Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 130-C**

Smart Trash Sorting for Zero Waste in Minnesota

Category: C. Environmental Education

Sub-Category:

Total Project Budget: $ 394,709

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

We aim at enhancing recycling in Minnesota by providing a recycling-at-source solution, which is to help Minnesotans make immediate recycling decisions by a smartphone application connected to trash bin networks.

Name: Ce Yang

Sponsoring Organization: U of MN

Job Title:

Department:

Address: 1390 Eckles Ave

St. Paul MN 55108

Telephone Number: (612) 626-6419

Email ceyang@umn.edu

Web Address: yanglab.bbe.umn.edu

Location:

Region: Statewide

County Name: Hennepin, Ramsey

City / Township: St. Paul, Minneapolis

Alternate Text for Visual:

Smart Trash Sorting for Zero Waste in Minnesota by a Smartphone Application Connected to Trash Bin Networks.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Smart Trash Sorting for Zero Waste in Minnesota

I. PROJECT STATEMENT

The proposed project aims at enhancing recycling in Minnesota to achieve 'zero waste' with our citizens' efforts. Towards this end, this project will leverage modern technology to provide a *smart* and *precise* public trash sorting tool. The major goal of this tool is to increase recycling rates in Minnesota, by reducing recyclables to landfill, as well as recyclables contaminated by landfill garbage. **This project has immediate and long-term impact on the education of Minnesotans, especially our next generation, in recycling practices.**

The proposed tool consists of: (i) a smartphone application for real-time trash recognition, sorting, and education, and (ii) a mesh/network of connected trash bins with information about the bin location, bin type and fill-level for busy areas such as the University of Minnesota, the Minneapolis-Saint Paul airport, and the Mall of America.

The importance of the proposed project stems from the fact that in Minnesota, waste management systems have not received as much attention in the city planning process as other sectors, such as water and energy. However, waste materials have value and recycling can save the state money, hence providing economic benefits. In 2010, Minnesota wasted recyclable materials worth $285 million and spent an additional $200 million to throw them away into landfills. These numbers suggest that several things can be done in Minnesota to improve recycling.

Various waste categorizations exist in public spaces in Minnesota, such as recyclable/landfill, organic/paper/bottles/landfill and compost/plastic/landfill. With limited education in waste disposal practice, such kind of categorizations usually cause confusion and lead to wrong trashing decisions. If materials go to the wrong bins, it will cost extra time and money to remove them at a sorting facility. In many cases, the mistake is not recoverable because recyclables can be easily contaminated if tossed in the landfill bin. To make the situation even worse, non-recyclable items tossed in the recycling bin will contaminate other recyclables, which results in a further waste of resources. For instance, soiled papers from food packaging can cause the whole paper bin to landfill. In the worst-case scenario, improper trash sorting poses a threat to public health and the environment.

We propose to enhance trash sorting at its source, which is to help people accurately sort trash onsite in public areas. Towards this end, the smartphone application represents an ideal tool to educate Minnesotans to properly recycle resources and protect our environment. Thus, the proposed project has the broad impact of guiding our citizens, especially the next generation, in trash sorting and achieving 'zero waste' in Minnesota.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Developing real-time and precise trash sorting algorithms on mobile platforms.

We will leverage the latest evolution of machine learning, i.e., deep neural networks, for developing algorithms to help users make a *real-time* and *precise* decision on where to toss a particular trash item. Our trash sorting is expected to be implemented on embedded platforms with limited computing capabilities. Thus, our neural network model has to be deployed using efficient structures targeted for mobile applications, e.g., MobileNets. Towards this end, we will first select a high-performing model based on detailed analysis of the state-of-the-art achievements in deep learning, and then adapt it to our needs through transfer learning. We plan to capture around 2000 training images for each category as our systematic dataset and label them according to expert suggestions. Once the data is ready, we will train our model using the collected data for efficient trash sorting. During this process, we may also need to adapt the model structure for optimal performance. Finally, we will deploy the trained model in mobile platforms and further improve its performance upon feedback analysis.

ENRTF BUDGET: $ 125,594

Outcome	Completion Date
1. Collect a systematic image dataset for training and testing	*June 2021*
2. Create an efficient deep learning network model tailored for mobile platforms	*November 2021*
3. Repetitively tune the model to get improved results on the mobile platforms	*June 2022*

Activity 2: Building a public trash bin network aware of the bin type and level of filling.

