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Introduction

From the beginning of the human civilization, people used various methods of waste disposal to get rid of unwanted material. Sometimes it was buried in the land, thrown in the sea, fed to the animal or burnt. Getting rid of unwanted material is always a major concern for the modern society. Trash has played a tremendous role in history. The Bubonic Plague, cholera and typhoid fever, to mention a few, were diseases that altered the populations of Europe and influenced monarchies. They were perpetuated by filth that harboured rats, and contaminated water supply [1]. When wastes are not properly managed then it may cause serious hazard, as seen in 1350. "Black plague" erupted and more than 25 million people from all over Europe fall victim to it in just five years [2]. There is an increasing rate of waste generation in Bangladesh and it is projected to reach 47,064 tonnes per day by 2025. The Waste Generation Rate (kg/cap/day) is expected to increase to 0.6 in 2025. A significant percentage of the population has zero access to proper waste disposal services, which will in effect lead to the problem of waste mismanagement [3]. The total waste collection rate in major cities of Bangladesh such as Dhaka is only 37%. When waste is not properly collected, it will be illegally disposed of and this will pose serious environmental and health hazards to the people of Bangladesh [4]. This is not the only problem of Dhaka city but also for other big cities around the world [5]. With so much concern recently about being greener and economically friendly, waste management has become a very important topic. People and companies are starting to realize that the things they use and the way they dispose of them can make a big impact on our world. Proper management of waste plays a vital role in global environment. That is why a waste sorting system is designed which can be used in houses, offices as a part of smart waste management system.

Learning Outcomes

The four learning outcomes that your report should demonstrate that you have achieved are:

1. Identify, plan and commence a project that leads to the solution of an authentic IoT problem;
2. Deploy an appropriate combination of knowledge, research, analytical methods, cross-disciplinary learning skills, and creativity to conceive, design, and develop a solution to a complex IoT problem with intellectual independence;
3. Develop a project management plan that outlines objectives, activities, resources, timeline and risk assessment to demonstrate self-discipline, self-management skills, and personal responsibility; and
4. Reflect upon and critically review project work and apply advanced communication skills to convey progress.

What problem is being solved?

There are millions of cup used in a day but 70% of them left unrecycled because of their material looks same, dump in the same bin and cannot be identified by a human due to lack of knowledge. Human is confused about where to recycle things, and consumers are confused about the actual material the packaging is made of. There are hundreds of materials out there that look the same, but can't be recycled in the same ways. Millions of waste material used in a single day. Only Starbucks produce 4 billion waste material per year and from which 3 billion left recycled therefore it needs smart sorting technology to sort them.

Benefits of solution

If these cups sorted by a smart sorting bin can help to increase the recycling rates of waste material and help to make a cleaner environment. It helps the shop to save their money and time to manage their waste. Unique design in terms of safety of bin, the safety of human and animals from diseases, no-overflow, need compact space, huge bins capacity, non-smelly bin. It automatically sorts waste accordingly just put waste put in a single bin. The device can sort cup in a different bin, it will be easy to recycle it further.

What if the problem is left unsolved

If unsolved it will lead to an environmental disaster. Unsorted waste degrades the quality of material which leads the material to dump at landfills site and near the road (where it emits harmful gases, leaching). It needs more time and money to recycle and sorting. It leads to diseases and environmental changes as some material need special handling.

Its scope and limitation

It will only be used for a shop where the frequency of plastic cup, bottle, metal cup, can, the bottle is high. It cannot be placed on the road as it only detects the single material at a time, It cannot detect/identify the mixed things at a time. It is not compatible for home, the municipal corporation only compatible for shops like Starbucks, CCD, Mcdonals and other beverages shop.

Summary

In the today world, there were millions of waste material produced in a day. It was a huge problem and need to be solved. Intellgent sorting bin was a solution for seperating the different type of waste material(metal, plastic, paper).It will direct benefit to shops, waste management vendors, environment. If left unsolved ,this affect the shop business , environment. Its limitation was only used in shops where consumption of drinks are huge.

