

Pet Brush Project

Conceptual Design Review

Group C

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Conceptual Design Review

1. Conceptual Development

1.1. Process Description

Using the data obtained from the Problem Definition Review [1], the group identified cleaning up after pets as a major issue faced by pet owners. After a further survey, this was refined - specifically, pet owners dislike cleaning up pet waste and have trouble with pet maintenance. Participants in the survey felt that many currently available pet cleaning products are not as reliable or helpful as they would like. They wanted lower costing products that were easy to use.

With these characteristics and the time limitation of this project, in mind, several concepts are created. Priority was given to being able to fulfill the user needs that were identified in the Problem Definition Review, ease of use, and reliability [1]. In addition, it is important that a potential solution is viable to design, test, and produce within the allotted time, ruling out complicated mechanical or computerized solutions.

After the team has decided to work on the Pet Care Project, the group proceeds to do a preliminary survey to choose what type of pet care would be the best to work on. Based on the responses, the group discovered that pet cleaning was ranked the lowest compared to other pet care. The group created and distributed another survey that focused on pet cleaning to gauge the improvements pet owners needed. Overall, furniture coverings have been ranked low in the average user rankings because they are not widely used by pet owners. However, it would be best if the group could design better furniture covering which fulfill the user needs. The cover would have to be easy, helpful, low cost, reliable, and pet safe [1]. Even though there will be some constraints to the covers, they need to have varying sizes to account for different types of furniture. The group will work towards making an easily producible and adaptable furniture covering for pets.

From the data gathered from the surveys, pets can be hard to brush and it is difficult to clean up all the fur. There are a lot of other pet care products and problems when cleaning up after a pet, but fur is something that a lot of pet owners hate as it gets all over furniture and clothes [1]. The main idea around the brush is that it sucks up the hair as pet owners brush their pet (Appendix A, Figure A4). It is handheld and cordless. The advantages of this device is that it would be a fast and easy alternative to regular bushes where owners have to pluck out the hair in the brush. The hair doesn't get all over the place because the device would suck the hair up and store it. The brush is meant to take some frustration and time out of brushing pets.

Another idea of the brush is by placing it on the palm side of the gloves (Appendix A, Figure A3). The gloves will be produced in a variety of sizes so that all pet owners could use them. However, it would be troublesome for the users to buy different sizes of the gloves in order to brush their pets. The advantage of this design is that its brush has papillae-shaped bristles which

imitates cats' tongues. The design of the bristles will be so efficient to brush and trap the pets' fur on the bristles.

1.2. Brainstorming Results

From the data gathered from the surveys, pets can be hard to brush and it is difficult to clean up all the fur [2]. There are a lot of other pet care products and problems when cleaning up after a pet, but fur is something that a lot of pet owners hate as it gets all over furniture and clothes. The group wants to focus on cleaning up pet fur and managing fur when brushing pets.

Several different solutions were roughly drawn up to try and solve this problem. Ranga's first design focuses mainly on the bristles of the brush (Appendix A, Figure A2). These bristles would mimic the papillae on a cat tongue that allow them to efficiently clean themselves [2].

The second design by Dan follows a similar concept to the first with the bristles, but the concept is a glove that allows owners to easily brush their pet. The bristles are located on the palm of the glove and could offer a pet-friendlier alternative that helps pet owners clean their pets with just a wave of a hand (Appendix A, Figure A3). However, the bristles are not created to hold the pet hairs and have to be cleaned manually.

Design three from Anglina is a brush that would suck up the hair as the pet was brushed (Appendix A, Figure A4). The advantage of this device is that it would be a fast and easy alternative to regular bushes where owners have to pluck out the hair in the brush. The hair doesn't get all over the place because the device would suck the hair up and store it. The brush is meant to take some frustration and time out of brushing pets.

Mira's design is furniture covering that would be sturdy enough to hold up to pets' claws. At the same time, it would be able to wrap the entire furniture piece. It would be waterproof and reusable, so it could handle leaks from pets, saving owners money. It would be sturdy enough to be used for longer periods compared to other covers, so owners would not have to buy many covers. There is a zip underneath it, so it will be easy to attach and remove the cover (Appendix A, Figure A6).

Two designs were generated as a group based on elements of each individual design. These two are presented in Appendix A, Figures A7 and A8. The first design is a pivoting hairbrush with a two-axis joint similar to one found in some razors (for example, the Gillette ProGlide razors). The pivoting head of the brush would ideally enable it to conform to the contours of a pet more easily.

The second design proposed was an attachment for a vacuum cleaner that would specialize in removing pet hairs from couches and other surfaces, which can be very challenging for normal vacuum cleaners. A system of hooks (similar to those found on hook-and-loop fasteners such as Velcro) could trap fur more effectively than a standard vacuum cleaner and be easier to clean.

2. Concept Selection

Using the user needs to be discussed in the Problem Definition Review [1], concepts were selected down to two viable concepts. The first was the swiveling hairbrush (Appendix A, Figure A7), and the second was the pet grooming glove (Appendix A, Figure A3). These were chosen as they were deemed to be feasible in the time frame given and to satisfy the user needs to be identified in the PDR (ease of use, reliability, and pet safety) [1].

A Pugh scoring matrix was generated using weights from the pairwise comparison chart generated in the PDR. The two concepts were scored against a control product, a self-cleaning slicker brush found on Amazon [3]. This control product was chosen as it was indicated as a best-seller on Amazon.

