CONCEPTUAL DESIGN & EVALUATION OF ALTERNATIVES FOR A SMART DUSTBIN

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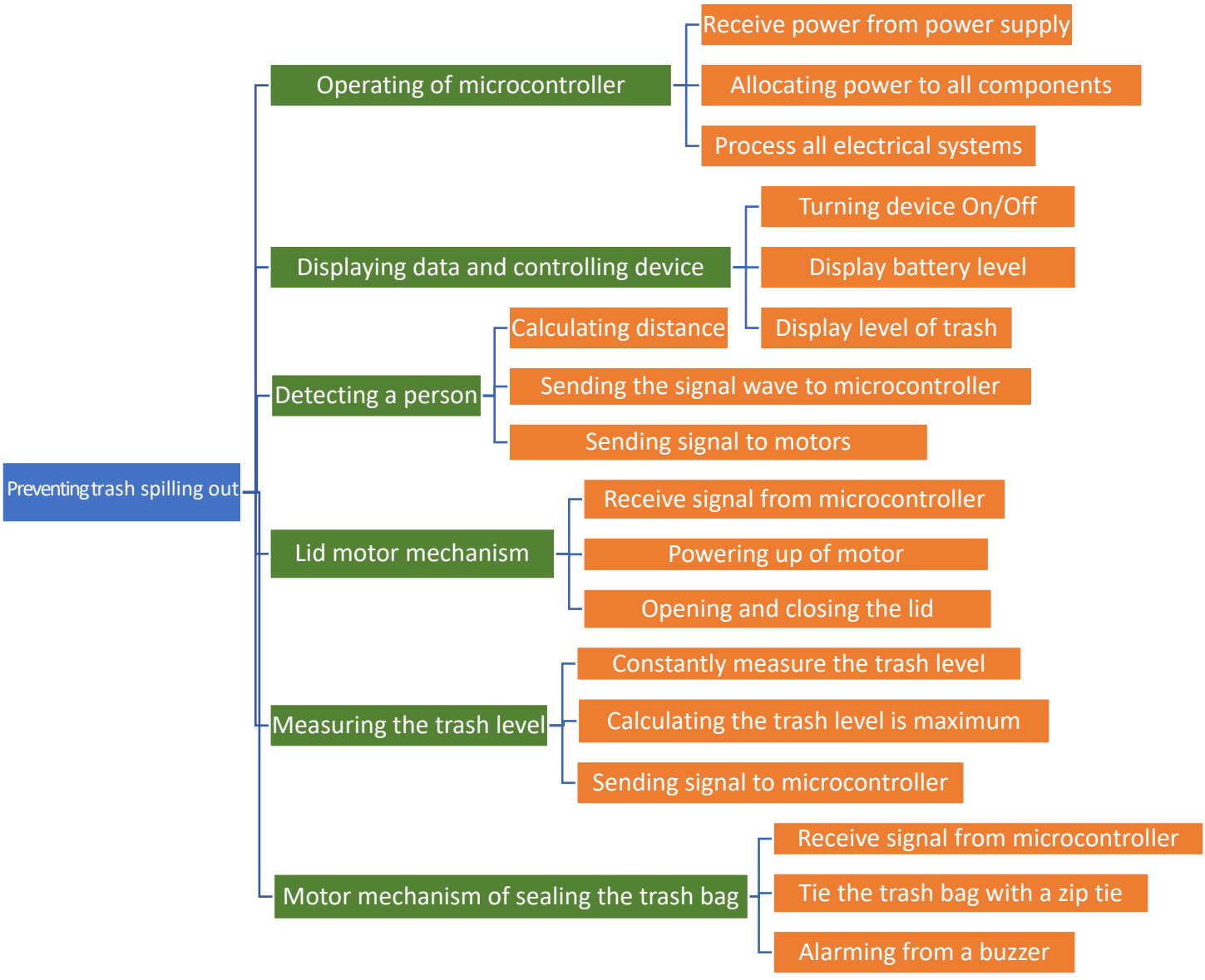
4.1 Functional decomposition diagram



4.2 User interaction activity

User	Function	Process
Cleaning staff	Setup	Unbox package Read the user manual Assemble components Charge batteries Testing
	Daily use	Remove filled trash bag Charging Batteries Changing zip ties Changing trash bags
	Maintenance	Replace malfunctioning components Clean the trash bin Oiling the Tires
	Disposal	Disassemble the trash bin Separate into trash categories Dispose of according to rules and regulations
Patients / Hospital staff	Daily use	Getting closer to the trash bin Dumping trash

4.3 Identification of sub-functions

- **Operating of microcontroller –**

This unit receives power from power supply unit. It allocate power to all componants and process all electrical systems.