Literature Review and Market Research

Contents of the Literature Review

You will need to explicitly address the following points:

Market Research

1. Industry analysis

1.1. Political

- The Supreme Court directed the government of India, state governments, and municipal authorities to take the necessary actions.[6]
- The Ministry of Environment and Forests was directed to expeditiously issue rules regarding MSW management and handling Regulation defines the process that waste should be sorted at the initial dumping time and collect the waste in different container.

- Contract of system is only for 5 years and need to be renew.

1.2 Economic
- Opportunity costs of clean up campaigns and behavior change initiatives.
- Financial support as capital investment need to grow.
- Inflation rate affect the price of system and ongoing operation.
- Urban location is the main market.
- 25 % Corporate tax and 18% GST tax affect the cost of system.[7]

1.3 Social
- Awareness of segregate the waste at home and collection of waste in different container help us to grow faster.
- Increase the urbanization increase the sale of system and help the citizen to learn to sort waste.[8]

1.4 Technology
- Artificial intelligence, IOT, Machine learning, Computer vision help to develop the system efficient
- Internet access and IOT help to reduce the cost of system .
- Cloud service price are high of waste detection .
- Lithium ion battery for good power backup.

1.5 Industry

- Low use of waste sorting bin because of less awareness on waste.
- Increasing of population, increase in waste and improper waste management, hence help to grow faster but competition is also increasing.
- Need to invest millions to money to just awareness and then sell and not have faster cash flow.

2. Competitor analysis

2.1 Competitor analysis for Clean Robotics[9]
  1. Established date Oct 2015.
  2. Product
  - Clean Robotics has built an autonomous system that uses robotics, computer vision and artificial intelligence to detect and separate landfill from recyclables.
  - It does this more accurately than human beings, captures high quality waste data and it lets staff know when it's getting full. Cloud connectivity allows individual units to learn from the global.
  - It does this more TrashBot fleet, becoming more intelligent over time. It also has a monitor for corporate communications, education and advertising.

3. Market share 10%.

4. Value to customers their AI is 3x more accurate than human beings at the point of disposal.

5. Strengths

- Diversion, expense and savings projections.
- On-demand and exportable waste audits.
- Fullness and TrashBot status for custodial operations.
- Customizable AI for compliance.
- Granular data for decision insights.

6.Weakness

- Clean Robotics' AI enabled sorting technology separates recyclable vs. landfill items with only 90% accuracy.
- Only one item dump in bin at a time.
- Sometime confuse where to push the material
- No process that can teach system about new waste where to dump when it is confused.

2. Competitor analysis for Cambridge consultants[10]

1. Established date 1960.
2. Product
   - Product design and development firm Cambridge Consultants has developed a smarter recycling concept which tackles the challenge of improving the efficacy of recycling and incentivizing consumers to recycle, whilst addressing the end-of- life problem faced by consumer brands.
   - The technology within the system is designed to identify the type of waste the consumer wants to dispose of using image recognition. The system combines machine vision with machine learning and can be trained to recognize new items over time.
   - It can also detect the difference between a recyclable cup and a compostable cup, potentially challenging to the untrained eye. It then indicates which section of the waste disposal unit the item should be placed in.
3. Market share 28%
4. Value to customers smart bin can distinguish between PET, PP, compostable.
5. Strengths
   - Have fund to develop accurate prototype
   - It acts as a marketing tool, to show that the brand is proactively leading the way to a sustainable future.
   - Provides additional consumer insights such as when and where products are consumed.
6. Weakness
   - Only developed for high profile shop like Starbucks.
   - Not feasible for outdoor waste.

2.3 Competitor analysis for E-bin[11]

1. Established date 2015

2. Product
   - Bin-e is an IoT-based smart waste bin that recognizes, sorts and compresses the waste automatically. It was born out of the need for a smart waste separation solution in places where an efficient sorting system is hard to introduce.
   - In public and office spaces people often don't sort the waste properly due to lack of motivation, knowledge or proper infrastructure. Bin-e improves the recycling chain by increasing the amount of recovered resources and reducing the amount of waste that goes to landfills. It transforms waste management into an integrated system to facilitate the way towards a circular, sustainable economy.
   - automatic separation – the smart waste bin identifies the type of waste thanks to a recognition system based on Artificial Intelligence and image processing
   - compression of plastics and paper – an embedded mechanism reduces the volume of plastics and paper
   - fill level control – the fill level of each bin inside of the device is displayed on the touchscreen and in the app
   - Automatic notifications - the waste management company gets notified via the app when one of the bins is full and needs to be emptied • data collection – the device gathers data about each object and uploads it onto a cloud; the app delivers real-time data and summary reports.
   - IoT Platform – for optimizing all waste management operations.

