INTEGRATED SENSORS

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ABSTRACT

The purpose of this report is to explain the results of our real-world product development project. The explanation of how our team approach and finalize the conceptual design into final product. The process involves our design process, solution, research, and assumptions, which will all included in the summarization of the work that had been done in each deliverable to justify our final solution is most appropriate one. Furthermore, there is also a clear description for the plans of how the product will be attach into Bowie.

TABLE OF CONTENTS

LIST OF FIGURES:

LIST OF TABLES:

INTRODUCTION

Problem Motivation

Bowie from Robot Missions is a robot that travels through the sandy Ottawa beaches and picks up after OUR waste. There are five different replicated robots and these robots have collectively travelled over 1200 meters, collected 3.1 kg of non-natural debris.

Our clients terminate goal is to improve the natural environment by achieve serval applications, such as environmental clean-up, observation, and rehabilitation, with the help of robots. Thus, come up useful ideas and create valid prototypes that can add to existing robot as an accessory to improve the efficiency of robot for environment restoration are the needs of clients. Furthermore, the robot had already tested for the applications of clean up small size population, wild observation, and artic exploration during the summer.

User's Requirement

There have been various updates for the robot since the organization was started by Erin Kennedy in 2016, but the robot still experiences its troubles and requires maintenance at times.

The continuous intake of soft sand creates a problem for Bowie when the robot is travelling through sand. A key focus is having a secure storage where Bowie can go to, to dock and recharge when placed there. Erin wants to also focus on wildlife monitoring and remote surveillance adapted into the robot. When there is rainfall, the user will usually just place a raincoat over Bowie in order to protect it from the rain, but it is not very efficient. Another problem is the breaking mechanics for the robot, as it can sometimes hit a hard object and cause the robot to lose control/tip over.

Design differentiation and Key aspects

The main idea of the design is to improve the major requirements in the problem statement- wildlife monitoring and breaking system. We intensively to put one infrared sensors in the front of the robot to detect the temperature of the wild life two detective sensor under the end effector of the robot to predict braking. In addition, we adding a temperature and humidity sensor to hence the function of environmental detection.

The sensor under the end effector will help robot to detect barrier in front of it, and it is set up in 15-degree respect to horizontal and plus itself detective angle that will leave a blank area which not be detected as the safety/braking distance to ensure robot will not crash with barriers while

braking. The temperature sensor used to send the average atmosphere temperature back to the robot, and the system of robot can used it as the standard to find the difference between the atmosphere and object's temperature, and according to this difference, robot can decide whether the object is wildlife or not.

Thus, our primary idea is using several types of sensor to create an integrated system to improve wildlife monitoring and braking system.

MAIN BODY: SUMMARIZATION OF ALL DELIVERABLES

In order to enable our team to keep our tack and be more effective to develop and finalize the product, our group decide to choose design thinking as the appropriate design process to follow due to the following reasons: our project requires to have empathy with clients in the purpose of getting both their needs and feedbacks, it is essential to discuss and prioritize the needs and decisions with clients before add new or eliminate old functionalities to/from the prototype, each modification require the generation of new ideas and then use the prototype to establish these priorities with the clients, and finally iterate the proceeds to constantly refine our prototype to the final product.

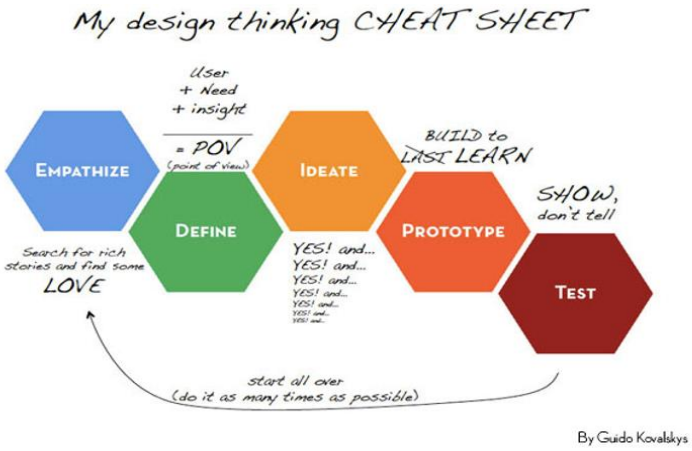

Figure 1. Illustration of Design Thinking Process.

The following subsets will present our critical components during the design process. Not only is to illustrate how we approach our final product step by step, but also justify that our final solution is the most appropriate one.

Need identification and product specification process

Targeted client' needs:

Table 1. List of prioritized needs of client

Number	Needs	Importance (5-1)
1	Reduce the amount of intaking soft sand.	4
2	Short battery runtime	3
3	Better wildlife monitoring and remote surveillance.	2
4	Have the ability to works in certain weather.	4
5	Undependable Breaks.	5

During first client meeting, Erin mentioned that there is not a way yet for robot to deal with the situation of roll-over, which means if the robot flips over, the robot will return back to work only if people find it and flip it back. This process will definitely involve extra works and reduce the efficiency of robot, so we rank this as most important need. Secondly, both continuous intake of soft sand and cannot works in certain weather are big limitations for robot, so we rank these into second importance. The problems of 'charge manually and often' and 'wildlife monitoring and remote surveillance' are the minor limitations which will not affect the efficiency and ability much, so we give them importance of 3 and 2 respectively.

Product specification process

1. Problem statement:
   A need exists for Robot Missions to improve the functionalities and efficiency of Bowie robot for environmental restoration by create several types of sensors to improve its objects detection, wildlife and environmental monitoring.
2. Need translation into design criteria:

Table 2. List of design criteria

#	Needs	Design Criteria	Importance (5-1)
1	Reduce the amount of intaking soft sand.	Shaking frequency (Hz), Motor capacity (Kg-cm), Size of storage tank (mm), Weight (Kg)	3
2	Short battery runtime	Battery capacity (mAh), Charging voltage (V & A), Amount of charging platforms	4
3	**Better wildlife monitoring** and remote surveillance.	**Number of Cameras & Sensors,** GPS & GPRS,	2
4	Have the ability to works in certain weather.	Configuration/Size of robot platform (mm),	4

		Operation Temperature (Celsius),	
5	**Undependable Breaks.**	**Weight (Kg), Stopping distance (mm), Performance of Sensors, Response time (s)**	5
6	The Robot is low cost.	Cost ($)	2

3. Benchmarking:

Table 3. List of benchmarking information about ultrasonic sensors

Sensor Device / **Specifications**	**Kuman Ultrasonic Distance Measuring Sensor**	**Smraza Ultrasonic Distance Measuring Sensor**	**Elegoo Ultrasonic Distance Measuring Sensor**
Company	Kuman	Smraza	Elegoo
Cost	$13.19	$13.29	$12.54 CAD
Voltage	5V	5V	5V
Static Current	Less than 2mA	Less than 2mA	-
Sensor Angle	Less than 15°	Less than 15°	Less than 15°
Detection Distance	2cm-450cm	2cm-500cm	2cm-500cm
Date released	Feb 23, 2016	May 24, 2017	June 11, 2016

Due to the reason that our solution is using integrated sensor, our group is more focus on the techniquical information about sensors, instead of ideation.