- **Displaying data and controlling device -**

The device can turn on and off when needed. The Power supply unit delivers the necessary power to the components when it is required. The battery level is shown by 3 LEDs rather than a display. This saves battery. There is a button to use the zip tie and seal the trash bag if needed to the cleaning staff.

- **Detecting a person –**

We use a sensor to detect a person who moves near the trash bin. After detecting this sends the signals to the microcontroller. It sends signals to the motors.

- **Lid motor mechanism –**

After receiving signals from microcontroller, it sends power to the motors to open and close the automatic lid. The motors will stop working when the lid touches the switch which is placed on top of the trash bin. This prevents the motors overspinning and ensures a tight fit between the trash bin and the lid.

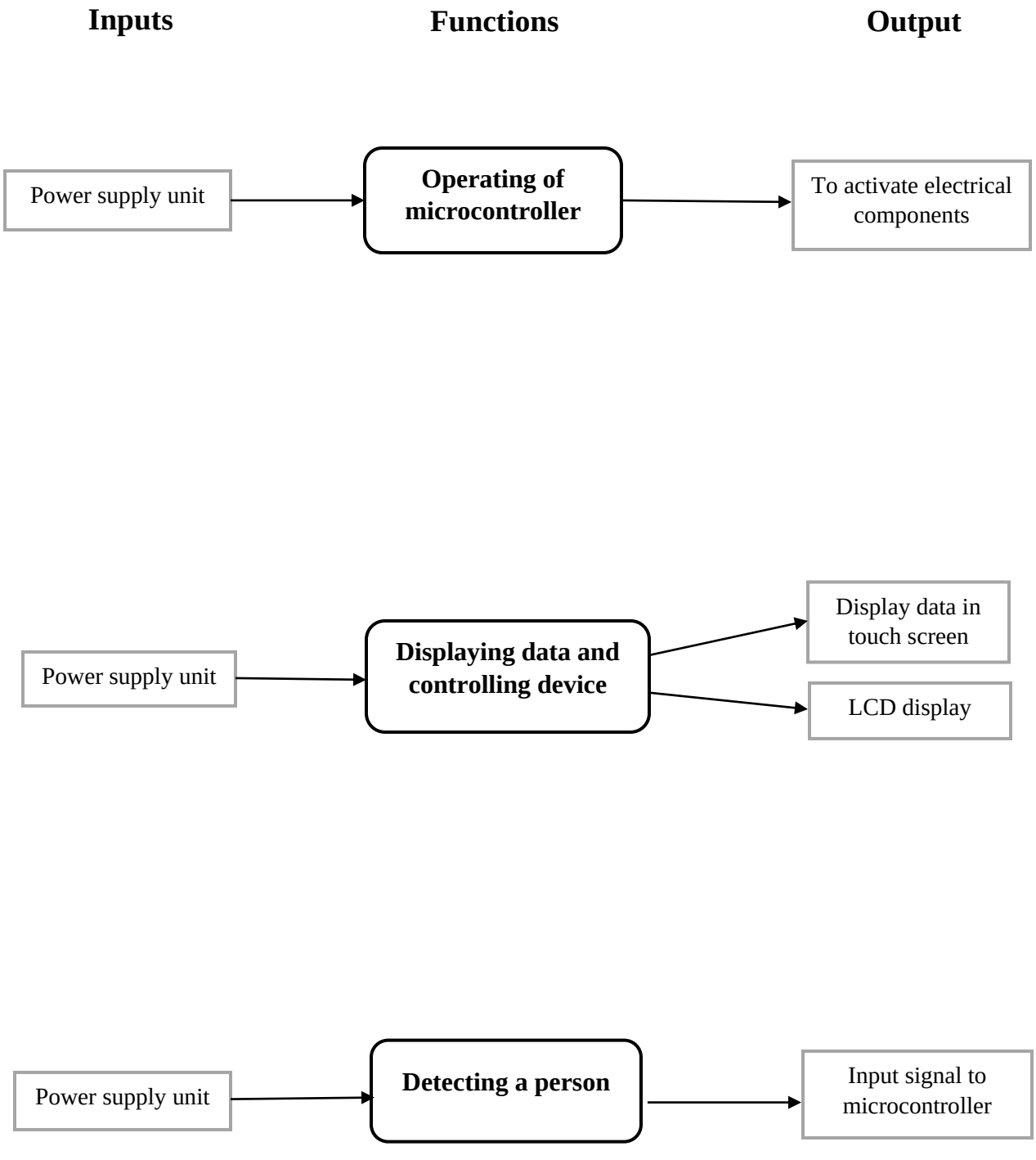
- **Measuring the trash level –**

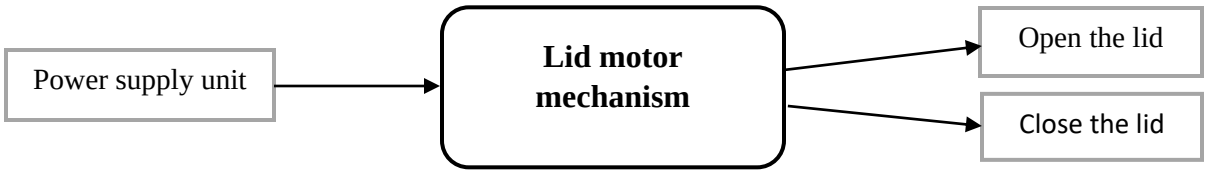
Constantly measure the level by a sensor to detect inside the bin. This sensor Calculates the trash level, and when it is maximum this sends a signal to microcontroller when filled.

- **Motor mechanism sealing the trash bag –**

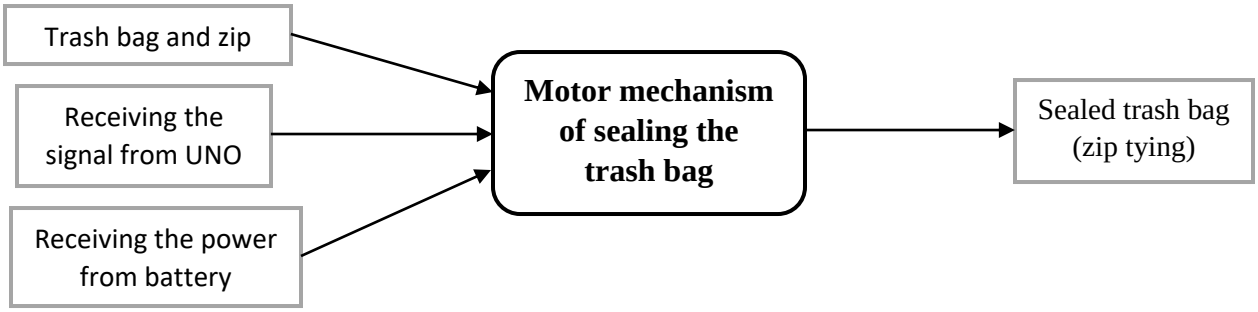
