Auto Cat Toilet

Kolby Silim, Yuntong Lu, Paul Brown, Haoze Zhang

Abstract—**Both cats and their owners will approve of the Auto Cat Toilet. This device will be convenient for owners because they will no longer have to deal with the smelly excrement of their pets. The goal of this project is to construct an automated cat toilet device and an associated software application that will allow the user to control how the device operates after their pets have used the product. Our design has been completed and is compact, practical, and fully functional.**

I. Introduction

Since cats are liked by humans, people all around the world are interested in adopting cats as their pets or life partners. As computer engineers of the University of Utah, we have the responsibility and opportunity to create and improve upon the technology for cats and kittens in the world. This project will focus on a cat servicing machine which is called the Auto Cat Toilet (ACT). This toilet shall have a very presentable look, so that both cats and humans will love it.

This project has improved upon the foundation of existing cat toilet revolutions. In the past, traditional litter boxes required the owner to be responsible for maintaining the cleanliness of the pets waste. This has often led many households to be very filthy as cats and their owners are often spelled with disaster by dirty litter boxes [1]. People find that cleaning their pets waste is an unpleasant task. The best way to solve this problem is to design and create a machine that can clean the litter box automatically.

Thus, the main goal of the ACT is to benefit both cats and their owners by freeing the owners from the responsibility of cleaning dirty litter boxes. In order to do this, we have ensured that owners are able to control the machine using an associated android phone application and use weight sensors in order to drive the cleaning process.

Upon researching other types of automated toilet products on the market today, both hardware and software parts are needed to accomplish creating the ACT. Cats are supposed to experience a convincing and natural place for relieving waste and the owner should be able to trust that their cats are safe from harm. The outer shell of the ACT will be created using a 3-D printer. We have designed the toilet to function as comfortable as possible for cats to use, it is spacious enough for the cat to move around in as the cat is doing its business. The design of the ACT looks like Fig. 1.

As the ACT will be automatic, there will need to be several hardware components needed to drive the cleaning process. We have decided to use a shovel driven by a large stepper motor in order to initiate the cleaning process. The ACT will also use weight sensors in order to determine if it will activate the cleaning cycle.

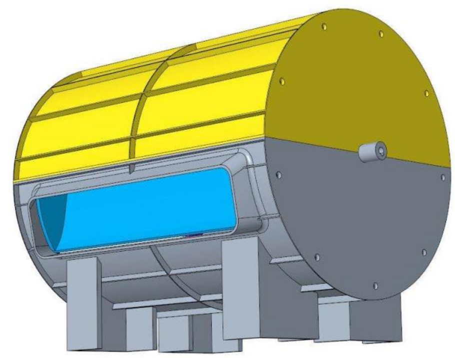


Fig. 1. Auto Cat Toilet design

Furthermore, the ACT would not be modern enough for today's standards without an application for an owner to communicate with the device. Since the goal for his project is to make the litter box more modern, an android application will be designed for the owners to track data from the ACT and control the device through their phones.

Since we don't want our users to worry about the status of the ACT at any given point, they can view when their cats use the toilet. As cats are using the ACT, numerical data will be collected and displayed; this is especially useful for people who want to know their cats physical data on a daily basis. For example, knowing when their pets use the toilet can be useful when trying to train kittens. Knowing the weight of a cat could also be beneficial for people who want to know how healthy their cat is, especially for a cat with health issues.

II. Background

A. History of the automated litter boxes

One of the earlier technologies of automatic litter boxes was patented by Peter Orgias. This patent created a framework that many other existing technologies follow. The Interactive automatic kitty litter box has a base that activates a retractable cover when the motion sensor detects a pet. As the cat approaches the litter box, the cover opens revealing the base for the cat's use. A camera and a phone app allows the user to track their pet. This design uses a solar panel to power the electronics [2]. Although this design does not have an automatic scoop functionality, the cover has a similar function of triggering when the pet is present.

Another design that was patented by Donald D. Reitz uses a shovel that rotates around a round housing. This shovel has slots for the litter to pass through and catch the cat waste. There is an opening for the waste to go as the shovel is spinning. However, this design is a manual process where the user has to activate the shovel to spin [3].