The Pugh scoring matrix (Appendix B, Table B1) indicated that the swivel brush design would be most useful and appealing to end-users. Compared to the HERTZKO self-cleaning slicker brush, the swivel brush would be more pet-safe, affordable, easy to use, and reliable. Brushes like the HERTZKO self-cleaning slicker brush allow users to push the fur off of the bristles with a button, yet it does not work efficiently enough. Fur is still left at the end of the brush and is difficult to get out. The group believes the swivel brush design to be more efficient than the HERTZKO brush and the glove brush design. The glove design would be faster and more helpful in the Pugh scoring matrix, but after further consideration, the group believes that it could be less effective than more traditional bristles. The swivel brush design gives a more versatile range of motion when brushing and allows for more fur to be caught with the bristles. The group finds the swivel hairbrush to be the best solution among the three and will pursue it going forward (Appendix A, Figure A7).

3. Grand Concept & Prototyping Plan

3.1. Grand Concept Design

The swivel brush design will be chosen as the group's Grand Concept Design because after some reconsiderations, the group think it is the best option compared to the others (Appendix A, Figure A7). The product is designed to have horizontal and vertical pivots, so it will be easy to contour around the body shape of the pet allowing for the owner to easily brush the pet. The pivots are attached to ordinary bolts which will form hinges that let the pivots rotate and turn smoothly. In the survey conducted, the participants described having trouble brushing their pets [1]. The prototype brush would allow pet owners to brush difficult areas on their pet (Appendix A, Figure A10 and Appendix C, Figure C1). The swivel brush is also expected to have semi-flexible bristles all over the bottom of the brush since these soft and durable bristles can provide a therapeutic combination of deep pressure and tactile stimulation to help self-regulate and calm down the pets (Appendix C, Figure C2). This design is great for the users to brush the pets because sometimes pets act aggressively and it is hard to brush them. The size of the swivel brush is 3" x 4" inches with approximately 100 of papillae-shaped bristles while the handle will be 5" inches.

Papillae-shaped bristles are chosen because the shape enables the fur to stick on the bristles easily since it looks like a hook. However, in Figure A10, the bristles are not shown since the sketch is not finalized. The challenge to make these bristles comes in the process of manufacturing them. Their small size makes them challenging for FDM 3D printers that have not been carefully calibrated. The durability of bristles and body parts should also be tested before the product is delivered to market.

3.2. Prototyping Plan

The main objective of this prototyping plan is to create a pet hairbrush that adapts to the differing body shapes of pets. The detailed sketch focuses more on the mechanism that allows the brush to contour to different surfaces (Appendix A, Figure A10 and Appendix C, Figure C2). The mechanism is a greater focus for the group to make it as efficient and reliable as possible. Pieces like the handle and bristles will be easier to manufacture and create. End users want a product that they can rely on to be easy to use. A simple prototype will be created first as a proof-of concept to test the validity of the idea. Additive manufacturing is ideal for prototyping several of these parts, as they are fairly small and do not need to bear significant loads. These include the swivel and the brush. As for the materials, the group aims to use wood for the handle, ABS for the swivel and the brush holder and bristles.

Several pieces are more simple, and as such ordinary bolts can be used to form the hinges of the horizontal and vertical pivots. While these will not be very smooth, and will wear away the plastic over time, for a proof of concept they are acceptable. In addition, a small strip of steel will serve as a spring which acts to keep the brush in its centered orientation. For the prototype, many joints are far larger than necessary due to the relative weakness of 3D printed materials (and the large $\frac{1}{4}$ "-20 bolts planned). These can easily be scaled down or replaced with smaller pins for future iterations of the design (Appendix A, Figure A10).

A 3D-printed preliminary bristle assembly (Appendix A, Figure A11) was created to test the basic papilla design. This prototype proved to be rather sharp, scratching human skin when tested on it. Its durability was acceptable, and no bristles broke under casual testing. Due to the sharpness, it was decided not to test this prototype further. Instead, a second prototype will be 3D-printed with bristles that are angled further down and have a larger tip to make them duller. The new bristles are shown in Appendix C, Figure C2. In addition, the backplate was redesigned to use laser cutting instead of 3D printing for faster manufacturing (Appendix C, Figure C3).

4. Prototype Design Requirements & Verification Plan

4.1. Prototype Design Requirements

Six design requirements were identified and established. For values, consult Table 1. These design requirements are used to guide further development of the project and identify what changes need to be made to a prototype.

Table 1: Design Requirements

Design Requirements	Value Range	Ideal Value	Design Impact
Time to clean hair out of brush	0 - 120 seconds	< 30 seconds	Bristles modified to lower value (easier to use)
Total brush mass	0 - 500 grams	< 100 grams	Parts optimized for lower mass (lighter)
Brush material cost	\$0 - \$10	< \$5	Optimized for lower cost (cheaper brush)
Force to break one bristle	0 - 3 lbs	> 3 lbs	Bristle must withstand normal use (higher breaking force is better)
Brush strokes to adequately clean pet	1 - 10	< 3	Bristles modified to lower value (quicker cleaning)
Pet opinion	1 - 10	> 8	Bristles modified to minimize discomfort and increase pet opinion (more pet-safe)

4.2. Testing Methodology and Verification Plan

Tests are established for all of the design requirements identified in Table 1. These tests will be used to evaluate whether a prototype meets the requirements.

1. To test the time to clean the hairbrush, the hair brush will be used for some time until it has some hair trapped in it. A timer will be started, and the amount of time required to remove the trapped hair (fewer than 20 hairs remaining) will be recorded. This emulates the typical use of a hair brush. 5 trials.
2. The total brush mass will be measured using a balance after cleaning the brush of any trapped hair. 1 trial.