4. Target specification:
   a) Functional Requirements:

Table 4 Functional Requirements

#	Imp	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method
1	3	Shaking frequency for storage tank	=	5 ~10	Hz	Test & Analysis
2	3	Charging voltage for robot	=	3.3V at 0.5A, 5V at 3A, 6V at 8A	V & A	Background information
3	5	Breaking/stopping distance	<=	0.3	m	Test
4	5	Time of detect and response	<	1	s	Test
5	2	GPS & GPRS	=	Yes	N/A	Test
6	4	Breaking Speed for breaks/sensor	>	0.4	m/s	Test & Analysis
7	**5**	**Sensor Angle**	**<**	**15**	**degree**	**Test**
8	**5**	**Sensor Current**	**<**	**2**	**mAh**	**Test**
9	**5**	**Sensor detective distance**	**=**	**2~500**	**cm**	**Test**
10	**5**	**Sensor voltage**	**=**	**5**	**A**	**Test**

b) Non-functional Requirements:

Table 5. Non-functional Requirements

#	Imp	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method
1	2	Number of cameras & sensors	>=	2	N/A	Test
2	1	Aesthetics	=	Yes	N/A	Test
3	2	Product life	>	5	Years	Test
4	2	Number of charging platforms	>	2	N/A	Test

c) Constraints:

Table 6. Constraints

#	Imp	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method
1	3	Weight	=	3	Kg	Test
2	4	Motor capacity	>=	6.8	Kg-cm	Test
3	3	Size of storage tank	=	30 x 10 x 60	mm	Analysis
4	3	Specialized outfits size for different weather (Platform)	=	100x100x60	mm	Analysis
5	4	Operation Temperature	=	-5 ~ 30	deg C	Test
6	4	Battery Capacity	>=	5000	mAh	Test
7	2	Cost of sensors and other related accessories	<=	100	$	Estimate, final check
8	2	Maximum Payload	>=	0.8	Kg	Test

Conceptual designs:

During this step, our group firstly generate three global conceptual design and then apply our design criteria to select one of the best designs for forward development.

1) Overall Explanation of first global design:

   In this design, we are using for detective sensors in each corner of the robot to help robot trigger braking effective and avoid flipping. In order to do this, sensors will detect the distance between itself with big barriers to predict whether trigger braking or not, and each sensor's detective is in 15 degree, which works as a spirit level, to ensure there is not a big angle difference respect to original to avoid flipping.

2) Overall Explanation of second global design:

   The sensor under the end effector will help robot to detect barrier in front of it, and it is set up in 15-degree respect to horizontal and plus itself detective angle that will leave a blank area which not be detected as the safety/braking distance to ensure robot will not crash with barriers while braking. The temperature sensor used to send the average atmosphere temperature back to the robot, and the

system of robot can used it as the standard to find the difference between the atmosphere and object's temperature, and according to this difference, robot can decide whether the object is wildlife or not.

3) Overall Explanation of third global design:

There is a sensor at the back of Bowie that goes on when mode in contact with liquid (raindrops), it will detect the speed of raindrops and send the information back to system to decide whether open the umbrella or not. Thus, there is an umbrella package protector at the top of Bowie and it expands when rain hits the sensor. It protects Bowie from rain (water can damage the interior and flaw its functionality. Furthermore, the touch sensor will keep robot from crash with barriers, and the extension arm has detective sensor in it to help the prediction of perform braking.

Analysis & Evaluation process:

1) Functional requirement:

Table 7. Analysis & Evaluation process for Functional requirement

#	Conceptual Design / Specifications	Imp (Weight)	First design	Second design	Third design
1	Shaking frequency for storage tank	3	1	1	1
2	Charging voltage for robot	3	3	3	2
3	Breaking/stopping distance	5	2	3	3
4	Time of detect and response	5	2	2	3
5	GPS & GPRS	2	1	1	1
6	Breaking Speed for breaks/sensor	4	2	2	3
7	Sensor Angle	5	3	3	2
8	Sensor Current	5	3	3	2
9	Sensor detective distance	5	2	3	3
10	Sensor voltage	5	3	3	3
	Total		97	102	103

2) Non-functional requirement:

Table 8. Analysis & Evaluation process for Non-functional requirement

#	Conceptual Design / Specifications	Imp	First design	Second design	Third design
1	Number of cameras & sensors	2	3	3	3

2	Aesthetics	1	1	1	1
3	Product life	2	3	2	3
	Total		15	13	15

3) Constrains:

Table 9. Analysis & Evaluation process for Constrains

#	Conceptual Design / Specifications	Imp (Weight)	First design	Second design	Third design
1	Weight	3	3	3	1
2	Motor capacity	4	3	3	1
3	Size of storage tank	3	1	1	1
4	Specialized outfits size for different weather (Platform)	3	1	1	3
5	Operation Temperature	4	2	3	2
6	Battery Capacity	4	3	2	1
7	Cost of sensors and other related accessories	2	3	2	1
8	Maximum Payload	2	3	3	1
	Total		59	57	35

4) Total score:

Table 10. Final score of evaluation for each conceptual design.

Conceptual Design	First design	Second design	Third design
Score	171	172	153

5) Decision:

According to the analysis and evaluation of these conceptual designs by performing the lists of design criteria form previous work, we decide to use second conceptual design as the solution for further development due to its highest score-172.

