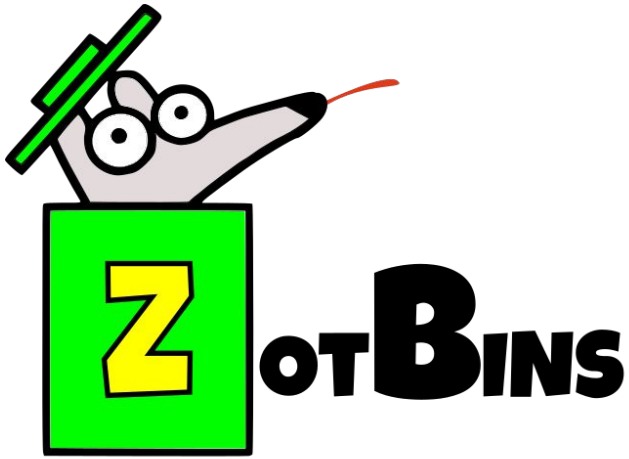
UCI Donald Bren School of Information & Computer Sciences



A Smart Space Initiative for Zero Waste

Primal Pappachan

How climate change could impact the world

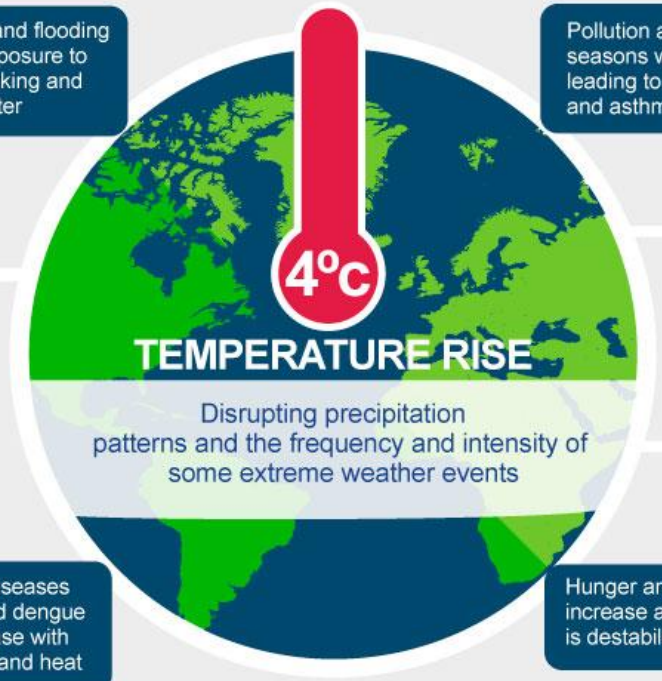
Warmer water and flooding will increase exposure to diseases in drinking and recreational water

Pollution and pollen seasons will increase, leading to more allergies and asthma

250,000

DEATHS FROM DISEASE BY 2030

Mainly due to malaria, malnutrition, diarrhoea and heat stress



7million

DEATHS FROM AIR POLLUTION

$2-4bn

COSTS BY 2030

Vector borne diseases like malaria and dengue virus will increase with more humidity and heat