B. Hardware Related Work

In terms of related work, there have been several attempts by different companies that have managed to create an automated litter box. We have found information on different brands and there are some key functionality components that are common for this type of product. Firstly, it must be noted that there are very few produced machines that have incorporated a phone application. We have taken two of the automated cat litter boxes on the market today and will give a critique on how their results have been for general public consumers; the two products are the Litter Maid Mega and the Litter-Robot 3 Connect.

The simpler of the two products is the Litter Maid Mega; it uses an infrared sensor to detect when a cat enters the box and after 10 minutes, triggers a scoop which collects the droppings and deposits it into a disposal box [4]. For more details on how the machine looks like refer to Fig. 2. The Litter Maid Mega was first introduced in Japan by a company named Tokyo Harvest Japan [4]. In our research of the Litter Maid Mega, we found that there were a lot of customers who had issues regarding the functionality of the device. The shovel would often get stuck when emptying the litter box and users would have to reset the machine several times before the litter box was completely clean.

Fig. 2. Litter Maid Mega [5]

In order to improve upon the technology of the Litter Maid Mega device, we are going to design the ACT to have better mechanisms. We want to focus on improving two aspects of the Litter Maid Mega, the sensor and the shoveling system. Detecting a cat using an infrared sensor was an option that we considered, but using a weight sensor would improve the functionality of the ACT. With the weight sensor, we could retrieve more data while also maintaining the automatic functionality. For the cleaning design, we aim to have the shovel travel vertically up and down on a rotating hinge system to ensure that the waste will not get stuck inside the bowl. After the shovel has scooped up and retracted into its compartment, the waste will naturally fall into a trash bin hidden inside the ACT.

The second existing technology is called the Litter-Robot 3. This technology is very advanced as this model has an associated mobile application that has several unique functions. This model is an improvement to its previous generation the Litter-Robot 2. Even with the second generation model, this automated cat litter box was ahead of its time; there was no mobile functionality, but still performed the function of cleaning cat waste in a efficient manner [6]. The upgrade from the Litter-Robot 2 to the Litter-Robot 3 was that the sensor was changed. In the former, a weight sensor was attached to a ledge protruding from the machine, in the latter the sensor was changed to an infrared sensor.

The outer shell of both the Litter-Robot models is complex; it has an entire rotating body that the cat can fit into. For reference please refer to Fig. 3.

Fig. 3. Litter-Robot3 [7]

After researching this product, it doesn't appear that anyone has had an issue with the product itself. It is worth mentioning that this product is at the highest echelon as the price for this litter box is $500. As a group, we do not think that the revolving nature of the container is necessary. Its main advantages are that the smell will be contained within the litter box and the litter is not exposed to the outside environment. The main issue with this product is that the price is very expensive; for the same amount of money, you could buy 5 or 6 Litter Maid Mega devices.

C. Software Related Work

An example of related work regarding software is a mobile application made by the Litter-Robot 3 Connect. This interface displays a graphic that tracks the level of waste, shows times of the litter box cleaning, and a graph tracking the amount of uses each week/month. More detail about how it relates to our design will be discussed in a later section.

III. Project Construction

Since we have already designed, assembled, and tested the implementation of the ACT, we are going to discuss the process in how we finished the project. First, we will go into detail about the specific roles that each member had during the development of this project. Then, we will discuss the contributions that have been made by each member for the completion of the project. Lastly, we will discuss details about the final implementation of the project that was used for a demonstration for the public.

A. *Group Management/Communication*

The group breaks down into these roles. Kolby is the leader and monitored how progress was being made on the project. He also had the responsibility to communicate with the rest of the members if any changes were made during construction of the project. Paul is the communication between the professor and the group. He was in charge of weekly updates for the progress of the project. If there were any issues that the group ran into and the issue was addressable by the professor, he was be the one to do so. Paul also took the position of the main coder for the android app as Haoze's situation was difficult. Lu is the contractor, he was in charge of researching the parts needed for the project; while the other members helped in his research, he was the one who decided what components were used for the project. Haoze was in another country for the majority of the initial development phase, but he was the reason we were able to test the 3-D printing designs before deciding to ship the device from China to America. He is in charging with 3-D printing details and assemble wholes parts together then do the test.