Sketches of design:

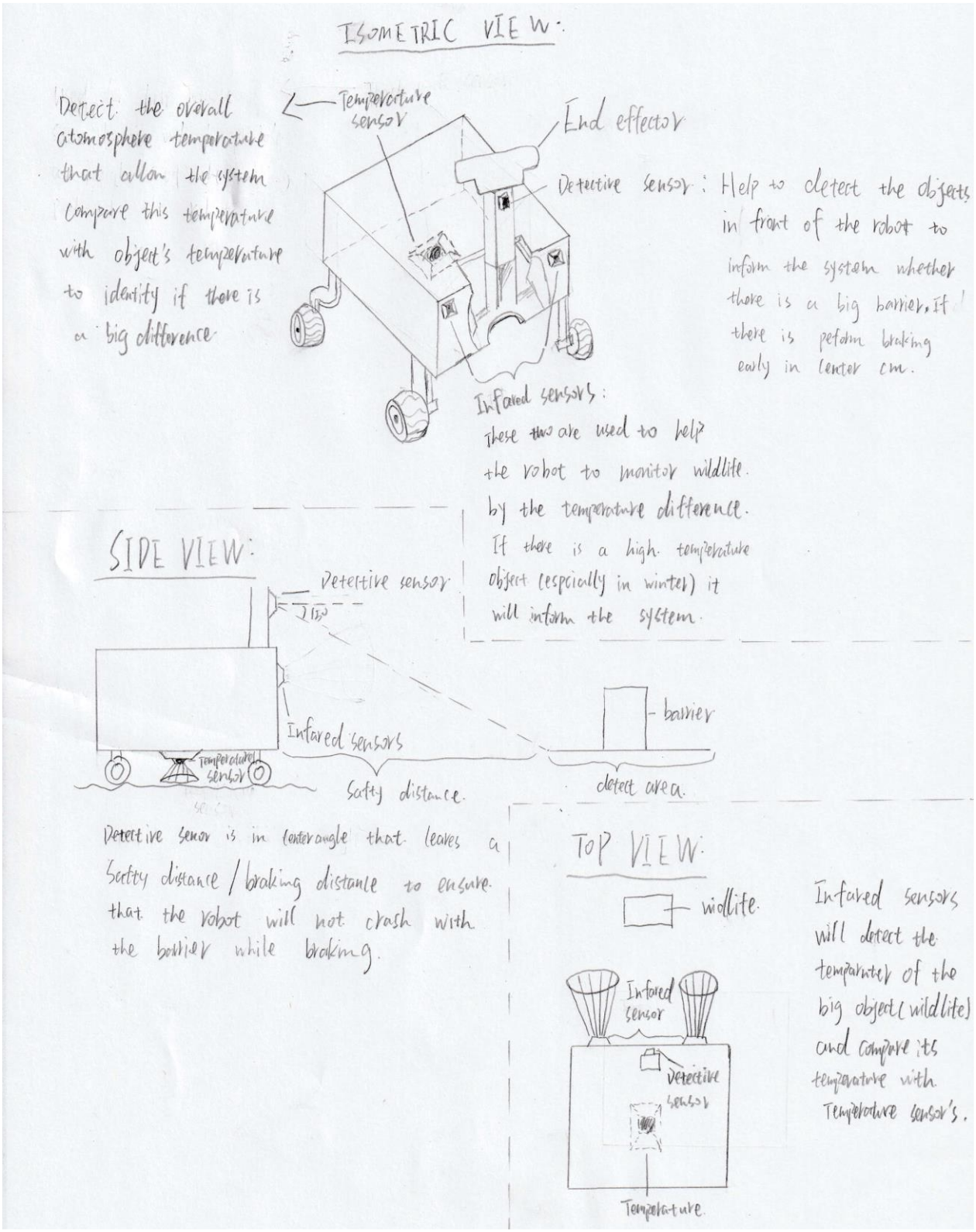

Figure 2. Sketch of selected conceptual design.

Project planning:

The following pictures are the screenshots of our Gantt chart diagram that illustrate our plan of reaming tasks from prototype I until the end of the project.

