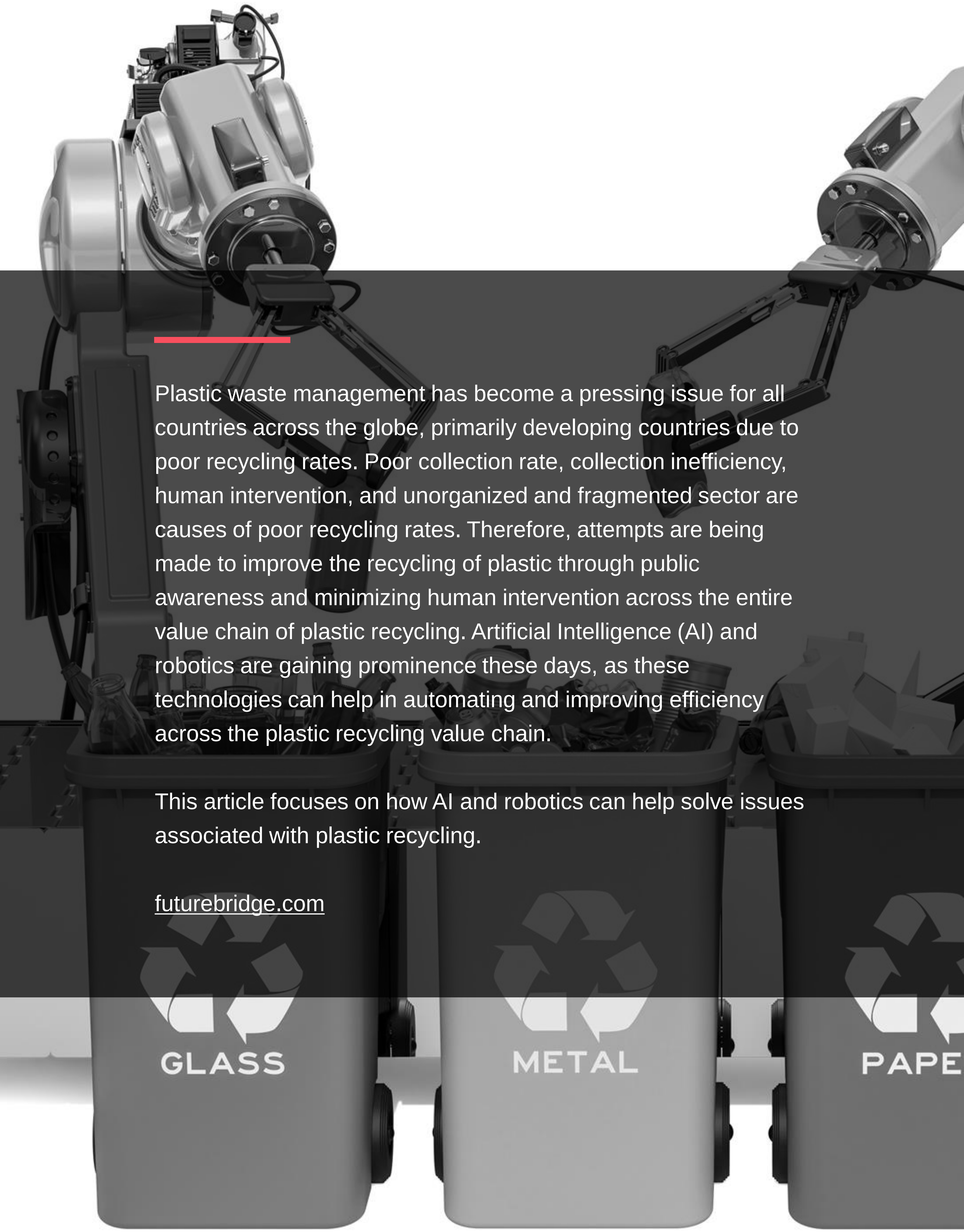
WHITE PAPER

AI and Robotics: Future of Waste Management

FutureBridge



Plastic waste management has become a pressing issue for all countries across the globe, primarily developing countries due to poor recycling rates. Poor collection rate, collection inefficiency, human intervention, and unorganized and fragmented sector are causes of poor recycling rates. Therefore, attempts are being made to improve the recycling of plastic through public awareness and minimizing human intervention across the entire value chain of plastic recycling. Artificial Intelligence (AI) and robotics are gaining prominence these days, as these technologies can help in automating and improving efficiency across the plastic recycling value chain.