During construction of the project, two people were assigned as mini-partners. Kolby and Paul were in charge of creating the application and the integration of hardware components. Lu and Haoze were in charge of the designing, printing, and testing of the device body while Haoze was abroad. If one of the mini teams needed help, the entire group would help each other figure out the problem. For normal updates, Discord was used to communicate effectively and swiftly during the course of the construction. When more difficult tasks needed attention, like helping each other with coding or needing to share more information on a local computer, the group met on a call to discuss the next course of action. As a group, the team met once a week to update each other on the progress that each mini team made during that week.

B. *Bill of Materials*

The Auto Cat Toilet needs a physical body and several hardware components. The following explains the materials used. The individual parts will be listed in the order of part number, product description, unit cost, vendor. Refer to Table I.

TABLE I
BOM

Hardware Component	Component	Price	Obtained From
IG-C-PLAPRO300H1	3-D printing material	24.88	Amazon
LRS-350-24	24V power supply	29.67	Amazon
24HS39-3008D	Nema 24 Motor	45.89	Amazon
DM556T	Motor driver	47.39	Amazon
ST-M2	Mounting bracket	5.66	Amazon
B010N1SPRK	ESP8266	6.99	Amazon
SEN-10245	weight sensor	10.95	Sparkfun
B07J5J34HQ	motor coupling	6.99	Sparkfun

IV. Hardware

For the physical body of the project, we decided to use a 3-D printer to generate the geometric parts. We found that the 3-D printer provided by the Marriott Library and/or the 3-D printer from the University's Senior Hardware Lab was not enough to print the design created by Lu and Haoze. They realized that they needed to use factory 3-D printers in order to print the curves required in the design. We also found that the price of printing the design in America is far greater than it was to print in the country that Haoze was in. We purchased resin material in order to print the body of the device, shovel, filter, and the outer casing.

A. *Physical Device Construction*

To design the physical part of the device, Lu had studied the Computer-Aided Design (CAD) tools to make the whole design digital. Starting from the basic part of the design, Lu used Solid Works as the design software. After testing several small parts of the design, the real work can be started.

The first step is planning. Designing a device that meets our specifications was not easy. When Lu sketched the device, he referenced the Litter-Robot as a base for his design. In Fig. 3, by creating a cylinder-like design, the cleaning process would be much like a washing machine. The waste can be cleaned out to a waste hole. During the planning process, Lu found the routing table created in China; the base of the routing table is the metal hoop. This metal hoop has two layers. When the outer layer is fixed, the inter-layer can turn. This is the core component of the design. It is shown in Fig. 4.

Fig. 4. Metal Hoop.

After the planning process, we moved to the design phase using SolidWorks as the core software. To achieve the design, Lu followed online videos to learn the details of this modeling software. The bottom support was the least difficult part of the design. First, Lu created the curves shown in Fig. 1. After extending the curves and adding the four support squares, the bottom support is completed.

The top cover was also not as challenging because it used the same method as the bottom support. However, Haoze found that the original design was not structurally enough to support the overall housing. Lu asked the printing company to help and as suggested, a support bar was added.

Next, the shovel is another one the core parts of the design. To achieve this part of the digital design, Lu gained help from a friend that can model the shovel. After following the picture model, Lu used SolidWork to make the design look like the model. Then, with the help of the printing company, the shovel was printed.

The motor interface was the hardest part of the design. We tried four motors and had to change the motor interface design as well. The motor interface is formed by connecting part of the shovel and the motor's cylinder bar. The size of the interface depends on the size of the motor. For several weeks, Lu changed the motor interface before we found the right fit. The final schematic looks like the Fig. 1 Auto Cat Toilet Design. Also, the final construction of each piece from the schematic is from Fig. 5.