3. Market share 50%
4. Value to customers
   - Combined automatic sorting, compression, fill level control and data processing into one device. All these functions allow to transform waste management into an integrated system.
   - It's the key for reaching our global recycling goals and a circular economy.

5. Strengths
   - More resources recovered & higher quality of raw materials.
   - Less waste on landfills.
   - lower frequency and costs of waste disposal
   - optimized waste collection routes & convenient waste management.
   - Reduced costs, time and labor of waste management.

7. Weakness it is very costly 5800$

2.4 Competitor analysis for R3D3[12]

1. Established date 2010.
2. Product

- An iron first in a beautiful case, R3D3 revolutionizes the world of sorting bins. R3D3 is a linked bin that recognizes, sorts and compacts cans, waste material and plastic bottles.
- Dedicated to any space where beverages are consumed, in public spaces, at the workplace, R3D3 invites you to participate actively in sorting drink packaging, whilst improving how this waste is recycled.
- Drop the package.
- It compact and sort.
- Stay connected, It send an email of bin is full
- Real time monitoring of your fleet and sorting statistics.
- It can sort paper, can, bottle less then 50 cl.

3. Market share 11%.
4. Value to customers
- Combined automatic sorting, compression, fill level control and data processing into one device. All these functions allow to transform waste management into an integrated system.
- It's the key for reaching our global recycling goals and a circular economy.

5. Strengths
- 1. 100% reliable sorting
- Time saving.
- Connectivity
- Capacity*10
- Hygiene

 6.Weakness

- NOT work for municipality
- Can handle limited waste type only
-

Products and/or services (Intelligent sorting bin)
- It is an IoT based device which identify the plastic, paper, metal, glass, wet waste, and e -waste material.
- Each type of waste have separate compartment inside the bin. After the identification of material, it transferred to its compartment.
- This device have sensor to detect the material type and camera take two photo of it and feed the photo to computer vision algorithm to predict the material. Further the data generated by sensor and CV algorithm feed to Machine learning algorithm to identify the material and then transferred.
- Information on the weight of material and bin fullness level and other factors can be viewed on app. Information feedback to system for better identification of material.

- A consumer goes to a Starbucks and orders a latte in a paper cup (or a juice in a plastic bottle, or a milk in a carton, etc.). Once he's finished, he goes up and taps his phone against the bin, registering his identity with the bin app via Bluetooth.
- He then dump his cup into the bin where sensors identify the properties of cup and bin's cameras, which take two photos. The computer vision and machine learning identifies the cup lights up the correct area and transferred to that area. If the user didn't want to use the app or register his identity, He simple dump his cup.
- Price range 2000$.

Market position
My targeted customers are who produce similar type of waste daily like Starbucks café. They compare my product as this is low cost product then other.

Benefits to customer
- Total containment eliminates overflow, windblown litter, resulting aesthetics and a safe environment,
- Encourage recycling and reduce carbon footprints &green house emission
- Our system leaves the labour free other productive tasks
- Saves lot of money

Pricing strategy

Product	Forecast total sales ($)	Forecast costs ($)	Mark-up (%)	Gross profit ($)	Gross profit margin (%)
Intelligent sorting bin(per unit)	2000	1500	33.3%	500	25%
Intelligent sorting bin(10 unit)	20000	13500	48.1%	6500	32.5%

Summary
In today secnerio, there are millions of cup produce in a day and present solution provide the solution for this but dumping a one cup take 1.5 minute –2 minutes and was not capable for handling large quantity of cup in an hour.It need large investment to setup the bin.
This solution take only 20 sec to complete the process and can handle large quantity of cups and low cost was market advantage.

Requirements

After the problem and potential solution become clear, they define each stakeholder's potential interaction(s) with a solution, including the solution objectives, success, and acceptance criteria from the perspective of the stakeholder.