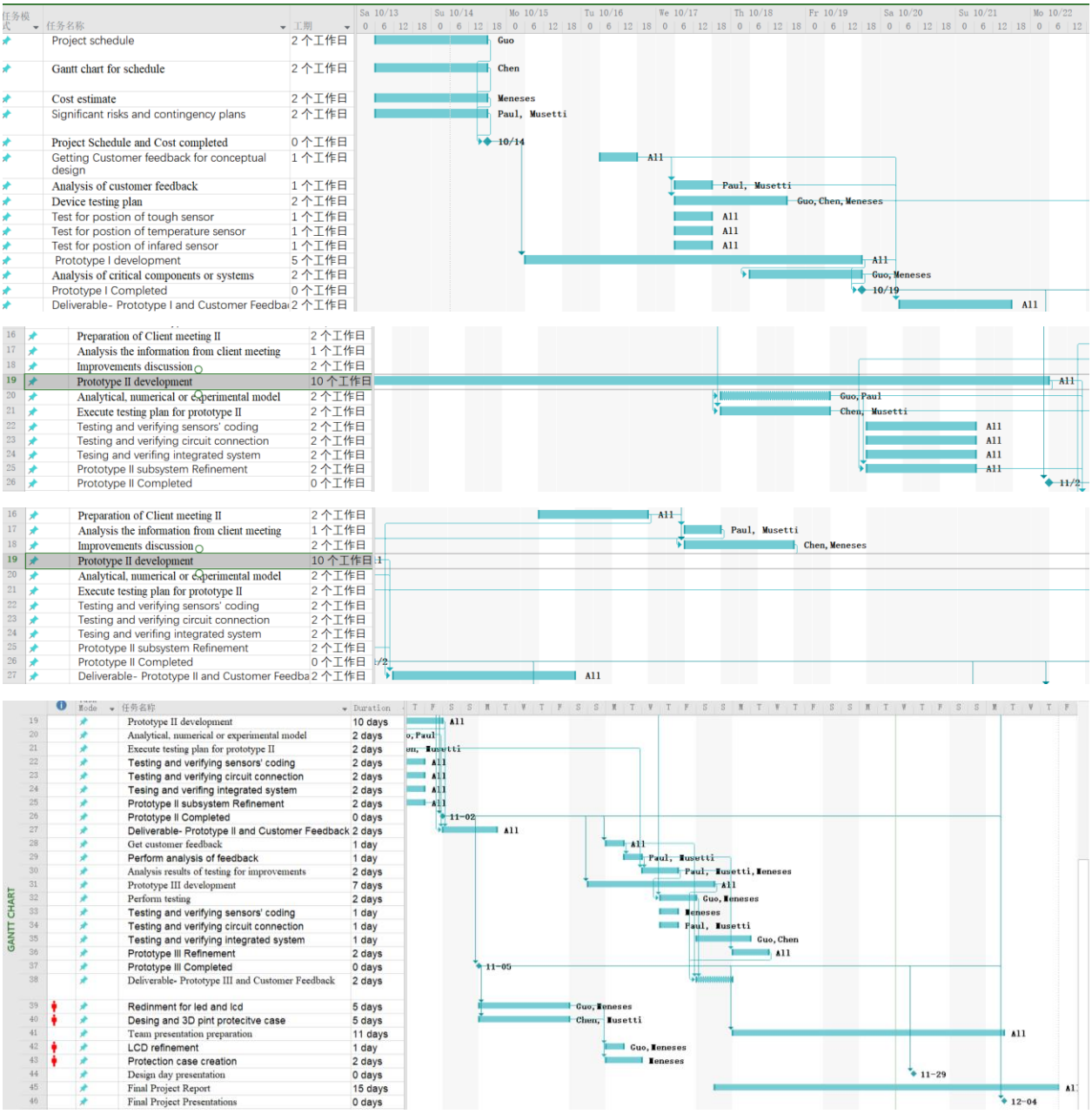

Figure 3. Screenshots of Gantt chart diagram

Prototyping & Testing process:

Prototyping Objectives:

Our main objectives for prototypes are to physically interpret our solutions to client, with the purposes of communicate ideas, ensure fidelity, reducing the risks and uncertainties of the solution, and measure the performance of our solution. In order to achieve these, we will form three different fidelity levels, low, medium, and high, prototypes.

1) Low fidelity prototype (Prototype I):

   We will use limited resource to made a model of our solution that works as a basic proof for our concepts with simply analysis of significant components and systems to explore different ideas.

2) Medium fidelity prototype (Prototype II):

   In this stage, we will focus on the subsystem of our solution in order to ensure our final solution works. Thus, our prototype will involve more details of the solution but with some limited functionality. An analytical, numerical or experimental model will include that help us to gain better senses and approximation of final prototype to refine the solution.

3) High fidelity prototype (Prototype III):

   This is our final stage of prototype that will very close to our final design, which may be our final product. This prototype is fully functional that have expected features and functionality, that help us to analyze the whole functionality with experience purposes also to ensure the satisfaction of client's needs.

Prototype I & Testing:

a) Prototype I:

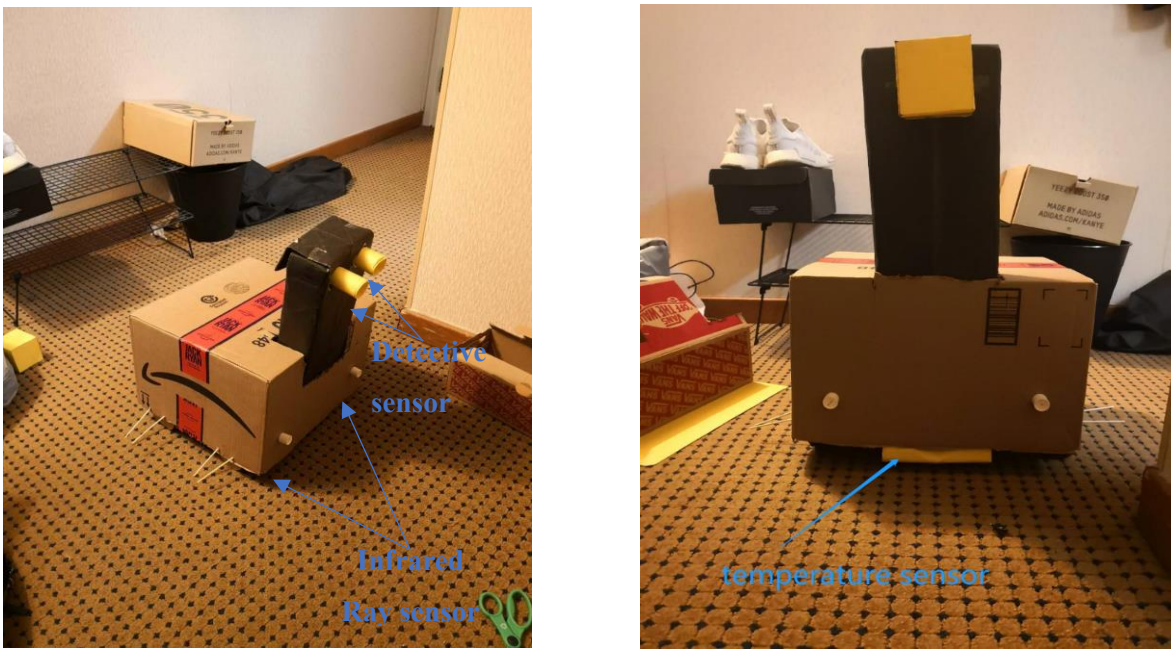

Figure 4. Prototype I

b) Testing objectives:

1) Verifying the position of multiple sensor, demonstrate whether these sensors are placed in reasonable and suitable positions on Bowie.
2) Determine to what extant will the detective sensor under end effector get damage.
3) As a tool for communication in our next client meeting, to better illustrate our conceptual design, seek for feedbacks and improvements from our client.
4) Explore for different new ideas about the solution and improvement, especially for the solution to minimize the damage to sensors during the operation process of Bowie.

c) Testing result:

By using this model, we physical approximate the positions of sensors on Bowie. There is not any problem for infrared ray and temperature sensors, since they are not position depended. Furthermore, temperature sensor is used to measure the ground temperature and system will compare it with the information from infrared sensors to determine wildlife.