3. The brush material cost will be calculated from CAD models. This does not include the cost of manufacturing, as the manufacture of the prototype is significantly different from the manufacture of a mass-market prototype. 1 trial.
4. To test the bristle breakage force, one bristle, mounted to a base, will have a force applied to its tip horizontally and will be tested to destruction. The final failure force will be recorded. This test aims to ensure that a bristle design is not fragile and can stand up to usage, drops, and handling. 3 trials.
5. To test the efficacy of the bristles, the number of brush strokes needed to adequately clean a pet will be measured. First, the brush will be used on a small section of a pet. Brushing continues until there is no more significant accumulation of fur on the brush (fewer than 20 individual hairs on the last stroke with no large clumps), which is cleaned between strokes. The number of strokes is recorded. 5 trials.
6. To test the comfort of the brush for the pet, pets' opinions will be scored. The brush will be used on a pet. Brushing continues for up to five minutes. A score from 1 (bad) to 10 (good) is given based on whether the pet seems to enjoy the brushing. 3 trials.

4.3. Correlation Matrix & Verification Scorecard

To generate the correlation matrix (Table 2) and scorecard (Table 3, page 9), design requirements and user needs are compared and given correlation values. Based on these, the design requirements are given weights that represent their importance to the design. Then, a rubric for each test is generated for the scorecard.

Table 2: Correlation Matrix

Prototype Requirements Correlation	Time to clean hair brush	Total brush mass	Total brush material cost	Force to break one bristle	Strokes to clean pet	Pet Opinion	Weight from PDR [1]
User Needs							
Pet-safe					3	9	5
Fast	9				9	3	0
Affordable			9				1
Helpful	3	1		1	9	3	4
Reliable				9			2
Easy to use	9	3		3	9	3	3
Importance	39	13	9	31	78	66	

Table 3: Testing Scorecard

Requirement	Range	Score Rubric									Score
		8	7	6	5	4	3	2	1	0	
Time to clean hair out of brush (5 pts)	0 - 120 seconds				≤ 80 s	≤ 90 s	≤ 100 s	≤ 110 s	≤ 120 s	> 120 s	
Total brush mass (1pt)	0 - 500 g									< 250 g	> 250 g
Brush material cost (1pt)	\$0-20									$< \$10$	$> \$10$
Force to break one bristle (3pts)	0-3 lbs of force					≥ 3 lbs	≥ 2 lbs	≥ 1 lb	< 1 lb		
Brush strokes to adequately clean pet (8pts)	1-10	1	2	3	4	5	6	7	8	≥ 9	
Pet opinion (7pts)	1-10		10	9	8	7	6	5	4	< 3	

References

- [1] L. Barone, M. Faizul, D. Haikal, & R. Rutiser Sundar, “Pet Cleanup Project Problem Definition Review,”
<https://github.com/rutisersundar1/ENGR1182GroupC/blob/main/Technical%20Documentation/Problem%20Definition%20Review.pdf> (accessed Apr. 20, 2022)
- [2] A. C. Noel & D. L. Hu, “Cats use hollow papillae to wick saliva into fur,” *PNAS*, vol. 115, no. 49, pp. 12377-12382, Dec. 2018, doi: 10.1073/pnas.1809544115.
- [3] HERTZKO. “HERTZKO self-cleaning slicker brush for dogs and cats pet grooming dematting brush easily removes mats, tangles, and loose fur from the pet’s coat (original).” Amazon.com, <https://www.amazon.com/dp/B00ZGPI3OY/> (accessed Feb. 27, 2022).

Appendix A: Brainstorming Concept Sketches

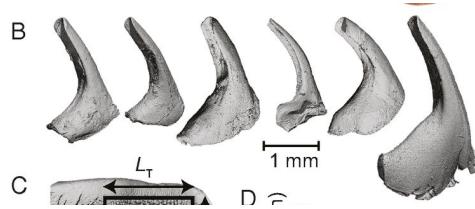
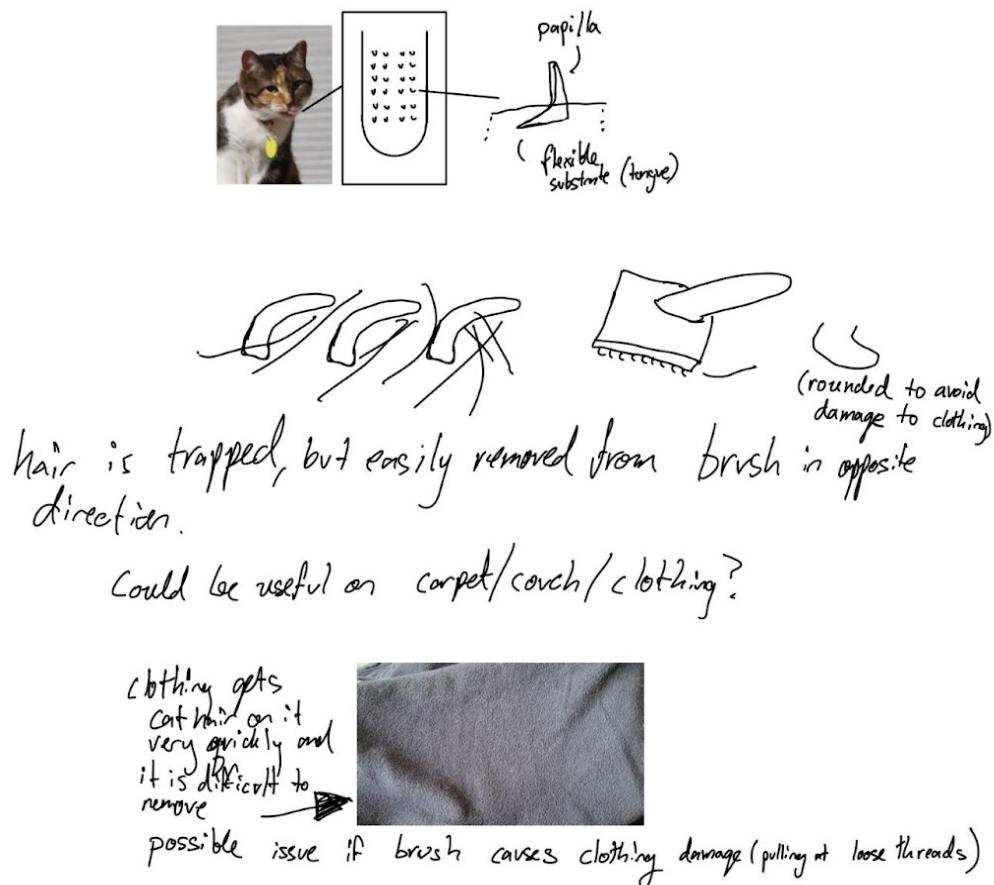


Figure A1. Papillae of various feline species (from [2]).