Hunger and famine will increase as food production is destabilised by drought

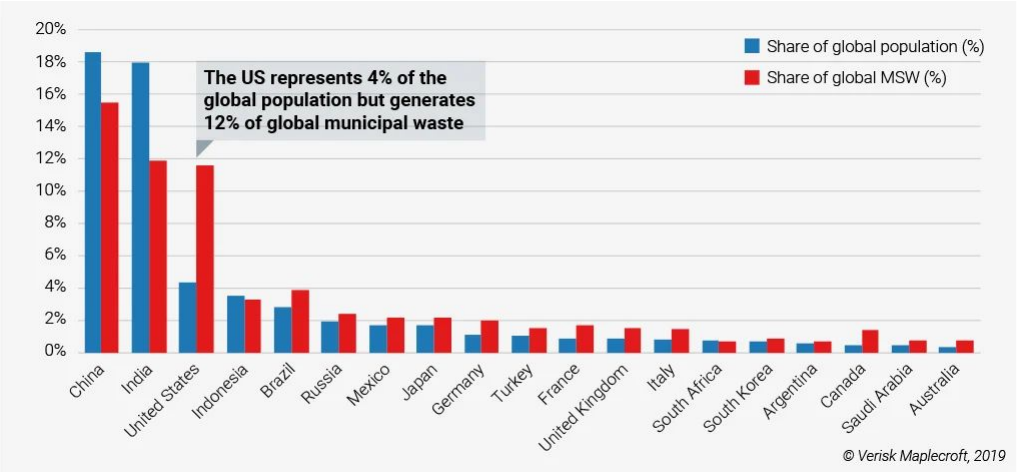
Source: WHO

Credit: Rebeccah Robinson/LSHTM

Waste Management contributes to Climate Change

HARVEST AND TRANSPORT

Source: EPA Reports 2018

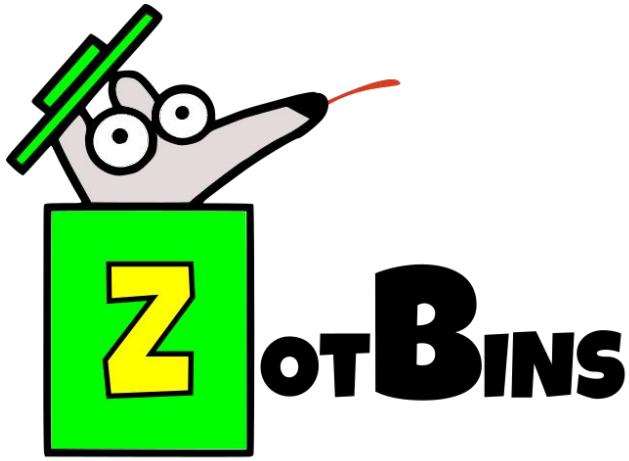


Better Waste Practices - 5 R’s

Zero Waste as a Movement

zero waste UCI

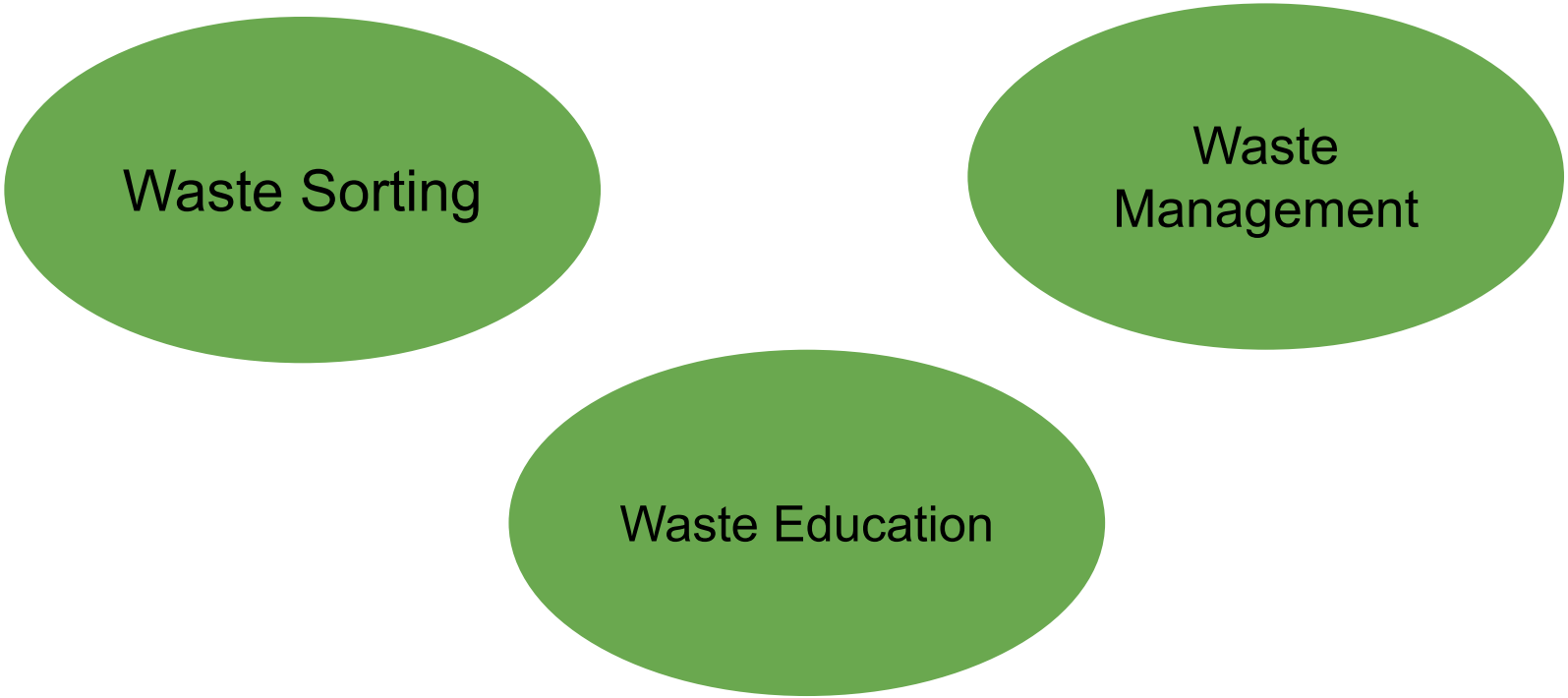
I ♻ USC



A Smart Space Initiative for Zero Waste

Help keep communities clean, make waste management more efficient, and encourage the practice of zero waste

