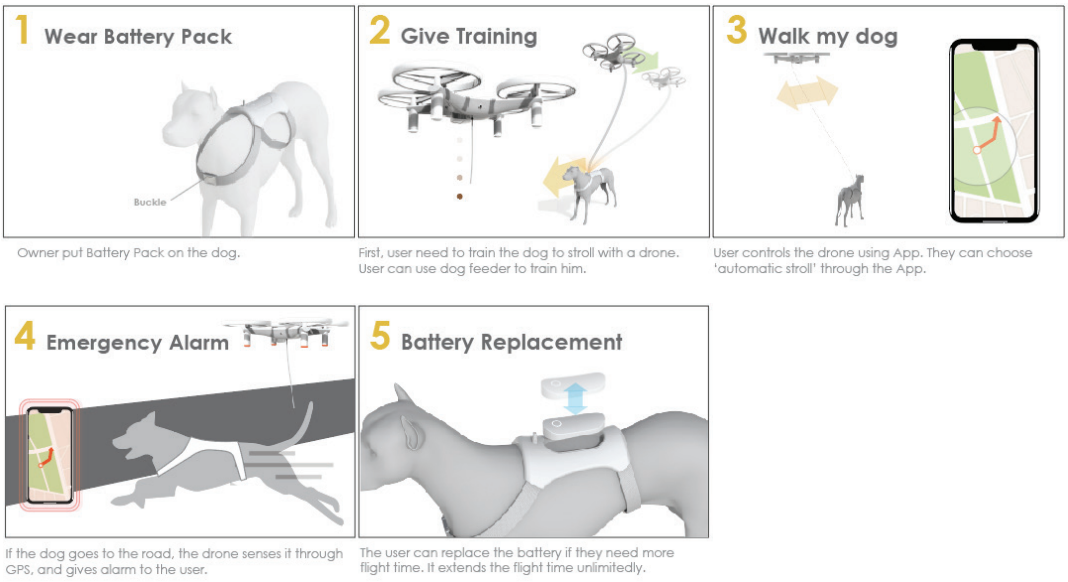


Figure27. Use scenario of dog walking drone

C. Delivery Drone

The Delivery Drone assists the delivery of parcels. It is for an uphill road to assist the user transporting loads instead of the cart. In addition, it could be used for delivery inside of the buildings, such as apartments or villas. Usually, mailman uses large carts, leaving it at the entrance of the apartment, they take out several boxes and deliver it inside. This drone has compact size and can be loaded up to 15kg. When using steps, it loads boxes to support the user. The wired drone moves as the mailman moves, without control it.

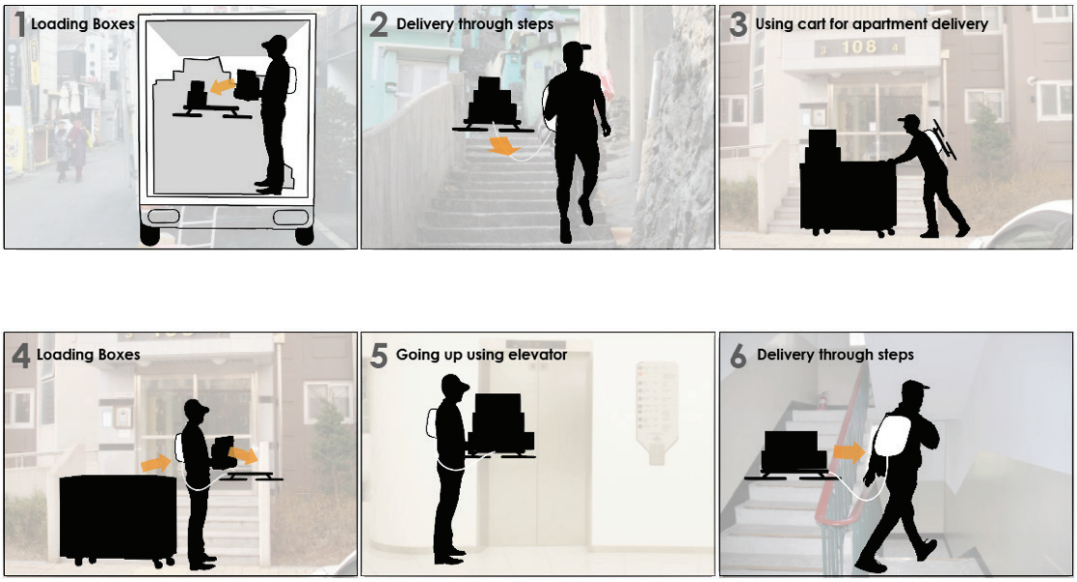


Figure28. Use scenario of delivery drone

5.2 Ideation

A. *Rescue Drone*

The ‘Rescue Drone’ is for the life-saving, thus it has very compact size to go through the forested mountains. Thus, the beams connecting each propeller should be very compact in width (Figure29).

It carries patient efficiently by flying over the rugged area. It only needs 1 rescuer, who carries battery pack on his back. The below is ideation sketches for this concept.

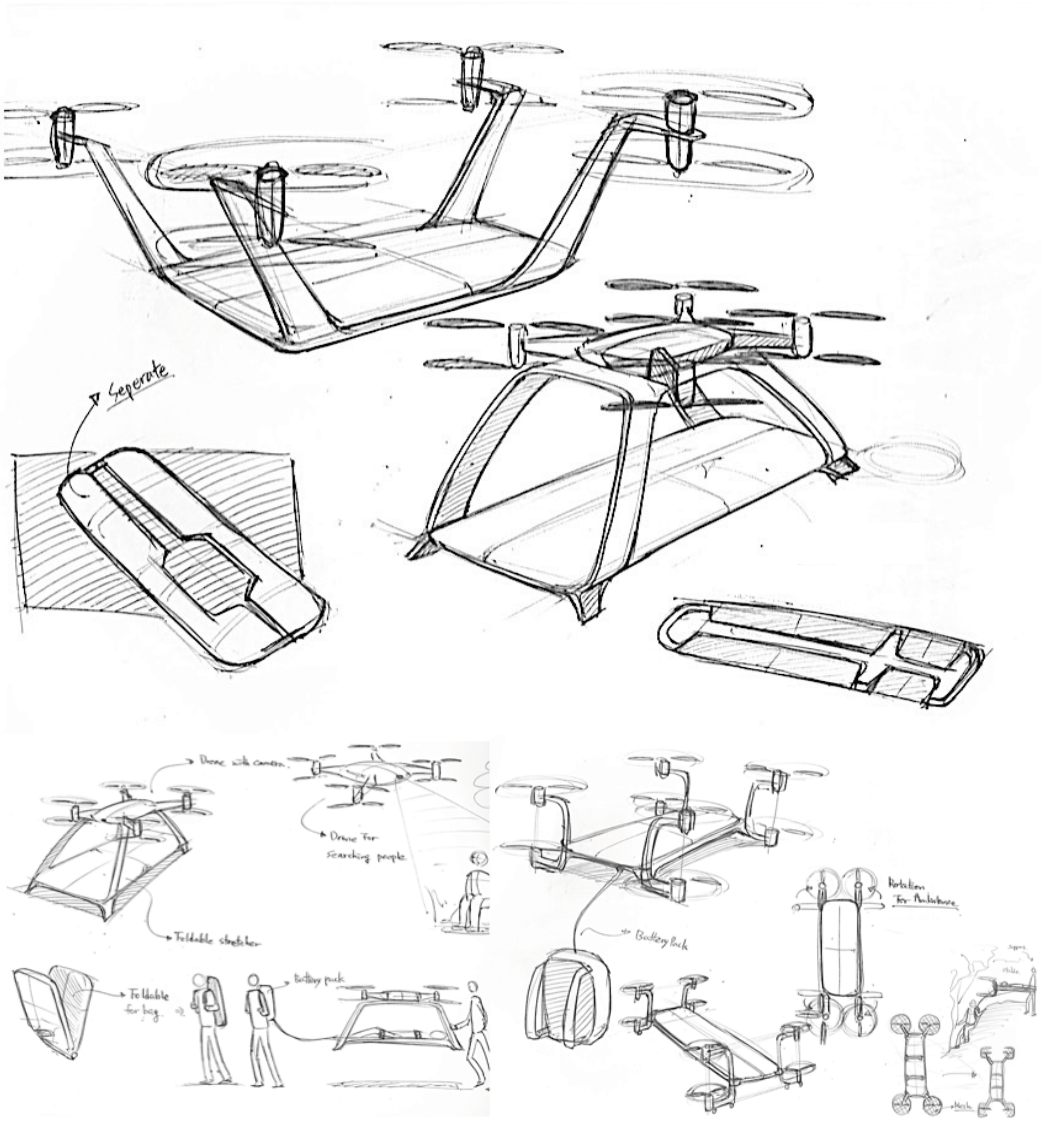


Figure29. Rescue Drone sketch

B. Dog Walking Drone

This drone flies within in 4-5m radius of the user, since it needs to give alarm to the user in case of emergency. The main function of the App is 'Training mode' & 'Control mode'. The drone needs lead the dog for walking (Figure30). The drone pulls the leash oppositely or makes sound if the dog goes to the different direction for training. In case of dog not following, user can also use snacks to lure him.

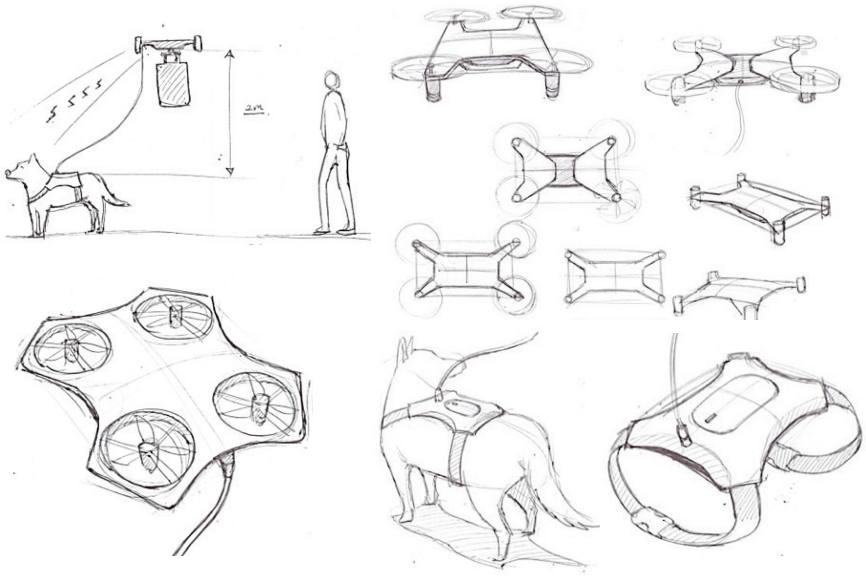


Figure30. Dog Walking Drone sketch

C. Delivery Drone

This drone helps user to carry heavy boxes, especially when user walks through the stairs. The ideation simply started from a framed shape, having a very light weight. It carries boxes weighting up to 15kg. To lift such heavy objects, it has total 8 compact propellers, which is about D=25cm each (Figure31).

Considering the low stair ceiling height, this drone features propellers placed at the bottom. In addition, a fastening belt is needed to prevent the box from shaking in a busy situation.

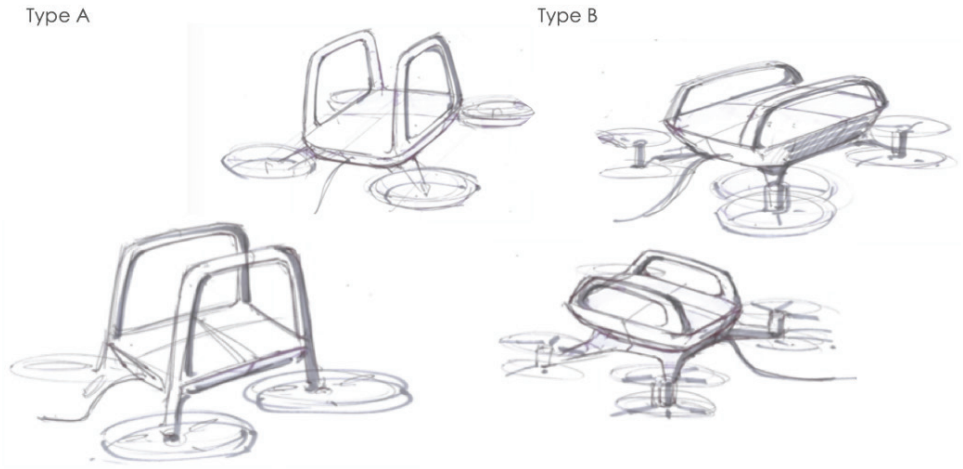


Figure31. Delivery Drone ideation sketch2

5.3 Testing & Refinement

It has conducted an interview to test and refine the Dog Walking Drone. Through the interview, it verifies whether this concept is needed & suitable in the real context and asking any improvement points in this concept.

5.3.1 Method

Participants

It has been conducted with 5 interviewees, who raises dog in their home. Total 4 males and 4 females were interviewed. Their average age was about 36 (3 of them were workers and the rest 2 were students). Two of them had face-to-face interviews, and three of them had the phone interviews. Each interview took about 20 minutes.

