

Self-cleaning Cat Litter Box

By

Jian Chen

Weiman Yan

Chi Zhang

Project Proposal for ECE 445, Senior Design, Spring 2021

TA: Xihang Wu

18 Feb 2021

Project No. 48

Contents

1	Introduction	1
1.1	Objective	1
1.2	Background	1
1.3	High-Level Requirement List	1
2	Design.	2
2.1	Block Diagram	2
2.2	Physical Design.	3
2.3	Functional Overview	4
2.3.1	Detection Module.	4
2.3.2	Control Module	4
2.3.3	Power Module	5
2.3.4	Motor Module	5
2.3.5	User Interface Module	5
2.4	Block Requirements	5
2.4.1	Detection Module.	5
2.4.2	Control Module	5
2.4.3	Power Module	5
2.4.4	Motor Module	5
2.4.5	User Interface Module	6
2.5	Risk Analysis	6
3	Ethics and Safety.	7
	References	8

1 Introduction

1.1 Objective

Cleaning the cat litter box might be the most disliked work for people who have cats. First of all, the cat litter box is smelly and hard to clean. While people need to bear the bad smelling, they also need to use shovels to find droppings of the cat. Since the droppings are small, it is usually time-consuming to only remove the droppings. Second, cleaning the cat litter box needs to be done everyday, which makes this job even more tedious.

Therefore, we want to design a self-cleaning cat litter box to help people. As its name suggests, the self-cleaning cat litter box could clean the cat litter box and bag the waste automatically and remotely. People would be able to use an app on devices to control it to save time and effort.

1.2 Background

Self-cleaning cat litter box is an existing product. However, many in the market have some downsides. Some products, like the “ChillX AutoEgg” [1], do not support remote control features. Another product, the “Litter-Robot 3 Connect” [2], is WiFi-enabled and is known as the best smart self-cleaning litter box in the market [3]. However, the cost of the product is nearly \$ 500, which is not a friendly price to most cat owners. Most importantly, nearly all products in the market could only deposit waste into a drawer or plastic bag but not fully seal the waste bag, thus the smelling is still bad inside the box and the parasite from cat waste may cause infection [4].

Our design aims to solve these problems. We want to make the Self-cleaning cat litter box to be more affordable for most people. Also, with the auto-bagging and IoT, this design could really save people from the painful work of cleaning the cat litter box.

1.3 High-Level Requirement List

- This system must be able to remove at least 90 % of the waste from the litter box.
- The user must be able to remotely control the system under wifi environment with 95 % reliability.
- The project must be as low-cost as possible, ideally under \$ 300.

2 Design

2.1 Block Diagram

The design contains five modules for successful operation: a detection module, a control module, a power module, a motor module, and a user interface module. The power module ensures the system can be powered all the time with proper 5 V for control module and 12 V for motor module. The control module contains an ESP8266 microcontroller. It would be used to control the motor module for cleaning and bagging, the detection module for notice the cat's usage of the box, and the user interface module for manually and remotely control the machine.