Focus of ZotBins

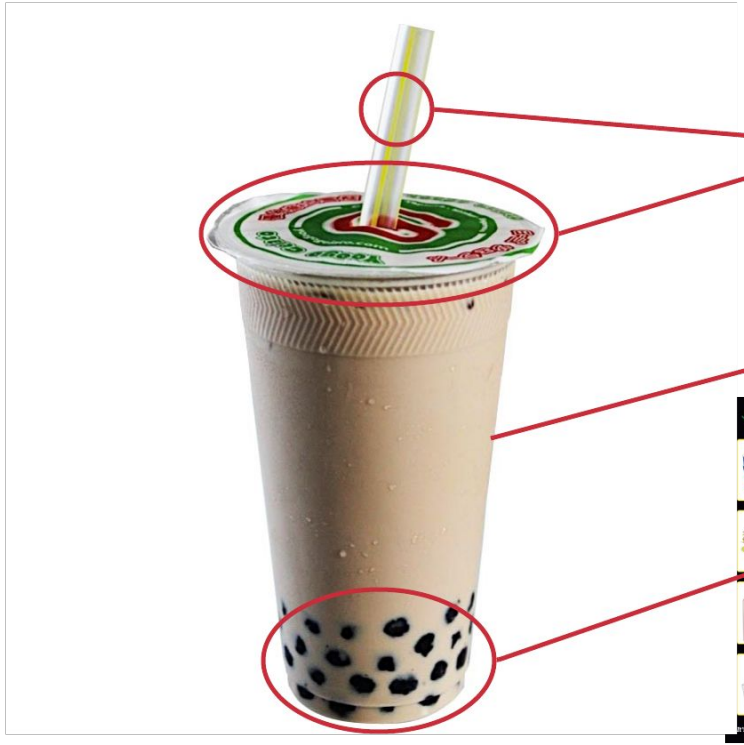


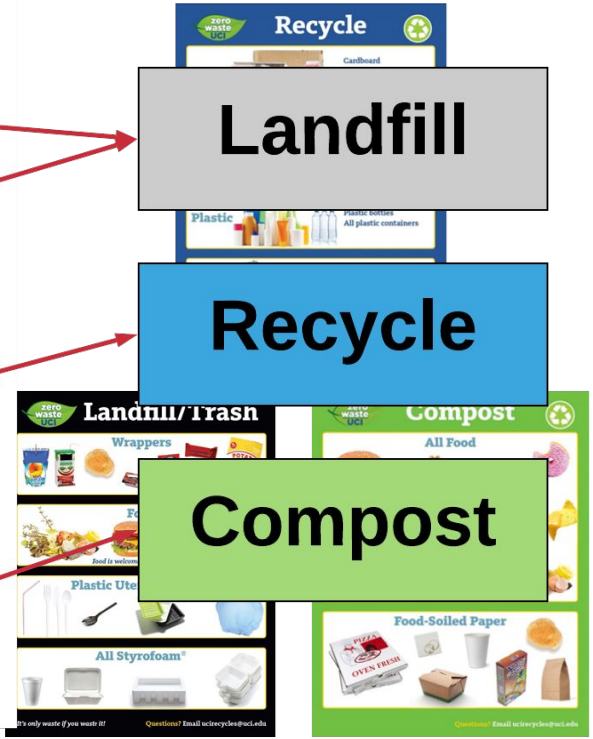
Waste Sorting

Waste Sorting

Waste Management overhead

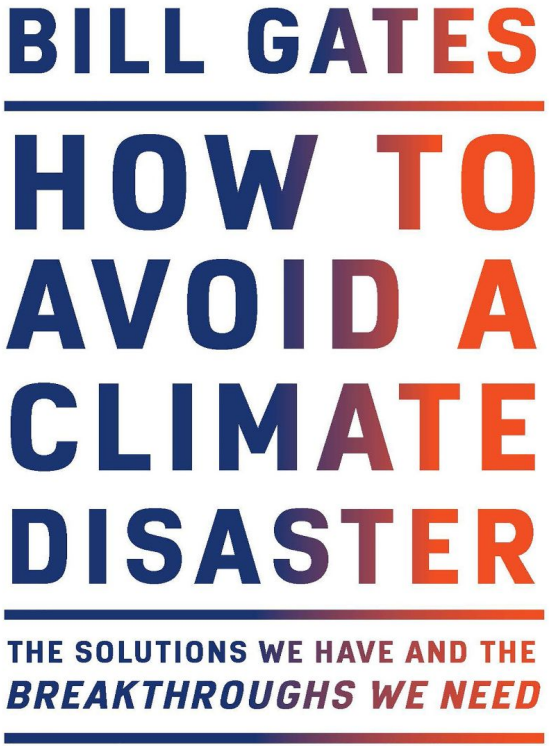
Waste Education





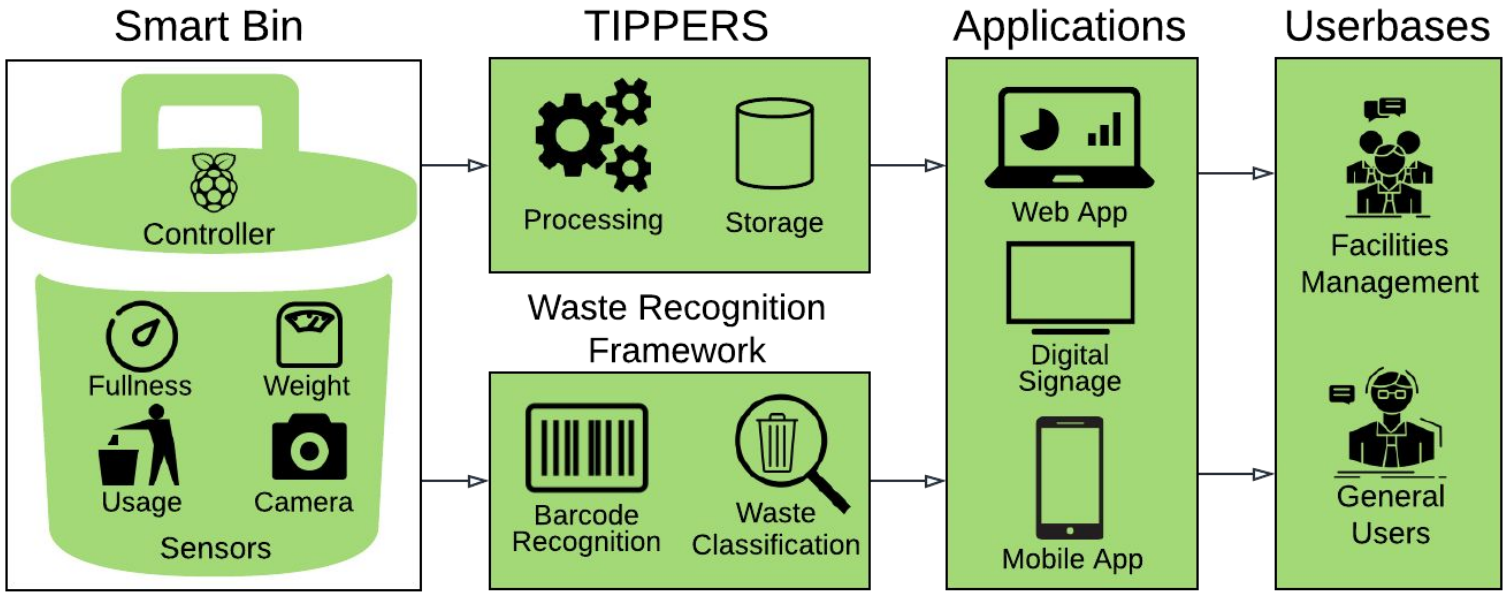
What is the solution?

"Another has developed a "smart bin" that uses image recognition to track how much food is wasted in a house or business. It gives you a report on how much you threw away, along with its cost and its carbon footprint. The system may sound invasive, but giving people more information can help them make better choices."



Transforming Waste Management

ZotBins System Overview



Smart Bin

- A smart bin is a regular bin equipped with **microcontroller and multiple sensors** that is connected to the internet
- Ideally deployed in a set (landfill, compost, recycling) but some are deployed individually
- The main challenge in building the smart bin are the placement of sensors
  - Accurate measurement
  - Does not get in the way of waste disposal and emptying of bins

Evolution of ZotBins

Prototype 1

Deployed in Apartment Kitchen

Summer 2017

Prototype 2

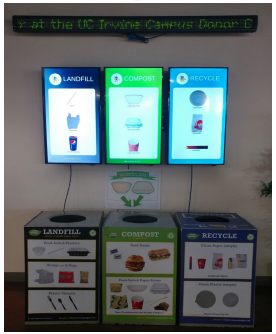
Deployed in Donald Bren Hall

Summer 2018

Prototype 3

Collaboration with Digital Waste Bins, deployed in UCI Food Court

Summer 2019



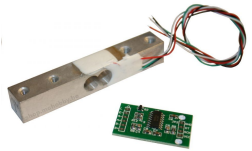
Prototype 4

More flexible design to account for various types of bins, simpler design for quicker set up

TBA

What Sensors Are We Using?