Then we put the arm down to see the distance between detective sensors and ground. However, there is an angle between arm and ground when Bowie picking up garbage in reality, and we will fix the exact position of it in next prototype. Because it requires the actual detective sensor and Bowie robot which we did not get it yet for this prototype.

d) Required materials & Costs:

Table 11. Required materials & Costs of Prototype I

Material	Cost (CAD)
Hardboard	$5
Glue	$3
Total	$8

Prototype II & Testing:

a) Prototype II:

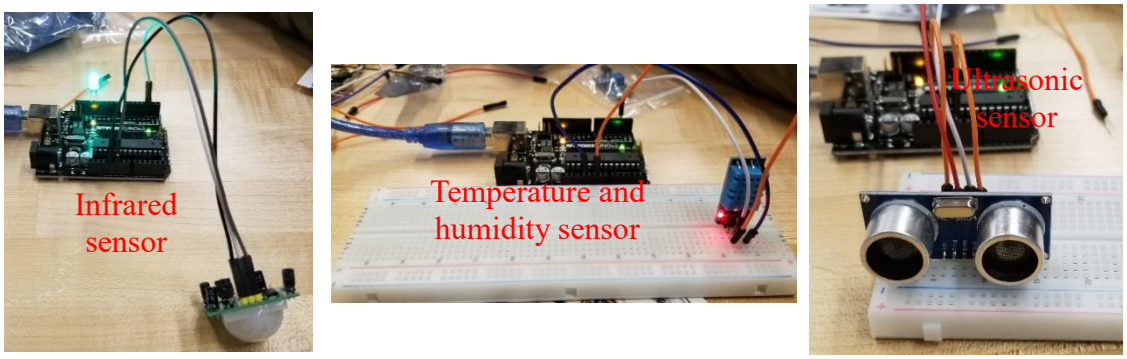

Figure 5. prototype II

b) Testing objectives:

1) Verifying the feasibility of coding for different types of sensors, as well as to determine whether the codes will make sensors functional.
2) Verifying the feasibility of circuit connections between Arduino and different sensors.
3) Analyze the potential problems and risk of failure of the coding.
4) Explore new integrated ideas that improve the efficiency of the sensors, and acts as the communication tools for next client meeting.

c) Testing results:

These results came from serial monitor in Arduino IDE.

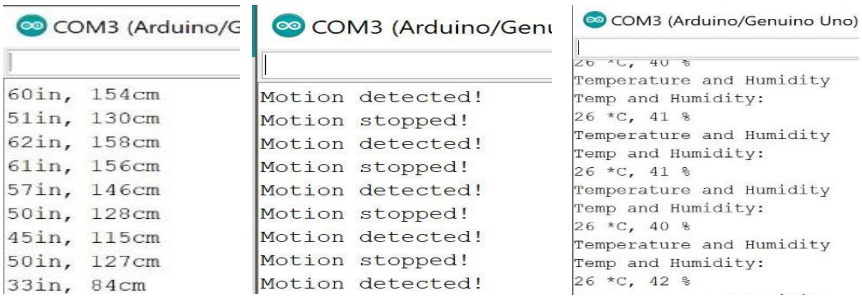

Figure 6. Testing results of prototype II

d) Required materials & Costs:

Table 12. Required materials & Costs of Prototype I

Material	Cost (CAD)
Detective sensors	$ 12.54
Temperature sensor & Infrared sensor	$ 39.99
Arduino board & other accessories	$ 38.99
Discounts	$ 9.25
Total	$82.27

Prototype III & Testing:

a) Prototype III:

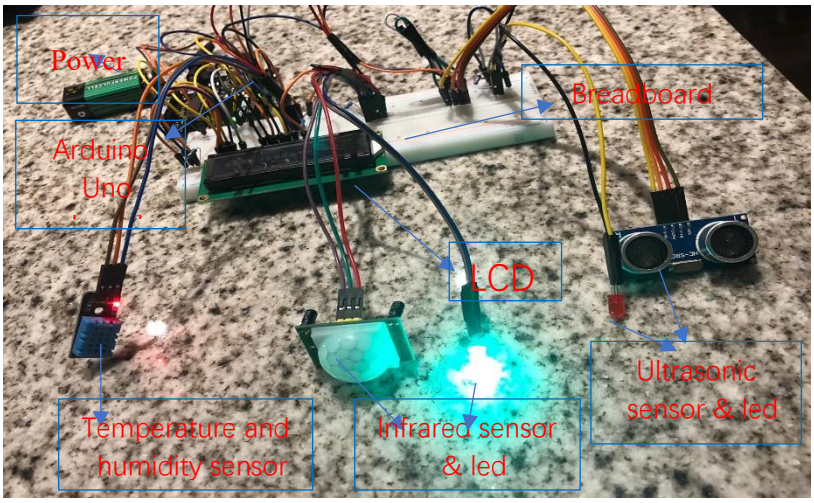

Figure 7. Prototype III

b) Testing objectives:

1) Learning new ideas about improvements of this prototype for final product.
2) Verifying the feasibility of integrated Arduino coding, determining whether the sensor will be functional under same Arduino board and system.
3) Verify the feasibility of circuit connections of Arduino board, breadboard, and sensors.
4) Analyze the potential problems, uncertainty, and risk of integrated system.

c) Testing results:

These results came from serial monitor in Arduino IDE.

Figure 8. Testing results of prototype III

d) Required materials & Costs:

Continue usage of the materials from prototype II.

Difference between initial conceptual design and final product:
Our group's original plan is measure related data and information of bowie that come up a modification of our prototype that will finlike into our selected conceptual design after we create and test the codes and functionalities of design in prototype II. However, we do not have access to bowie. Thus, we decide to mainly focus on the functionalities of our design which is to demonstrate of how will us integrate sensor working and skip the step of how to put sensors into bowie.

In addition, our client desired to have some indicators to demonstrate the working condition/ the information gather by the sensor after several client meeting. Thus, we add LEDs for both infrared and ultrasonic sensors individually, and an LCD for temperature and humidity sensor. Beside this, we increase the number of ultrasonic sensors to two and reduce the number of infrared sensors to one to maximize the functionalities of our final design.