This article focuses on how AI and robotics can help solve issues associated with plastic recycling.

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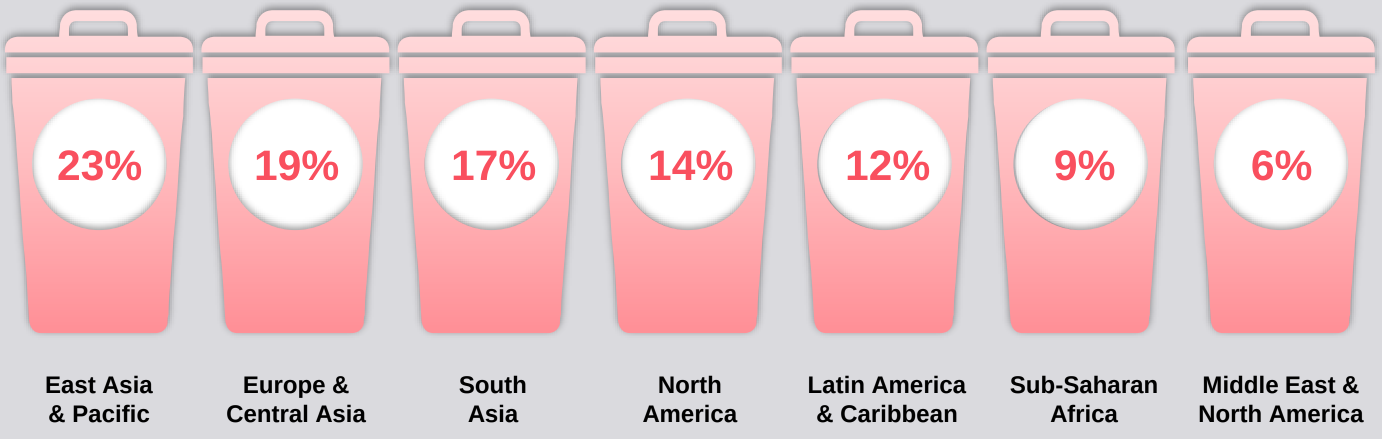
Status of Plastic Waste Generation

Solid waste management has become a pressing issue for all countries across the globe, primarily the developing countries. It affects every individual on Earth, whether it is about individuals managing their wastes or governments providing waste management services to their citizens. The amount of solid waste generated can be linked to the per capita income of the countries. As countries are transitioning from being developing to developed economies, their waste management practices are also likely to evolve and be challenged during this transition period. Rapid urbanization and an increase in population not only result in increased amounts of waste being generated but also complicate waste management practices (e.g., procuring of land for waste treatment will become difficult). As per the report published by the World Bank, the waste generation is likely to increase from 2.01 billion tons in 2016 to 3.40 billion tons by 2050.

The *Exhibit 1* indicates waste generation by different regions. High-income countries such as Europe and North America account for approximately 33% of the total waste generated globally.