- Ultrasonic Sensor (HC-SR04)
  - Measures the current fullness of the waste bin



- Strain Gauge Load Cell (HX711 amplifier)
  - Measures the current weight of the waste inside the bin

- IR Break Beam Sensor
  - Indicates that trash has been placed in the bin

- Camera
  - Located in some bins, takes a photo of the contents of the bin

- Raspberry Pi platform (RPi3)
  - Manages the sensors and detects failures
  - Stores data locally and sends it via an API

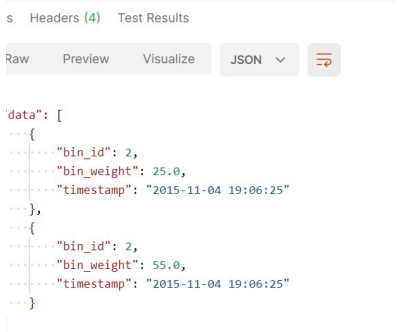
TIPPERS

- TIPPERS is a system that manages collected sensor data and can help build smart applications like ZotBins.
- We use TIPPERS as IoT data management system for our sensor data.
- E.g., ultrasonic data points are turned into fullness level data points.
- https://tippers.ics.uci.edu/

TIPPERS + ZotBins

- ZotBins REST API
  - All of the sensor data is sent to TIPPERS using APIs where it is processed and saved to a DataBase Management System
  - Our web and mobile team uses these APIs to build different services for waste management
- Mock Sensors
  - are used to generate mock data for our web and mobile app team to continue development due to the inability to access the bins
- Error detection
  - In the case of sensor failure, the system will notify the API, so our team can fix the faulty sensor

#	Method	Endpoint
1	POST/GET	/bin-info
2	GET	/bin-info-all
3	POST/GET	/weight
4	GET	/weight-all
5	POST/GET	/fullness
6	GET	/fullness-all
7	POST/GET	/usage
8	GET	/usage-all
9	POST/GET	/image



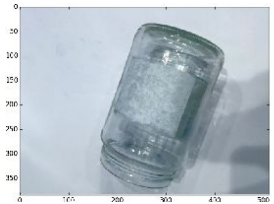
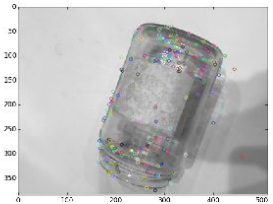
Waste Recognition

Objective - user inputs information about type of waste they have and are given proper waste disposal instructions

Waste Recognition - Barcode

- Pros
  - Relatively simple to implement Low room for error
  - Reliable and fast
- Cons
  - Requires item has a barcode
  - Not all barcodes will be stored and labeled on database
  - Must be updated as barcodes are updated
- Current Status
  - API in place on mobile app already
  - Collab with UCI Dining who is providing us with 13,000 of the most common barcodes on campus

Waste Recognition - Image Classification


- Pros
  - Waste doesn't need a barcode
  - Easier from a user standpoint
  - Won't require updating as product names or barcodes change
- Cons
  - Hard to develop, Requires lots of data!
  - Larger room for error

Current Status

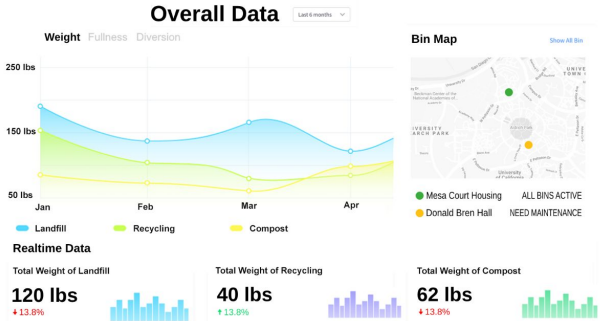
- Achieved 93% accuracy on 10 different classes of waste (close to ideal for image recognition which is 99%)

Image Classification steps

1. **Collecting Data**: *ImageNet, Interns Collecting Data, etc.*
2. **Preprocessing Images**: *Resizing, Segmentation, Removing Noise, Data Annotation*
3. **Data Augmentation**: *Helps with enlarging of a small data set*
4. **Training the Models**: *Utilizing distinct architecture of CNN and Resnet (Pytorch, Keras)*
5. **Fine-tuning hyperparameters**
6. **Testing the performance** *of different models on tensorboards for common data set*.
7. **Predicting the accuracy** of each model on test data set.

Applications

- Three applications that allows people to interact with our system



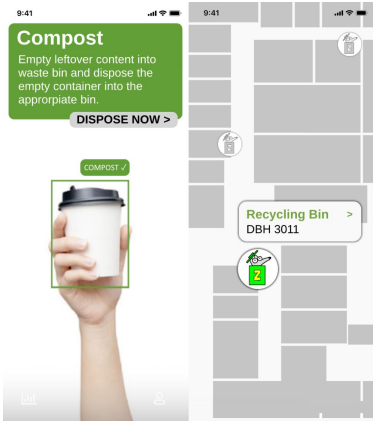
Web App

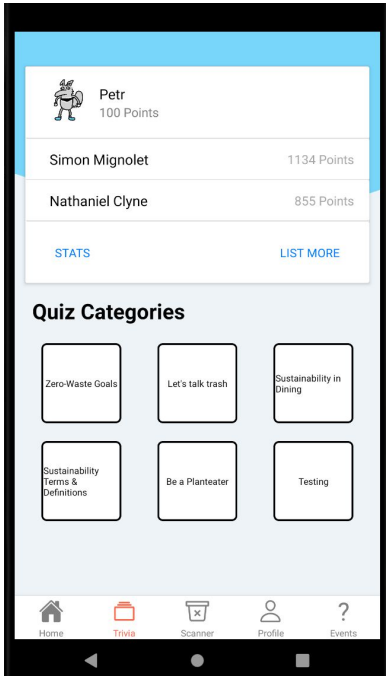
Mobile App

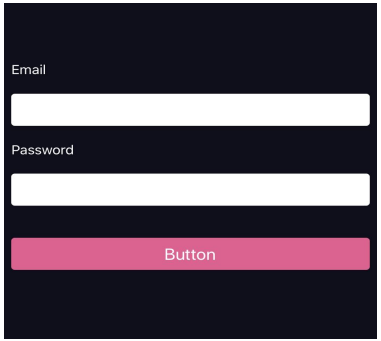
Digital Signage

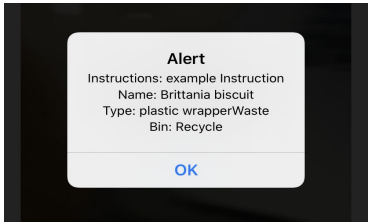
Applications: Mobile App

- **Map:** Displays the locations of all the ZotBins on campus and provides directions to the nearest ZotBin.
- **Barcode scanner:** Scan a barcode and learn how/where to dispose the item.
- **Image Recognition:** Click picture of the trash to learn how/where to dispose item.
- **Login/Sign up:** Allows users to track points, update their profile.
- **Trivia:** Trivia questions on waste management for incentivization. Leaderboard maintained (amongst all users) based on user Trivia performance. Top users get prizes from UCI Dining.
- **Events:** Events page containing the latest/upcoming events from UCI Dining.