Apparatus

- This interview is composed of total 12 questions. 7 questions are inquiries about their dog raising, such as type & size of their dog and where they raise their dogs. Next 3 questions are about their dog walking context. Rest of 2 questions are asked to know the improvement points of the Dog Walking Drone.

Main question	Questions
How they raise their dog?	Q1. What is the type & size of your dog? Q2. Where is the place of residence? Q3. What is the characteristics of your dog? Q4. What is your dog's favorite activity? Q5. What is your dog's habit? Q6. How much time does your dog spend in home alone? Q7. Does your dog show any depression behavior when he/she is left in home alone?
How they walk their dog?	Q8. Where do you walk your dog and how much time do you spend per a week? Q9. Have you ever trained your dog to walk? Q10. What do you worry the most when walking the dog?
Is there any improvement points of the concept?	Q11. Would you use the Dog Walking Drone? Q12. What do you want to improve in this product?

Table 1. Interview questions of Dog Walking Drone concept

Procedure

The face-to-face interview were done at the participant's home. Rest of the interviews were done through the phone and voice recording. During the interview, the participants watched the short video of Dog Walking Drone concept before asking the question 11 & 12.

Data analysis

For the question 11~12, qualitative data was derived from the interview. The Affinity Diagram has been conducted to derive the data analysis.

5.3.2 Results

From Q1~10

- From the interview, most of the dogs they raised were small size. They also had various time range of dog walking, but generally they spend 10~40 minutes once or twice a week. The place they walk their dogs were usually near the apartment.

The biggest worries about the dog walking were their dog barking or biting someone because of fear. Since some dogs are unsociable, they feared such situation the most.

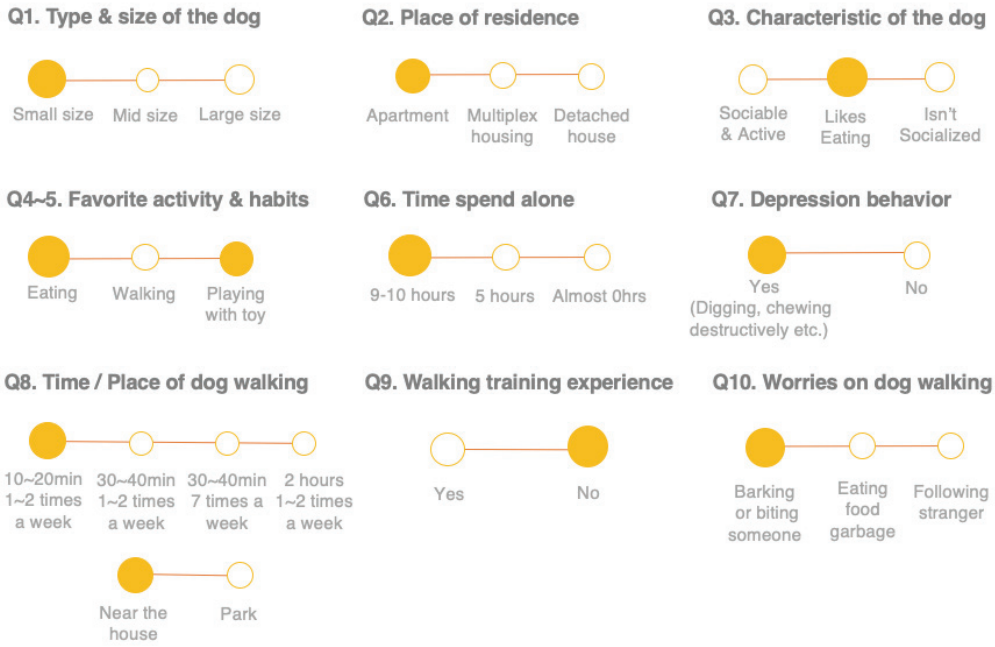


Figure32. Result of Q1~11

From Q11&12 (regarding the Dog Walking Drone concept)

- The biggest part was psychological issues & social factors. The psychological issue means how the dog feel and react about the drone. The dog must be get used to walking with the drone and should be in a comfortable pace while walking with the drone. The subtle interaction such as change in pulling power of the leash could be the physical language when walking the dog.

Another issue was social factors, which they worry the most. There are a lot of dog haters, who have trauma of got bit by the dog. If they walk without control of the owner, it needs to have enough control to stop the dog from frightening other people. Also, the drone needs to have enough power to control the dog with enough thrust for emergency control.

Figure33. Affinity diagram from the interview (Q11&12)

Summary

- Since the drone can be used for park or sidewalks where other people walk by, such context needs to be taken into consideration. As the interviewee concerned, the drone needs to control the dog in case of emergency. It needs to have enough power to restrain the dog from running, barking or frightening other people. The power of the drone needs to considered to have required specification of the drone. Also, for the further refinement, various tests and studies need to be done to analyze the psychological issues of the dogs. Especially, whether the dog follows the drone well or if they feel stressed or not could be important issues for the further study.

There were also worries about potty-problem, since the owner needs to clean after the dog. For the potty-problem, tracking the dog's path and checking its time are needed. Using GPS sensor, user needs to know where the dog walked by to clean up after the dogs by their own smartphone.

5.4 Develop

In this chapter, Rescue Drone and Dog Walking Drone were chosen to be developed into 3D modeling.

A. Rescue Drone

Develop 1

In this process, it has propeller meshes & guides for safety of rescuers and patients. It also has an emergency light on the edge of each propeller (Figure34).

The stretcher carries patient stably by fastening the belt, which is located on the patient's chest and leg. It has short leg under the stretcher, which supports the stretcher when it is on the ground.

Figure34. Rescue Drone modeling process1

Develop 2

Considering the lifting power of each propeller, the propeller size should be enlarged to 45~50cm (Techholic, Oct 6, 2019). Thus, this drone has a narrow 2500mm in width, lifting total 80kg during the flight.

Furthermore, considering folding process into the ambulance, the stretcher has a space for the folded propellers on the middle of its body, so that the propellers supports the stretcher inside of the ambulance. In this folding process, it also has foldable legs.

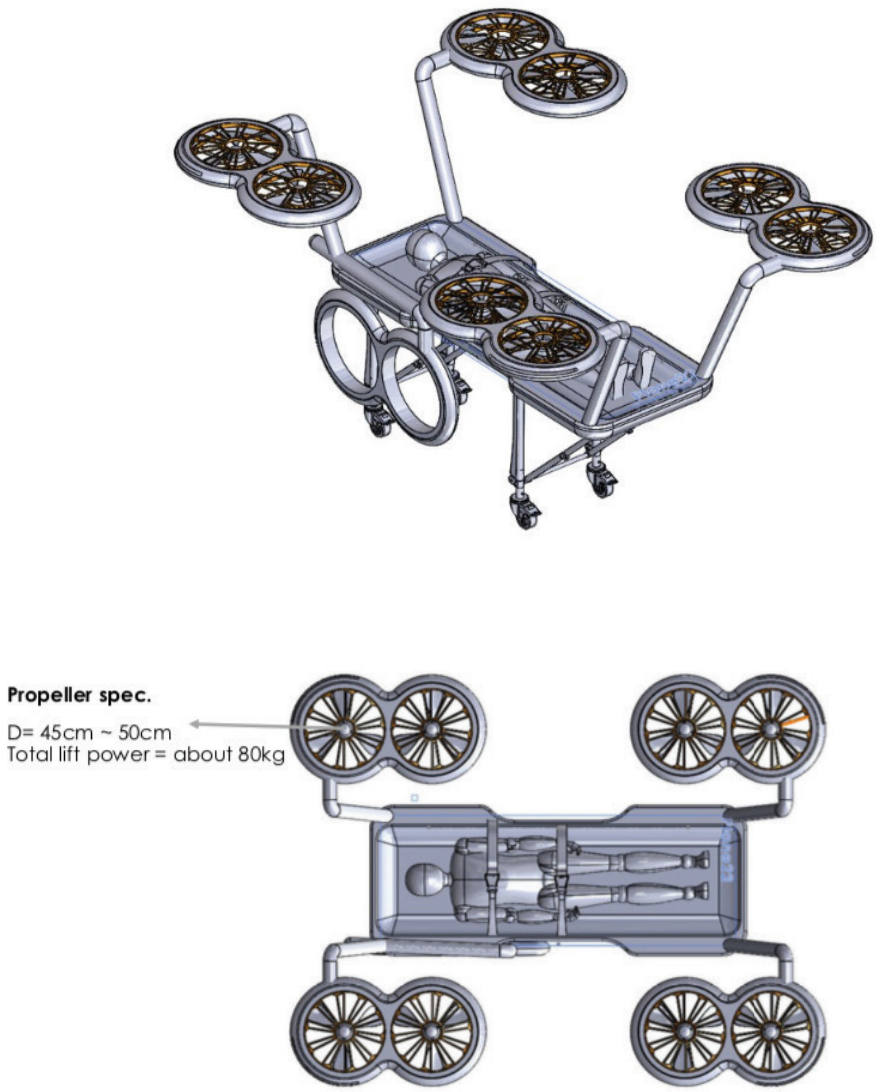


Figure35. Rescue Drone modeling process 2

Develop 3

To increase the efficiency of rescue and prevent crushes in the mountain, the propellers have been minimized in the width and length (Figure36). The propellers are placed at the bottom, overlapping with the stretcher to minimize total width as efficient as possible. Through this, the width has been reduced by 45% than Develop2. To increase its safety, propeller mesh is designed to the dome shape. This structure distributes the external force, helping to withstand the pressures without breaking. It also makes gap between the propeller and external elements, which prevents accident by rotating propeller. Also, mesh spacing became narrower than Develop2, to lower the risk of accidents with the propeller.

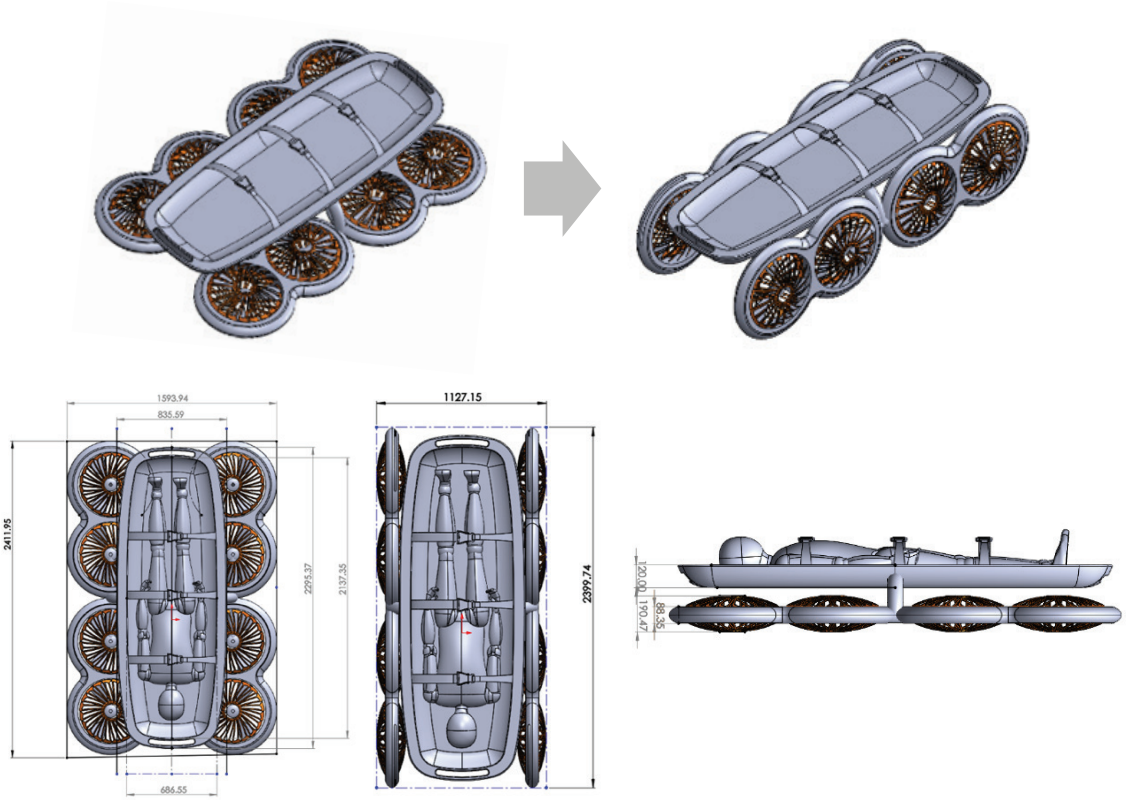


Figure36. Rescue Drone modeling process 3

Battery Pack

Figure37. Rescue Drone - Battery Pack

The Battery Pack is a backpack type of battery with 4 lithium battery cells inside. By wearing it, rescuer does not need to control the direction of the drone. Guided through wire, this structure helps the rescuer to concentrate on the rescue. Also, by replacing the lithium battery cells, rescuer can extend the flight time unlimitedly.