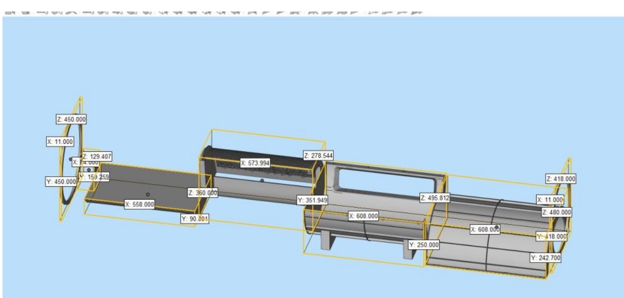


Fig. 5. Design Model

B. Printing and Testing

Since Haoze was in China, we decide to print in China, because price was much cheaper. After Lu finished his schematic, Haoze was in charge the printing details, then he contacted different companies to see if they were able to print the design. The first problem was finding the right material. Different materials such as Polylactic Acid (PLA) have been tested; But, this material has trouble creating curves. Even after successfully printing curves, the structure can be broken easily. Plastics was also considered for the material for printing, but this had the same problem with PLA. We decided to use resin because it was cheapest when compared to the other materials. It also had the quality to support curves, and it was easy to attach screw threads to connect the motor with housing.

Our first printing was a failure, printing parts had many problems. The curve was not perfect, the screw thread cannot be made after 3-D printing cool down etc. Whole parts cannot be assembled together. Haoze delivered problems to Lu, Lu redesigned schematics, then reprint, and let company attach screw threads during printing instead of after cool-down. After assembly, even though curve were still not perfect, whole parts could be attached together.

The printing method was another problem. Haoze checked the weight and percent of "Hollow". Hollow is the amount of resin that is used to 3-D print a structure. 0% hollow means that 3-D printed parts will be full of resin. 70% means that only 30 percent of the structure is filled with resin during the printing process, and this satisfied our needs for decreasing weight, so that a smaller motor will be able to carry the system since it is an anti-pulley mechanism which requires more force.

The second printed product was able to be assembled together but it got stuck when the shovel reached the bottom of the curve. This was the design that was ruined during the international shipping process. We then had to do a third printing; this time, Haoze built a wood box to cover the printed body. Lu redesigned the schematic to cut the length in half, the rest remained the same. For fear that the motors being tested at this point were not enough to drive the device, we cut the shovel in half as well for testing.

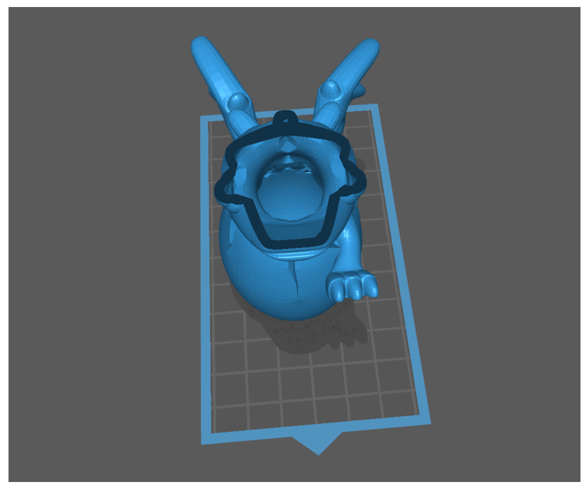


Fig. 6. Hollow printing method [8].

C. Hardware

As the main body of the device was being built overseas, Kolby and Paul were busy starting the application and implementing the hardware components. The first component successfully implemented was the weight sensor. Using a NodeMCU and the HX711 weight sensor, weight readings were being read through.

After building the main body for our device, we also needed to incorporate a number of hardware devices that will allow the ACT to be autonomous. The ESP8266 WIFI module is convenient for connecting the physical device with a phone application. We decided to use this development board because it is cheap and widely used. We also needed to control several motors using some circuit devices in order for the shovel and toilet to operate smoothly.

A motor driver was also considered and required for this project. The ESP8266 was only able to drive the motor with the motor driver which converted the current provided by the 24V power supply into the maximum current the motor was able to operate under. The hardware is also responsible for sending data to a Structured Query Language (SQL) database. With this data, the software group can receive the data from a SQL database wherever they are. To do so, we needed buy a hosting server to publish the database [9].