This activity aims at creating an Internet of Things (IoT) network of bins to assist users in locating the *nearest non-full* bin. In this project, we will focus on *indoor* spaces covered by Wi-Fi, with a special focus on busy areas at the University of Minnesota, Malls of America, and the MSP airport, where 200 trash bins will be selected and used. We will leverage the existing Wi-Fi infrastructure to *locate* and connect the trash bins to the network. In particular, a group of bins (for different types of materials) will be located close to an access point and paired with it. When a user's phone connects to an access point, it will be directed to the group of bins connected to that access point given the bins are not full. We will use ultrasonic sensors to detect the fullness of the bins. If a bin is full, a signal will be sent to a central server to mark the bin as *not available* on the map and the user will be directed to the next closest bins. This study and its outcomes will provide useful insights to analyze other scenarios such as: (i) a trash/recycle bin positioning system across the city area, (ii) facility staff being notified on the fill-level of the bins for timely management, and (iii) outdoor solar powered bin networks.

ENRTF BUDGET: $ 138,378

Activity 3: Developing a smartphone application with real-time trash sorter, bin finder and a recycling game

Outcome	Completion Date
1. Mark the trash/recycle bins in study on the bin map and install fill-level sensors	*August 2021*
2. Pair the bins with the WiFi access points and create the IoT network	*January 2022*
3. Enable communication between bin networks and the smartphone application	*February 2023*

We will develop a smartphone application that integrates the precise trash sorting algorithm developed from activity 1. App users will be asked to take several photos of their trash in hand, so that the deep neural model can provide sorting suggestions based on these images. We will also integrate the bin networks from activity 2 into the application so that, after the recognition and sorting, app users can be guided to find the closest non-full bin for tossing their trash in hand. To achieve a long-term educational goal, we will design an interactive recycling game for kids to learn while playing. We will leverage the opportunity of undergraduate design project advisory for the smartphone app development. In particular, each semester during *the funding period*, we will provide a project aimed at developing/improving the app to a group of undergraduate students.

ENRTF BUDGET: $ 130,737

Outcome	Completion Date
1. A smartphone application with image acquisition and trash sorting abilities	*November 2021*
2. The above app with an educational recycling game	*June 2022*
3. The above app with communication with the public trash bin network	*June 2023*

III. PROJECT PARTNERS AND COLLABORATORS:

Dr. Ce Yang oversees the project. Dr. Martina Cardone from the Department of Electrical and Computer Engineering will be responsible of building the IoT trash bin networks, and of the supervision of the undergraduate student groups for the development of the smartphone application. *Dr. Youbing Wang* from the College of Science and Engineering will advise and work on the trash recognition and sorting algorithms.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

This project is foreseen to have a significant positive impact on the education of Minnesotans, especially younger citizens, in recycling practices. The education on recycling will take effect immediately and last a life- long time for our citizens. The project will pave the way to improve the overall recycling of Minnesota and embraces the ambitious goal of expanding the bin network to all public areas and redefining household recycling goals. Upon completion, the project team will continue to secure funding from the United States Department of Agriculture (USDA) and the Environmental Research & Education Foundation (EREF).