Stretcher

Figure38. Rescue Drone – stretcher

It prevents the secondary accident with stable and safe movement on the mountainous areas. Furthermore, the stretcher only requires gyroscope sensor since it does not need other components for obstacle avoidance or direction control. Thus, it could be produced in more simple structure with the reduced cost in the market. With 50cm diameter the of 8 propellers, the stretcher holds a patient weighting 80kg. The 8 propellers are comprised of 4 pairs of twin propellers for the narrower width. It helps transporting patient to be efficient keeping the golden time for the narrow or forested paths. It has a compact and foldable structure to be transported on the ambulance. The propellers rotate 90 degrees counterclockwise around the bar on the middle. It becomes compact size to be carried with the patient.

Renderings

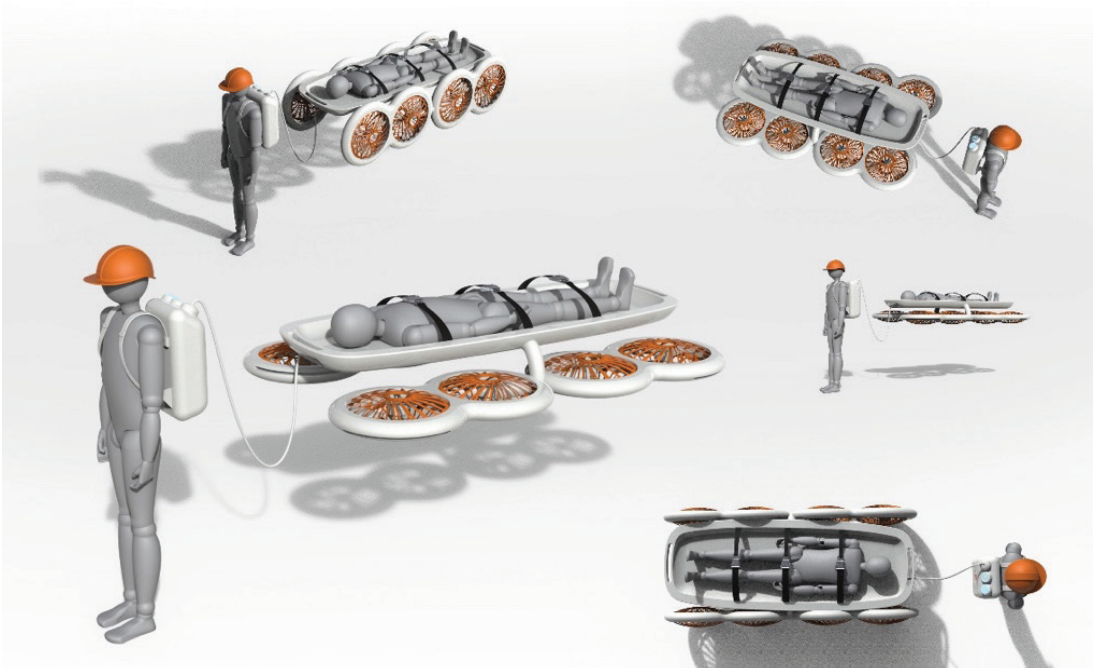


Figure39. Rescue Drone Final Renderings

B. Dog Walking Drone

Develop 1

The Battery Pack has a flexible form to fit on the dog (Figure 40). Also, users can choose the size of battery packs – large, medium and small, suitable for their dogs. The power button at the center of the battery, indicates how much battery is left. During the walk, if the power button turns red, user need to replace the battery for an extra time to walk.

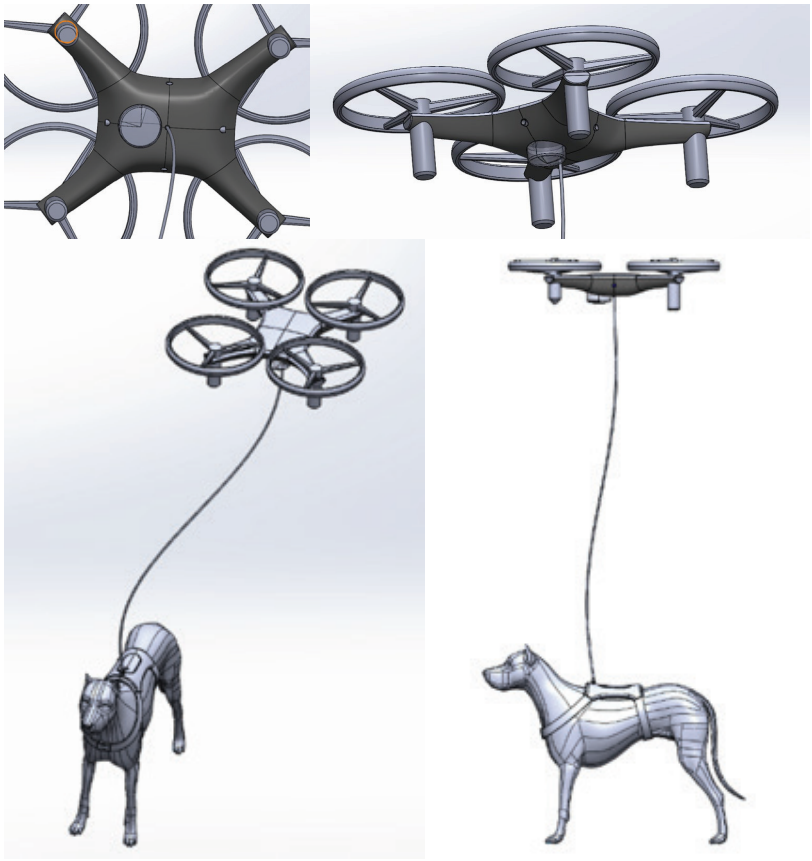


Figure40. Dog Walking Drone modeling process 1

The drone detects obstacles using sensors on the front, rear, left and right of the drone. The wire is connected to the dog's battery pack through a hole at the bottom of the drone (Figure 40). In case of the dog to turn around, a wire is 360 degrees freely rotatable. Referring to the rotatable charging jack in the market, the leash was designed to remain untwisted. According to the research, dog has very sensitive hearing than human (Lipman, E., & Grassi, J.,1942). Thus, it uses a low-noise propellers and duct to minimize the noise. The drone also keeps the flight height of 1.5~2m while walking to keep about 45dB of daily life noise.

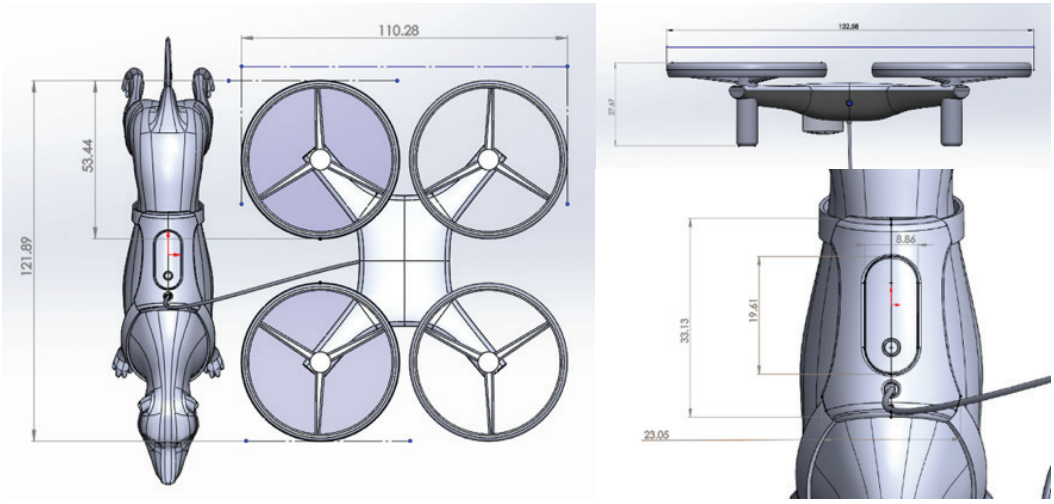


Figure41. Dog Walking Drone modeling process 2

Develop 2

Form & Shapes

This developed design is refined version through the 5.3 Testing & Refinement session. From the question 12, one interviewee answered that the emotion of the drone can look threatening to other people. Reflecting the feedback, the emotion of the form and shapes has been changed to give less aggressive feelings as inspiration image shows below (Figure 42).

Also, according to the data, the targets had small size of the dog mostly. Thus, the size of the propeller has been changed into the smaller ones which has enough power to restrain while walking their dog. The size of the propeller has an enough thrust to control the small sized dog such as Chihuahua or Maltese weighting less than 8kg.

Figure42. Dog Walking Drone inspiration image

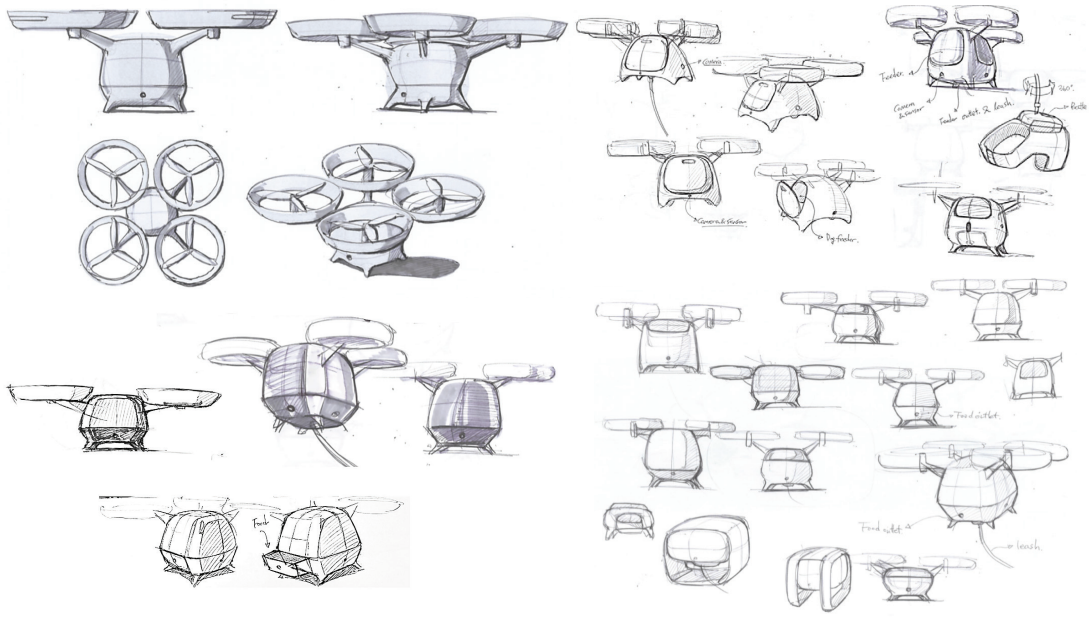


Figure43. Dog Walking Drone develop sketch

Propeller sizes

Since the drone has been designed to lead small dogs weighting below 8kg, it needs to have enough power to lead the dog for walking. Referring to the motor and propeller specifications of 5048S Tri Blade propeller of DJI SNAIL (SNAIL Racing propulsion system, June 15, 2020), total 8 propellers of 14cm diameter were used. Each of its propeller has maximum 1.32kg of maximum thrust, thus the total thrust is 10.56kg (Figure44).

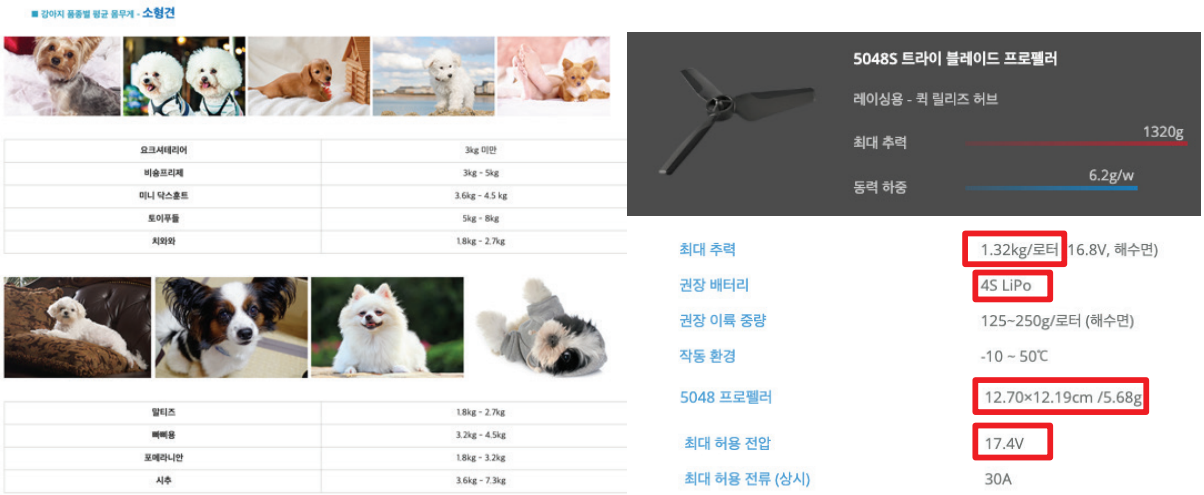


Figure44. Types of the small size dog(left), Propeller & Motor specification of DJI SNAIL(right)

Stability of landing

This is the various versions of the (Figure45). From the modeling of sketches above, the ‘landing gear’ part was too short for landing safely. To keep it stable, the point that legs are attached should be on the upper side of the body. To find the most harmonized shape with the body, various forms of the leg sketches have been done.