V. Software

Paul worked on developing an android app to act as a communication for controlling the functions of the ACT. The code can be found on our GitHub page [10]. The app was developed using Java, Extensible Markup Language (XML), and SQL. The integrated development environments (IDE) we used are Java software development kit (SDK) and Android Studio. We emulated a Pixel 2 device to test the functionality of the app. Our biggest goal was to use this app to control the ACT and monitor the cats behavior. For example, this app could give users statistics on how often their cats are using the ACT. In addition, we collected the cat's weight so that users can have an idea of how healthy their cat is. This means that ACT will not only be a toilet, but is also a way to track a cat's physical health.

We also familiarized ourselves with the concept of software design system. This outlines the basic processing flow of our application design: The processing flow includes the basic software structure, module division, function allocation, program interface design, user operation design, data structure, and error handling design etc.

Classic software structures were used including graphical user interface (GUI), back-end, and databases.

Fig. 7 is an example of another mobile application made by the Litter-Robot 3 Connect. We implemented more features to our application such as displaying the cat's weight, having an accessible layout that is intuitive to use for controlling the toilet. We made the user interface (UI) simple to look at but very functional at the same time. Our graphics contain some cat-themed elements that were not overly stylistic. The development of the software portion was divided into 4 sections.

1) Layout of the program using XML for the basic layout and format.
2) After the layout has been created, we will used Java to read the XML and begin programming the main application to communicate with the SQL database.
3) An emulator will run the app on a simulated android phone. This will allow us to view what the user will see in the app.
4) Optimization on graphics, GUI, and the main program.

A. Schedule and Milestones

We ended up meeting our milestones but from September we had to shift our projections to a month later due to a shipping problem that will be discussed later. For better reference, refer to Table II and Table III.

TABLE II
Software Milestones

Phase	Action	Dates
1	Familiar with all tools	3/16/2020 - 4/16/2020
2	GUI program	4/16/2020-5/16/2020
3	Back-end program	5/16-2020-6/16-2020
4	Connect to databases	7/1/2020-10/20/2020
5	Optimization and Testing	10/21/2020-Demo day
6	Modifications and improve	10/21/2020-Demo day

TABLE III
Software Milestones

Phase	Action	Dates
1	Purchase components	3/16/2020 - 4/16/2020
2	WIFI Module	4/16/2020-5/16/2020
3	Motor Driver	5/16-2020-6/16-2020
4	Geometric designing	7/1/2020-10/20/2020
5	Install component	10/21/2020-Demo day
6	Connecting with software	10/21/2020-Demo day
7	Testing, Fixing, Updating	10/21/2020-Demo day
8	Ready for Demo	10/21/2020-Demo day

VI. Testing and Integration Strategy

1) Hardware Testing: There were two parts that were required in testing the hardware. First, we needed to ensure that the ACT will transfer data through the WiFi module. The second part is to test that the ACT will actually perform the function of automatically scooping cat waste.

Since the weight sensor was easily attainable at the start, it was the first component to be tested. Setting up the weight sensor was the most difficult part. It required the use of Soldering in order to ensure that the pins were properly connected with the attached PCB module. There was enough power provided by the NodeMCU to power this device which was connected through 4 pins. 3.3 V VDD, Ground GND, DT, SCK were the pins used. DT and SCK are the data values that were sent from the sensor to the NodeMCU so that it could be send to the database.

Next, we obtained a couple of steppers motors in order to test if they would be big enough to handle the stress of driving the shovel in the ACT. The first couple of motors were far too weak to drive the system, it wasn't until we got a 4 N/m motor that we were successfully able to drive the shovel through somewhat gritty litter for the system to work. Programming these motors had to be done through their associated motor drivers provided by the manufactures who distributed the motors. Programming the motors was not difficult as the correct configuration is needed to have the motor spin and these configurations were given in the manuals of these devices.

After 3-D printing the required materials and constructing the ACT with the integrated hardware, driving the motor was the next task. This is used for spinning the shovel to start the cleaning process. To simulate how the consumer will use it, we used mud to represent cat waste and cat litter. The shovel will rotate around the motor attached from the outside in the counter clock-wise direction. The shovel contains slots for the mud to be caught and the litter to filter back into the bowl. We were only able to test this function a month before the project was to be complete because of the shipping issues discussed later.