After receiving the signals from uno the motor receives power from the power source. When the motor turns the zip tie runs through the gear rods. This system works when the cleaning staff place a zip tie prior in between the two gear rods which is connected to a motor. When the process is done automatically the buzzer will alarm.

4.4 - Identify Input/Function/Output relationship of each sub function




Power supply unit
Lid motor mechanism
Open the lid
Close the lid


Detecting the trash level
Measuring the trash level
Level of the trash


Trash bag and zip
Receiving the signal from UNO
Receiving the power from battery
Motor mechanism of sealing the trash bag
Sealed trash bag (zip tying)

4.5 - Develop three alternatives for each sub function

Sub functions	Alternatives		
	1	2	3
Operating of microcontroller	Arduino UNO board	Arduino Mega	Arduino Leonardo
Displaying data and controlling device	LED – Button system	LCD Display	Touch screen
Detecting a person	IR sensor	Ultrasonic sensor	LiDAR sensor
Lid motor mechanism	Servo motor	Stepper motor	AC standard servo motor
Measuring the trash level	Ultrasonic sensor	Infrared sensor	Position sensor
Motor mechanism of sealing the trash bag	Stepper motor	Hydraulic system	Servo motor

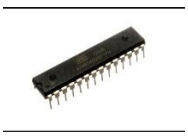
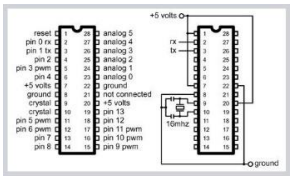
4.6 – Physical principle of each alternative