Figure45. Dog Walking Drone modeling process 3 & develop sketch

Below is the modeling that has been developed through the form sketches (Figure 46). The layer that links the propeller with the main body covers upper part, and it stands the main body stably. It also feels mono-body shape by giving unity in terms of the form.

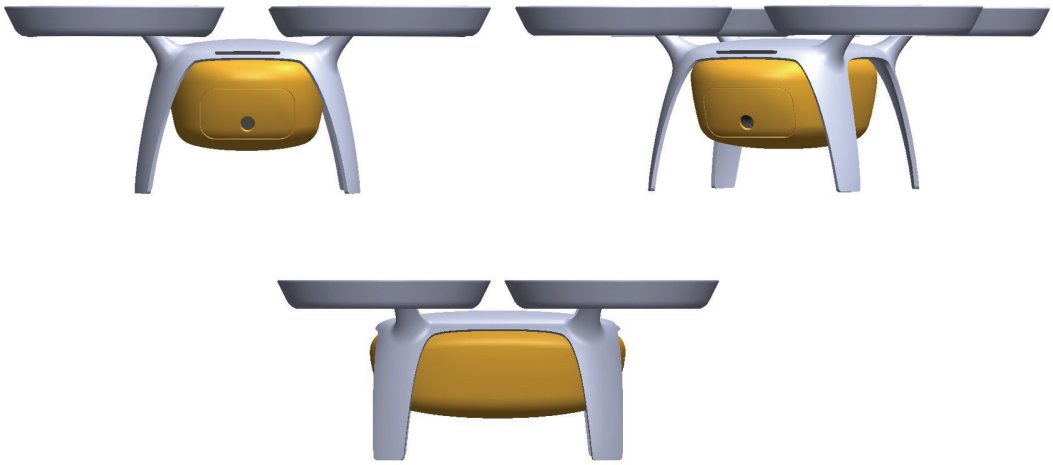


Figure46. Dog Walking Drone modeling process 4

Function & Structure

From the long shaped main body, the final model has been modified into square shaped one (Figure47). By changing its form, it is freer to move through any directions. Also, its leg shape has been modified connecting two legs on each side and it stands more stable for landing.

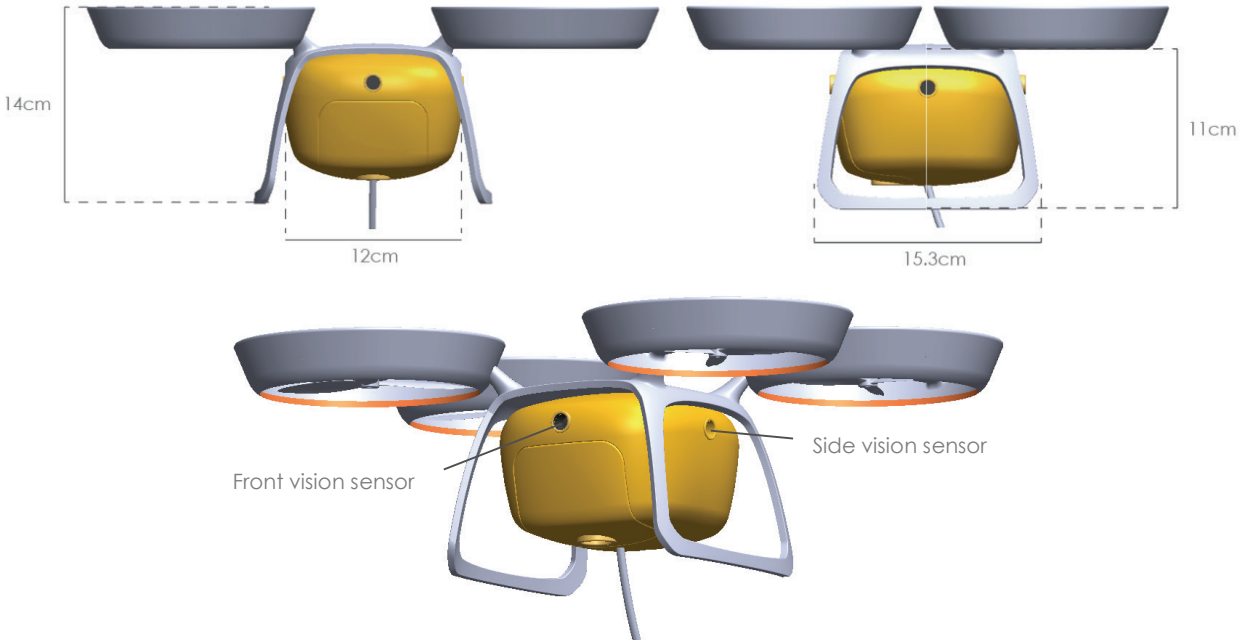


Figure47. Dog Walking Drone modeling process 5.1

On the main body, vision sensors are located to avoid obstacles such as trees or people during automatic flight (Figure48). It is also equipped with GPS and camera to sense the exact location of the drone. Also, on the center of the body, it has food dispenser and the food outlet on the bottom which can be used for training the dog.

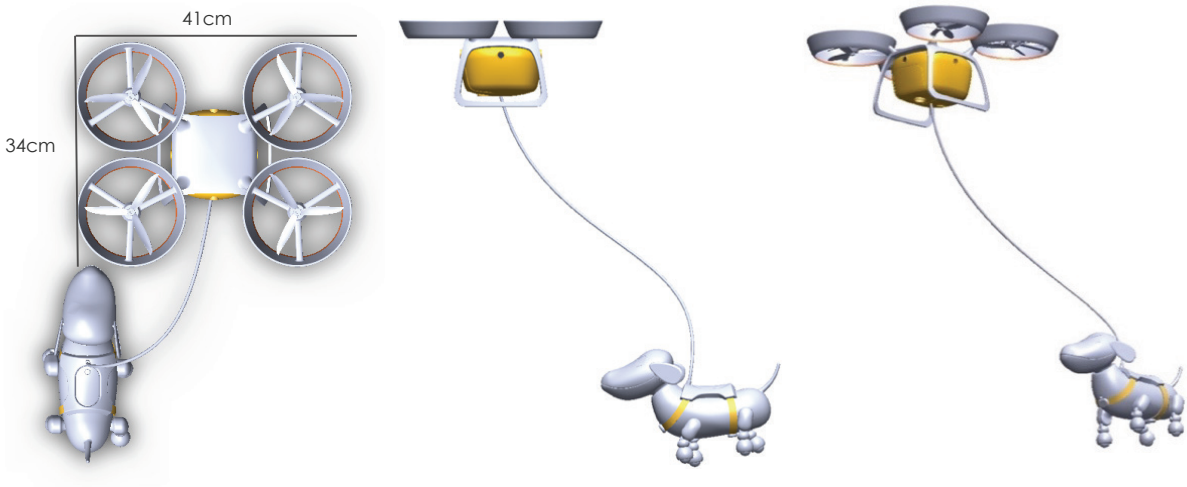


Figure48. Dog Walking Drone modeling process 5.2

How does a user control the drone?

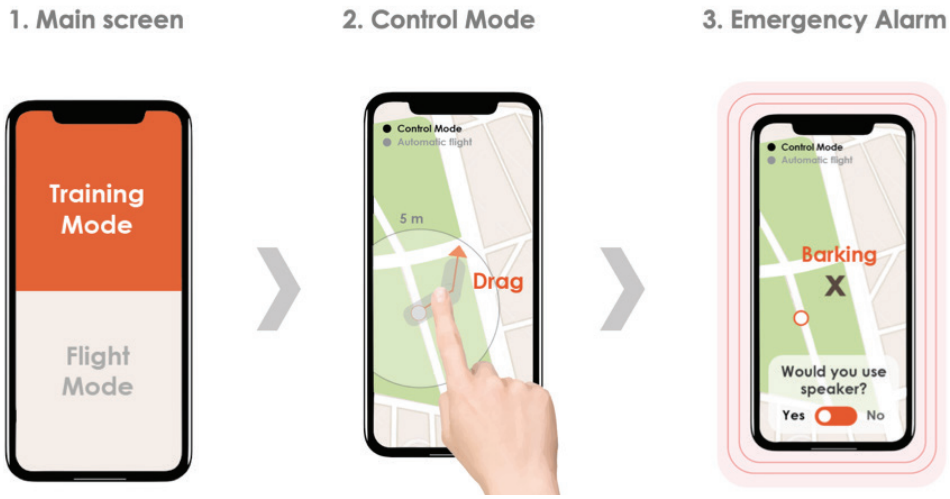


Figure49. Dog Walking Drone App example screens

Using the App, user can control the direction of the flight and can also choose an autonomous mode. Through the GPS, user can control the drone and send the location to the user. The App provides two modes for the drone, Training mode and Flight mode.

The Training Mode guides the dog who needs to be trained to walk along with the drone. When dog walks in the opposite direction, it pulls the leash or drops the snack from the food dispenser. Using snack can be also used for the meaning of a reward (PetExpertise, November 09, 2016), which is effective training method for dog walking (Dreater, November 09, 2019).

The Flight mode provides two main functions – direct control of the drone and autonomous flight. By dragging the path on the screen, it gives direction or saves the information for the autonomous flight within 4~5m. Also, the App control allows control of the drone or dog with such functions for such circumstances:

- *User can control the drone by dragging on the App screen. The built-in GPS receives the route as the user input.*
- *The drone moves within 4~5 meters around the user and it stops when it crosses the boundary and notifies to the user that it is fixing the route.*
- *When the dog urinating or smelling while walking, it detects its movement of the harness and waits for the dog to some extent, by pausing for a while.*
- *If the dog does not follow the drone, user can check through the camera whether there are people or vehicles moving around the dog. It also could restrain the dog by increasing its thrust power or through verbal restraint through the speaker.*
- *With the GPS sensor, it is possible to detect the current location of the dog, so when it crosses the road or barks at the other person or dogs, the sensor detects the sound and gives an alarm to the user. The user who gets the alarm can speak verbal restraint such as 'stop' or 'stay' through the speaker or depending on the situation, user can go directly and physically restrain the dog.*
- *The user can easily find location to clean after the dog by tracking the path the dog walked by using the App.*

6

Final Output

6.1 3D Data

6.2 Prototype

This chapter describes final output of the Dog Walking Drone concept with final modeling and explanation of their main features.

6.1 3D Data

B. Dog Walking Drone

Use Scenes

The Dog Walking Drone can be used for the owners who need leisure, relax at the park.

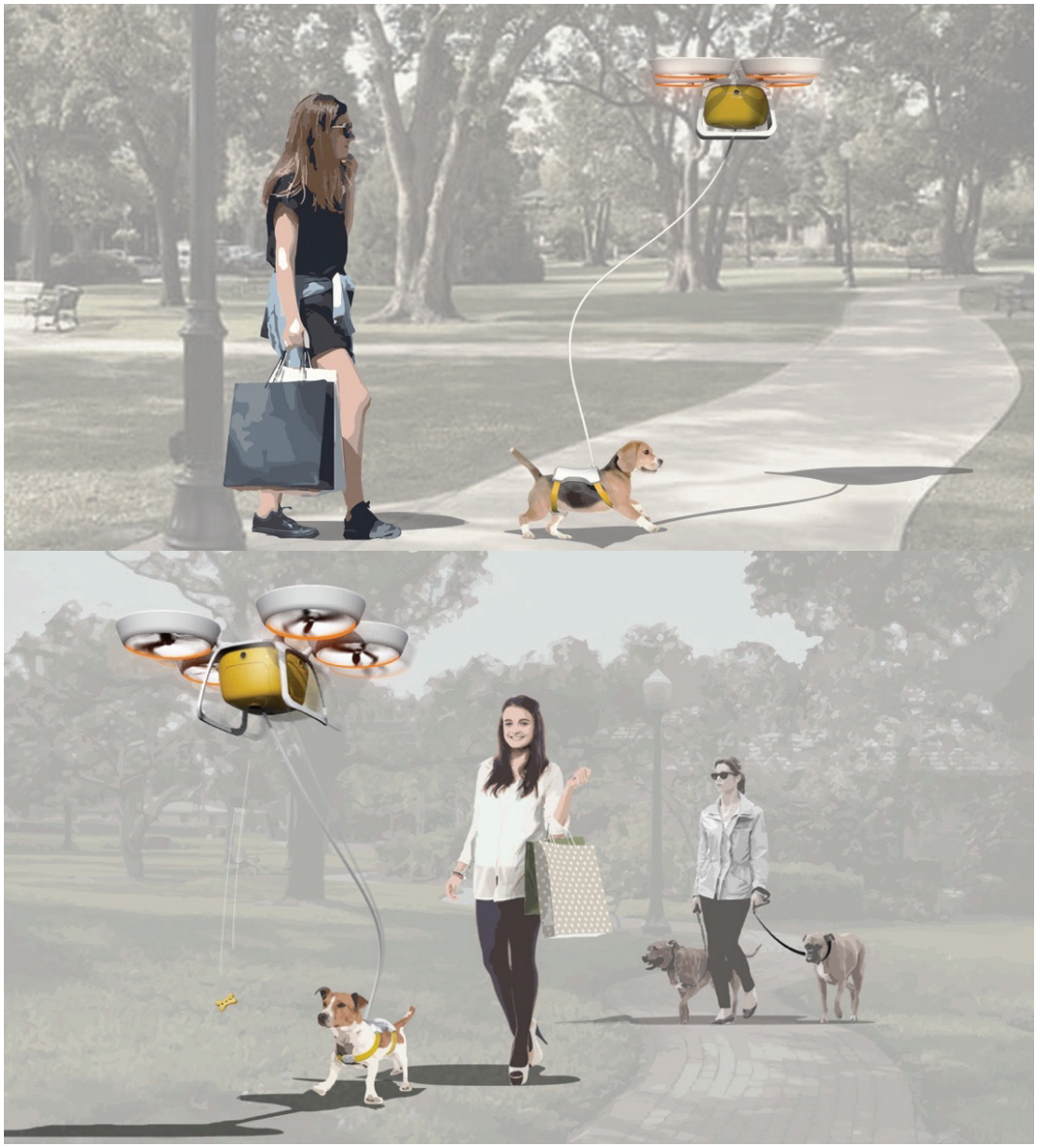


Figure50. Dog Walking Drone poster & use scenes

Main features

Dog Walking Drone is a guiding & training drone for the dog walking. For the busy workers who needs time to afford for their dog, it provides useful functions such as autonomous flight and leash training. This drone is comprised of two parts - drone and a dog harness part.