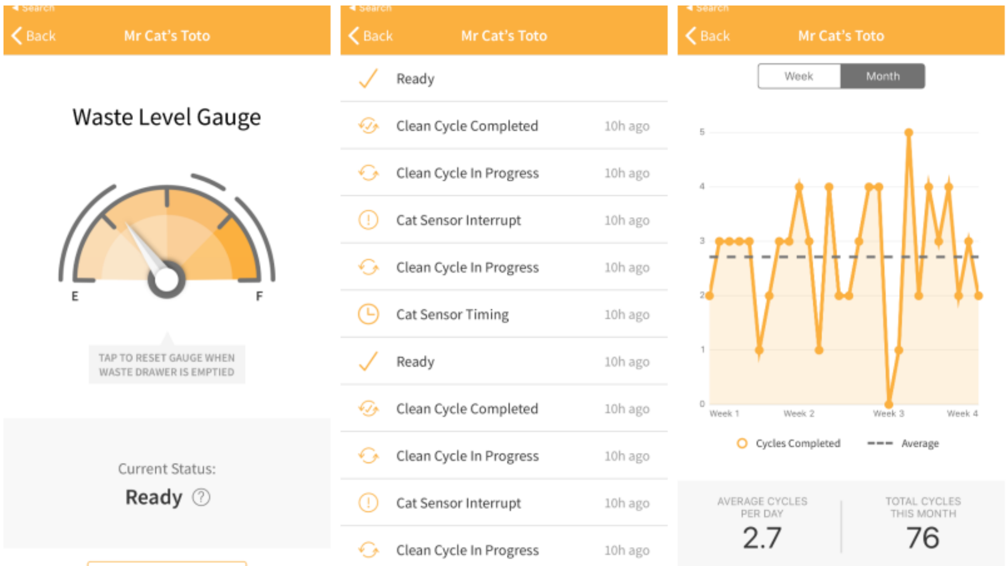


Fig. 7. UI example [11].

2) Software Testing: We developed and tested the software concurrently while the hardware was being made. For the software portion, we first built a GUI interface for interacting with the litter box. It includes options like controlling the shovel and displaying the data of the cat in some form. To display a chart and gauge, we researched open source options and tested them until we found ones that worked well with reading our database values. Next, we created a communication channel between the hardware and software. These steps involved testing small applications first like activating LEDs, then progressing towards the motor drivers and sensors.

There was software for the android application and the hardware components which was done through the Arduino ino interface. In order to control the hardware components within the Arduino software, we used techniques like Interrupts to instruct the NodeMCU to turn on the motor for the cleaning process. Overall, for the purposes of this project, the design of the hardware code was not too complex. We utilized simpler pieces of code that worked together through delays, interrupts, and webserver html to complete this part of the project. The one issue that none of the group members could figure out was the implementation of the activate button directly controlling the motor. It was far too complicated and we could not find any resources that would help us figure out this implementation.

VII. Risk Assessment

Over the summer of 2020, we 3-D printed the original design and shipped it from China to America. During shipping, that design was damaged and we were left with a shovel that could not spin and cracks throughout the housing. This arrived in October and we quickly printed another body which arrived in November. We made modifications to the new body such as reducing the length by half to decrease the cost of printing another one. This new housing had no signs of damage and the shovel could spin properly.

Integrating the software with the hardware was the hardest challenge. Considering that we have not published an app before, we needed a way to understand how to make a user-friendly interface that interacts with the litter box in a meaningful way. Furthermore, we researched more about transmitting data between the app and the sensors we used.

Progressing towards a toilet that can spin at an appropriate speed was one of the big challenges. The motor's speed was adjusted through trial and error with factors being taken into account. This includes the amount of weight that the motor needs to overcome factoring in the shovel and the litter. Another risk was the timing the shovel to begin the cleaning process so that the cat would not be injured after using the device. Our design of the shovel must be a certain length and shaped to sync with the curvatures present in the body of the device.

The software design will be difficult with all the communication that we needed to setup. The application will communicate with the database. The ACT device will be controlled under multiple phones allowing for flexibility of the user. The user information will be different for multiple users and stored in the SQL. This will require extensive testing on how we will communicate with the SQL database to properly send and receive data.