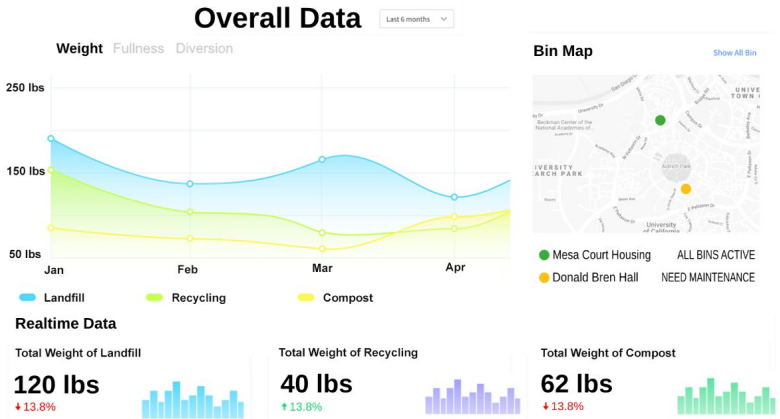


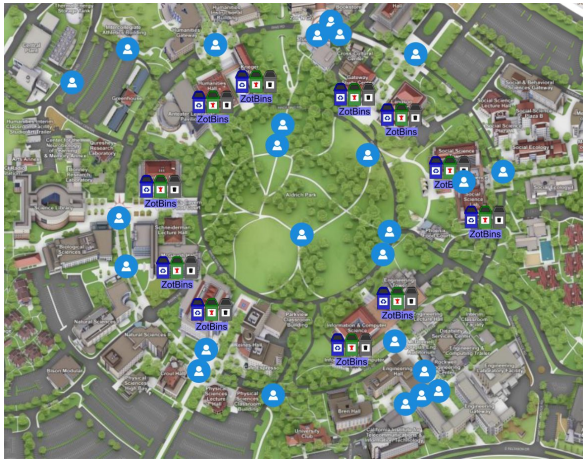


Applications: Web App

Data visualization in charts and graphs
- Total trash collected over time
- Tracking diversion rate
- Types of trash collected over time (Recyclable, Landfill, Organic, E-Waste)

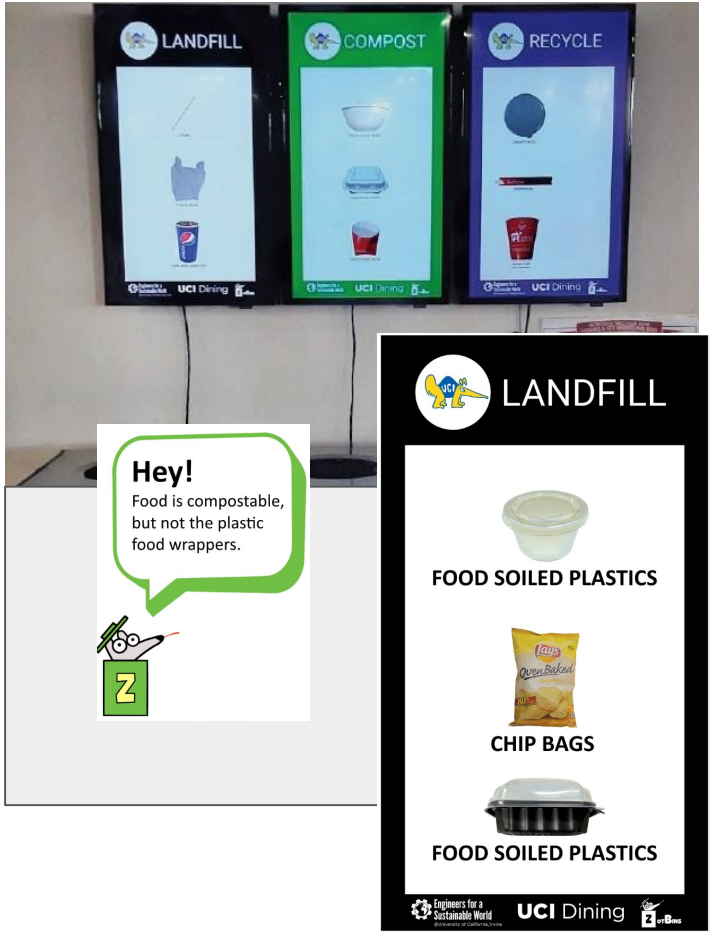
Check individual bin status
- Checking if a bin needs maintenance
- Tracking the weight in each bin
- Check if bin is full
- Registering new bins to collect data