1) Dog harness

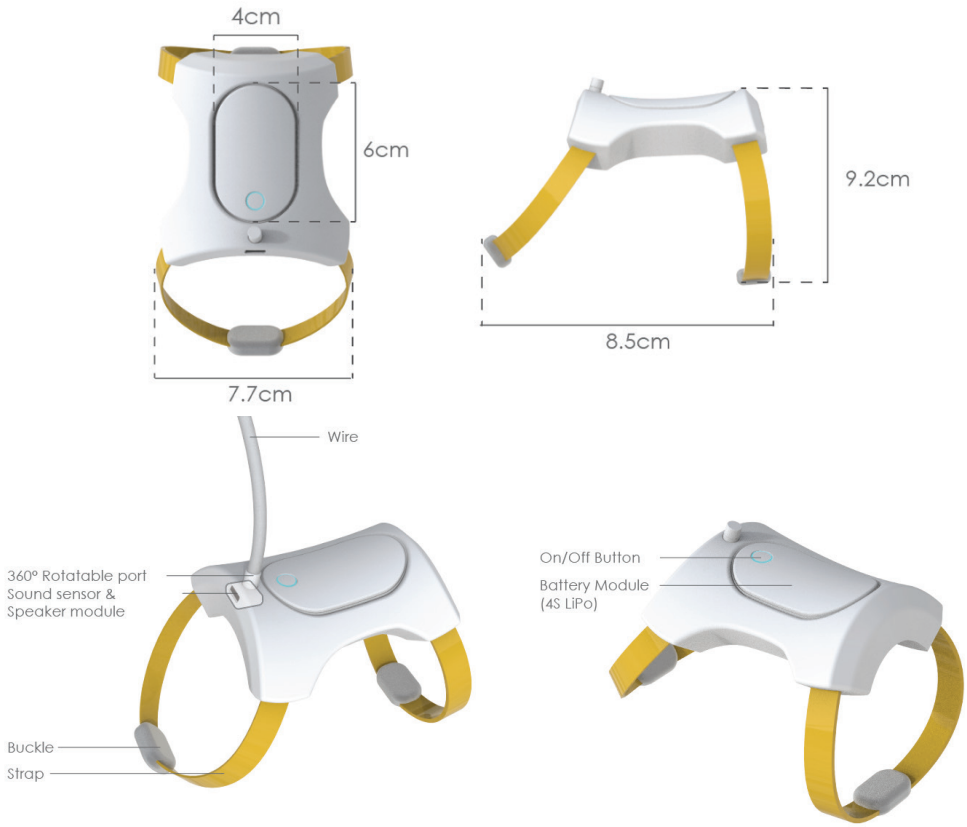


Figure51. Dog Walking Drone (Dog harness annotation & size)

Dog harness has a battery cell, which is wired with a drone to supply power. Since this structure reduces weight of the drone, it brings efficient flight of the drone. User can also expand the flight time unlimitedly by replacing battery cell. The Dog harness is composed of battery cell, wire, adjustable strap & buckle, speaker and a sound sensor.

Using the strap and buckle, user can adjust the strap to fit on the dog. User also can be notified of emergency by App through a sound sensor. It senses dog barking and sends vibration alarm to the user. Using the speaker on the harness, user can also order the dog to stop barking.

2) Drone

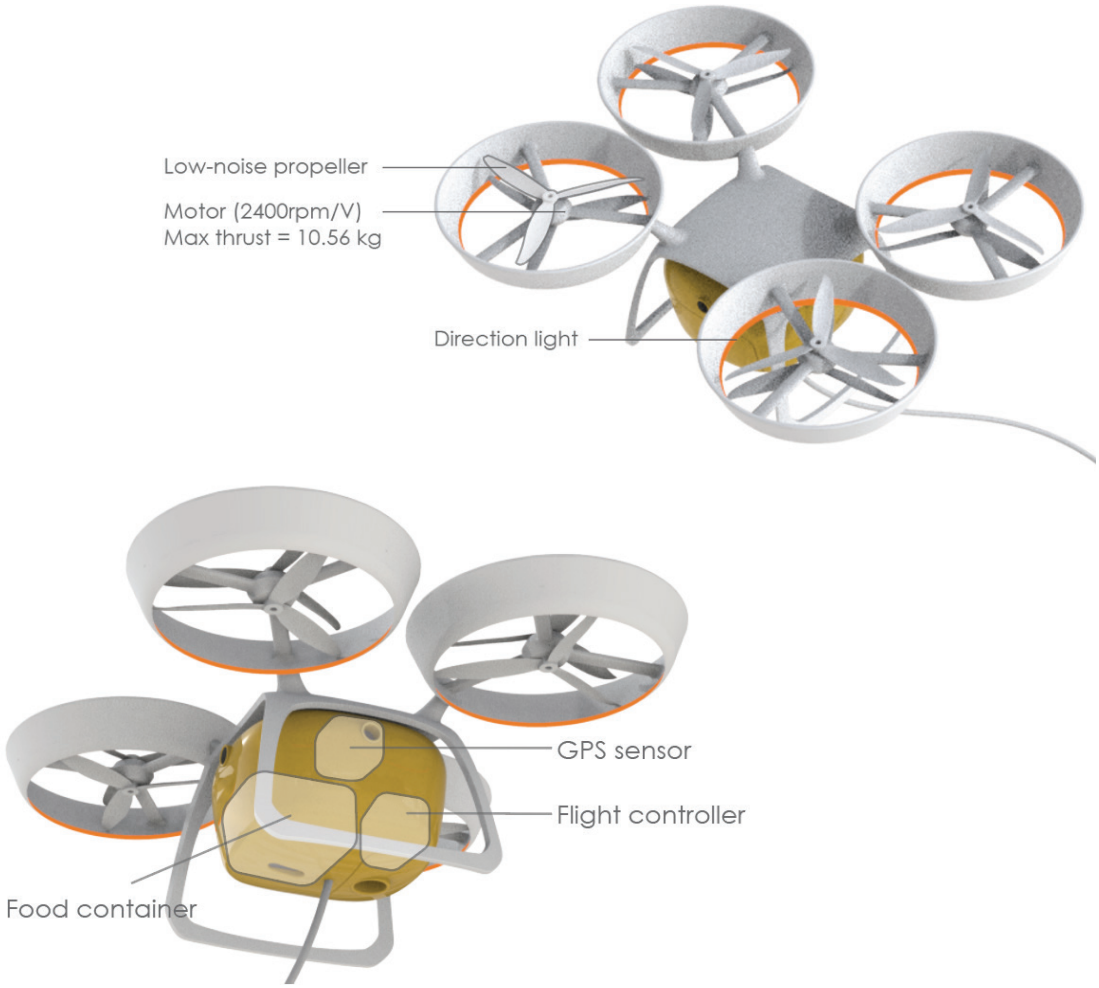


Figure52. Dog Walking Drone with annotation & specification

The drone is supplied of electricity from the dog harness by wire. It also guides the dog by pulling through wire or dropping snack from the food dispenser. This drone can fly only within 4~5m within the user's visibility. This range helps user to keep close with the dog and easy to restrain the dog.

The drone also keeps the flight height of 1.5~2m while walking. Also, the 8 low-noise propellers and noise reducing propeller ducts helps to decrease the noise of the drone up to 45 dB. The motors and propellers have maximum thrust 12.5kg, which is enough to sustain dog walking from and lead the small dogs weighting maximum 8kg.

Design posters

Below are the design posters which contain main image, problem, solution and how to use.

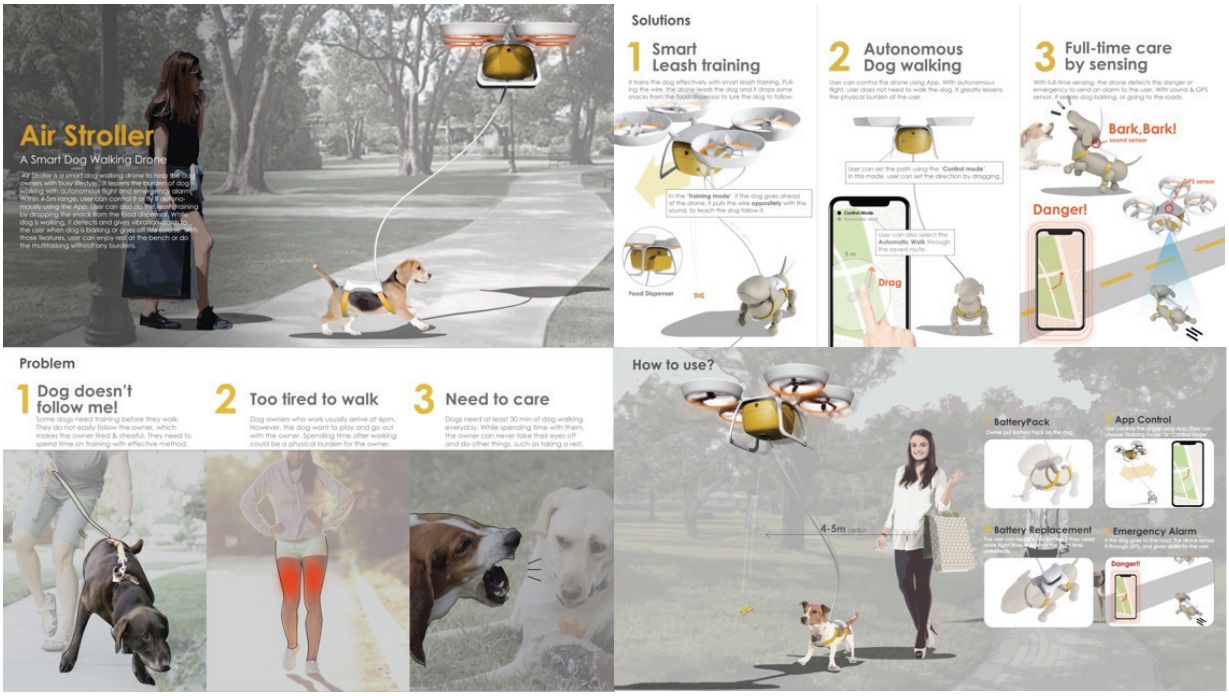


Figure53. Design posters

Prototype

The prototype was made in 3:1 scale with 3D printing. To display its wired structure, it has been made to be floated in the acrylic box.

Figure54. Dog Walking Drone prototype (3:1 size)

7

Discussion & Conclusion

7.1 Discussion

7.2 Conclusion

7.1 Discussion

In this chapter, it summarizes various applications of a Wired battery structure and discussions on the concepts.

7.1.1 Impact of Design

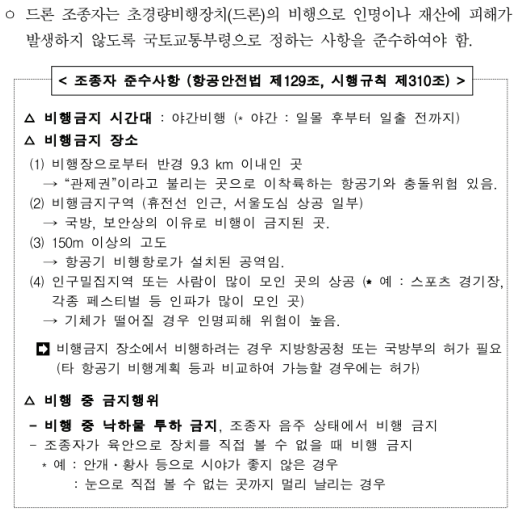
The Wired battery structure provides new use contexts which requires sufficient supply of battery power especially. It suggested 3 different Rescue Drone, Delivery Drone and Dog Walking Drone, which can inspire other usages. Easy to sustain the long-term flight with heavy loads, it is open to the variety of applications from the heavy furniture transportation to the daily route guidance for the visually impaired person.