Ranga Rutiser Sundar
14 Feb. 2022

Figure A2: Brush using simulated papillae (Ranga Rutiser Sundar)

PET HAIR GLOVES

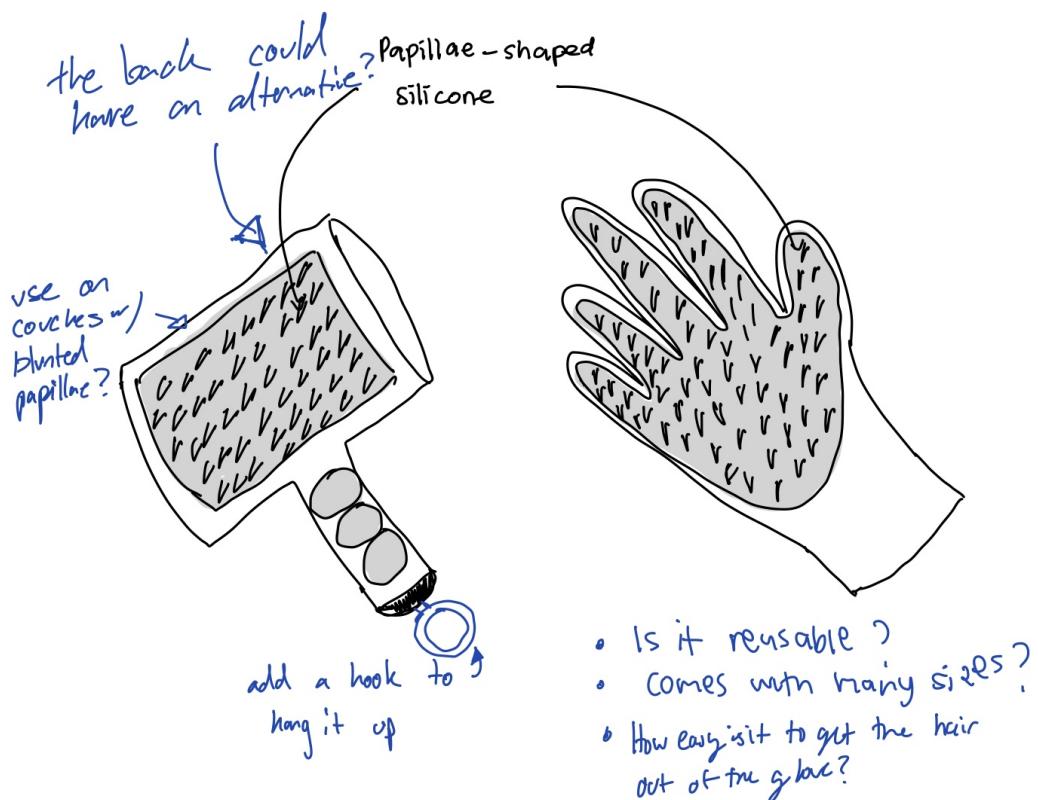


Figure A3: Pet grooming gloves using simulated papillae (Dan Haikal)

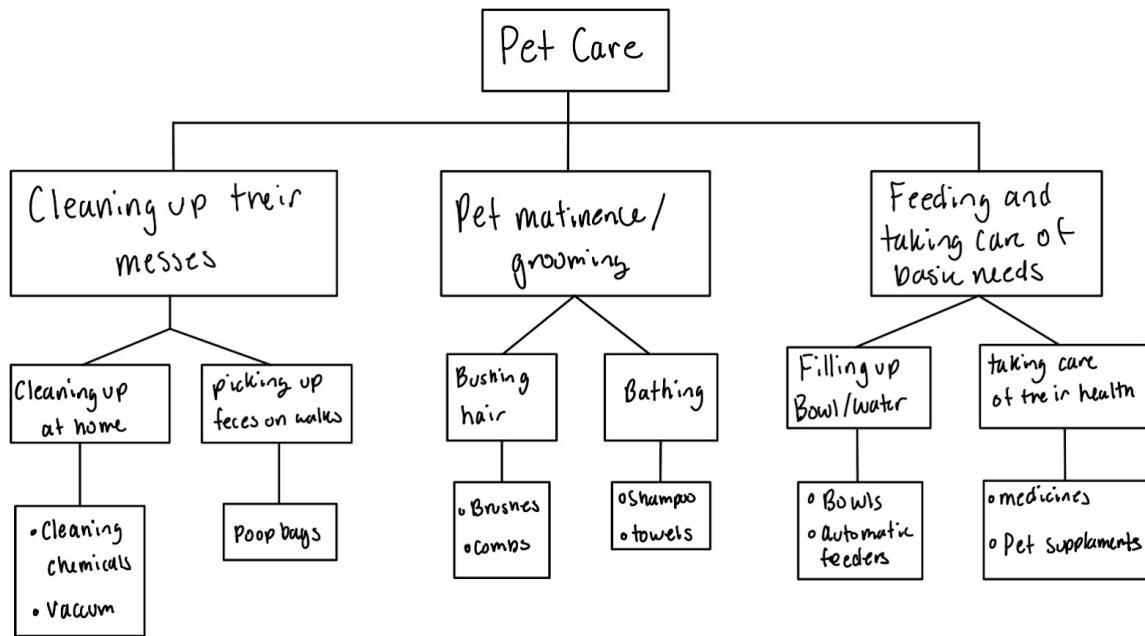


Figure A4: Concept chart (Angelina Barone)