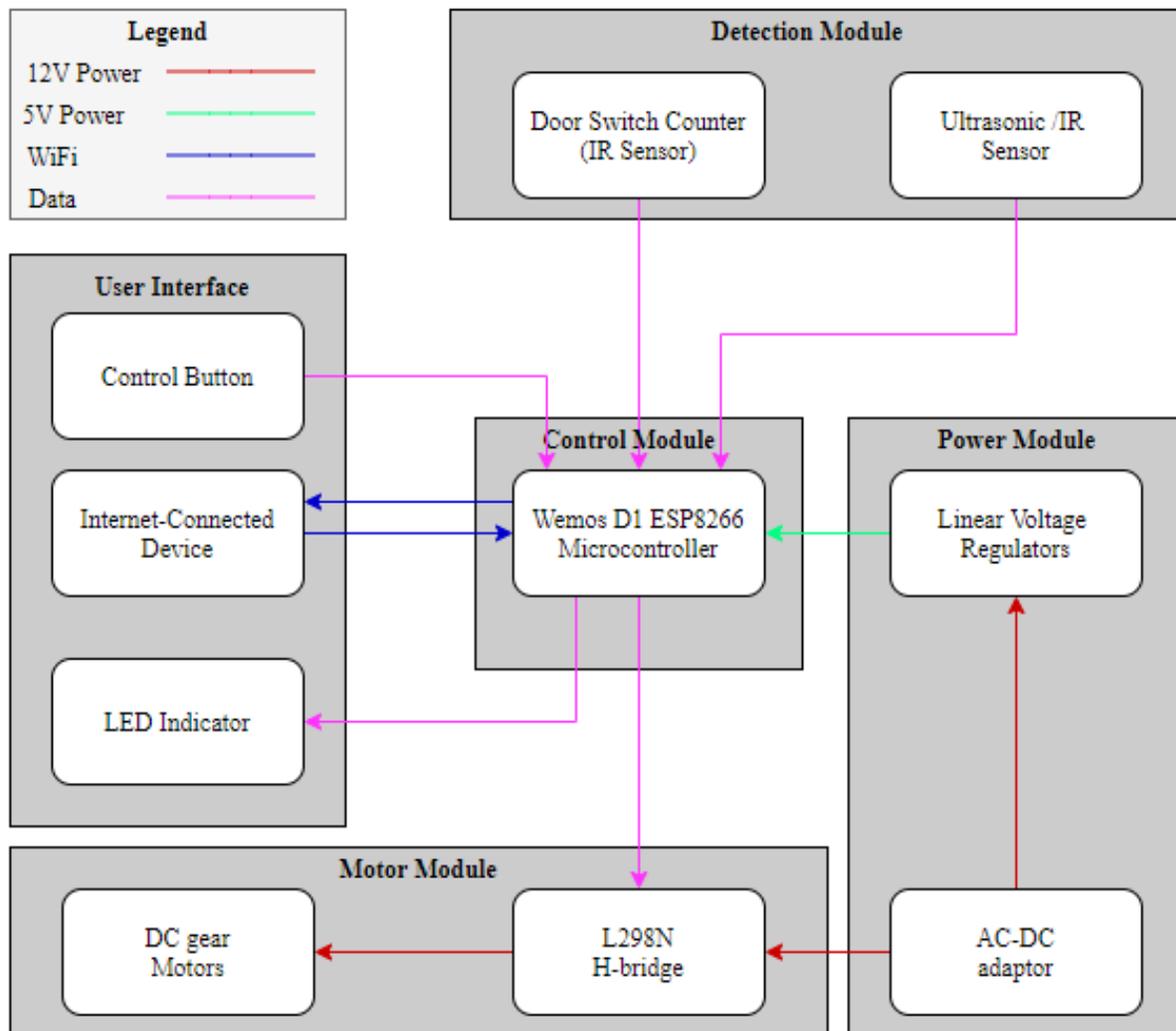


Figure 1: Block Diagram

2.2 Physical Design

The litter box will be a boat-shape box with around 40 "(1 meter) in length, 20 "(0.5 meter) in height, and 20 "(0.5 meter) in width. We plan to design a comb shape cart to do the filter work. The size of the comb-gap should be around 1 cm which would be sufficient to let the cat litter through but gather the waste. The comb cart is controlled by four motors that can move along the sidewall of the box. The cart has two modes of motion: one is pushing from one side to another to do the filtering; second is pushing the waste up to pour it into the plastic bag. An open pouring area would be made at the back of the box. Motors would be used to operate the auto-bagging function by pulling two strings to tie the bag.