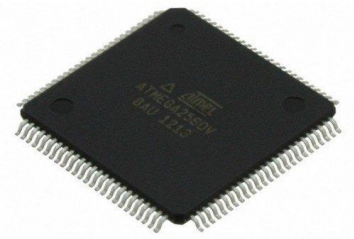
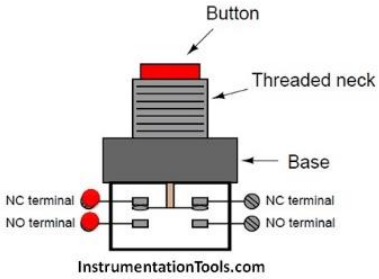
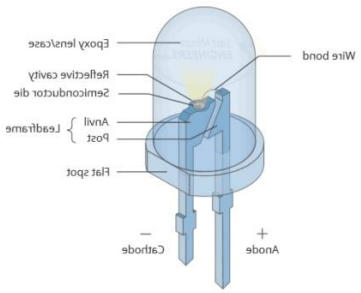
Sub function	Alternative	Physical principle
Operating of microcontroller	Arduino UNO board	Digital signal conversion with C+ programming
	Arduino mega	
	Arduino Leonardo	
Displaying data and controlling device	LED – Button system	Electro-luminance
	LCD Display	An electrical current is applying to the liquid crystal molecules, the molecule tends to untwist
	Touch screen	The body electrical induction
Detecting a person	Infrared sensor	Reflected light waves
	Ultra-sonic sensor	Emission and reflection high frequency ultrasonic waves
	LiDAR sensor	Emission and reflection of light waves from a laser

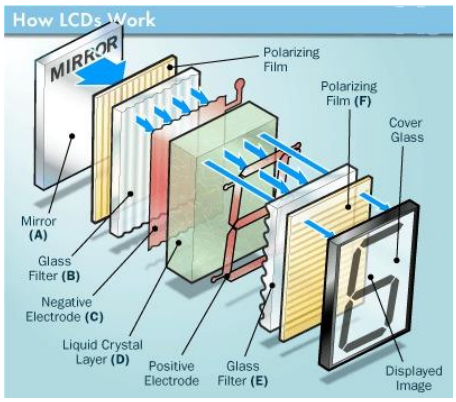
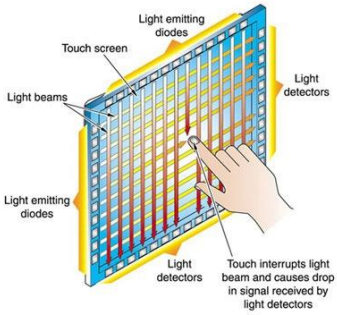
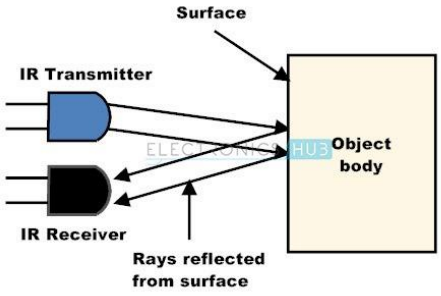
Lid motor mechanism	Servo motor	PWM principle (Pulse Width Modulation) (Its angle of rotation is controlled by the duration of pulse applied to its control PIN.)
	Stepper motor	By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor aligns with this field
	AC standard servo motor	PWM principle (Pulse Width Modulation)
Measuring the trash level	Ultra-sonic sensor	Emission and reflection high frequency ultrasonic waves
	Infrared sensor	Reflected light waves
	Position sensor	Light is transmitted from an emitter and sent over to a receiver at the other end of the sensor
Motor mechanism of sealing the trash bag	Stepper motor	By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor aligns with this field
	Hydraulic system	Pascal law

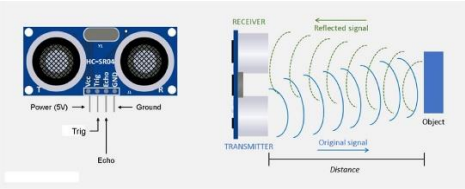
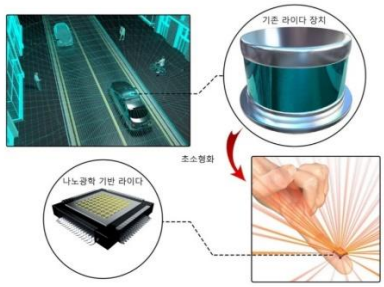
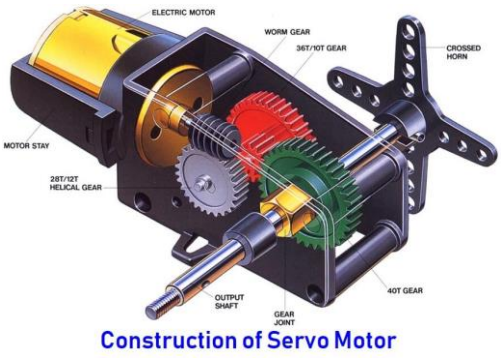
	Servo motor	PWM principle