VIII. Final Implementation

A. Hardware Results

For the final result of our device refer to Fig. 8. We were able to accomplish this design by opening the body of the device so that viewers are able to see what is happening inside the device as the cleaning process is activated. We set up the weight sensor so that there is a base for the device to sit on top of the sensor for accurate measurements. We further supported the device on the back side by mounting the motor and having

Fig. 8. Final Implementation

Fig. 9. Final Implementation Back

it rest on top of a plank of wood glued to the base of the device as shown in Fig. 9. We taped a trash bag to device where the opening is so that the waste would be emptied as the shovel has finished rotating. As for the hardware components we decided to put them in the back so that all the wires would be hidden from plain view as the device was being demonstrated.

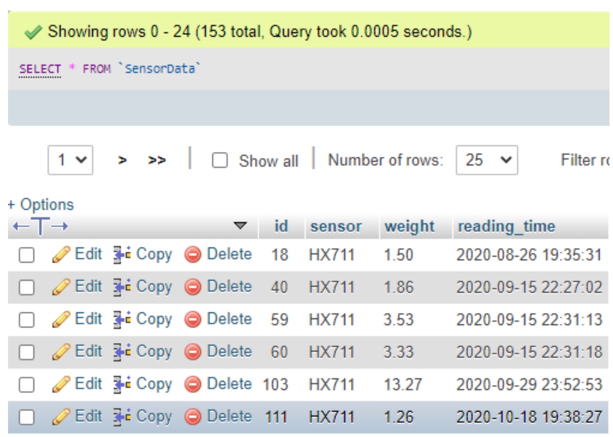
B. Software Results

The final android application implemented the described features. Referring to Fig. 11, we implemented a button to turn on the motor, a chart and a gauge to show the waste level. To turn on the motor, the user can press the activate button that will lead to a local web page with turn on and off buttons that controls the motor.

For the chart, it displays the cat's weight over a period of time that the database has stored. Each column represents one day and displays the most recent cat weight for the specific day. The y-axis is the weight in pounds and the x-axis is the date in the format YYYY-MM-DD. Clicking on one of the columns will show the user the specific weight data for that day.

To show the waste level, the gauge will display the amount of times the shovel has cleaned the waste into the waste bag. Once the user decides to empty the waste, they can press the empty button and reset the gauge to zero. This gauge number is saved locally on the phone to prevent the gauge from showing an incorrect number after the user exits and re-opens the application.

For the database, we stored each data with a column containing the data sent from the weight sensor. Referring to Fig. 10, there are four columns that contain the data. The two columns the application reads from are the weight and the reading time columns. The app reads the YYYY-MM-DD part of the reading time data and the weight to send those data in conjunction for the chart.



Showing rows 0 - 24 (153 total, Query took 0.0005 seconds.)

SELECT * FROM `SensorData`

1 > >> Show all | Number of rows: 25 Filter r

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	id	sensor	weight	reading_time
Edit Copy Delete	18	HX711	1.50	2020-08-26 19:35:31
Edit Copy Delete	40	HX711	1.86	2020-09-15 22:27:02
Edit Copy Delete	59	HX711	3.53	2020-09-15 22:31:13
Edit Copy Delete	60	HX711	3.33	2020-09-15 22:31:18
Edit Copy Delete	103	HX711	13.27	2020-09-29 23:52:53
Edit Copy Delete	111	HX711	1.26	2020-10-18 19:38:27

Fig. 10. Sample of the data stored in the SQL database.

IX. Conclusion

The Auto Cat Toilet was a very interesting project. It can not only improve the quality of life for cats by making the toilet environment more advanced, but also gives the owner a more convenient way to take care of their pets litter. The construction of the ACT device and phone application was built in a way for communication to happen between the