7.1.2 Opportunity Seeking Approach

Its applications create new opportunities which is close to our daily life with differentiated benefits from the existing market with industrial usage. The Wired battery structure can be applied in various contexts as proposed in the context tree. By reducing the weight of the battery, the flight efficiency is increased, and replacement of the battery cell can extend the flight time unlimitedly. Thus, it is useful for both of long-time flight and heavy load transportation.

The applications of Wired battery structure can be divided into two main categories. Transporting human for the rescue purpose or rehabilitation treatment and transporting objects for the delivery or human assistance purposes - such as heavy furniture delivery or guiding visually impaired person in the city.

7.1.3 Limitation



○ 드론 조종자는 초경량비행장치(드론)의 비행으로 인명이나 재산에 피해가 발생하지 않도록 국토교통부령으로 정하는 사항을 준수하여야 함.

< 조종자 준수사항 (항공안전법 제129조, 시행규칙 제310조) >

△ **비행금지 시간대** : 야간비행 (* 야간 : 일몰 후부터 일출 전까지)

△ **비행금지 장소**

(1) 비행장으로부터 반경 9.3 km 이내인 곳
→ "관제권"이라고 불리는 곳으로 이착륙하는 항공기와 충돌위험 있음.

(2) 비행금지구역 (휴전선 인근, 서울도심 상공 일부)
→ 국방, 보안상의 이유로 비행이 금지된 곳.

(3) 150m 이상의 고도
→ 항공기 비행항로가 설치된 공역임.

(4) 인구밀집지역 또는 사람이 많이 모인 곳의 상공 (* 예 : 스포츠 경기장, 각종 페스티벌 등 인파가 많이 모인 곳)
→ 기체가 떨어질 경우 인명피해 위험이 높음.

비행금지 장소에서 비행하려는 경우 지방항공청 또는 국방부의 허가 필요
(타 항공기 비행계획 등과 비교하여 가능할 경우에는 허가)

△ **비행 중 금지행위**

- **비행 중 낙하물 투하 금지**, 조종자 음주 상태에서 비행 금지
- 조종자가 육안으로 장치를 직접 볼 수 없을 때 비행 금지
  * 예 : 안개·황사 등으로 시야가 좋지 않은 경우
  : 눈으로 직접 볼 수 없는 곳까지 멀리 날리는 경우

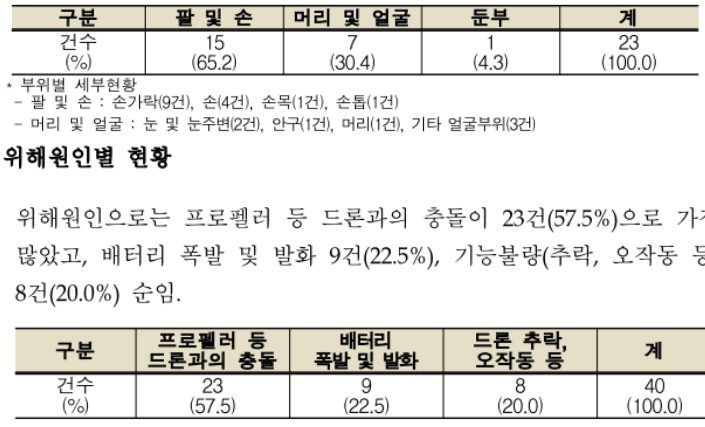
Figure55. Aviation law (Korea)

Regulations

Drones are still controversial regarding safety regulations. The aviation law prohibits the flight of the drone after sunset because it is dangerous without visibility. Thus, controlling Dog Walking Drone at night can be restricted for such safety issue.

In terms of place, flight within 9.3km range around airport or the Military Demarcation Line is also prohibited. Also, the place with large transient population, such as sports stadium or festival is a restricted for flight, since the drop of drones could make a big accident for the people. Thus, such contexts of use can be restricted for the assistance drones such as Dog Walking Drone or guidance drone for the visually impaired person.

Safety issues



구분	팔 및 손	머리 및 얼굴	둔부	계
건수 (%)	15 (65.2)	7 (30.4)	1 (4.3)	23 (100.0)

* 부위별 세부현황
- 팔 및 손 : 손가락(9건), 손(4건), 손목(1건), 손톱(1건)
- 머리 및 얼굴 : 눈 및 눈주변(2건), 안구(1건), 머리(1건), 기타 얼굴부위(3건)

□ **위해원인별 현황**

○ 위해원인으로는 프로펠러 등 드론과의 충돌이 23건(57.5%)으로 가장 많았고, 배터리 폭발 및 발화 9건(22.5%), 기능불량(추락, 오작동 등) 8건(20.0%) 순임.

구분	프로펠러 등 드론과의 충돌	배터리 폭발 및 발화	드론 추락, 오작동 등	계
건수 (%)	23 (57.5)	9 (22.5)	8 (20.0)	40 (100.0)

Figure56. Korea Consumer Agency safety condition research (2017.6)

There is an issue of a collision or drop of the drones. Recently, there have been several accidents of the heavy drone which dropped during its flight. The wired battery drone is relatively safer than existing drone since it flies within the restricted altitude. However, the collision of the Rescue Drone with surroundings such as rocks or trees could bring fatal injury to the patient.

The propeller is also another important issue. According to the Korea Consumer Agency (Figure56), 57.5% of drone accident is caused by collision with drone and its propellers. Mostly, the injury was on arms or hands by 65.2%, and face or head was 30.4%.

Thus, it is more important to keep safety with large sized propellers, since they rotate faster and are made of harder materials than the smaller ones. Further study of propeller guards or mesh structures that properly protects the propeller from collision will be needed to reduce this risk.

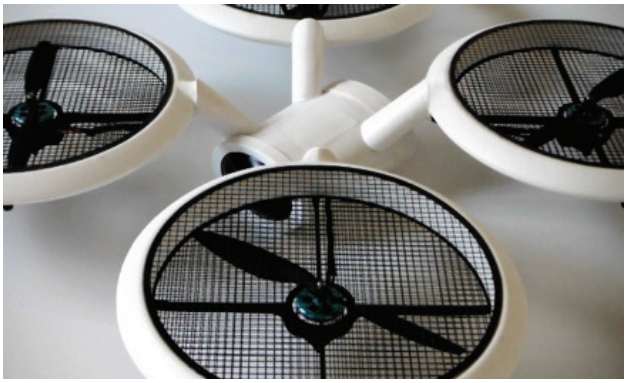


Figure57. Propeller mesh and guard example

Technical issues

The noise problem is also a technical area to be solved. Existing drones make about 75- 80dB (Dronethusiast, Oct 7, 2019) of noise, which is very unpleasant to users. Especially, since the Rescue Drone uses a large sized propeller of about 50cm of diameter, its noise is expected to be very large enough to be harmful for both of patient or the rescuer.

In addition, for the Dog Walking Drone, the propeller noise could be harmful for the dogs since they have 16 times sensitive hearing ability than human.

Even considering the effects of the low-noise propellers and noise reducing ducts which are currently available on the market, it is still one of the main issue that must be solved.

Manufacturing

For the Dog Walking Drone, the obstacle detection sensor is important. Especially, since it is expected to be used in a park or trail where people walk by, avoiding collision with walking human is very important. However, current obstacle sensors cost a lot and containing such components will highly increase the price. The estimated price of the drone will be at least $2000 (estimated price refer to the Mavic Pro 2). Then, the target needs to be changed to be suitable for the high-end.

In developing software, there are various situation to consider. It requires software side testing and development to control the unpredictable dog behavior such as biting up the leash or staying still and not following the drone etc., and prepare for various situations of emergency.

7.2 Conclusion

7.2.1 Project Summary

First, from the market research, it could identify how current battery issue limits the applications of drones. Especially focusing on the drone with the loads, various fields such as agriculture, photography & inspection, light and heavy weight delivery drones were researched and analyzed in terms of their limited usage by flight time limitation and weight capacity.

Second, by comparing 5 types of current battery solutions, the benefits and practicality of the Wired Battery structure compared to other types of battery solutions – such as inductive charging station or hydrogen fuel cells were identified.

Third, using Wired Battery structure the context tree was derived. They were classified by what they transport, which purpose they are used for etc. There were several ideas of applications such as furniture delivery, rehabilitation treatment or guidance for visually impaired person, which could be used closer into our real life contexts.

Fourth, among them, three main contexts were selected – which is rescue in mountainous areas, walking the dog, delivery service and their design requirements were described.

Fifth, the ideation & development was processed, suggesting use scenarios including the interview result from the real dog owners for the further development. help the user's work or to load objects, and by defining an identity and a use scenario, finally, it was possible to specify the details of each inside through development.

7.2.2 Expected Contribution

Social aspect

By extending the applications of the drones with Wired battery structure, it is possible to increase the usability of drones that were previously limited to industrial fields such as reconnaissance, agriculture, and photography. In addition, since the drone can move faster than the existing ground-based transportation methods such as motorcycle or truck, it greatly improves the transportation efficiency especially for the mountainous, forested or flooded areas.

Also, the Wired battery structure does not require any complicated direction control, as seen on the Rescue drone and delivery drone. Thus, user can more focus on their tasks than using the controller, and it increases the efficiency of their work performance.

Furthermore, with its unlimited flight time, drone can assist and perform various tasks to lessen the physical burden of the users. For instance, the drone for visually impaired person can visually guide them or also could help them by carrying heavy loads such as shopping bags with its sufficient battery life. The Dog Walking Drone also reduces the physical burden of walking and caring the dogs, it brings healthy lifestyle for both of dog and the owner. The dog walking plays an important role of physical and the mental health of dog and the owner (Rebecca A.J, Alan M.B & Sandra M, 2011). This would be greatly helpful for both of dog and busy owner by increasing the activity time spending together with less effort and energy. Also, there will be an economical benefit from the user's point of view as there is no need to separately call the dog walking assistant.

7.2.3 Future works

Improvement

Currently, drones still have many controversial issues in technological aspects. Although battery problem was one of the main issue for its function, but still the noise and safety issues are also important for its commercialization in a daily use. Especially, for both of Rescue Drone and the Dog Walking Drone, its decibel level shouldn’t be stressful for the user or dogs. The hearing sensitivity of the dog and their stress level should be measured through the tests for the further study.

Various tests are needed to verify whether the drone can walk with the dogs. From the user study, there are still various views on walking the dog with a drone. Some interviewee answered that it feels like a means to abuse their dogs. They were skeptical for the machine taking role of the owner instead of the human, and they were also not sure whether the dog would follow the drone since it lacks interaction that owner and dog can give each other. To provide objective view on this issue, various verification process is needed by testing with diversity of dog characteristics – playful, sociable, shy, bold etc.

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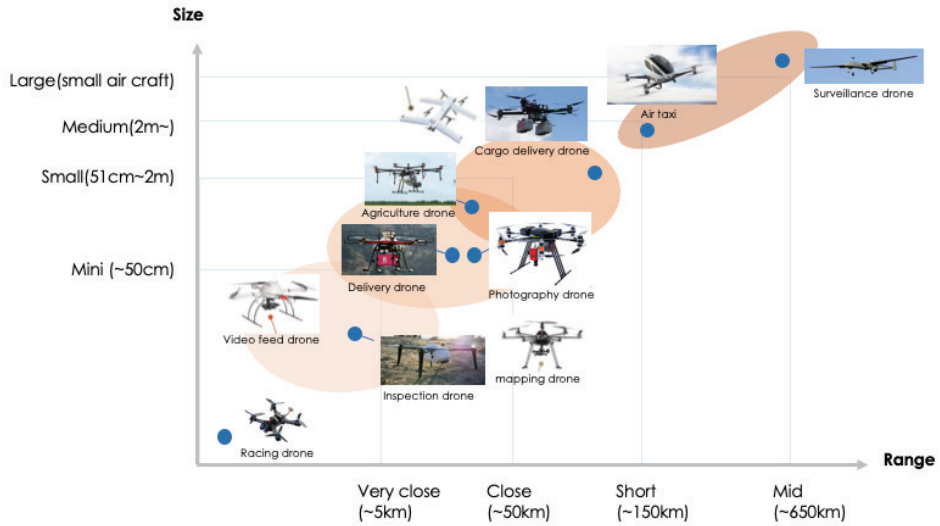
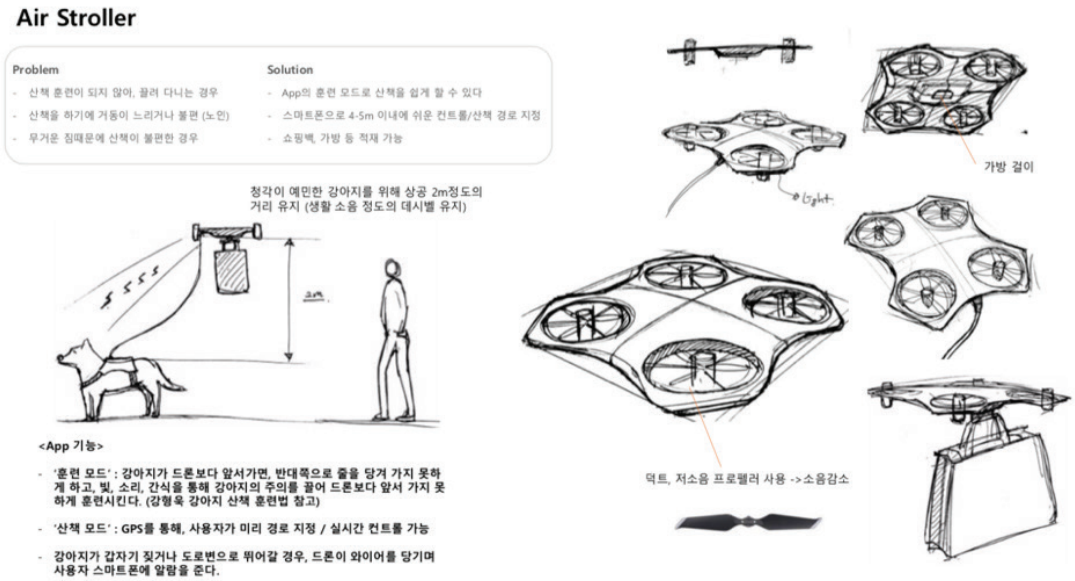
Appendices