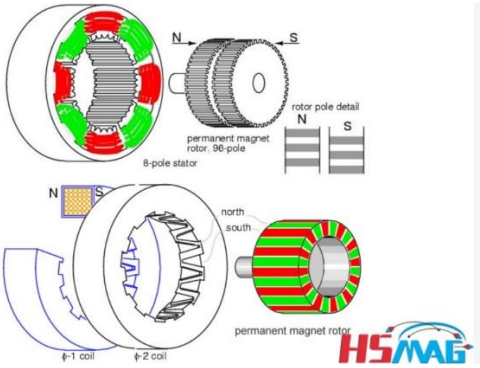
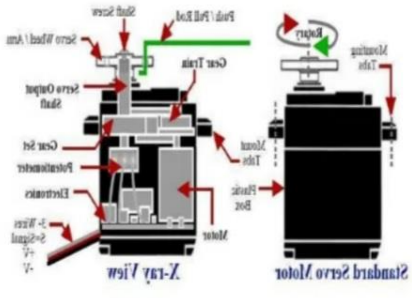
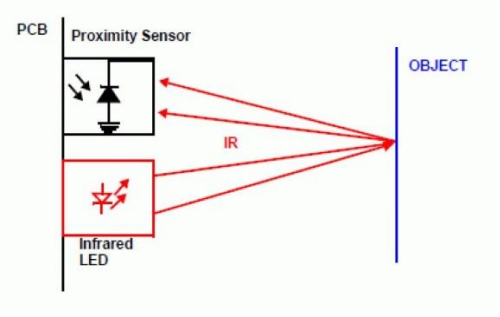
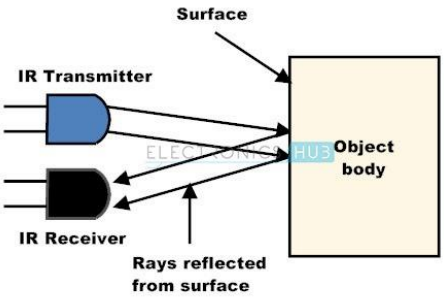
4.7 - Working principle and abstract embodiment of each alternative

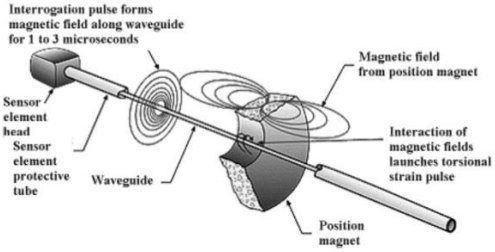
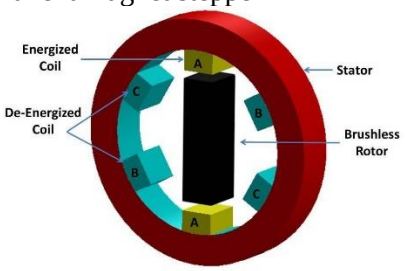
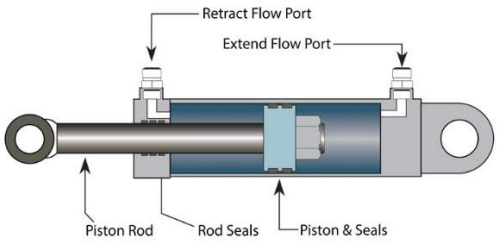
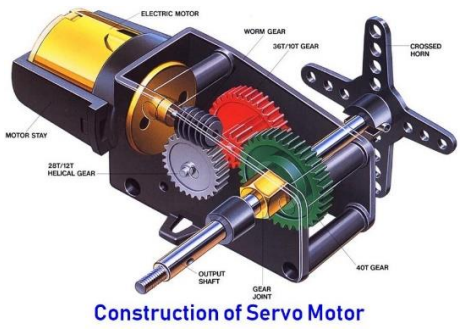
Sub function	Alternatives	Working principles	Abstract embodiment
Operating of microcontroller	Arduino UNO board	Microcontroller runs the commands stored in flash memory, interacting with GPIO, or calculating something. Microcontrollers may be programmed to emulate the functions of digital logic gates in addition to wide variety of combinational and multivibrator functions.	ATmega328  

	Arduino Mega		ATmega2560 
	Arduino Leonardo		ATmega32u4 
Displaying data and controlling device	LED button system	An emitting diode (LED) is a semiconductor light source that emits light as current flows through it. The electrons in the semiconductor reconnect with the electron holes and release energy in the form of photons.	3 LEDs with 2 buttons  