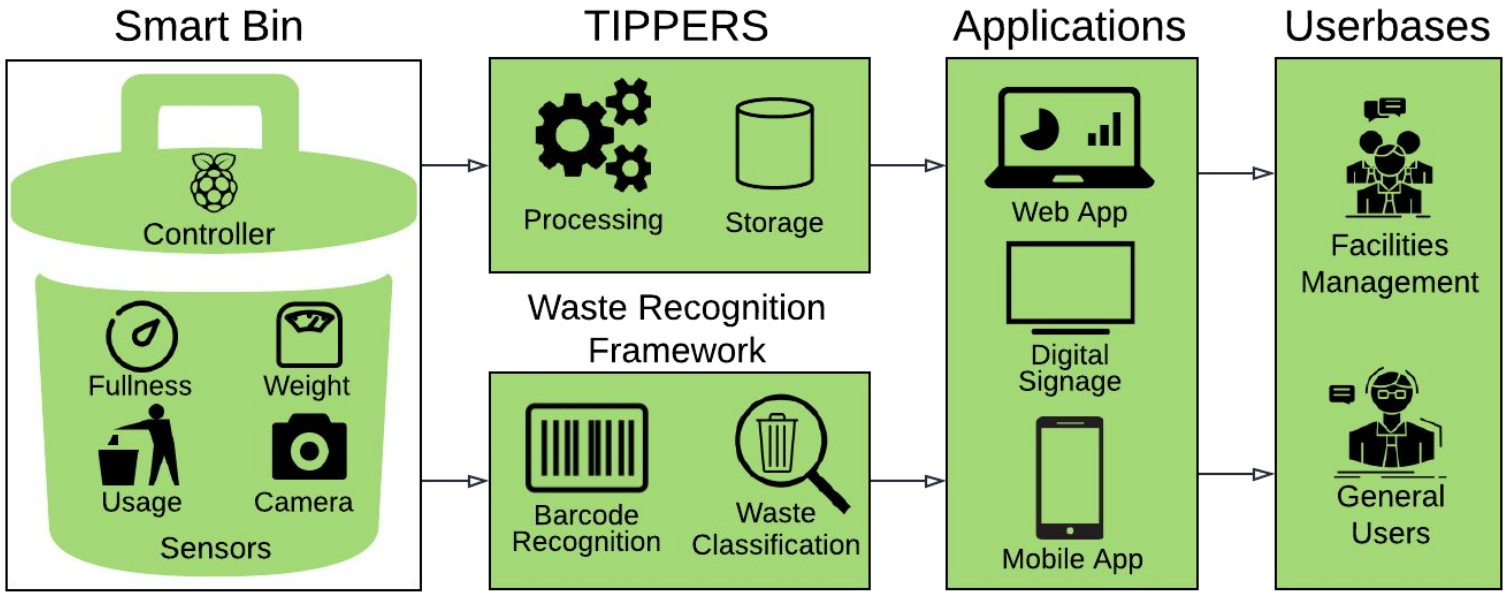


Digital Signage

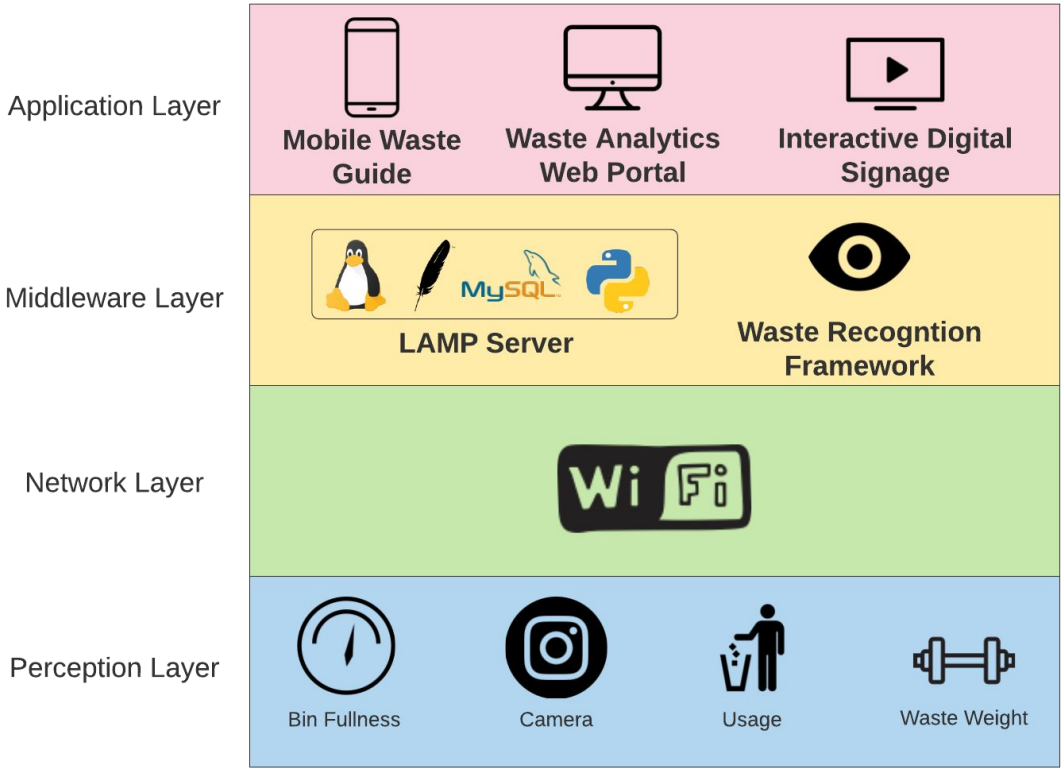
- Provide immediate feedback for users as they dispose their trash
- Mounted on the smart bins
- Displays animated customized signage and interactive pop-ups of educational content whenever a waste item is thrown away
- Disposal instructions for waste items most commonly thrown away at a particular location
- Plan to leverage the camera inside of the bin along with the Waste Recognition Framework in order to identify and provide feedback for incorrectly disposed waste items



ZotBins System Overview

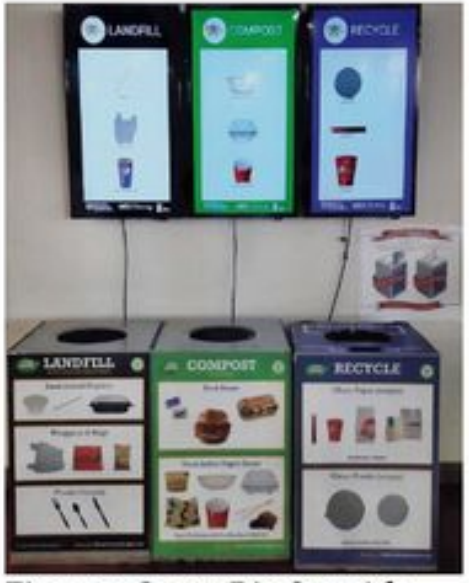


IoT Architecture



Deployment Story So Far

- 8 bins deployed on campus
  - 6 bins in UC Irvine's cafeterias
  - 2 bins in our computer science buildings
- Collected over **100,000** weight and ultrasonic data points
- Over a period of 3 months, ZotBins was recorded to have **increased composting by 22.72%** and **recycling by 5.53%**
- One set of bins have an estimated **$20,000 savings** from recovering more compost and recycling material over 10 years (estimated lifetime of a ZotBins' set w/ regular maintenance)



ZotBins Set deployed in West Food Court

ACM SenSys 2020 Publication

Poster abstract: The ZotBins solution to Waste Management using Internet of Things

Joshua Cao, Jesse Chong, Marissa Lafreniere, Owen Yang, Primal Pappachan, Sharad Mehrotra, Nalini Venkatasubramanian
University of California, Irvine
{caoj11,chongjl,mlafreni,okyang}@uci.edu
{primal,sharad,nalini}@ics.uci.edu

ABSTRACT

The growing use of Internet of Things (IoT) technologies has the potential to improve waste management. In this work, we present *ZotBins*, a system that facilitates sustainable practices for individuals and improves waste management efficiency for organizations. ZotBins consists of smart bins fitted with sensors, a waste recognition framework, and a variety of user applications. Currently, eight smart bins have been deployed in University of California, Irvine (UCI) campus and the preliminary estimates show that it improves the diversion rate (percentage of waste diverted from landfills through methods such as recycling) by about 20% while generating tens of thousands of dollars in revenue over the course of next ten years for the university.