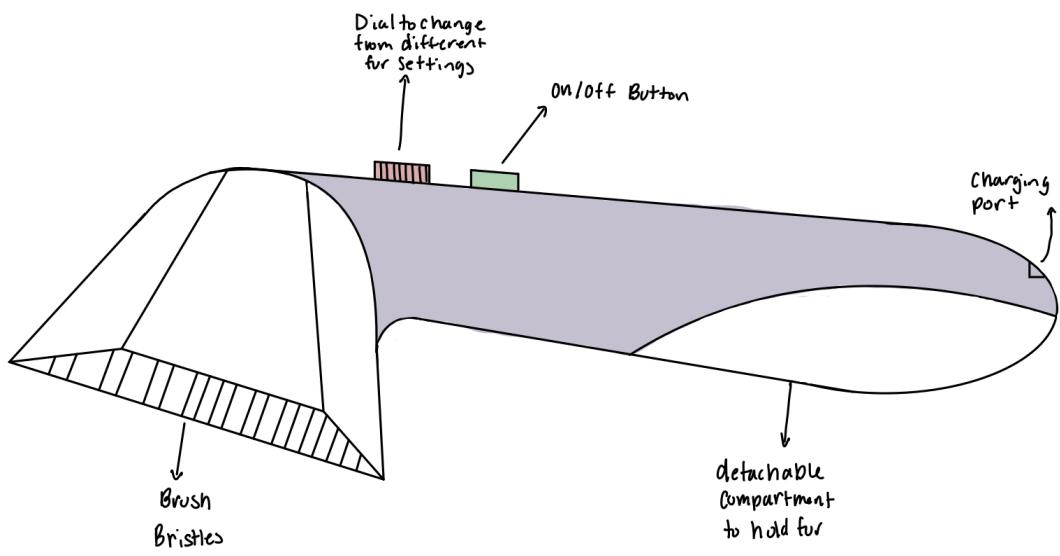


Figure A5: Brush design concept 2 (Angelina Barone)

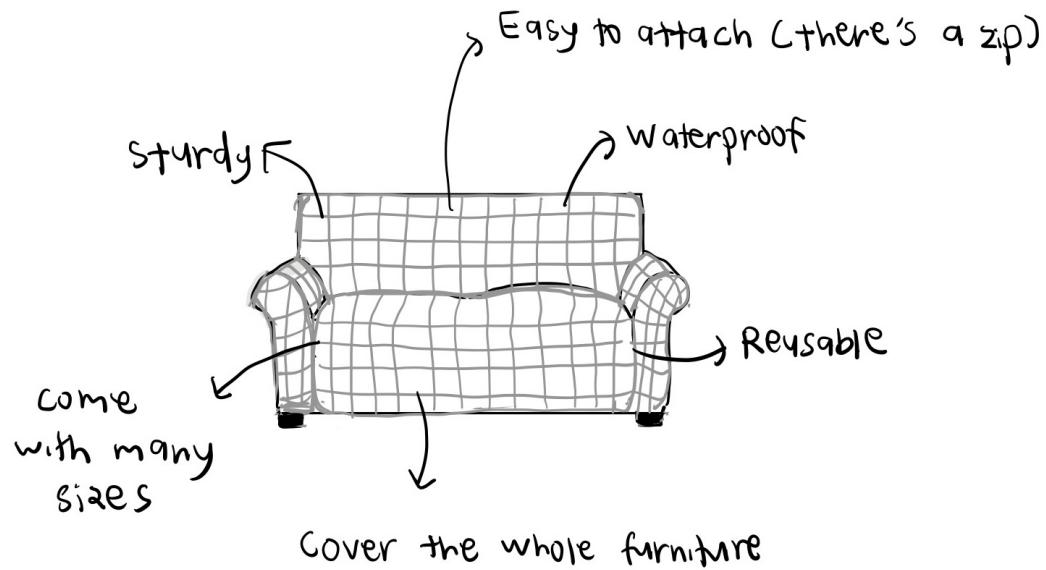


Figure A6: Furniture covering (Mira Faizul)

Pet hairbrush with swiveling handle like some razors could allow better coverage of pet contours

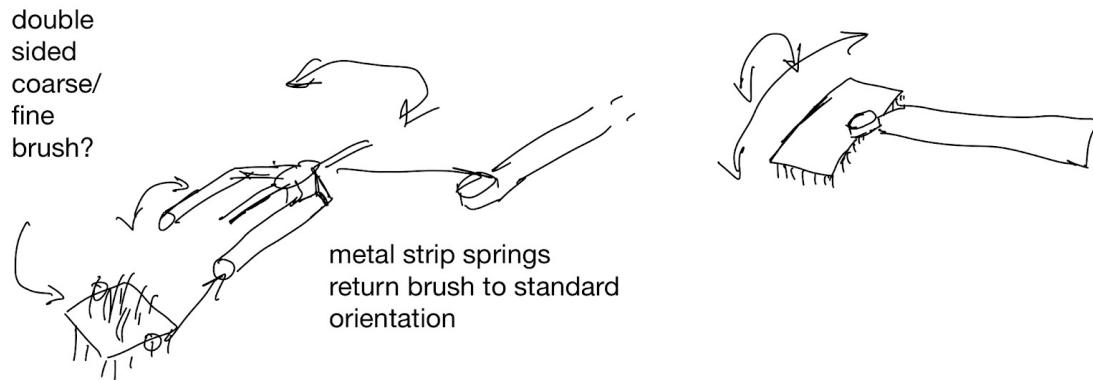
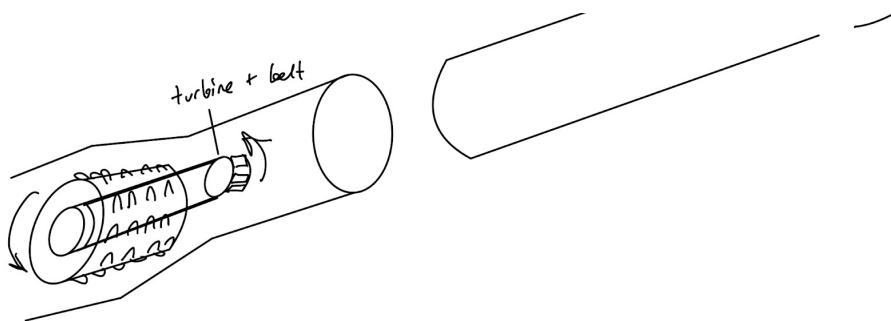


