SORT - E

SEI: Automation and Robotics

PRINCIPAL ACADEMIC TUTOR

Marina Indri,
Electronics and Telecommunications Department,
Politecnico di Torino.

EXTERNAL INSTITUTIONS

SEI, School of Entrepreneurship and Innovation.

EXTERNAL TUTORS

Raghu Movva - SEI,
Dijala D'Aveni - SEI,
Massimo Pescarollo - SEI,
Marco Cassino - FabLab Torino.

TEAM MEMBERS

Luca Cavalli
Computer Engineering
Politecnico di Milano

Tomas Monopoli
Electrical Engineering
Politecnico di Milano

Giulia Piccitto
Architecture
Politecnico di Torino

Elena Giaccone
Architecture
Politecnico di Milano

Francesco Pignatone
Electrical Engineering
Politecnico di Torino

Executive Summary

Waste management is a huge, capillary and established problem with which every inhabited cluster is concerned.
Recently, recycling of waste has proved to be a good solution to give value back to a potentially consistent portion of produced waste, however each material requires a different process to be restored for reuse, hence the need for the differentiation of produced waste.
However, the responsibility of differentiating waste is currently left to the person producing the waste, which is not always willing to make any differentiation or is not aware of the specific differentiation rules reflecting the technical needs of the recycling plants (e.g. a very common mistake in Italy is throwing non-packaging plastic like plastic toys in the plastic bins).
Later differentiation in waste collection plants is possible but extremely slow and inaccurate as a manual job, and extremely complex and expensive to be automated.

As a solution to this problem within waste management, we propose to provide relatively cheap waste bins which can autonomously identify and segregate different waste categories by leveraging on the most recent advances in computer image classification.
Such method would solve the current paradox of leaving the responsibility of correct differentiation of waste to waste producers who are only indirectly affected by the quality of their contribution, while collecting data about waste production at the same time.
Collected data can themselves be used not only for data analytics about geographical consumption and waste production, with applications like waste logistics optimization, but they can also be used to improve the classification algorithm within every bin.
Moreover, the hardware components required to build a bin with image based waste classification capabilities are extremely cheap (the core electronics on our prototype are worth 50€ and they could be made cheaper), thus allowing for a competitive price over standard bins.

Key Words

Waste Management | Computer Image Classification | Smart Bin

AR SEI Team at the Inaguration day of the Italian Tech Week, Turin, 28 June 2019.

Project description from the academic tutor.

The project was developed by the team within the SEI Pioneer program in partnership with ASP. The goal of designing, prototyping and testing an innovative robotic product was pursued exploiting the entrepreneurial formation program, offered by SEI. During the project development, technical matters were successfully dealt with, together with start-up issues, like problem vision and ideation, lean startup methodology, customer definition and market validation.

The result is the development of the prototype of an innovative robotic waste bin (Sort-E), which can autonomously identify and separate different waste categories. The main strong point of the project from the technical point of view is the adoption of recent approaches of computer image classification for the waste identification. From the entrepreneurial side, the team has developed a solid structure for the work organization, suitable for exploiting the heterogeneous competencies of the members, and excellent presentation skills.

Future improvements of the current prototype have been already envisaged to enhance its potentialities and the application domain.

Team description by skill

The team includes five master students from the Universities of Politecnico di Milano and Politecnico di Torino.
First there is **Elena Giaccone** who is an student of architecture. Her contribution was fundamental to team as she is an expert in utilizing various CAD and design softwares, that were essential in the prototype design and assembly and all the presetations.
She also has a strong passion for sustainability and green solutions that was a driving force for the team direction and vision.
Next we have **Tomas Monopoli**. He is an electrical engineer whose expertise were essential for the dimensioning of Bin-e's mechanical and electrical components. He also has a passion for the innovation market and the launching of sustainibility driven ventures. This made him extremely valuable in finding contacts and enriching connnections with other players in the field and the experts.
Next we have **Giulia Piccitto**. She is an Architect with a very strong character and a lot to prove to herself and others. She has a strong desire to be successfull and recognized as a strong leader in the world of start-ups.
Finally we have **Luca Cavalli**. He is an ITC engineering with a master in Machine Learning Techniques. Thanks to his efforts it was possible to create the core of our product, i.e. the image recognition software. Everything "smart" about the bin was written by him. His technical council was also crucial for the design of the prototype.
Last but not least, **Francesco Pignatone** is a Master Student of Electrical Engineering. He has a strong passion for sustainability and green ventures that was important for the team vision and morale. He has a natural curiosity that was essential in the conception of the prototypes mechanical functioning and mechanisms.

Understanding the problem

Nowadays only 31% of trash is differentiated worldwide. This is due to the fact that we are producing more and more waste, and we still don't have the correct infrastructure system nor we educate people about how to perform waste separation correctly.