CCS CONCEPTS

• **Hardware** → **Sensor applications and deployments**; • **Applied computing**;

KEYWORDS

Internet of Things, Waste Management, User Applications

ACM Reference Format:

Joshua Cao, Jesse Chong, Marissa Lafreniere, Owen Yang, Primal Pappachan, Sharad Mehrotra, Nalini Venkatasubramanian . 2020. Poster abstract: The ZotBins solution to Waste Management using Internet of Things. In *The 18th ACM Conference on Embedded Networked Sensor Systems (SenSys '20), November 16–19, 2020, Virtual Event, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3384419.3430441

1 INTRODUCTION

Waste poses significant economic, environmental, and public health threats if not addressed properly. At the current rate where 64.8% of waste (specifically municipal solid waste) is being sent to landfills, the economic opportunity to reuse materials is lost, greenhouse gas emissions are produced, and air and water quality are compromised for certain communities [1]. To maximize the diversion rate, three critical challenges must be solved: 1) in-depth analysis of waste trends [5]; 2) maximizing material reuse potential through waste recognition [2]; 3) reduction of facilities management overhead [3].

SenSys '20, November 16–19, 2020, Virtual Event, Japan

ACM ISBN 978-1-4503-7590-0/20/11…$15.00
https://doi.org/10.1145/3384419.3430441

ZotBins [1] is a holistic IoT based solution that provides many useful features to assist organizations (e.g., facilities management) and general users in maximizing diversion rate by addressing these challenges.

ZotBins consists of smart bins fitted with a suite of sensors that monitor data about various waste events. ZotBins helps organizations analyze this data using different visualizations to study real-time and historical diversion rates and to determine appropriate strategies for waste pickup and bin placement. It also includes different user applications that guide users to appropriately dispose of their waste. In this work, we present a detailed overview of ZotBins and describe the current deployment status of ZotBins on UCI campus.

2 ZOTBINS SYSTEM

ZotBins consists of the following three modules. First, the *Sensors and Controller* are attached to the waste bin and are used for the collection of sensor data and the sending of collected data to *TIPPERS*[4] through API calls. TIPPERS is a cloud based IoT data management system that is used to process and store all sensor data. Second, the *Waste Recognition Framework* identifies images or barcode numbers of waste from the smart bin or user applications. Third, *User Applications*, built on top of TIPPERS APIs, allows facilities management and general users to utilize various useful features. The data flow through these different modules in ZotBins is demonstrated in Figure 1.

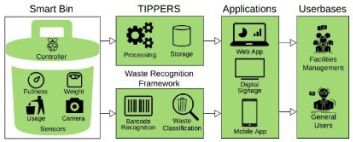


Figure 1: ZotBins System Data Flow

Sensors and Controller

Smart bins consists of the following sensors: 1) Weight (implemented using a load cell) measures the total weight of waste inside a bin, 2) fullness (implemented using the ultrasonic sensor) determines the percentage fullness of the bin, 3) usage (implemented using the break beam sensor) detects every time a bin is used, and 4) camera captures images of waste thrown away which is later used

[1] https://zotbins.github.io/

Recognition

Bren school home / Community / News

In The News

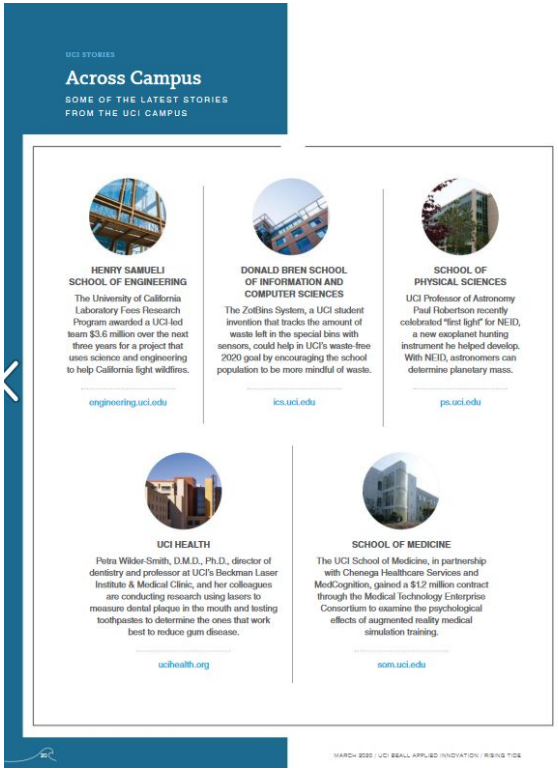
January 13, 2020

ZotBins and Zero Waste Anteaters Support UC Goal for 2020

For almost a decade, the University of California has been pushing for zero waste by 2020, even implementing a #MyLastTrash campaign in 2017. The once far-off deadline is finally upon us, and although none of the 10 UC campuses have conquered the ambitious goal of diverting 90% of waste from local landfills, UCI is leading the pack at 80%. Now, as UCI approaches the finish line, it could get a boost from a group of ZerO Waste Anteaters (ZOWA) and their deployment of ZotBins.

ZerO Waste Anteaters (ZOWA): (from left, front) Joshua Cao, David Pham, Danny Tran (alumnus), Owen Yang and Primal Pappachan; (from left, back) Anthony Luu, Diego Torres (alumnus), Sid Lau (alumnus), Marissa Lafreniere and Kathy Nguyen. (Not pictured: Grace Seung-Mi Choe, Mohammed Haque, Jesse Chong, Tedi Sr Zadouri and Marawin Chheang.)