To provide a comprehensive picture of the subject gait many parameters are required to be measured. Due to time and budget, only certain parameters will be measured. The device must be:

- Device help shops to decrease the waste management budget and able to focus only on their business
- It helps to increase the recycling percentage of waste material and make a cleaner environment
- User is now free from knowing the type of cup material, device sorts for them automatically
- Data generated from the device help developer to develop a more accurate system (feedback control system)
- Collection service company knows free from sorting the waste material and directly send to the treatment facility

Specifications

Specifications are the requirements of the project expressed using technical language.

Sensor:

1. **Sensor**: A distance proximity sensor is a <u>sensor</u> able to detect the presence of nearby objects without any physical contact. A typical sensing range for proximity sensors is 1 inch to 2 inches.
2. **Sensor**: Inductive proximity sensor an inductor develops a magnetic field when a current flows through it; alternatively, a current will flow through a circuit containing an inductor when the magnetic field through it changes This effect can be used to detect metallic objects that interact with the magnetic field. Non-metallic substances such as liquids or some kinds of dirt do not interact with the magnetic field, so an inductive sensor can operate in wet or dirty conditions. It is used for the detection of metallic properties of the metal.
3. **Sensor**: The Raspberry Pi Camera Module v2 is a high quality 8 megapixel Sony IMX219 image sensor custom designed add-on board for Raspberry Pi, featuring a fixed focus lens. It's capable of 3280 x 2464 pixel static images, and also supports 1080p30, 720p60 and 640x480p60/90 video.It was used in the project from taking images of material and that image sends to AWS rekognition for analysis of the image.[13,14,15]
4. **Actuator**: TowerPro SG90 1.2kgCm 180 Degree Rotation Servo Motor used as actuator because it has the capability of rotating at 180 degrees, Operating voltage: 3.0V~ 7.2V.When device predicts the output metallic or nonmetallic, For metallic motor rotate clockwise 90 degrees, non-metallic motor rotate anti-clockwise 90 degrees. It was used to transfer the material in a particular bin.[16]
5. **Microcontroller**: The Arduino Mega 2560 is a microcontroller board based on the <u>ATmega2560</u>. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.Its Operating Voltage:5V, Input Voltage

(recommended):7-12V, Input Voltage (limit):6-12v.It was used for controlling the sensor and actuator.

6. **Microprocessor**: The Raspberry Pi 3 Model B builds upon the features of its predecessors with a new, faster processor on board to increase its speed. It also features Wi-Fi and Bluetooth low energy capabilities to enhance the functionality and the ability to power more powerful devices over the USB ports. Quad-Core 1.2GHz Broadcom BCM2837 64bit CPU, 1GB RAM, BCM43438 wireless LAN and Bluetooth Low Energy (BLE) on board, CSI camera port for connecting a Raspberry Pi camera.[17,18]

7. **Connectivity**: Wifi is used as connectivity because power is not a constraint and LoRa, NB-IoT,4G, SigFox not needed as they have more than 10Km coverage.

8. **Power supply**: This prototype is designed indoor area like shops so the power supply is not an issue, it can be taken directly from the shop. But any fluctuation in voltage can damage the device so the voltage regulator was used and AAA rechargeable battery was used for power backup.

9. **Cloud service**: AWS is a platform that enables you to connect devices to AWS Services and other devices, secure data and interactions, process and act upon device data, and enable applications to interact with devices even when they are offline. Aws provides the cloud service which provides security, integration with other services of AWS.[19]

10. **AWS IoT SDK**: The AWS IoT Device SDK helps you easily and quickly connect your hardware device or your mobile application to AWS IoT Core. The AWS IoT Device SDK enables your devices to connect, authenticate, and exchange messages with AWS IoT Core using the MQTT, HTTP, or WebSockets protocols. The AWS IoT Device SDK supports C, JavaScript, and Arduino, and includes the client libraries, the developer guide, and the porting guide for manufacturers. You can also use an open-source alternative or write your SDK.

Evaluation of alternative solutions

Sorting of waste waste material is the global problem and has different solution around the globe.