In Italy we reach a 53% of trash differentiation rate, meaning that the rest of waste, which is 65K tons, is left in landfills or burnt in incinerators: this corresponds to 30K extra tonnes of CO_2 released in the atmosphere every year.
In 2017, the amount of municipal waste collected in Italy was almost 500 kilos per inhabitant. The largest quantities were collected in the Northeast (549 kg/inhabitant) and in the Centre (548 kg/inhabitant). Production was lower in the Northwest (482 kg/inhabitant), the Islands (460 kg/inhabitant) and the South (444 kg/inhabitant).
In the Northeast, the highest percentage of separate waste collection was also found (66.6%, since it meets the target of 65% set by the regulations). It is slightly lower in the Northwest (62.3%). The levels of separate collection in the Centre (48.6%), the South (43.3%) and the Islands (26%) are very distant, although Sardinia exceeds 60%.
In 2018, 85% of households declare to collect plastic and paper separately, 84% of glass and over 74% of aluminum.
However, not all of the differentiated waste can actually be recycled.

Thanks to household interest in the problem, the indoor differentiated waste collection contamination rate is generally under 30%, thus it produces good enough waste for recycling plants, however the contamination rate of trash collected in public spaces is often higher than 80%, which clearly makes the material unsuitable for actual recycling. The reason for this difference is mostly associated with user behaviour in public spaces, however sometimes the lack of proper infrastructures can play a significant role (like inconsistencies on the category colors and differences in recycling rules).

Circo Massimo, Rome - The day after the Rolling Stones concert (2014).

Exploring the opportunities

Recently the consolidated system has been improved with many gradual innovations to cut costs and improve efficiency.
One of the simplest tech innovations is having IoT connected bins with embedded level monitoring, that allows logistics to know the filling level of each bin to better optimize the routes over time while ensuring that bins are rarely full.
Although very simple, this simple additional monitoring information can save a significant portion of the costs of logistics. The same principle has been applied to more all-around bin monitoring systems including fire risk detection, vibrations, operators performances, and GPS location for movable bins and stealth detection.
Sometimes coupled with filling level monitoring, another common small innovation is adding compression to bins: incoming waste is compressed to reduce its volume and increase the storage capacity of bins, at the cost of more complex mechanics and higher energy consumption.
Compression, however, is limited to reducing air spaces without actually compressing the material itself, which would change its physical properties and make it unsuitable for recycling.

A further improvement to bins has been proposed more recently with the explosion of artificial intelligence applications: bins equipped with extra sensors that can have a clue about the material are able to recognize the material of incoming waste through machine learning applied to all its sensor readings.
The main advantage of these AI-based solutions is that the designer of the system does not need to explicitly model the sensor readings for different materials on incoming trash, which would be a very complex problem due to the unpredictable conditions of the trash thrown in, instead data-driven machine learning techniques can learn such statistical model directly from data. Therefore, these bins are able to additionally classify trash categories autonomously within some level of confidence and with some accuracy that can ensure an average quality standard of collected trash.
AI based solutions have been also developed in a centralized framework, innovating in the waste sorting post-processing conventionally based on human labour. In particular, recent research on robotic manipulation and object recognition allowed proposing to substitute human sorters with robotic arms equipped with sensors to detect, locate and recognize individual objects in a waste stream. Available robotic solutions can be trained to perform different sorting tasks, proving to be a very flexible solution to the problem, while being much faster than humans and suitable for demanding sorting processes with sustained load.

Centralized solutions, however, must cope with the problem of physical waste separation: impurities in waste streams can be entangled, and much more difficult to be actually recognized and segregated with respect to localized single wastes.
This entails an increased complexity, thus cost and time to market, for reduced performances compared to decentralized solutions like smart bins. On the other side, light smart bins embedded with sensors for logistics optimization and risk prevention are not directly facing the core problem of incorrect waste differentiation: they contribute to reduce waste management costs but they do not increase the rate of effectively recyclable waste. As the increase in hardware complexity is much lower than the increase in actual value, we finally aim at developing a smart bin with automatic differentiation capabilities.

Generating Solutions

The development of our smart bin has been carried out in cycles, following the lean methodology, thus integrating different prototyping phases with potential users feedback collected at showcase events, producing variations on our concept each time.
Every concept of ours has a common feature, which is our core value, the value proposition we wanted to deliver: the ability to automatically differentiate waste.

On the other hand, there are a lot of different possibilities concerning the hardware of our product and some potentially additional features. The main design variables that we considered around differentiation are bin mobility for autonomous waste logistics, which was discarded at this initial stage of development, trash buffering to reduce processing time between consecutive uses of the bin, which is important only when there can be high usage peaks, and separation mechanics, which entail many tradeoffs in volume, weight, reliability, energy efficiency and cost.

Following the lean methodology, we developed subsequently more advanced prototypes of our main concept based on feedbacks from the previous prototype at different events. In particular we developed:

1. Idea demonstrator: the first prototype, very small, cheap and simplified to show the idea at the first Demo Day (16th November 2018) to SEI tutors and possible investors of the sector.

2. Full sized demonstrator: an improved version of the first prototype, with more robust materials, improved look, faster processing of trash and realistic size. This was exposed at the Mini Maker Faire (4-5th May 2019) at Fablab Torino to have usability feedback and general suggestions from technology enthusiasts.

3. MVP for Universities: the first prototype meant to be actually viable for a specific customer, i.e. universities. It is the first linear design prototype, allowing for much bigger storage. This was presented at the Torino Tech Week opening ceremony (24th June 2019) to possible investors in the sector.

Moment of prototyping, FabLab Torino, May 2019.

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