Plastics, due to its properties (e.g., less weight, less cost, etc.), have replaced a wide range of traditional materials, including glass, steel, wood, and even concrete. They are increasingly used in the development of single-use products, such as packaging materials and long-lasting products, such as bottles. Apart from this,

EXHIBIT 1: Waste Generation by Region

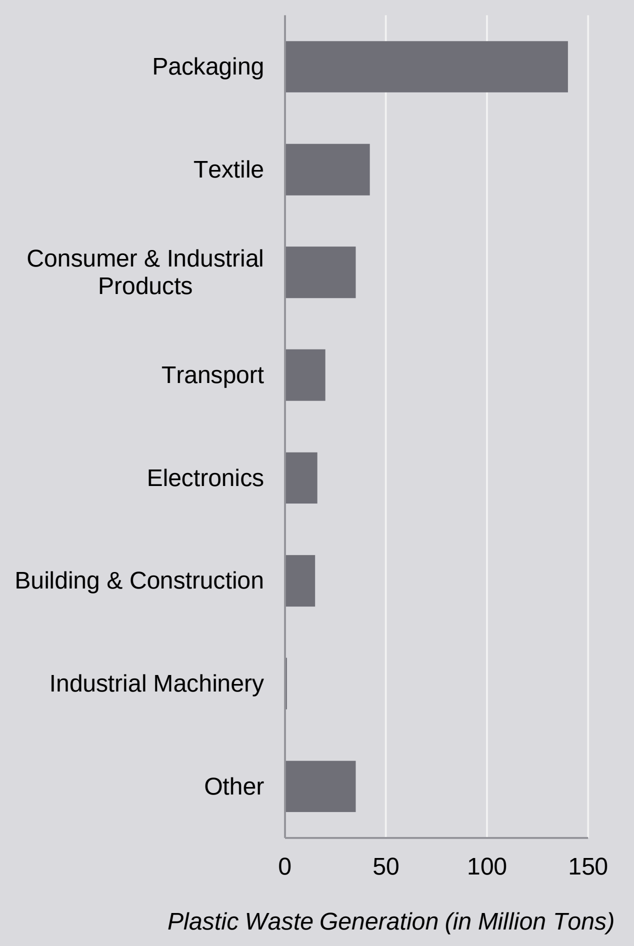


Source: What a Waste 2.0

plastics find a wide range of applications in the furniture, protective clothing, building materials, and automotive components. The amount of plastic consumed has grown consistently over the last decade and reached over 300 million by 2017. It is expected that plastic consumption may double than its current value, owing to the increased demand from developing countries, such as India and China. It is evident from the *Exhibit 2* below that plastic packaging accounts for a major share of the plastic generation globally. Most of the packaging waste is generated due to the increased use of single-use food wrapping and PET bottles and containers.

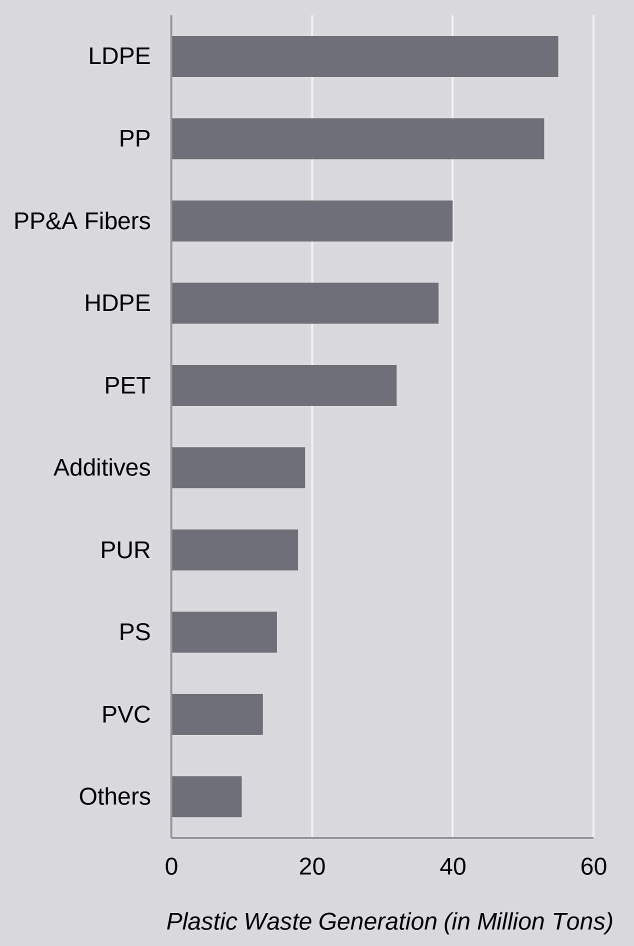
It is evident from the *Exhibit 3* that polyethylene and polypropylene are the two major types of plastics that contribute significantly to the total waste generated. This could be attributed to the increased use of flexible packaging in the food & beverage and consumer products industries.