1. Cambridge Consultants has provided a smart bin solution which has smart camera detection of waste material and four-compartment inside the bin each has light indicators. When the cup placed on the device identify it and the right container light glow, then user picks and put the cup inside the bin. It takes 1 min to identify and put the cup inside the bin, might affect the business

2. Collect the mixed waste material and send to sorting facility, then sort the waste material but it takes a lot of resources and money.

3. Choosing the intelligent sorting bin is designed for minimizing the time to dump the waste material within 30 sec and help to save resources and money in long term. When the user put the cup inside the bin, then firstly sensor identifies the material properties and the camera takes two photos of it and CV algorithm identify its shape and properties, then all the data feed into ML algorithm to predict the material, and send the predict data to a device for actuation function.

Prototype progress

1. Arduino MEGA 2560 was used as a microcontroller and configured with raspberry pi 3 model B.

2. Inductive proximity sensor used as an input to Arduino Mega 2560 and all connection and wiring all been done.
3. Distance proximity sensor connected to Arduino mega 2560 and had been configured and all wiring had been done.
4. The pi camera had been connected to a raspberry pi.
5. For communication between Arduino mega and raspberry pi, use simple serial communication over the USB cable was completed.
6. Aws IoT SDK and aws rekoginition SDK were installed in raspberry pi.
7. Wifi built-in raspberry pi used for internet connectivity between device and Aws IoT and had been configured.
8. All the data publish and subscribe over MQTT protocol to aws IOT.
9. When user put the cup in bin aws IoT triggers the aws lambda function to analyze the data of inductive proximity sensor.
10. Image data was analysed on raspberrypi using aws rekoginition sdk.
11. Combination of analysed proximity sensor data and analysed image data sent to cloud for predicting whether material was metallic or not.
12. If it predicts metal,aws lambda function triggers the servo motor to turn on 180 degrees clockwise.
13. If it predicts non-metal,aws lambda function triggers the servo motor to turn on 180 degrees anti-clockwise.

Summary

In this module,requirments of stakeholder had been discused,prototype process,specification,and alternative solution of the problem was discussed

Evaluation and testing

For Metallic cup

When user put the cup inside the bin distance sensor identify whether there is something inside the bin and aws iot send trigger to aws lambda function to analysis the data of inductive sensor and pi camera take photo of material and send for analysis on raspberrypi aws sdk rekoginition. The combination of sensor data and image data decide weather it is metallic or not .If found it as metallic,aws iot triggers servo motor to rotate 180 degree clockwise.

For Non-Metallic cup

When user put the cup inside the bin distance sensor identify there is something inside the bin and aws iot send trigger to aws lambda function to analysis the data of inductive sensor and pi camera take photo of material and send for analysis on raspberrypi aws sdk rekoginition. The combination of sensor data and image data decide weather it is metallic or not .If found it as non-metallic,aws iot triggers servo motor to rotate 180 degree anti-clockwise.

Evaluation of progress

Work need to be done:

1. Optical sensor need to be connected with Arduino mega 2560 for detecting plastic waste material material.
2. Need to deploy advance algorithm to process optical sensor data to produce optimum output.
3. Need to deploy security at the data management and network.

Problems and/or delays are foreseen

1. Power issue is the concern when continuous power cuts,voltage fluctuations are there.
2. Security is the biggest concern when someone in shop knows the wifi password.
3. M2M IoT sim need to deploy for internet connection but it may be costlier.

Worst case Scenario

Worst case is when user put multiple cups in bin
When someone get wifi access ,it will affect the device so security step need to be taken.

Summary

There are some sensor need to be add and deploy advance algorithm to produce optimum output,Wifi might be the problem ,when someone try to access its password/

Conclusion

In this section the full report is summarised without any new information being added with the exception of a section describing future work.
An example is below:

This report has laid a sound and effective foundation for others to build upon and complete the solution for the intelligent sorting bin. The use of inductive proximity sensor has been found to be a suitable metal detection and pi camera is used as secondary verification using AWS rekoginition sdk.Wifi has been found to be a suitable transmission medium, provided that it is implemented correctly. Wifi communication systems are conveniently available in the Wifi access point at shop.However, the issue found with wifi access point, when new password entered, change of host name and someone try access the wifi.It need to be implement M2M sim for communication.