- Featured in UCI [ICS Article](#) (Jan 2020)



UCI STORIES

Across Campus

SOME OF THE LATEST STORIES FROM THE UCI CAMPUS

HENRY SAMUELI SCHOOL OF ENGINEERING

The University of California Laboratory Fees Research Program awarded a UCI-led team $3.6 million over the next three years for a project that uses science and engineering to help California fight wildfires.

engineering.uci.edu

DONALD BREN SCHOOL OF INFORMATION AND COMPUTER SCIENCES

The ZotBins System, a UCI student invention that tracks the amount of waste left in the special bins with sensors, could help in UCI's waste-free 2020 goal by encouraging the school population to be more mindful of waste.

ics.uci.edu

SCHOOL OF PHYSICAL SCIENCES

UCI Professor of Astronomy Paul Robertson recently celebrated "first light" for NEID, a new exoplanet hunting instrument he helped develop. With NEID, astronomers can determine planetary mass.

ps.uci.edu

UCI HEALTH

Petra Wilder-Smith, D.M.D., Ph.D., director of dentistry and professor at UCI's Beckman Laser Institute & Medical Clinic, and her colleagues are conducting research using lasers to measure dental plaque in the mouth and testing toothpastes to determine the ones that work best to reduce gum disease.

ucihealth.org

SCHOOL OF MEDICINE

The UCI School of Medicine, in partnership with Chenega Healthcare Services and MedCognition, gained a $1.2 million contract through the Medical Technology Enterprise Consortium to examine the psychological effects of augmented reality medical simulation training.

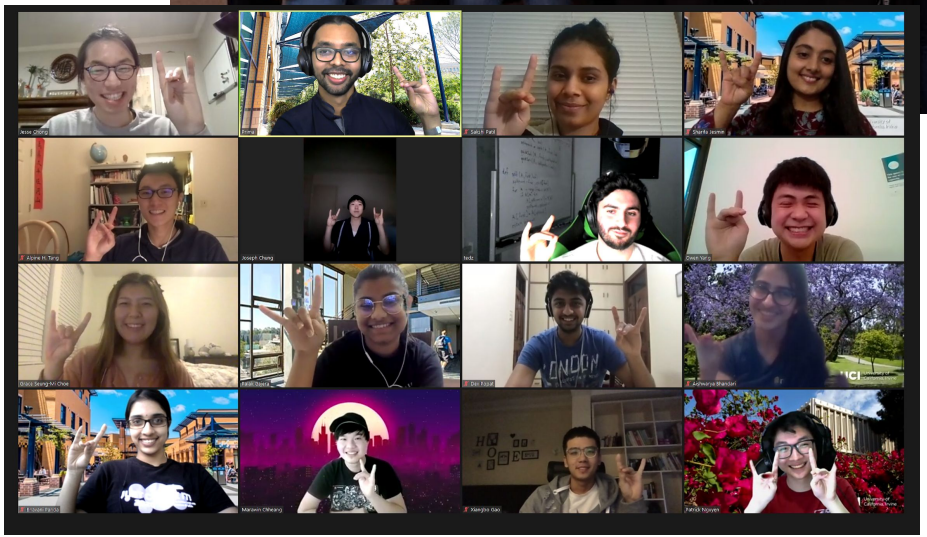
som.uci.edu

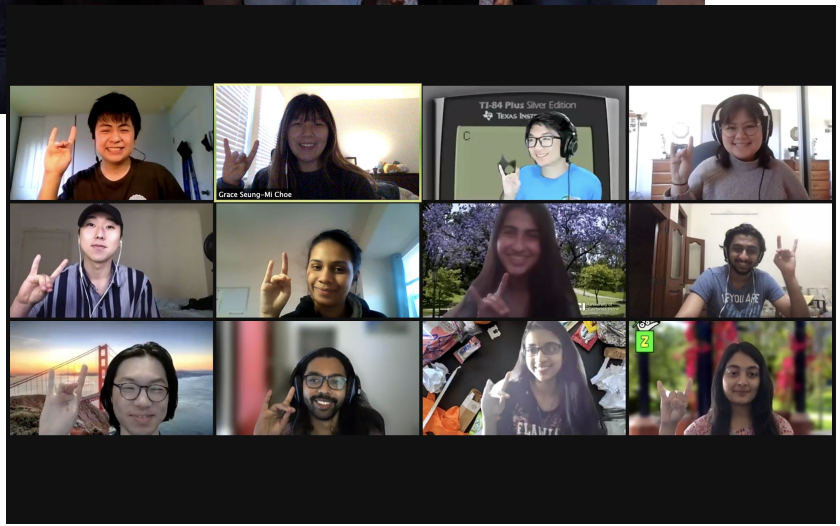
- Featured in UCI [Rising Tide magazine](#) (page 22) (Mar 2020).

Timeline of ZotBins

- **Won the TIPPERS Hackathon (Jun 2017)**
- Built the first Waste Monitor prototype and the web app (Aug 2017)
- Demoed the Project at ICS 50th Anniversary Gala (Oct 2017)
- **Deployed multiple bins in Donald Bren Hall and started collecting data (Jun 2018)**
- Demoed at UCI Sustainability Fair (Jan 2019)
- Demoed the project at UCI's Sustainability Co-Curricular Working Group (SCWG) (Feb 2019)
- Submitted the proposal for UC Carbon Offset Projects; invited to work with UC level Zero Waste Working group (May 2019).
- Submitted the proposal to NSF Smart and Connected Communities (Sep 2019).
- Demoed the project at UCI's Sustainability Co-Curricular Working Group (SCWG) (Sep 2019)
- **Organized First Zero Waste Symposium at UCI**
- Featured in UCI ICS Article (Jan 2020)
- Featured in UCI Rising Tide magazine (page 22) (Mar 2020).
- Submitted poster and presented to IEEE Sustech 2020 (Apr 2020).
- Submitted short paper to ACM BuildSys (Sep 2020).
- **Accepted poster paper to ACM SenSys Yokohama Japan conference (Oct 2020).**


esurance
UCI
NIKE AIR




TI-84 Plus Silver Edition
Grace Seung-Mi Choe

ZotBins Advisors and Mentors

Professor
Sharad Mehrotra

Donald Bren School of Information and Computer Sciences at UC Irvine

Professor Nalini Venkatasubramanian

Donald Bren School of Information and Computer Sciences at UC Irvine

PhD Candidate
Primal Pappachan

Donald Bren School of Information and Computer Sciences at UC Irvine

Owen Yang

B.S. Computer Science & Engineering '20
Lab Engineer @ Microsoft

Jesse Chong

B.S. Computer Science '21
Software Dev. Engineer @ Amazon

Our Collaborators

- UCI Housing
- UCI Dining
- UCI Facilities Management
- City of Irvine
- Orange County Recycling Coalition
- Irvine Unified School District
- Irvine Company
- USC

Opening it up to the broader community

- ZotBins Community Edition (ZBCE) is an open-source continuation of the ZotBins Project
- Designed so that any community, city, or school could implement a smart waste metrics system
- Join our Discord! https://tinyurl.com/discord-zbce

Contact Us

Website - ZotBins.github.io

Email - zotbinsuci@gmail.com