EXHIBIT 2: Plastic Waste Generation by Industry Type



Source: Citi Research

EXHIBIT 3: Plastic Waste Generation by Polymer Type



Source: Citi Research

Plastic Waste Recycling: Current Scenario

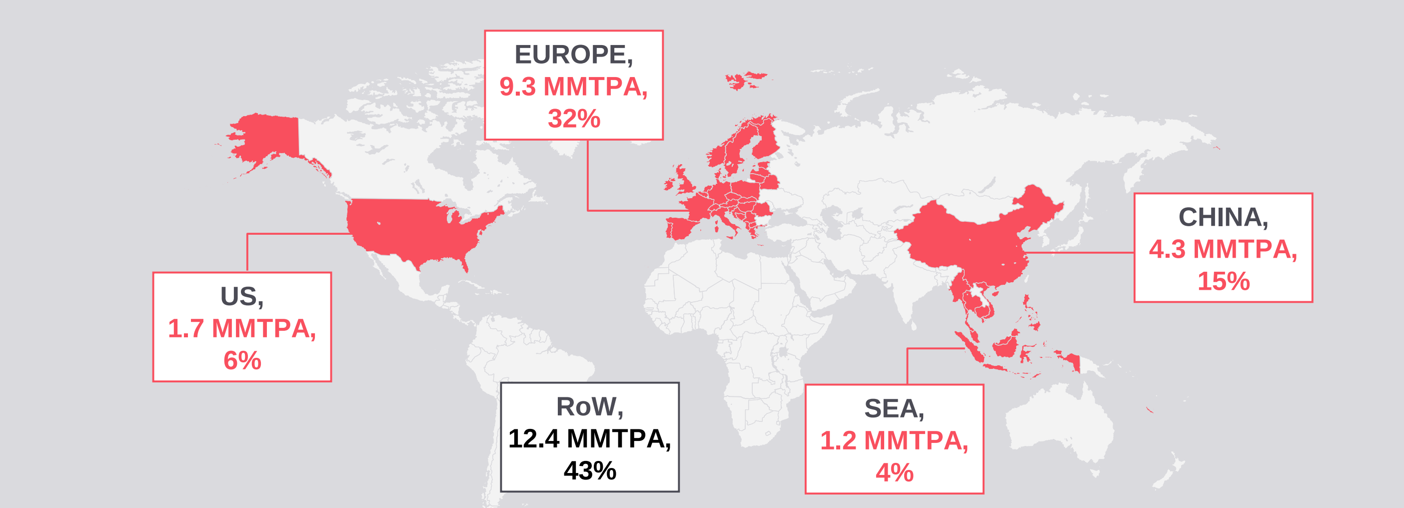
By consolidating data from various reports, it has been concluded that only 14% of the total plastic waste generated is collected for recycling while the remaining 86% is disposed (through landfilling & incineration) or littered. Europe leads the way for plastic recycling with a ~80% increase in plastic recycling over the last 10 years. This is mainly due to stringent environmental regulations regarding carbon emissions and ban on landfilling in most of the European countries.