	LCD display	The liquid crystal display screen works on the principle of blocking light rather than emitting light. LCDs require a backlight as they do not emit light them.	Liquid crystal 
	Touch screen	When an object, such as a fingertip or a stylus tip, presses down on to the outer surface, the two layers touch to become connected at the point. The panel then behaves as a pair of voltage dividers, one axis at a time. By rapidly switching between each layer, the position of pressure on the screen can be detected.	Infrared touch screen 
Detecting a person	Infrared sensor	Active infrared sensors both emit and detect infrared radiation. Active IR sensors have two parts: a light emitting diode (LED) and a receiver. When an object comes close to the sensor, the infrared light from the LED reflects off of the object and is detected by the receiver.	IR sensor 

	Ultrasonic sensor	Ultrasonic sensors emit short, high frequency sound pulses at regular intervals. If the strike an object, then they are reflected as eco signals to the sensor, which itself computes the distance to the target based on the time span between emitting the signal and receiving the eco.	Ultrasonic sensor 
	LiDAR sensor	A typical LiDAR sensor emits pulsed light waves into the surrounding environment. These pulses bounce off surrounding objects and return to the sensor. The sensor uses the time it took for each pulse to return to the sensor to calculate the distance it traveled.	LiDAR sensor 
Lid motor mechanism	Servo motor	Servo motor works on the PWM principle, which means its angle of rotation is controlled by the duration of pulse applied to its control PIN. Basically, servo motor is made up of DC motor which is controlled by a variable resistor and some gears.	SG90, MG995, MG90  Construction of Servo Motor

	Stepper motor	Stepper motors have a stationary part (the stator) and a moving part (the rotor). On the stator, there are teeth on which coils are wired, while the rotor is either a permanent magnet or a variable reluctance iron core. We will dive deeper into the different rotor structure later	Permanent magnet stepper 
	AC standard servo motor	Servo motor angle of rotation is controlled by the duration of pulse applied to its control PIN. Basically, servo motor is made up of DC motor which is control by a variable resistor (potentiometer) and some gears.	Positional rotation AC servo motor 
Measuring the trash level	Ultrasonic sensor	Ultrasonic sensors emit short, high frequency sound pulses at regular intervals. If the strike an object, then they are reflected as eco signals to the sensor, which itself computes the distance to the target based on the time span between emitting the signal and receiving the eco.	Ultrasonic proximity sensor 
	Infrared sensor	Active infrared sensors both emit and detect infrared radiation. Active IR sensors have two parts: a light emitting diode (LED) and a receiver. When an object comes close to the sensor, the infrared light from the LED reflects off of the object and is detected by the receiver.	Active infrared sensor 

	Position sensor	Potentiometric position sensor is operated based on the principle of resistive effect. A resistive track acts as a sensing element, and a wiper is attached to the body or part of the body whose displacement is to be measured. The movement of wiper changes the resistance of wiper changes the resistance between one end of the resistance between one end of the track and wiper.	Linear position sensor 
Motor mechanism of sealing the trash bag	Stepper motor	Stepper motors have a stationary part (the stator) and a moving part (the rotor). On the stator, there are teeth on which coils are wired, while the rotor is either a permanent magnet or a variable reluctance iron core. We will dive deeper into the different rotor structure later	Permanent magnet stepper 
	Hydraulic system	Hydraulic systems use the pump to push hydraulic through the system to create fluid power. The fluid passes through the valves and flows to the cylinder where the hydraulic energy converts back into mechanical energy. The valves help to direct the flow of the liquid and relieve pressure when needed.	Hydraulic cylinder 
	Servo motor	Servo motor works on the PWM principle, which means its angle of rotation is controlled by the duration of pulse applied to its control PIN. Basically, servo motor is made up of DC motor which is controlled by a variable resistor and some gears.	Dc servo motor 

4.8 All Alternatives Combination Table(Morphological Matrices)

Sub functions	Alternatives		
	1	**2**	**3**
Operating of microcontroller	Arduino UNO board	Arduino Mega	Arduino Leonardo
Displaying data and controlling device	LED – Button system	LCD Display	Touch screen
Detecting a person	IR sensor	Ultrasonic sensor	LiDAR sensor
Lid motor mechanism	Servo motor	Stepper motor	AC standard servo motor
Measuring the trash level	Ultrasonic sensor	Infrared sensor	Position sensor
Motor mechanism of sealing the trash bag	Stepper motor	Hydraulic system	Servo motor