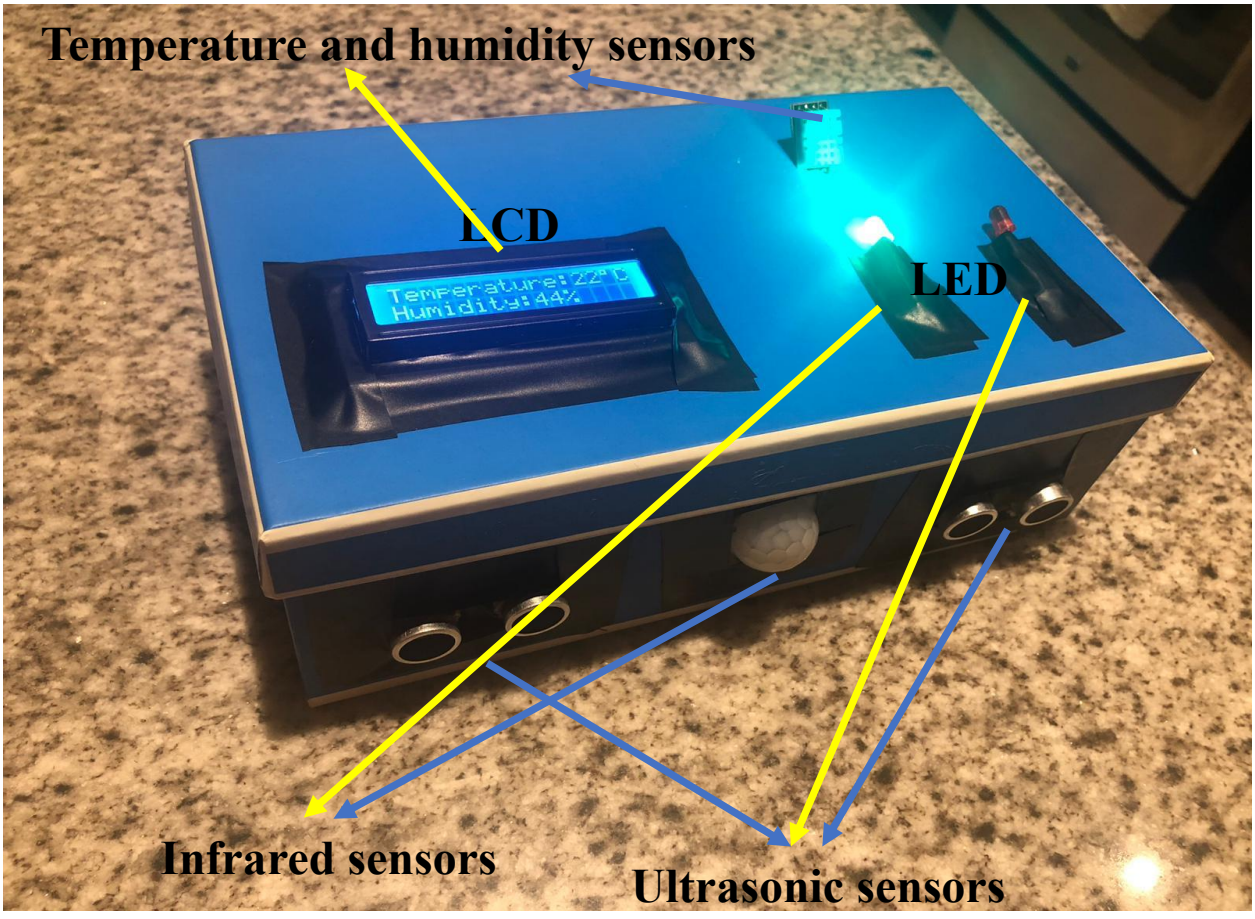

Figure 9. Final product

Analysis of critical system

The coding of sensors and circuit connections for the integrated sensor system can present several risks or problems. One of these risks is that while making the robot it is common for shavings to get into the Arduino board. Anything left lying around in the same compartment as the Arduino can end up shorting something. It should be kept well covered in order to prevent this from happening. Another risk is one that can easily occur which is changing connections while the Arduino is powered on. This should never be done because it makes it very easy to short something. Furthermore, overloading a pin can be a risk. The pins current limit should be known or else there is the danger of burning out the pin or the entire board. The total current being used by the integrated sensor system should be found as well as the current limit for the Arduino board. If the total current is more than the boards current limit, then there is the risk of frying the Arduino board.

To solve this problem an external power source may be required. Knowing how much power your integrated system needs compared to how much the Arduino board can provide is essential. Another risk is connecting more than 6 volts to any of the pins because it can overload it. Also, Arduino boards tend to heat up, affecting the temperature of the air surrounding it. This can affect the functionality of some of the sensors in the integrated system. Moreover, a risk is that the Arduino board should not be rested on conductive surface. It could cause it to short out. Another risk or problem is that wires can easily be mixed up. In order to prevent this from happening, a consistent wiring color code should be kept. For example, using red wires for power and black for ground. This keeps the integrated system well organized and easy to modify later. Additionally, another risk or problem would be connecting LEDs directly to addition pins without a current limiting resistor. Finally, a problem could be syntax errors in the code.

There are many mistakes to be made when coding and the most typical errors include: missing semicolons at the end of lines, missing/wrong type of brackets, spelling errors, etc. Any of these small errors can stop the code from working. Many of these risks or problems are similar or the same as those presented by prototype 2 in the last deliverable because both prototype 2 and 3 have the same critical components. The difference is that instead of being looked at individually, prototype 3 looks at the critical components together as an integrated system.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Lessons learned:

The most important lesson learned from this project is how to apply the knowledge that we learned into real world products. For examples, the differences between different types of prototype and how to choose the most suitable prototype, how-to device a testing plan and execute it to test the fidelity of our prototype, how to receive and apply feedbacks, and how to come up modifications for our final solution based on the feedback.

Second, we have practiced how to integrate several devices, such as different type of sensor, to the programming and circuit connecting part. We had no experience on how to use Arduino program and circuit connections, while from this project we learn many new skills such as IC bus for Arduino to connect multiple sensors, which will definitely useful for our furfure study/career.

Soldering is another good example of lesson learned from the project. Although our group did not have enough time and suitable material to transfer our circuit connection from breadboard into an extensive board by soldering, it is a necessary skill for future works.

Other lesson learned are: timing management ability, having everything done step by step and on time is a key part of this project; communication skills, how to communicate with groupmates and how to deal with conflicts within the group.; project planning, every complex task or design need plan to enable the team to keep on track and finalize the product on time.

Productive avenues for future work

At the current stage, the product is totally functional that reach the expected requirements in our original design. However, there are still amount of works left in order to make our product to work on Bowie due to the reason of our group did not have access to Bowie during prototyping. The future work includes: transfer sensors from breadboard into extension board, modifying the system into Bowie, and design a better protective case that allows our product to become attachable to Bowie.

Conclusion:

Overall, our project designing is successful. Although we did not finalize a product that can work directly on Bowie, we did learn a lot of knowledge that cannot gain from lecture but real-world practice.