Front View with Cover

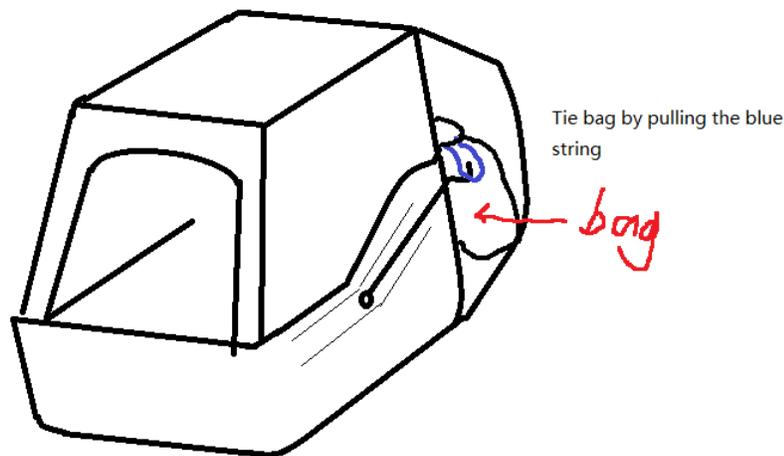


Figure 2: Front View with Cover

Inside View

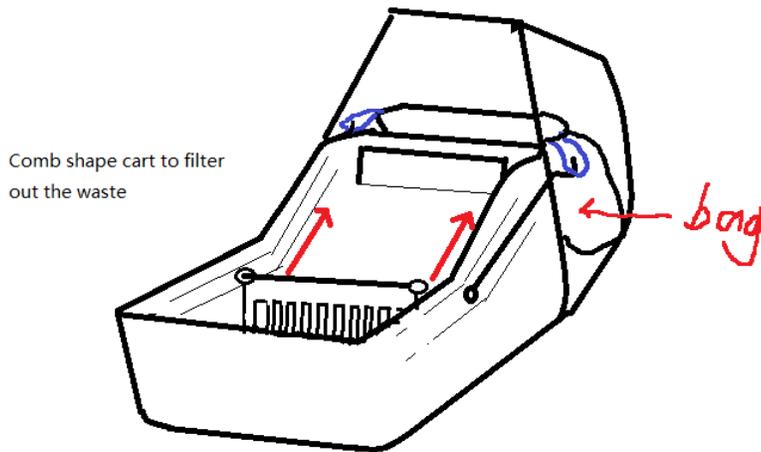


Figure 3: Inside View

2.3 Functional Overview

2.3.1 Detection Module

The detection module contains two parts: Door switch counter and Ultrasonic/IR sensor. The door switch sensor is used to count the number of times the cat has entered the box. If the counter reaches the trigger number, the control module would send a notification to remind the user to clean the cat litter box. The Ultrasonic/IR sensor is used to detect whether the cat is inside or near the litter box. If so, the machine should stop running for safety.

2.3.2 Control Module

The control module is an ESP8266 micro-controller [5] used to control the filter motors to move along the track and the bagging arms to close the waste bag. If it receives the command from remote apps or someone pushes the button, the control module could send signals to the motors and bagging arms so the litter box could start to clean itself.

2.3.3 Power Module

The power module should be able to drive the motors and support other electrical devices involved in our design. The system would be powered all the time with an AC-DC adaptor. A voltage regulator will convert input voltage to voltages usable by the corresponding components.

2.3.4 Motor Module

The motor module consists of several motors. It should be able to carry the comb shape cart to move along the rail smoothly. It also should be able to drive the bagging arms to bag the waste.

2.3.5 User Interface Module

The user interface module should be mainly implemented in the frontend of the app. It should be easy to understand and control. The physical interface is a button and a LED indicator for working status. Specific instructions about them should be attached. The ESP8266 will be able to communicate with the app under WiFi environment [5].

2.4 Block Requirements

2.4.1 Detection Module

1. The sensor on the door must be able to detect the cat entering the litter box.
2. The sensor could work under the dark environment.
3. The sensor should not mistakenly detect other irrelevant stationary stuff.

2.4.2 Control Module

1. General purpose IOs (GPIOs) must be able to control the H-bridge to drive multiple motors.
2. The cat litter box must be able to be controlled by both physical buttons and remote apps.
3. The response time must be within a reasonable time period, ideally 5 second.
4. When the comb shaped cart gets stuck, it should be able to adjust its position.

2.4.3 Power Module

1. The voltage regulator should be able to convert the battery output to 5 V and 12 V for the active component

2.4.4 Motor Module

1. The module must be able to carry the comb shape cart to move along the track smoothly.
2. The module must be able to drive the robotic arms to bag the litter.
3. The motors should be as quiet as possible.

2.4.5 User Interface Module

1. A user interface needs to be accessible in a browser through an internet connected device (computer/phone).
2. The button should be able to be pushed.
3. The LED indicator should be able to show the working status.

2.5 Risk Analysis

Detection module is the most risky part of the whole project. Since cats usually move fast and it is hard to trace their movements. It is really important that the sensor can detect cats and make a quick reaction to protect their safety. Also, the sensor has to correctly detect that the cats get inside into the litter box instead of just hanging out there. Since we want to notify users when to start the machine to do the cleaning job after a certain amount of time that cats use the litter box. So we have to make sure that it can work efficiently to send the signal to users at the correct time. The major difficulty that we encounter might be the way that we analyse the data collected from the sensors. We are considering using ultrasonic sensors, while the frequency that the ultrasonic sensor generates is often within 25 - 50 kHz and cats can hear frequencies from 48 Hz - 85 kHz. [6][7] It is possible that ultrasonic sensors will annoy cats that they don't want to use the litter box. We could also use IR sensors instead but IR may not have enough accuracy that we want.