Sub Functions

operating of micro-controller	Displaying data and controlling device	Detecting a person	Lid motor mechanism	Measuring the trash level	Motor mechanism of sealing the trash bag
1. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Ultrasonic sensor	Stepper motor
2. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Ultrasonic sensor	Hydraulic system
3. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Ultrasonic sensor	Servo motor
4. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Infrared sensor	Stepper motor
5. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Infrared sensor	Hydraulic system
6. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Infrared sensor	Servo motor
7. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Position sensor	Stepper motor
8. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Position sensor	Hydraulic system
9. Arduino UNO board	LED – BUTTON system	IR sensor	Servo motor	Position sensor	Servo motor
10. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Ultrasonic sensor	Stepper motor
11. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Ultrasonic sensor	Hydraulic system
12. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Ultrasonic sensor	Servo motor
13. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Infrared sensor	Stepper motor
14. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Infrared sensor	Hydraulic system
15. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Infrared sensor	Servo motor
16. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Position sensor	Stepper motor
17. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Position sensor	Hydraulic system
18. Arduino UNO board	LED – BUTTON system	IR sensor	Stepper motor	Position sensor	Servo motor
19. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Ultrasonic sensor	Stepper motor
20. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Ultrasonic sensor	Hydraulic system
21. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Ultrasonic sensor	Servo motor
22. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Infrared sensor	Stepper motor
23. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Infrared sensor	Hydraulic system
24. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Infrared sensor	Servo motor
25. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Position sensor	Stepper motor
26. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Position sensor	Hydraulic system
27. Arduino UNO board	LED – BUTTON system	IR sensor	AC standard servo motor	Position sensor	Servo motor
28. Arduino UNO board	LED – BUTTON system	Ultrasonic sensor	Servo motor	Ultrasonic sensor	Stepper motor
29. Arduino UNO board	LED – BUTTON system	Ultrasonic sensor	Servo motor	Ultrasonic sensor	Hydraulic system
30. Arduino UNO board	LED – BUTTON system	Ultrasonic sensor	Servo motor	Ultrasonic sensor	Servo motor

All the combinations.

https://docs.google.com/document/d/1AGfg4PnzNH6tYnKblsPzie2ZcNc7A62n9uYDsleg0Ak/edit

4.9 Evaluate alternative combinates using weighted rating methods

Rating	Value
Unsatisfactory	0
Just tolerable	1
Adequate	2
Good	3
Very good	4

1. Operating of Microcontroller

		Concept alternatives					
		Arduino Uno		Arduino Mega		Arduino Leonardo	
Criteria	Importance weight (%)	Ratings	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Low cost	25	4	1.00	0	0	2	0.5
Low Power rating	20	4	0.8	1	0.2	3	0.6
High reliability	10	4	0.4	4	0.4	4	0.4
High efficiency	30	2	0.4	4	1.20	3	0.9
No of ports	15	2	0.3	4	0.9	3	0.45
	100	N/A	3	N/A	2.7	N/A	2.85

2.Displaying data and controlling device

		Concept alternatives					
		LED – BUTTON system		LCD Display		Touch screen	
Criteria	Importance weight (%)	Ratings	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Low cost	40	4	1.6	1	0.4	0	0
Low power rating	30	4	1.2	2	0.6	1	0.3
Reliability	20	4	0.8	3	0.6	2	0.2
Quality	10	4	0.4	3	0.3	3	0.3
	100	N/A	4	N/A	2.5	N/A	0.8

3. Detecting a person

		Concept alternatives					
		Ultrasonic sensor		Infrared Radiation sensor		LiDAR sensor	
Criteria	Importance weight (%)	Ratings	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Accuracy	35	2	0.7	4	1.4	3	1.05
Range	25	1	0.25	4	1.0	2	0.5
Low cost	15	4	0.9	3	0.75	1	0.15
Efficiency	15	2	0.3	4	0.9	3	0.45
Low Power rating	10	2	0.2	4	0.4	1	0.1
	100	N/A	2.35	N/A	4.45	N/A	2.25

4.Lid motor mechanism

		Concept alternatives					
		Servo motor		Stepper motor		AC standard servo motor	
Criteria	Importance weight (%)	Ratings	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Low cost	40	4	1.6	2	0.8	1	0.4
Efficiency	20	3	0.6	0	0	4	0.8
Low Power rating	30	4	1.2	3	0.9	2	0.6
Reliability	20	4	0.8	4	0.8	4	0.8
	100	N/A	4,2	N/A	2.5	N/A	2.6

5. Measuring trash level

		Concept alternatives					
		Ultrasonic sensor		Infrared sensor		Position sensor	
Criteria	Importance weight (%)	Ratings	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Low cost	20	3	0.6	2	0.4	1	0.2
Accuracy	40	4	1.6	3	1.20	2	0.8
Power rating	15	3	0.45	2	0.3	1	0.15
High efficiency	25	3	0.75	3	0.75	3	0.75
	100	N/A	3.4	N/A	2.66	N/A	1.9