From the initial step of empathy with customer to understand their needs to the end of the design thinking process, we come up three different global conceptual design and selected best one by design criteria, planning our future works and follow the plan to grantee every task keeping on

track, and creating three prototypes to finalize our design. The whole process is a meaningful experience for every member in the group, and will definitely become a reference for our future works.

Codes for system:

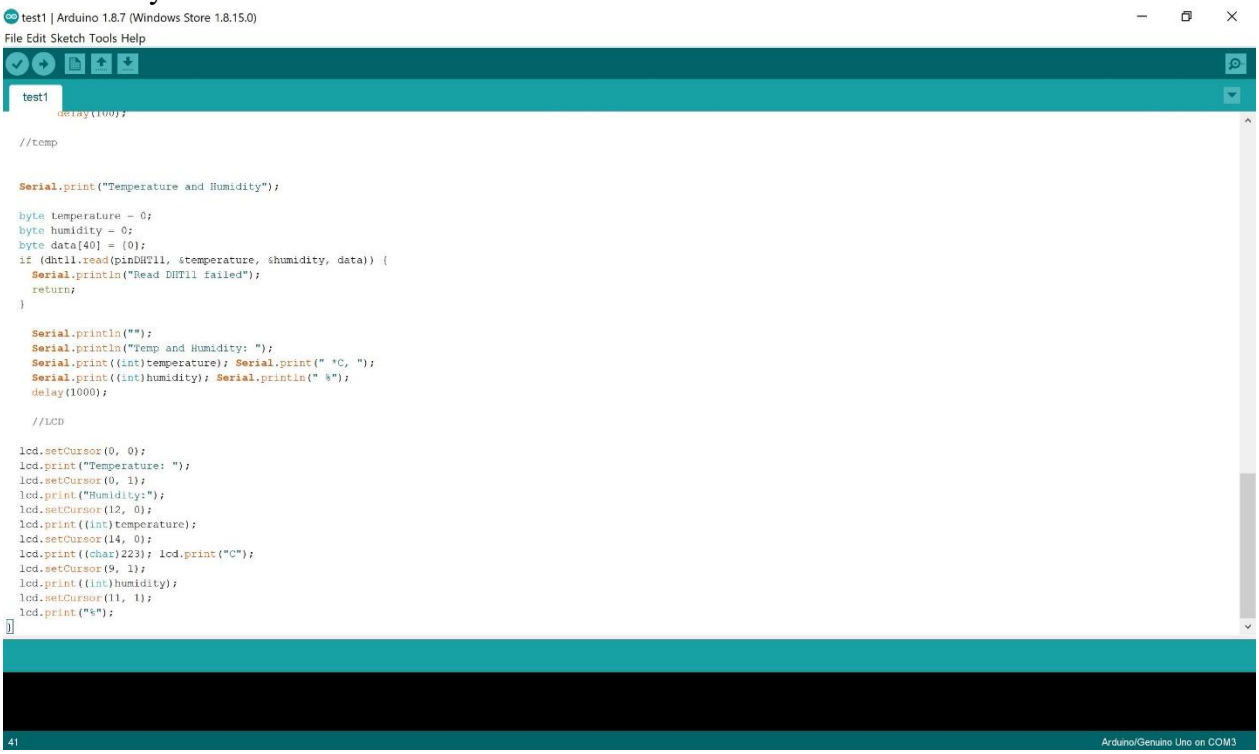

Figure 10. Codes for system

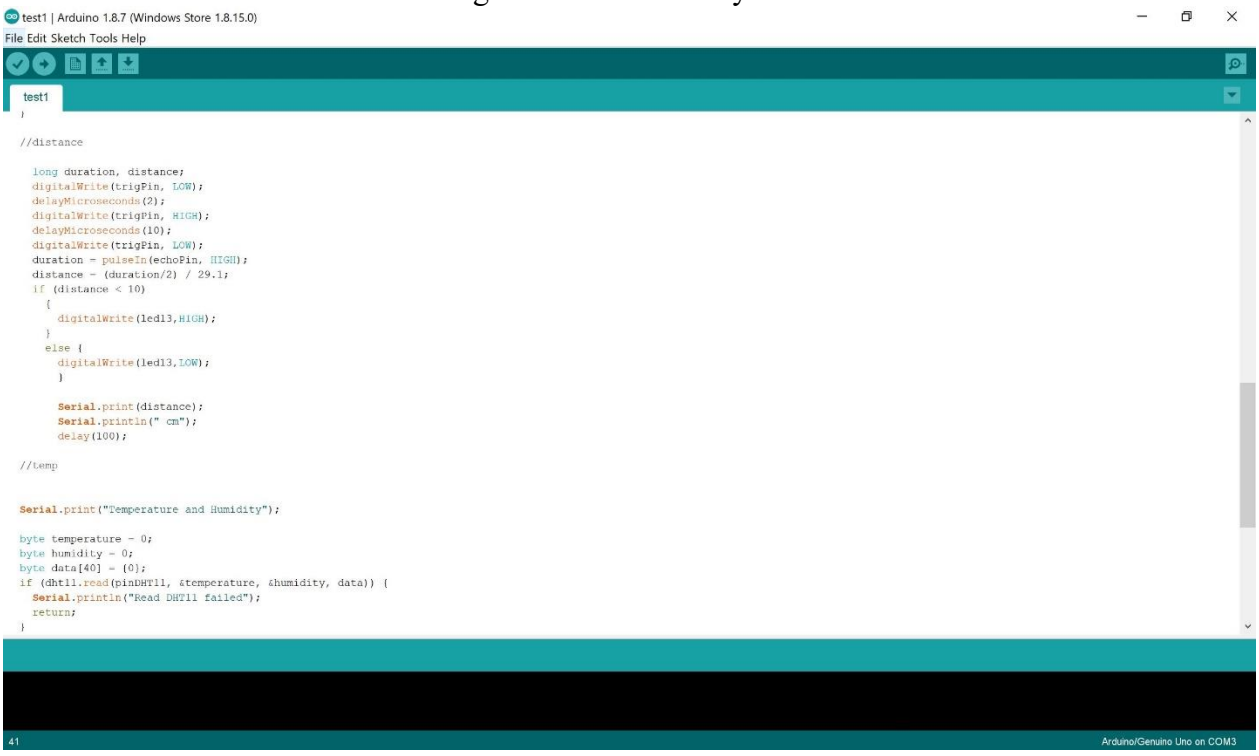

Figure 11. Codes for system

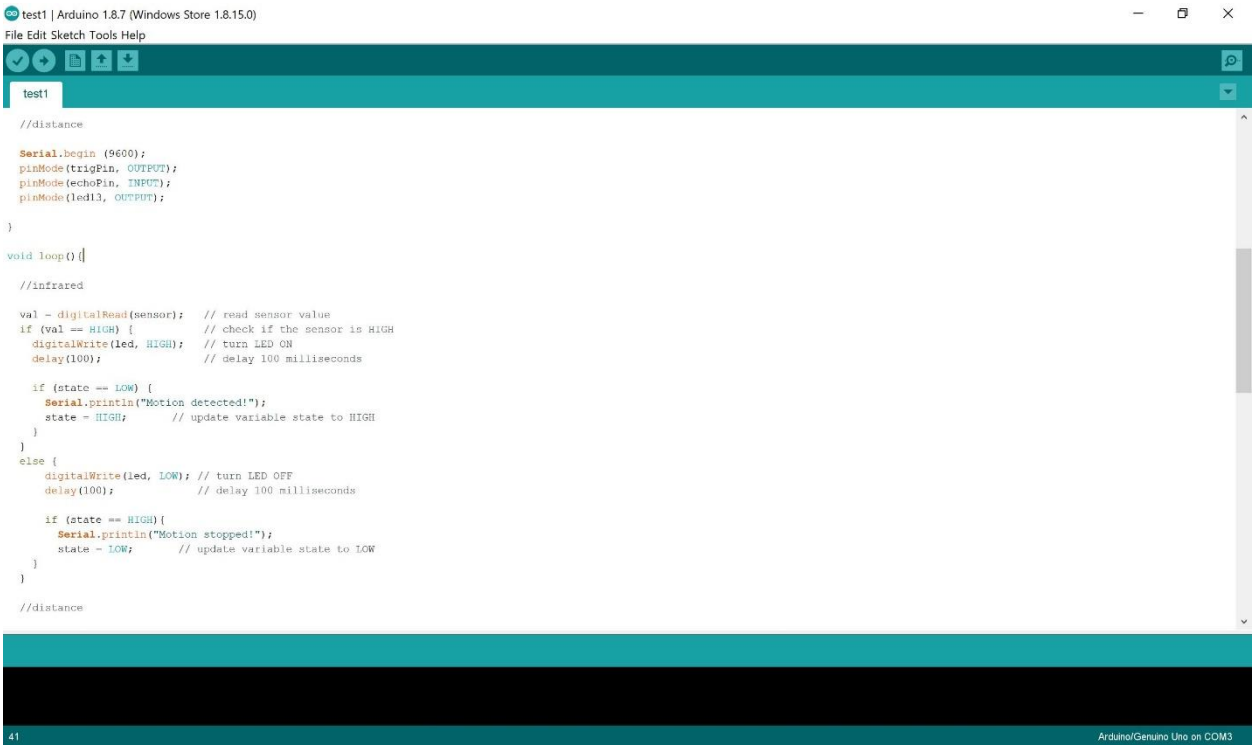

Figure 12. Codes for system

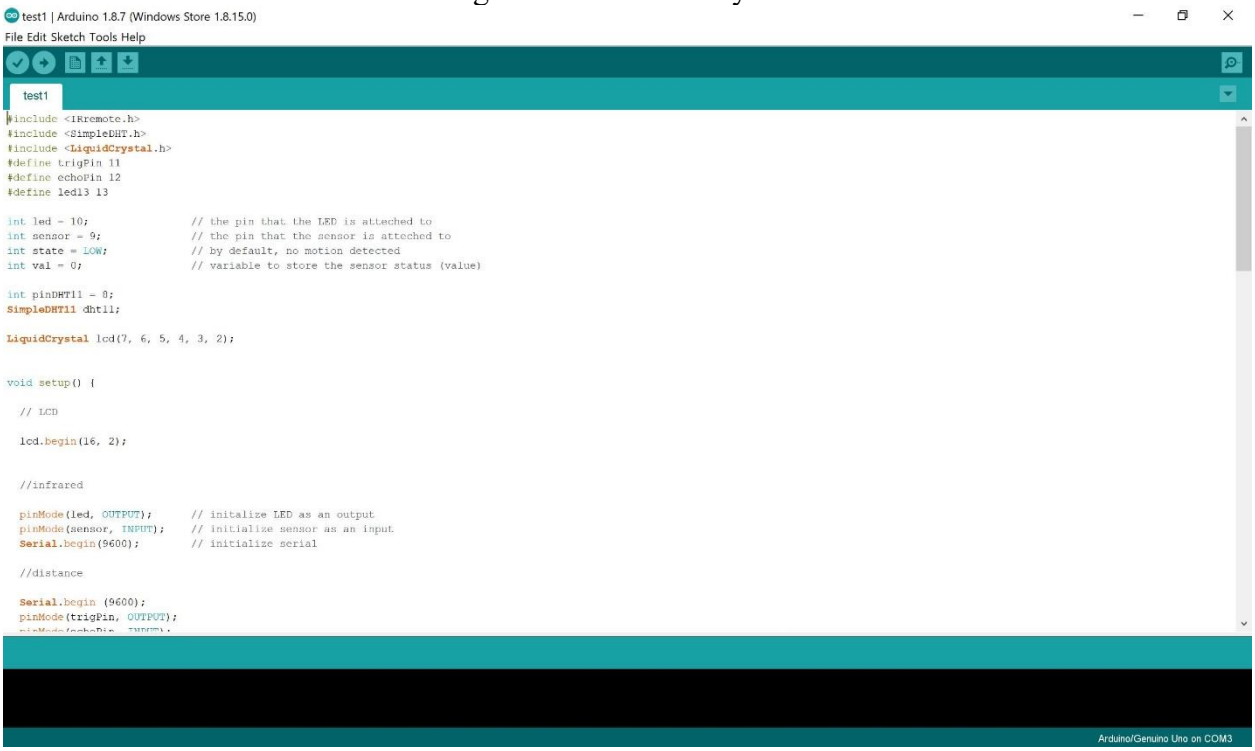

Figure 13. Codes for system