Figure A7: Swivel pet hairbrush (Group)



Vacuum attachment for cleaning up pet hair?

- could clog less than normal
- try to catch pet hair and put it in a bag at the attachment?

Figure A8: Pet hair vacuum attachment (Group)

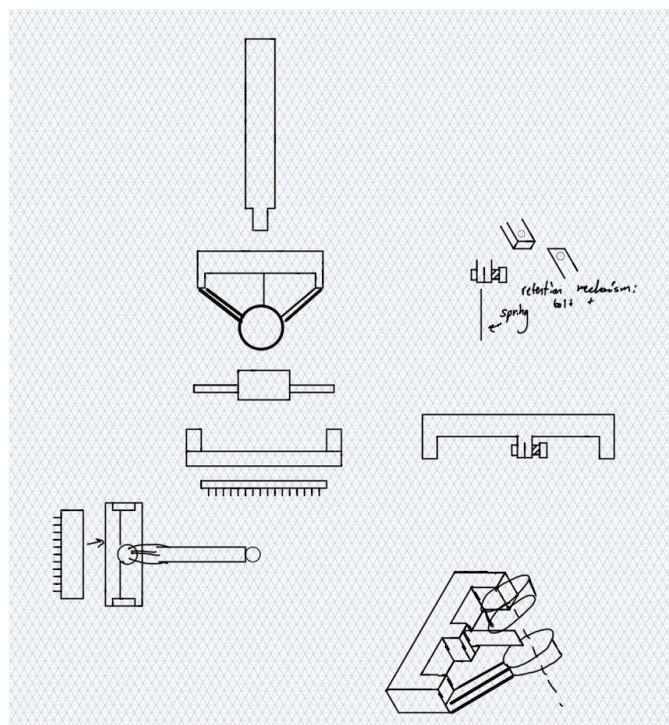


Figure A9: Prototyping plan drawing (parts)

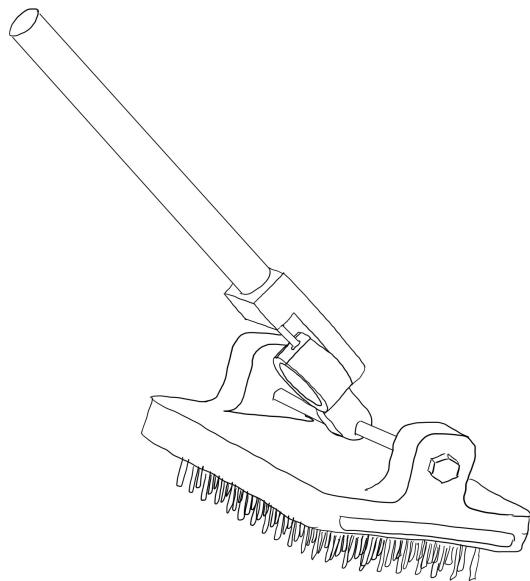


Figure A10: Prototyping plan drawing (whole assembly)