The motor module also has a relatively high risk to successfully complete the task. We want to seal the bag up for convenience, and string and heating are methods we are considering. For string methods, the difficulties are the design and movement of the robotic arm controlled by the motor and it is hard to completely block the odour. For heating methods, heating plastic might generate some toxic gas that might hurt cats and have bad smells [8]. We would need long term testing and debugging to find the best solution.

3 Ethics and Safety

There are some safety related issues for this project. First of all, the motors of the cat litter box are controlled by the control module. The movement of the comb shaped cart and robotic arms could potentially hurt humans. Once the motors start to move, there is no way to stop it. According to the #1 of IEEE Code of Ethics [9], we come up with several solutions to prevent the misuse. We also have an LED indicator to show if the cat litter box is cleaning itself. Visible instructions would warn people not to put their hands in the box when the LED is red, which follows #2 of IEEE Code of Ethics [9].

By communicating with an ESP8266 micro-controller, the remote app will constantly collect data from the cat litter box. Since the box would most likely sit in the house, it is possible to be a threat to user's privacy. According to the #1 of IEEE Code of Ethics [9], we would notify the user about the data collection and only collect the data if the user approved. Also, we will encrypt the data to protect the users from hackers. There are sensors on the box to detect the cat. It has the probability to be misused to detect people living in the room. To prevent such cases from happening, we need to make sure that the sensor could only detect the cats around the cat litter box.

One issue we might encounter is that: After testing with simulated waste and cats, we would need to have real cats as users to test our product. Since our circuit or the movement of the comb shaped cart has the possibility to hurt cats, we would have to address this potential threat according to Animal Protection laws of Illinois [10]. We need to make sure all our circuits are covered by insulation material and not exposed outside. We also have sensors to protect cats from staying around the box while it is working. We would put limits on the speed and movement distance of our comb shape cart to ensure that even if it crushes the cat, it would not cause much damage.

References

- [1] Chillx.co, “Chillx autoegg self-cleaning litter box,” Online, accessed: 17-Feb-2021. [Online]. Available: <https://chillx.co/products/chillx-autoegg-self-cleaning-litter-box-1-modern?variant=32121145229361>
- [2] Litter-robot.com, “Litter-robot 3 connet,” Online, accessed: 17-Feb-2021. [Online]. Available: https://www.litter-robot.com/litter-robot-iii-open-air-with-connect.html?sscid=21k5_ht1sz
- [3] Goodhousekeeping.com, “7 best self-cleaning litter boxes, according to home care experts,” Online, accessed: 17-Feb-2021. [Online]. Available: <https://www.goodhousekeeping.com/home/cleaning/g31206600/best-self-cleaning-litter-box>
- [4] C. for Disease Control and Prevention, “Parasites – toxoplasmosis(toxoplasma infection),” Online, accessed: 17-Feb-2021. [Online]. Available: <https://www.cdc.gov/parasites/toxoplasmosis/index.html>
- [5] E. Systems, “Esp8266ex series datasheet,” Online, accessed: 17-Feb-2021. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf
- [6] J. M. Armingol, J. Alfonso, N. Aliane, M. Clavijo, S. Campos-Cordobés, A. de la Escalera, J. del Ser, J. Fernández, F. García, F. Jiménez, A. M. López, M. Mata, D. Martín, J. M. Menéndez, J. Sánchez-Cubillo, D. Vázquez, and G. Villalonga, “Chapter 2 - environmental perception for intelligent vehicles,” in *Intelligent Vehicles*, F. Jiménez, Ed. Butterworth-Heinemann, 2018, pp. 23–101. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/B9780128128008000023>
- [7] H. E. H. R S Heffner, “Hearing range of the domestic cat,” *Hear Res*, vol. 85, no. 41, p. 8, 1985.
- [8] H. H. Publishing, “Is plastic a threat to your health?” Online, accessed: 17-Feb-2021. [Online]. Available: <https://www.health.harvard.edu/staying-healthy/is-plastic-a-threat-to-your-health>
- [9] IEEE, “IEEE code of ethics,” Online, 2016, accessed 17-Feb-2021. [Online]. Available: <http://www.ieee.org/about/corporate/governance/p7-8.htm>.
- [10] Aldf.org, “Animal protection laws of illinois,” Online, 2020, accessed: 17-Feb-2021. [Online]. Available: <https://aldf.org/wp-content/uploads/2020/12/Animal-Protection-Laws-of-Illinois-2020-Animal-Legal-Defense-Fund.pdf>.