Appendix 1. Usage of drones by drone size, flight range

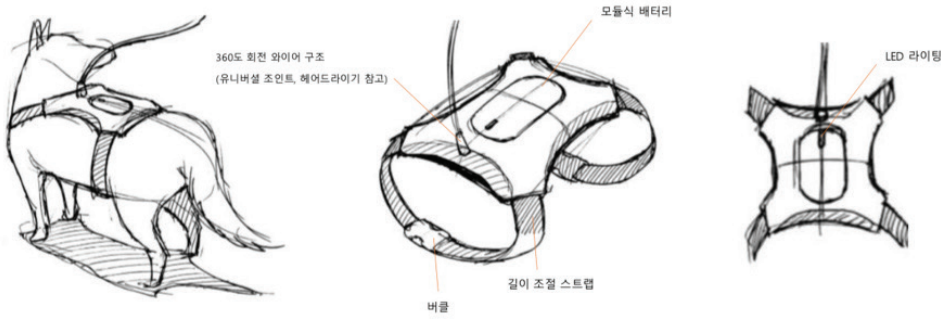


Appendix 2. Ideation sketches



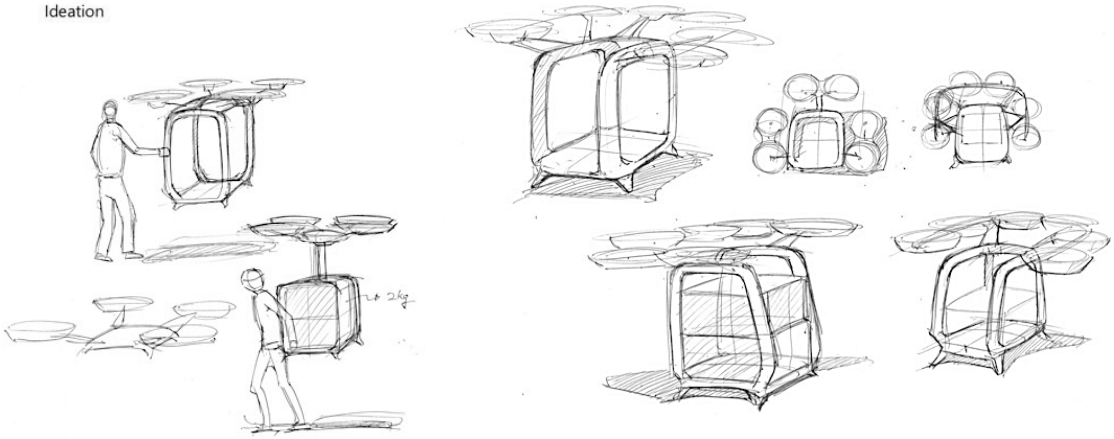
Air Stroller

- 강아지 등에 부착된 모듈식 배터리로, 드론에 무거운 짐 싣고도 1시간 비행 가능
- 강아지가 자유롭게 이동해도 꼬이지 않는 360도 회전 와이어 사용



Type A. 택배배송 돕는 드론

Ideation



Type A. 택배배송 돕는 드론

<Problem>

- 하루에 한 집배원이 100가구 정도 택배 배송
- 승강기가 있는 아파트라고 하더라도, 각 층마다 승강기 기다릴 시간이 없어, 계단으로 직접 내려오면서 배달
- 빌라나 주택의 경우, 승강기가 설치되어 있지 않은 경우 많음

<Solution>

- 평지에서 카트로 사용하다가, 필요시 계단으로 배송할 수 있는 드론 & 카트 모듈

<Design requirement >

- 부피가 큰 물건을 싣을 수 있어야 하며, 물건 고정시켜야 함
- 계단 이용시, 배터리팩의 무게가 너무 무겁지 않아야 함

Type B. 가구운반

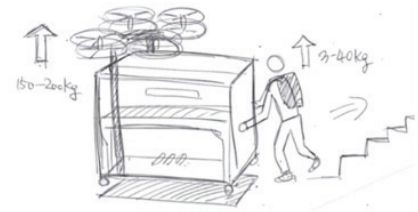
<Problem>

- 리프트 없이, 피아노 같은 무거운 가구를 운반해야 하는 경우
- 폭이 좁은 계단을 올라야 하는 경우 (많은 인력 필요)

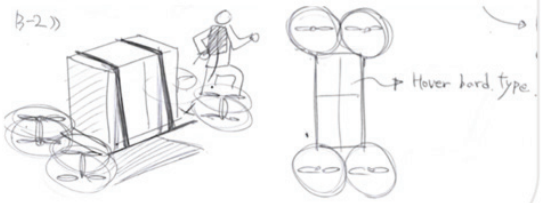
<Solution>

<Design requirement >
- 폭이 너무 넓지 않아야 함 (계단 혹은, 복도 폭 고려, 1~1.3m 이내)
- 드론 최소 적재용량 150-200kg 되어야 함 (일반 피아노 150kg 이내, 그랜드피아노 무게 최대 300kg) -> 엄청난 소음, 대형 프로펠러 사용될 것으로 예상

B-1) 한 쪽에서 사람을 대신해서 support 해주는 드론 (프로펠러 16개)



B-2) Hover board 형태로, 이동하기만 하면 따라 움직이는 컨셉 (프로펠러 16개)



Type C. 재활치료

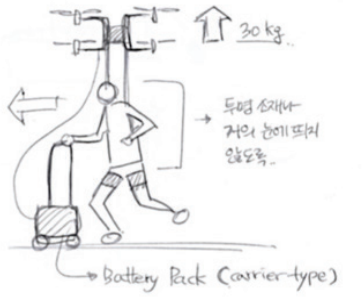
<Problem>

- 기존 보행치료 기기는 치료사의 도움 및 안내가 필요하고, 설치에 충분한 실내 공간이 필요해, 병원 내에서만 가능함

<Solution>

- 사람의 무게를 지탱해주는 보행치료 드론 (무릎에 가해지는 무게 최소화)
- 배터리팩은 배터리 가방의 형태보다는, 가볍게 끌고 다니는 캐리어 형태
- 재활치료를 돕는 AI정보 탑재

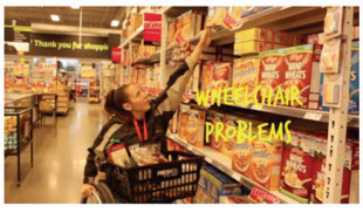
<Design requirement >
- 소음이 심하지 않아야 함
- 눈에 띄는 장비X, 최대한 자연스러운 모습 (환자라는 인식이 들지 않아야 함)
- 사람의 무게를 감당할 수 있는 적재중량 6-70kg 가까운 드론



Type D. 장애인 보조 드론

<Problem>

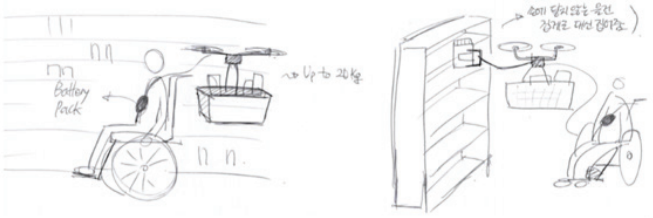
- 기존 휠체어 이용자는 양 손의 사용과 이동이 자유롭지 않아, 장바구니를 들고 쇼핑 및 이동하는데 어려움이 있음
- 먼 곳에 있는 버튼이나, 높은 곳의 물건을 잡기 어려움



<Solution>

- 장바구니를 들어주거나, 손을 대신하는 역할 (일종의 서포터)
- 손이 닿기 힘든 곳의 버튼을 대신 누르거나, 높은 곳에 있는 물건을 집을 수 있음
- 사용하지 않을 경우, 드론을 가방/패키지에 넣어서 보관

<Design requirement>
- 가능한 소형, 저소음 드론 (실내에서 사용)
- 집게 사용 간편해야 함

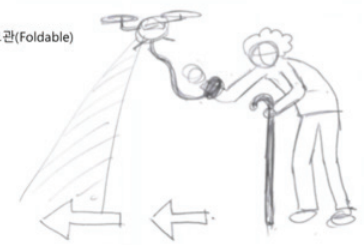


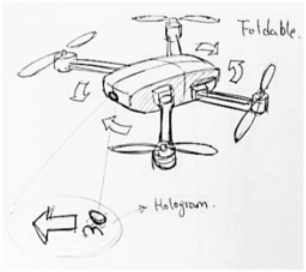
Type E. 노인용 보조 드론(mate)

<Problem>
- 기억력 문제로, 길을 잃기 쉬운 노인을 위한 보조장치 필요

<Solution>
- 길안내를 위한 AI 기능 탑재 & 라이팅
- 간단한 운반 역할 (개인가방, 물건 등 운반)
- 사용하지 않을 경우, 드론을 가방/패키지에 넣어서 보관(Foldable)

<Design requirement>
- 소형 드론
- GPS 탑재 -> 위치파악
- 안전장치 필요 (프로펠러 가드 등)





Type F. 마라톤 선수용 Face-maker

<Problem>
- 마라톤 훈련하는 선수의 경우, 훈련시 주기적인 체크 필요 (웨어러블)
- 훈련시 가방에 개인 물품 등을 보관

<Solution>
- 마라톤 훈련 보조역할 (칼로리, 심박수, 남은거리 등 체크) + 사진/영상 촬영
- 물, 수건, 핸드폰 등을 대신 들어주는 역할
- 암밴드(배터리팩)을 통해, 신체정보 감지

<Design requirement>
- 배터리팩 -> 간단한 암밴드/ 메신저백 타입
- 장시간 체공 가능해야 하며, 밤에도 사용 가능(라이팅)
- 안전장치 필요 (마라톤 대회)

Appendix 2. Questions for the interview

- Interview guide

- 인터뷰 시간은 20~30분 정도 소요됩니다.
- 전화 또는 화상채팅을 통해 직접 질문하는 방식으로 진행되며, 항목에 맞게 편하게 말씀해주시면 됩니다.

- Interview questions

A. 어떤 강아지를 키우시나요? (강아지 크기/종류, 성격, 좋아하는 행동)
B. 강아지를 어떠한 환경에서 어떻게 키우시나요? (장소, 키우거나 놀아주는 방법, 산책 등)
C. (영상 시청 후) 본 제품에 대해 어떻게 생각하시나요?

* 전화/화상 인터뷰의 내용이 녹음될 수 있습니다.
또한, 본 인터뷰를 통해 수집된 데이터는 연구논문 작성 이외의 용도로는 사용되지 않습니다.

A. 어떤 강아지를 키우시나요?

Q1. 키우는 강아지 종류 & 나이, 크기(소형견/중형견/대형견)

Q2. 강아지의 성격, 특징

Q3. 강아지가 좋아하는 것은 무엇인가요? (놀이/활동/음식 등)

B. 어떤 환경에서, 어떻게 강아지를 키우시나요?

Q4. 강아지를 어디서 키우시나요?

Q5. 강아지의 습관이 있나요?

Q6. 강아지가 혼자 있는 시간동안 어떻게 지내나요?
+ 혹시 오랜시간 집을 비우게 될 경우, 강아지에게 어떤 영향이 있나요? 어떤 방식으로 해결하나요?

Q7. 강아지와 산책은 주로 언제 혹은 어디서 하나요?

Q8. 강아지 산책훈련을 시켜본 경험이 있나요?

Q9. 산책을 하는데 있어, 가장 신경쓰이거나 힘든 부분이 있나요?

Q10. 강아지 산책과 관련해 구매한 제품이 혹시 있나요?