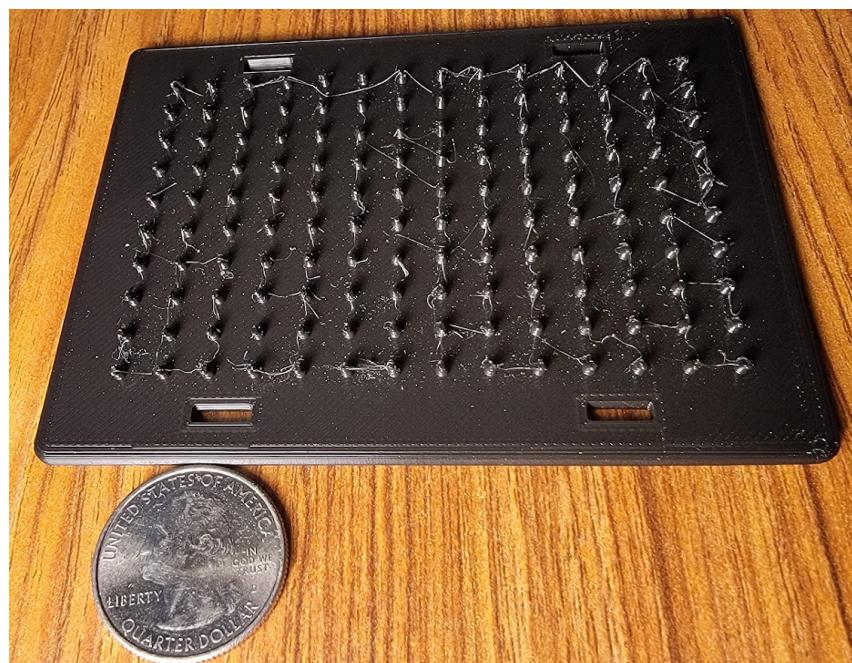


Figure A11: Preliminary bristle part

Appendix B: Pugh Scoring Matrix

Table B1. Pugh scoring matrix

Need	Weight (1-5)	Reference		Swiveling Brush		Glove Brush	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Pet-safe	4.96	3	14.88	4.5	22.32	4.5	22.32
Fast	4.2	4.2	17.64	3.8	15.96	4.4	18.48
Affordable	3.98	4	15.92	4.2	16.72	3.5	13.93
Helpful	4.82	4.5	21.69	3.5	16.87	4.2	20.24
Reliable	4.79	4	19.16	4	19.16	3.5	16.77
Easy to use	4.68	3.5	16.38	4.3	20.12	4	18.72
TOTAL			105.67		111.15		110.46

Appendix C: Grand Concept

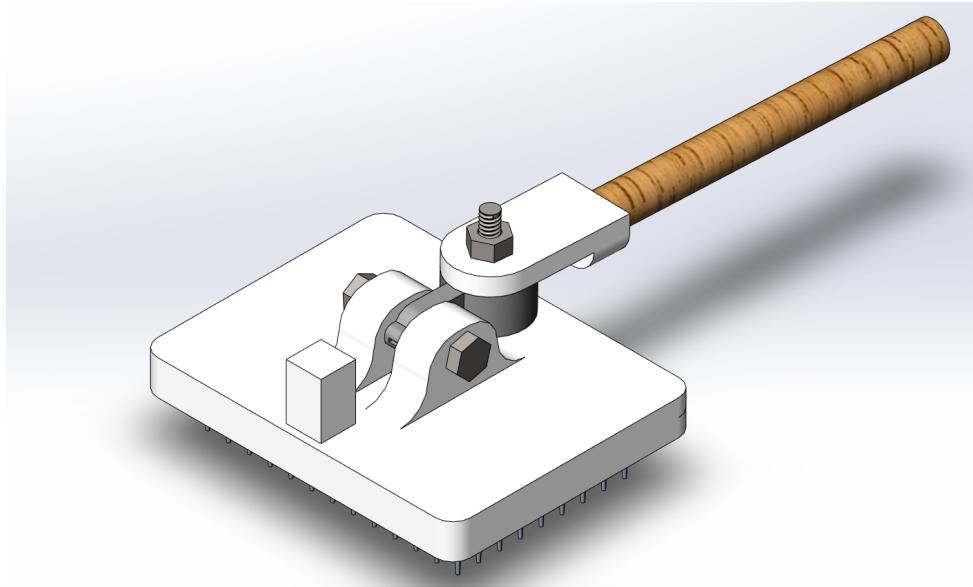


Figure C1. Brush initial concept model (Note: two metal springs are excluded from this model and bristles are not final.)