The relatively low percentage of plastic recycling in the US (refer *Exhibit 4*) is due to the implementation of the National Sword Policy by China. Earlier, the US used to export most of its plastic waste to China with very little domestic recycling facilities. However, post the implementation of the policy, the import of plastic waste has been banned in China, along with strict contamination limits set on recyclable materials.

Despite the push from the general public and regulatory bodies for increasing plastics recycling, some challenges are hindering the progress of plastic waste recycling globally. These challenges are mentioned below:

- Inefficient collection and sorting
- Varying feedstock quality
- Frequent innovations around packaging design and material
- Unorganized and fragmented sector

EXHIBIT 4: Plastic Recycling by Region

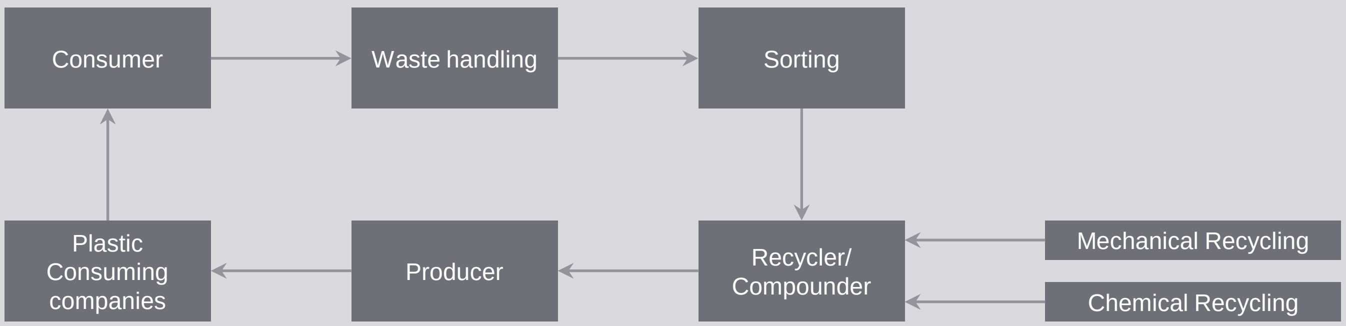


Source: FutureBridge analysis

Plastic Waste Management Value Chain

The act of plastic waste management is a complex process that starts with the collection of plastic waste and ends with the re-use of a value-added material to deliver a set of customer benefits (*refer Exhibit 5*).

EXHIBIT 5: Plastic Waste Management Value Chain



Source: FutureBridge analysis

Waste handling: This is an important step in the value chain. It involves the collection of post-consumer waste. Local authorities/government bodies are mainly responsible for the collection of post-consumer waste. Poor waste collection rate is one of the major barriers for poor recycling rate of plastics. Lack of knowledge of plastic types and the right ways to sort them are factors contributing to the poor waste collection rate.

Sorting of plastic: This step involves the separation of plastic from other waste materials. Plastic sorting can be achieved by using different technologies, namely, Near Infrared (NIR) sorting, Laser-induced Breakdown Spectroscopy (LIBS), X-ray Fluorescence (XRF) spectroscopy, and magnetic density separation. NIR is the most preferred technology for plastic waste sorting. Reasons for the widespread use of NIR technologies are listed below:

- It does not require any contact with the plastic substrate
- High detection and identification speed
- Multi-parameter detection

The current plastic sorting process is inaccurate and requires some sort of manual intervention. Efforts are being made towards automating the plastic sorting process, thereby minimizing human intervention.

Artificial Intelligence (AI) and Robotics

Artificial Intelligence (AI) and robotics are gaining prominence, as these technologies can help minimize human effort in a variety of fields. They are being explored in plastic recycling, particularly for plastic waste collection and sorting.