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Ce Yang
Project Title: Smart trash sorting for zero waste in Minnesota
Organization: University of Minnesota
Project Budget: $394,709
Project Length and Completion Date: 3 years; project ends on June 30, 2023
Today's Date: 3/4/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 331,309	$ -	$ 331,309
Ce Yang Project manager, Department of BBE, UMN, 0.08 FTE, $45,839 ((74.5% salary, 25.5% benefits)			
Martina Cardone, Assistant professor, Department of ECE, UMN. 8% FTE each year for 3 years , $52,039; 73.5% salary/26.5% fringe			
Youbing, Wang; Research assistant professor, College of Science and Engineering, UMN, 30% FTE each year for 3 years, $66,550 (73.5% salary/26.5% fringe)			
One graduate Research Assistant 50% FTE for 3 years, $148,881, 55% salary/45% fringe			
Undergraduate Research Assistants; Number TBD. 100% salary 0% fringe, $18,000.			
Professional/Technical/Service Contracts			
Equipment/Tools/Supplies			
Digital data collection for activity 1 and 2 for three years. Materials for eight trash/recycle categories will be collected and at least 2000 images of each category needs to be obtained ($16,000); 300 smart phone app tester survey data will be collected during the time window for the app development and improvement ($3,000). IoT device setup and maintenance for 200 bins in public areas: enhanced wireless microcontrollers ($10,000), micro cameras for online trash recognition for selective sites ($4,000), ultrasonic fill-level sensors ($1,500), battery power banks ($4,000), wires and circuits ($500), IoT antitheft devices ($3,000), K-12 education showcases: three tablets for app demonstration ($1,000), materials collection ($200)	$ 43,200	$ -	$ 43,200
Travel expenses in Minnesota			
Travel to trash bin network systems for testing and maintenance $2,000 each year for three years. Travel to K-12 schools, museums, MN State Fair to showcase the project and draw public attention $1,500 each year for three years.	$ 10,500	$ -	$ 10,500
Printing			
Printing posters for showcases in K-12 schools	$ 500		$ 500
Other			
Publication fees for four papers (page charges)	$ 9,200		$ 9,200
COLUMN TOTAL	$ 394,709	$ -	$ 394,709

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: University of Minnesota Indirect costs/facilities administration (54%)		$ 187,000	$ -	$ 187,000

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

Smart Trash Sorting for Zero Waste in Minnesota

Items: Pizza box
Bin Type: Landfill
Swipe to See Bin Locations!

Pizza boxes are made from corrugated card board. However the cardboard becomes soiled with grease, cheese, and other foods once the pizza has been placed in the box. Soiled paper cannot be recycled because the paper fibers will not be able to be separated from the oils during the pulping process.

IBM Watson IoT Platform

MALL OF AMERICA

Minneapolis Saint Paul
INTERNATIONAL AIRPORT
msp

*Locations for initial tests: University of Minnesota, Mall of America, and MSP airport.

Better Recycling Education for Our Next Generation

Nothing is better than a game. Hooray!

Project Manager Qualifications and Organization Description

This project will be carried out by a multidisciplinary group with a biological engineer, an electrical engineer and a computer scientist.

Dr. Ce Yang, Project Manager
Assistant Professor, Department of Bioproducts and Biosystems Engineering, University of Minnesota
Degrees:
Ph.D. Agricultural and Biological Engineering, University of Florida, 2013
M.S. Computer Science, University of Florida, 2014
B.S. Electrical Engineering, China Agricultural University, 2007

Dr. Martina Cardone
Assistant Professor, Department of Electrical and Computer Engineering, University of Minnesota
Dr. Cardone brings the expertise in wireless networks and Internet of Things.

Dr. Youbing Wang
Research Assistant Professor, College of Science and Engineering, University of Minnesota
Dr. Wang is an expert in computer vision, big data and deep learning.

Dr. Ce Yang is a MnDrive Robotics, Sensor and Advanced Manufacturing faculty member. Yang's laboratory works on remote sensing and sensor applications in the area of agricultural and biological engineering. Environment protection by various advanced sensing technologies has been the focus in Yang's group for five years. One long-term project is efficient fertilizer management using remote sensing to eliminate nitrogen runoff to MN groundwater and surface waters. In addition to agricultural operation, solid waste disposal is another major nonpoint source pollution that the group is working on in the past year. Yang's group is in connection with the Zero Waste event management team from the reuse center at the University of Minnesota and has taken many EREF courses including: General Solid Waste, Waste Diversion, Waste Collection, Waste Reduction, and Recycling. All three collaborators have access to the makerspaces and robotics labs in the College of Food, Agriculture and Nature Resource and College of Science and Engineering, where the team can work on the sample image collection, remodel of the trash/recycle bins with IoT sensors and controllers, and facility maintenance.

Organization Description
The department of Bioproducts and Biosystems Engineering of UMN tackles core issues in agricultural engineering, biological engineering and environmental engineering. The department has very dynamic interdisciplinary research activities and many researchers have received grant supports from the LCCMR program. The University of Minnesota provides a range of facilities and sufficient laboratory space to perform each of the activities described in this proposal. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.