Q11. 산책 관련 제품을 구매할 때, 어떠한 제품을 가장 선호하시나요?

C. 산책 관련 제품에 대해 어떻게 생각하시나요?

Q12. 드론이 산책을 도와준다면, 어떤 부분이 가장 편리할까요?
+ 왜 그 부분이 가장 편리하다고 생각하시나요?

Q13. 이 컨셉이 제품화 된다면, 충분히 구입할 필요가 있다고 느껴지나요?

Q14. 이 컨셉에 개선점이 있다면, 어떠한 부분이 있을까요?

Appendix 3. Results from the interview: Q 1~10

Interviee 1 M /(F) Worker

Q1. How do you raise the dog?

1 Dog type/size | Mongrel, large dog
2 Characteristic | Very active, likes to go out
3 Favorite activities | Eating
4 Where do they live? | Detached house
5 Habbit | Walking around
6 Time spending alone | From 8am-5pm
7 Any depression behavior | Digs the ground, frequent urination
8 Time/Place of dog walking | 10-20 minutes,1-2 times a week / near the house
9 Training experience of dog walking | Tried, but cannot control the dog. She's too strong & speedy.
10 Worries on dog walking | Biting someone

Interviee 2 M /(F) Worker

Q1. How do you raise the dog?

1 Dog type/size | Mongrel, small dog
2 Characteristic | Annoyed of walking, likes to eat
3 Favorite activities | Eating
4 Where do they live? | Apartment
5 Habbit | Eating, staying at home
6 Time spending alone | X
7 Any depression behavior | X
8 Time/Place of dog walking | 10-20 minutes,1-2 times a week / near the apartment
9 Training experience of dog walking | X
10 Worries on dog walking | Eating food on the ground

Interviee 3 (M)/ F Student

Q1. How do you raise the dog?

1 Dog type/size | Chihuahua, small dog (3 years old)
2 Characteristic | Sociable
3 Favorite activities | Likes to play & going for walk
4 Where do they live? | Apartment
5 Habbit | Playing with toy
6 Time spending alone | About 5 hours
7 Any depression behavior | Destructive chewing in home
8 Time/Place of dog walking | 30-40 minutes, 7 times a week / park near the house
9 Training experience of dog walking | X
10 Worries on dog walking | Afraid of other dogs, so she runs away when other dog barks. She also likes to follow strangers.

Interviee 4 M /(F) Worker

Q1. How do you raise the dog?

1 Dog type/size | Miniature pinscher, middle sized dog
2 Characteristic | Like to eat too much, have lot of fear, Lack of socialization
3 Favorite activities | X
4 Where do they live? | Apartment
5 Habbit | Likes to eat & sleeping
6 Time spending alone | From 7:30am-5pm
7 Any depression behavior | Ruins the house, digs the wall, lonliness(skin illness, hair loss)
8 Time/Place of dog walking | 30 minutes,1-2 times a week / Park near the house
9 Training experience of dog walking | Tried, but it doesn't work. Luring with snack.
10 Worries on dog walking | Watching training video & Snack luring

Interviee 5 M /(F) Student

Q1. How do you raise the dog?

1 Dog type/size | Miniature pinscher, small dog
2 Characteristic | Afraid of people, Lack of socialization
3 Favorite activities | Playing with toy
4 Where do they live? | Multiplex housing
5 Habbit |
6 Time spending alone | From 8am-5pm
7 Any depression behavior | Greets owner too much
8 Time/Place of dog walking | 2 hours,1-2 times a week / Park near the house
9 Training experience of dog walking | X
10 Worries on dog walking | Since lack of socializing education, she could bite someone. She could be afraid of people.

Appendix 3. Results from the interview: Q 11&12

Interviewee	*Response on Q11&12*
Interviewee 1	Yes, it would be helpful for training the dog. Since my dog is not trained but so active and big, we cannot control his power when walking. I think this drone will help us training him, since my dog likes the snack. In preparation for emergency, the control components such as giving physical shock can be helpful for restraining such a large dog. Also, I wish this product can help us to go our own family picnic rather than focusing on the dog caring.
Interviewee 2	No, I think this product would be better for other people who need help for dog walking. We go walking once or twice a week for 10-20 minutes. I don't feel any difficulties in walking her, since she does not have any problems in walking. I think, this product would be suitable for the elderly people who raises dog alone. Since they easily feel tired, this drone would be helpful. Or the dog walkers would be also nice target since they sometimes need to go walking with 2 or more dogs at the same time.
Interviewee 3	I think this product would be good for others who cannot afford time for walking, such as workers. My dog chews destructively or has potty-problem when she gets stressed. Early in the morning or at the dinner, on the way of going home from work, this drone would be useful to walk with the dog. For this product, I'm worried of potty-problems, since the owner need to clean it. Also, my dog looks back to check the owner following, and she turns back when I miss the leash. I think drone would not give such stability while walking. I'm worried that the dog might feel difficult to keep the pace.

Interviewee 4	No, since my dog hates walking. My dog is somehow different from other dogs. When she was young, she liked to go walking and we walked 30minutes 5 days a week. However, as she grows old, she just likes to stay in home without walking. I've done various efforts to train her walk. She likes food so much so I've tried to train her with snacks, but it failed. For this product, I'm worried about ethical issue, since it gives feeling that my dog is controlled by a machine. Also, I think the drone cannot control the dog of this size and the size of the drone could be threatening to others who walk by. There are quite many people who hates dog especially who have a trauma of got bit by a dog. Also, the leash needs to be tight it shouldn't be loose.
Interviewee 5	Yes, I especially like the idea of giving alarm to owner and training the dog with the snack. By giving an alarm, I can have more time without caring her. I think the dog needs time to get used to the drone.

Appendix 4. Dog Walking Drone poster & use scenes

Problem

1 Dog doesn't follow me!

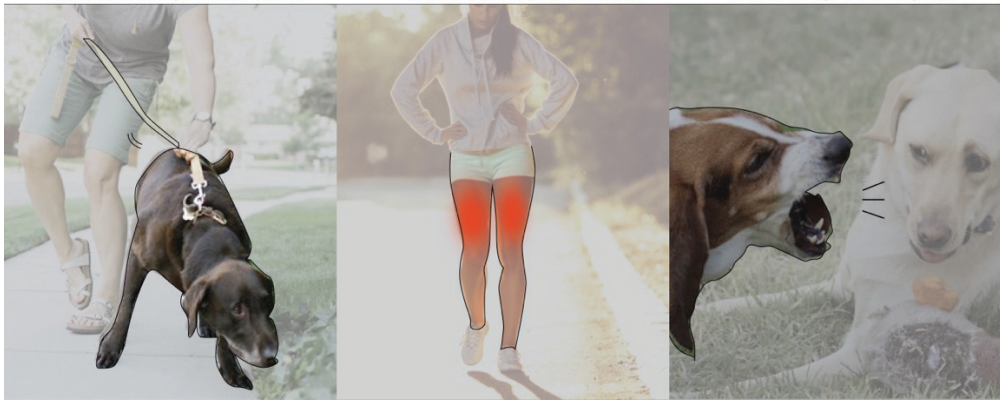
Some dogs need training before they walk. They do not easily follow the owner, which makes the owner tired & stressful. They need to spend time on training with effective method.

2 Too tired to walk

Dog owners who work usually arrive at 6pm. However, the dog want to play and go out with the owner. Spending time after working could be a physical burden for the owner.

3 Need to care

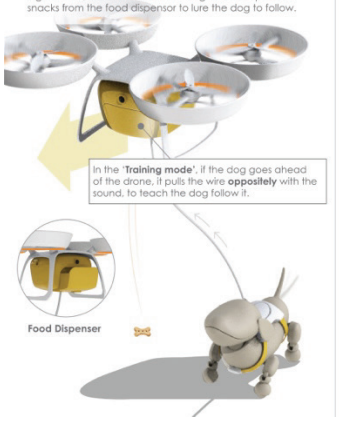
Dogs need at least 30 min of dog walking everyday. While spending time with them, the owner can never take their eyes off and do other things, such as taking a rest.



Solutions

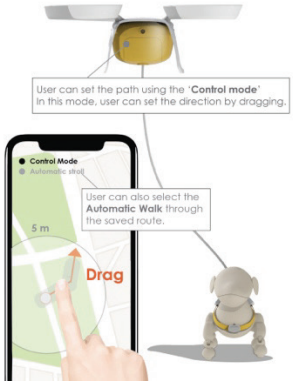
1 Smart Leash training

It trains the dog effectively with smart leash training. Pulling the wire, the drone leads the dog and it drops some snacks from the food dispensor to lure the dog to follow.



2 Autonomous Dog walking

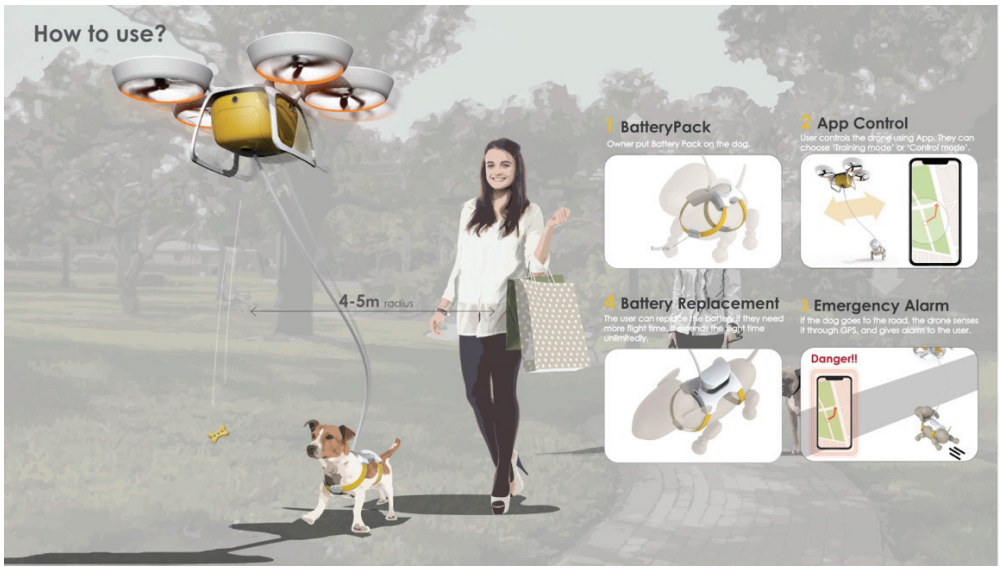
User can control the drone using App. With autonomous flight, user does not need to walk the dog. It greatly lessens the physical burden of the user.



3 Full-time care by sensing

With full-time sensing, the drone detects the danger or emergency to send an alarm to the user. With sound & GPS sensor, it senses dog barking, or going to the roads.

How to use?



Executive Summary in Korean

Wired Drone and Suggestions for its Applications

드론은 단순한 촬영과 레저의 용도를 넘어 여러가지 산업 분야에 적용되고 있다. 최근 아마존, 구글, DHL 과 같은 대기업들이 드론을 이용해 배송 시스템의 혁신을 시도하고 있다. 드론은 지상을 기반으로 하는 트럭, 스쿠터와 같은 기존의 운송시스템보다 인력 및 유지비용을 줄여줄 뿐만 아니라, 험난하거나 거친 지형이나 나무, 사람과 같은 주변환경의 영향을 적게 받아 더욱 빠르게 운송할 수 있다.

그러나 현재 기술로는 드론의 운송, 운반 수단으로서의 다양한 활용에 한계가 있다. 특히 고중량의 물체를 적재할 경우 단거리 이동 밖에 하지 못하며, 다양한 임무를 완성할 수 있을 만큼 충분한 체공 시간 확보가 어렵다는 점이다.

본 논문은 배터리 한계에 대해 비행 시간의 효율 문제 및 적재 무게의 한계를 해결 할 수 있는 배터리 솔루션을 제시한다. 또한, 단순히 배터리 효율을 높이는 것이 아닌, 여러 사용환경에서 실용적으로 적용 가능한 방안을 모색하며, 이를 통해 드론의 활용성을 높이고자 한다.

우선, 데스크탑 리서치를 통해 현재 드론 시장의 현황을 조사하였으며, 각 산업에서 배터리 한계가 사용성에 어떤 영향을 끼치는지에 대해 분석하였다. 또한, 기존의 배터리 한계를 해결하는 여러 솔루션들의 장단점을 비교 및 현 기술단계에서 시장에 적용할 수 있는 유선형 배터리 솔루션을 제안하였다.

또한, 본 솔루션의 다양한 활용 형태에 대한 아이디어 및 컨텍스트를 운반, 운송과 관련된 트리 형태로 정리하였다. 그 중, 3 가지 컨텍스트에 대하여 Problem & Design requirement 를 정리하였다. 또한, 해당 내용을 적용하여, 각 컨텍스트에 맞는 Use scenario 와 ideation & develop 을 진행하였다. 3 가지 아이디어 중, 최종안인 Dog Walking Drone 에 대한 최종 3D 모델링 및 프로토타입을 정리하였다.

키워드 : 드론, 운송, 운반, 유선 배터리, 체공 시간, 중량

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Wired Drone and Suggestions
for its Applications