The use of robotics for plastic recycling might have been inspired by the popular Hollywood sci-fi movie, Wall-E, where robot trash compactors were deployed on Earth to clean the planet. With the generation of nearly 1.3 billion tons of waste every day and awareness regarding the adverse impact of inefficient handling of waste by humans, the application of robots and machines to manage waste has become quintessential. However, it is not an easy task to program robots to sort out different types of plastics. The only way to teach robots to sort out plastic waste is by showing examples of different plastics. This can be achieved through the use of AI or machine learning. AI allows the programming of robots to sort out plastics and also helps them update and improve over a period of time.

Artificial Intelligence and Robotics in Waste Management

Solution providers for waste management are exploring the various intelligent waste collection and sorting systems by using AI capabilities. Most of these systems use a combination of computer vision and intelligent sensors to assist in smart waste management as discussed below:

Waste collection: Smart bin is fitted with computer vision sensors and AI capabilities to analyze waste items that are thrown into them, and then feed the data back to a central system that can identify all waste components. The AI program provides statistics and insights on the type of waste collected, which will be subsequently ready for sorting and appropriate processing.

For example, a system developed by Bin-e identifies and categorizes the types of waste thrown in and sorts them in different bins. Further, once full, this self-sorting waste bin automatically notifies trash collecting companies, allowing the collection schedule to be optimized. The use of AI for waste collection vehicle routes and scheduling optimization is the next step the company is looking forward after smart bin.

A company named Nordsense provides waste management solutions to reduce waste collection costs and eliminate overflowing waste. Similar initiatives are undertaken by the Intelligent Internet of Things Integration Consortium (I3) to create an AI-powered smart waste disposal truck. In the future, these trucks would connect with the city-wide system of sensors. These trucks would not only be aware of the most reliable and efficient travel routes but also would be capable of detecting waste that has been left outside of bins.

Waste sorting: AI is being utilized in waste sorting activity by training autonomous robots to identify various types of wastes. Using computer vision, robots will sort through waste and group garbage based on specific characteristics. More importantly, the AI algorithm will continue to learn over time and will become even more efficient.

One such example is the SamurAI robot developed by Machinex; it can recognize recyclable materials such as cartons, plastic bottles, and electronics and place them in the correct bin. Similarly, a robot named Oscar, developed by Intuitive AI helps humans in choosing the right bin after it recognizes the trash held by the person with the help of machine learning and computer vision. All these solutions cater to sorting activity done at the point of collection. However, even after such assistance from robots, it is possible that sometimes waste cannot be separated by consumers. In such cases, AI technology is being developed for downstream waste sorting. In 2019, TOMRA unveiled its GAIN technology that uses deep learning to remove PE silicone cartridges from a Polyethylene (PE) stream with the help of computer vision. The GAIN technology is provided with thousands of images of waste types to quickly identify various inputs, resulting in a 99% success rate for accuracy when two such systems are used in sequence.

Once proper collection and sorting are done, waste can be recycled depending on whether it is biodegradable, recyclable, or non-biodegradable in nature to solve the problem of waste management. A combined effort from society and industries is required to achieve such results on a large scale.

Future Outlook for Smart Waste Management

Currently, the waste collection process in cities encounter issues, such as;

1. All collected trash is combined together that complicates the sorting and recycling process
2. Some trash bins are overfilled, and some trash bins are partially filled at the time of collection

3. Excessive fuel usage and extra costs for waste collection trucks due to un-optimized routes
4. Unhygienic conditions due to overflowing open trash bins

All of the above problems can be resolved with the implementation of AI and robotics. However, there are some barriers to implement AI in waste management that are listed below:

1. The use of ultrasonic sensors can lead to a false level of fill measurement of dustbins, as trash can be non-uniformly distributed in the bin. There is a need for multiple sensors; however, it will lead to an increase in the cost of the overall system.
2. Computer vision systems require the input of thousands, if not millions, of photos of various waste types, to ensure that machine learning algorithms will identify the correct type of waste.
3. Large-scale implementation of smart systems across the city will be costly, as it will require the overhaul of all waste containers with smart systems.
4. There is an immediate need for a national waste framework for faster implementation of AI systems for waste management.

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