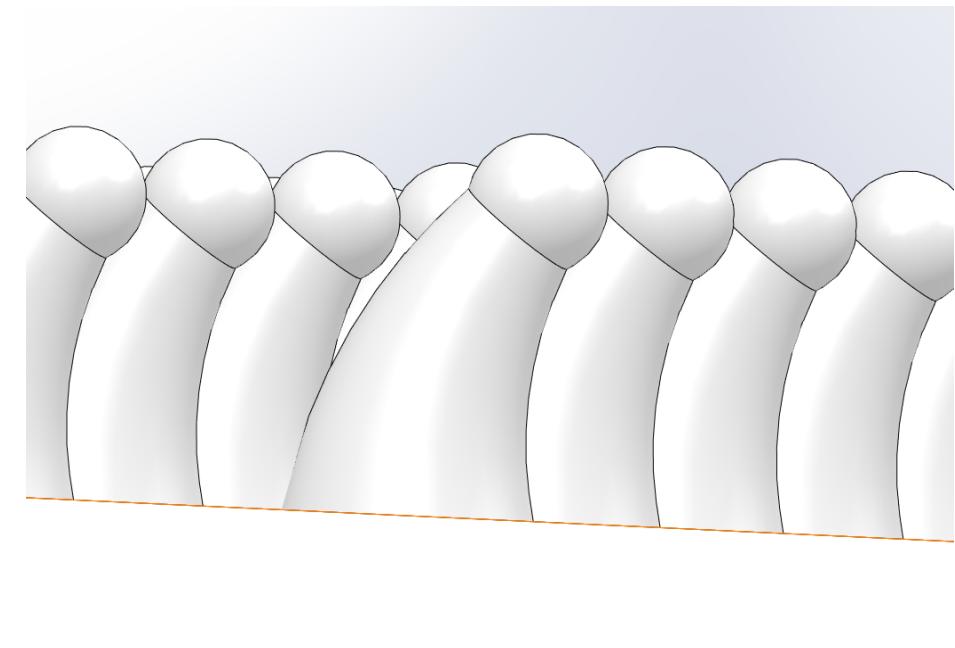


Figure C2. Redesigned bristles

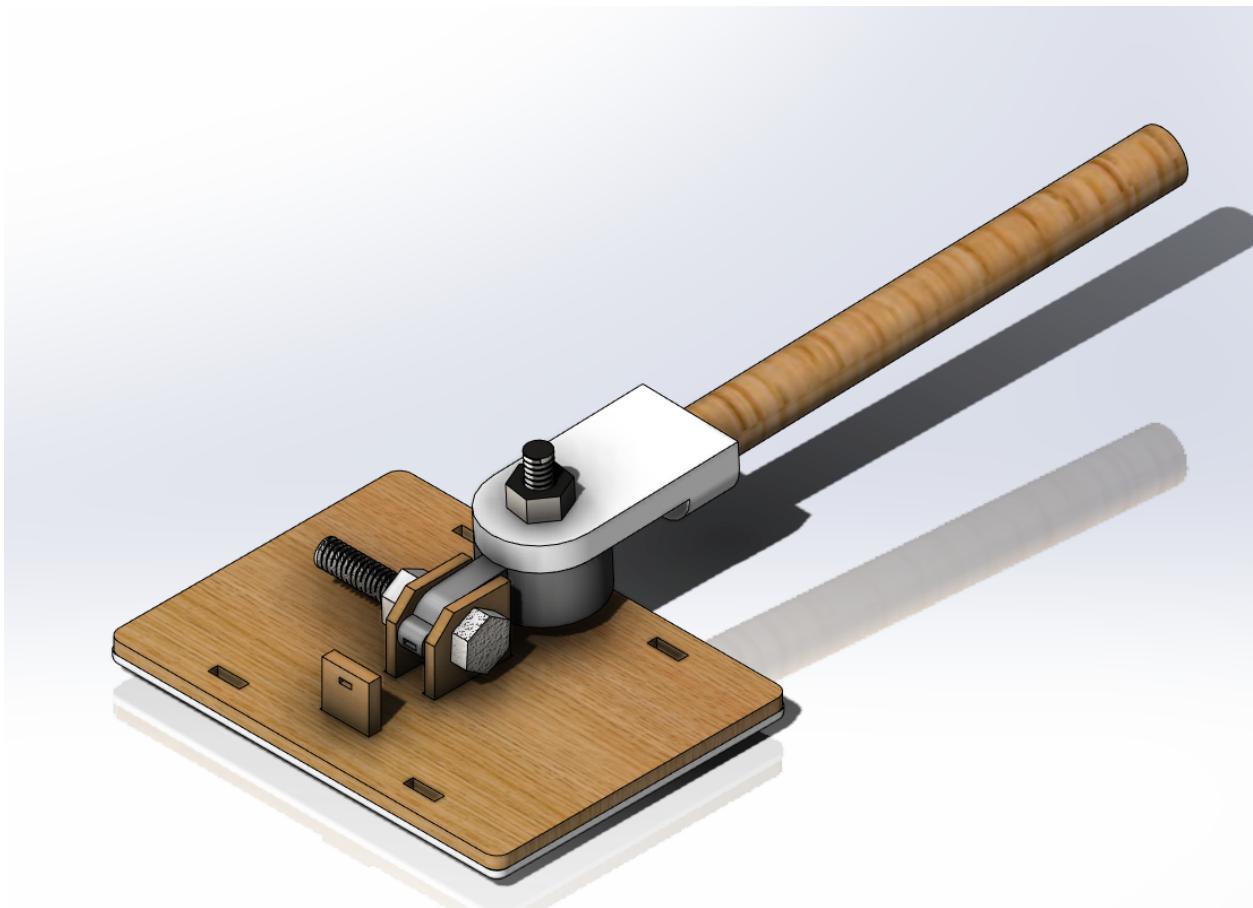


Figure C3: Redesigned backplate

Appendix D: Group Responsibilities

CD1: Individual Concept Brainstorming & Ideation			
Project Manager for Assignment	Angelina Barone		
Deputy Manager for Assignment	Mira Faizul		
Drafted Assignment	All group members	Revised Assignment	All group members
Reviewed Assignment	All group members	Proofread Assignment	All group members
Created Figures	Dan Haikal	Created Tables	Ranga Rutiser Sundar
Other Contributions			
N/A			
Problems Overcome			
Each team member was able to brainstorm ideas and come out with few conceptual solutions to solve the problem with pet cleaning.			

CD2: Group Concept Brainstorming & Ideation			
Project Manager for Assignment	Angelina Barone		
Deputy Manager for Assignment	Mira Faizul		
Drafted Assignment	All group members	Revised Assignment	All group members
Reviewed Assignment	All group members	Proofread Assignment	All group members
Created Figures	Dan Haikal	Created Tables	Ranga Rutiser Sundar
Other Contributions			
N/A			
Problems Overcome			
The group was able to brainstorm ideas and come out with few conceptual solutions to solve the problem with pet cleaning.			

CD3: Concept Selection			
Project Manager for Assignment	Mira Faizul		
Deputy Manager for Assignment	Dan Haikal		
Drafted Assignment	All group members	Revised Assignment	All group members
Reviewed Assignment	All group members	Proofread Assignment	All group members
Created Figures	Angelina Barone	Created Tables	Ranga Rutiser Sundar
Other Contributions			
N/A			
Problems Overcome			
The group managed to select the best design concepts that met the weighted user needs based on both end-user feedback and the Pugh Scoring Matrix.			

CD4: Grand Concept & Prototyping Plan			
Project Manager for Assignment	Angelina Barone		
Deputy Manager for Assignment	Dan Haikal		
Drafted Assignment	All group members	Revised Assignment	All group members
Reviewed Assignment	All group members	Proofread Assignment	All group members
Created Figures	Ranga Rutiser Sundar	Created Tables	Mira Faizul
Other Contributions			
N/A			
Problems Overcome			
The group was able to develop the final design concept and created a plan for the prototype.			

CD5: Prototype Design Requirements & Verification Plan			
Project Manager for Assignment	Mira Faizul		
Deputy Manager for Assignment	Ranga Rutiser Sundar		
Drafted Assignment	All group members	Revised Assignment	All group members
Reviewed Assignment	All group members	Proofread Assignment	All group members
Created Figures	Angelina Barone	Created Tables	Dan Haikal
Other Contributions			
N/A			
Problems Overcome			
The group managed to develop a Grand Concept Design to solve the issues with pet hair brushes and identify a plan to create a prototype for that concept.			