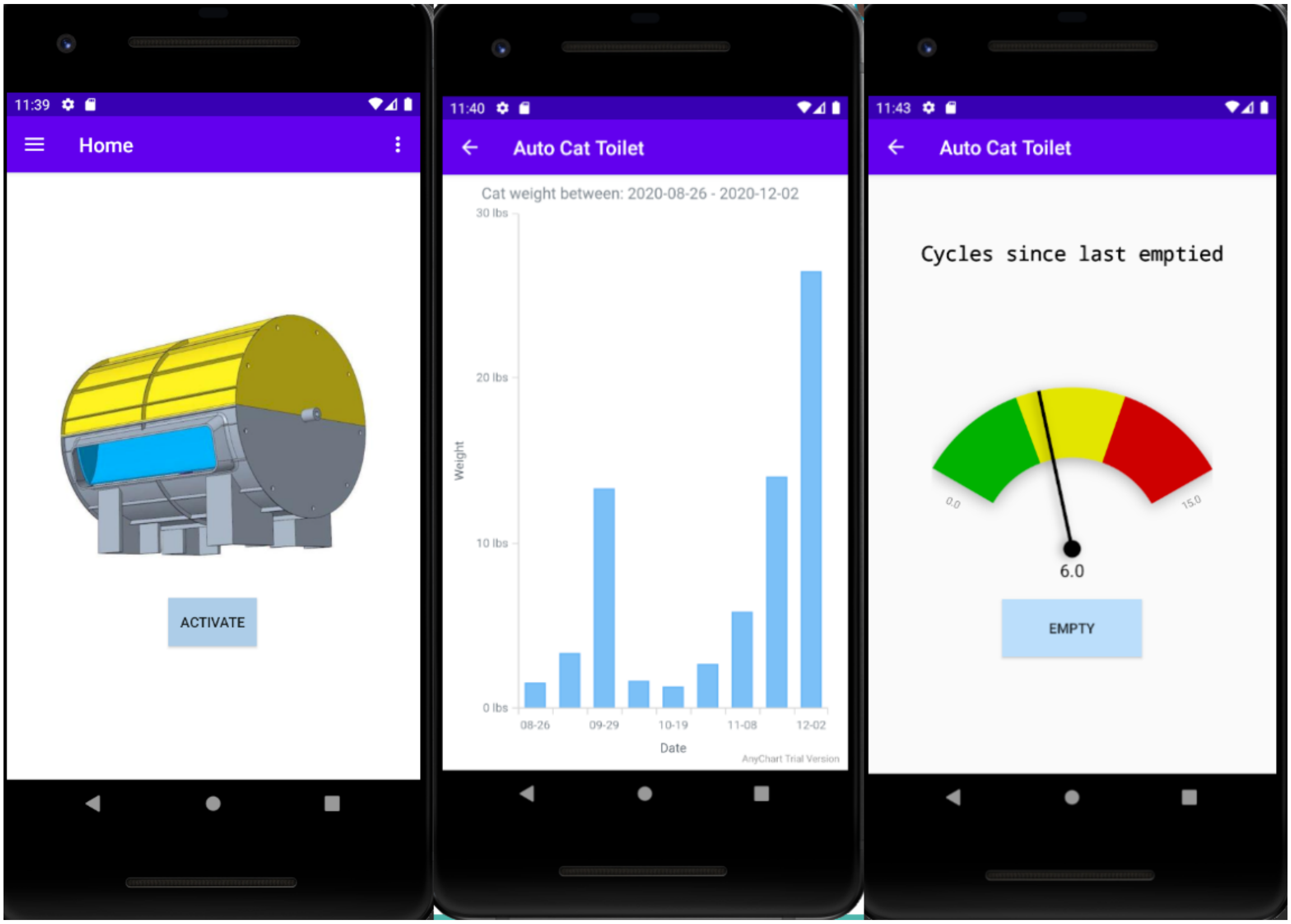

Fig. 11. Android application.

components. By the end of this project, we were able to demonstrate an automated cat toilet that has a bowl containing cat litter and a scoop to catch the cat droppings during the duration of the cleaning process. This cleaning process is then documented on the mobile app through the use of a database and visuals. For the demonstration, we were able to show that the ACT would run automatically when it detects that a cat is currently on the device through the weight sensor showing a reading above a certain weight threshold. As long as the weight threshold did not drop below 1, meaning that the cat was still on the device, the ACT would not start its cleaning process. We were also able to show that only the first reading is send to the database at any point while the cat is still using the toilet. The other function that we were able to show was that we can control the ACT through the android app with the activate button and a local web server.

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