Future work

Intelligent sorting bin is a automatic waste sorting device but it only sort metal material and non metal material into two compartment in the bin.It need to add more funcnality like sorting the types of plastic,paper,wet waste.It need to sort multiple thing at a time, right it only sort one thing at a time.After completing all need funcnality,then start production and send for test at real market places like shops.

Project Plan

Intelligent sorting bin project plan has user stories to complete it step by step from intial to end phase,but some of the user stories were left complete because of limited time and budget.

WBS NO.	Activity	Earliest start date	Latest End date	Resources	Timelines	Risk assetment
1	Project management					
2	Canvanizer	23-Jul-19	07-Aug-19	Time and Computer	Week 3-Week 4	
3	Video presentation	08-Aug-19	23-Aug-19	Time and Video caputing equipment	Week 4-Week 6	
4	Market research cost report	24-Aug-19	08-Sep-19	Time and research cost	Week 7-Week 8	
5	Prototype	01-Sep-19	25-Sep-19			
5.1	Process mapout	01-Sep-19	01-Sep-19	Paper	Week 9 Day 1	Need to identify required Input and output
5.2	Identify the control system	02-Sep-19	02-Sep-19	paper	Week9 Day 2	Control system affect the device performance
6	Required devices to be connected					
6.1	Identify the sensor	03-Sep-19	03-Sep-19	Inductive proximity sensor,capaciive proximity sensor,plastic detection sensor,pi camera.	Week 9 Day 3	Need to identify precision based sensor
6.2	Identify the Actuator	04-Sep-19	04-Sep-19	Servo motor 180 degree rotation	Week 9 Day 4	Need to identify actuator which can load upto 200g of weight
6.3	Identify the intermediate device	05-Sep-19	05-Sep-19	Arduino MEGA 2560 and raspberrypi	Week 9 Day 5	Need to identify mininal processing Micro and low cost
7	IOT protocol consderations	06-Sep-19	06-Sep-19	Range within the shop	Week 9 Day 6	need 24/7 internet connectivity

8	IoT protocol choice	07-Sep-19	07-Sep-19	Wifi	Week 9 Day 7	need 24/7 internet connectivity
9	Data					
9.1	Type generated	08-09-2019	08-09-2019	Volume, limited data range, partly processed in fog, analysis shared on web	Week 10 Day 1	Need to process data in low processing Micro
9.2	Storage solution	09-09-2019	09-09-2019	Local server, backed up	Week 10 Day 2	It will cost more
9.3	analysis overview	10-09-2019	10-09-2019	Identify the type of material and report to the device for functioning	Week 10 Day 3	Might not always identify the material
10	Programming Required					
10.1	device function	11-Sep-19	14-Sep-19	"Programming to record the type of material. Holds data for 24 hours unless in contact with wifi when it uploads data."	Week 10 Day 4-Week 10 day 7	May be sometime wifi not connect more than 24 hrs
10.2	networking requirment	15-Sep-19	15-09-2019	Data from sensor directed to wifi on AWS IOT.AWS Iot send data to device via wifi to direct actuator	Week 11 Day 1	Need 24/7 internet connectivity
10.3	data management	16-Sep-19	17-09-2019	Data needs algorithm to identify material that suggests	Week 11 Day 2-day 3	May need more time and cost

				whether the material is metallic or non metallic,help device to seprate the material in different bin		
11	Security and privacy consideration					
11.1	device	18-Sep-19	18-09-2019	Need to be secured from water,dust	Week 11 Day 4	May be liquid material push to bin and affect the device
11.2	network	19-Sep-19	19-09-2019	Resisit the wifi coverge outside the shop and stop being connected that wifi to other	Week 11 Day 5	Might be attackers try to access the wifi
11.3	data	20-Sep-19	20-09-2019	Protect historical data from being lost, stolen or ransomed, guard against re-setting of algorithm so shows all material are metallic or all non metallic	Week 11 Day 6	Data need to be protected from hackers
12	Final report	21-Sep-19	28-09-2019		Week 11 Day 7 - week 12	

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