6.Motor mechanism of sealing the trash bag

		Concept alternatives					
		Stepper motor		Hydraulic system		Servo motor	
Criteria	Importance weight (%)	Ratings	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Accuracy	40	4	1.6	3	1.2	2	0.8
Low cost	30	3	0.9	0	0	4	1.2
Efficiency	15	3	0.45	0	0	4	0.6
Low Power rating	10	3	0.3	4	0.4	4	0.4
Reliability	5	3	0.15	4	0.2	1	0.05
	100	N/A	3.4	N/A	1,8	N/A	3.05

4.10 present the best alternative combinations with proper justification

Sub Functions	Operating of microcontroller	Displaying data and controlling device	Detecting a person	Lid motor mechanism	Measuring the trash level	Motor mechanism of sealing the trash bag	Weighted rating
Combinations that were chosen before weighted rating analysis							
Concept Alternatives	Arduino UNO (3.0)	LED – BUTTON system (4.0)	Ultrasonic sensor (2.35)	Servo motor (4.2)	Ultrasonic sensor (3.4)	Stepper motor (3.4)	20.35
	Arduino Mega (2.7)	LCD Display (2.5)	Infrared Radiation sensor (4.45)	Stepper motor (2.5)	Infrared sensor (2.66)	Hydraulic system (1.8)	16.61
	Arduino Leonardo (2.85)	Touch Screen (0.8)	LiDAR sensor (2.25)	AC standard servo motor (2.6)	Position sensor (1.9)	Servo motor (3.05)	13.45
Combination with the highest and lowest weighted rating							
Highest weighted rating	Arduino UNO (3.0)	LED – BUTTON system (4.0)	Infrared Radiation sensor (4.45)	Servo motor (4.2)	Ultrasonic sensor (3.4)	Stepper motor (3.4)	22.45
Lowest weighted rating	Arduino Mega (2.7)	Touch Screen (0.8)	LiDAR sensor (2.25)	Stepper motor (2.5)	Position sensor (1.9)	Hydraulic system (1.8)	11.95

The above table represents the combination between highest and lowest weighted rating alternatives of each sub function. We have obtained the highest total weighted rating as 22.45 and the lowest total weighted rating as 11.95. By considering the above table, we have chosen the highest weighted component of each sub function as the best alternative. They are shown in the table below.

Sub function	Selected component
Operating of microcontroller	Arduino UNO
Displaying data and controlling device	LED – BUTTON system
Detecting a person	Infrared Radiation sensor

Lid motor mechanism	Servo motor
Measuring the trash level	Ultrasonic sensor
Motor mechanism of sealing the trash bag	Stepper motor

Including the above selected components, we are designing the shape of the trash bin according to Vilan's conceptual design (Design 1). The volume of the dust bin is cm. Apart from that we are including tyres and a handle to trash bin for portability. And we are using a battery pack for allocating power to all components. The main battery placed beneath the trash bin with a charger plugged to the back of the trash bin. Two servo motors are used to the lid of the trash bin when a person get closer. Using two servo motors increase the durability due to reduce of tress instead of a single servo motor. The main control panel of our design is located on the side of the trash bin. Battery level of the trash bin is displayed by three LED bulbs, placed in the control panel. Buzzer is also used to emit the signal when trash level reaches to the constant level 75cm. Rubber seal has been placed on the lid with a space in between allowing another rubber seal fit through it. An ultrasonic sensor has been placed beneath the lid of the trash bin. The ultrasonic sensor has a coverage angle of 30 degrees which increases accurately measure the trash level inside the bin. An IR sensor is used which has an angle coverage of 5 degrees as a maximum range of 80cm. It detects when a person is nearby. Rather than an ultrasonic sensor which has an angle coverage of 30 degrees and maximum range of 21m, IR sensor will have less errors.

In this design, the method to seal the trash bag was done according to the design which works when the cleaning staff initially insert a zip tie in between the gear rods according to Design 1. In the alternatives, we have found that there are many other types of motors that we can use. But as shown above each of them have their own drawbooks, which were identified. By considering them we have decided to use a stepper motor which has a high torque, efficiency, accuracy, low power, power rating and good reliability considering other alternatives. The trash bag will be sealed according to the design and a stepper motor will be also used.

Switch has been placed next to the rubber seal (on top of the trash bin) which is used to stop the servo motor used in the hinges. Use of a switch to stop servo motor over spinning after the lid has been closed will make the motors more durable.