Characterise-to-Sort: Advanced solid waste characterisation by multi-sensor data

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The strong temporal, seasonal and regional variations of waste and its intrinsic heterogeneity are a source of high insecurity and risk for the waste processing industry and puts high pressure on the applied processing technologies. Processing plants should therefore continuously adapt to the changing input variations to warrant optimal material valorisation. However, due to the lack of suitable (continuous and fast) characterisation methods this is often not possible. As a consequence, the input variability translates directly to the output streams. The variable quality of secondary materials strongly decreases market interest in these materials and hampers the transition to a circular economy. Quality assessment is traditionally performed by superficial visual inspection or manual separation of too small and possibly non-representative samples, and is therefore often not reliable. Moreover it is usually performed at the costumers place instead of the treatment plant, which forces struggles and prolonged negotiations between provider (processing plant) and consumer (recycling industry) of the secondary materials. In addition the task is tedious, time-intensive, subjective and rather unpleasant. To meet this need for a rapid, continuous, automatic, objective and reliable characterisation technology, a device, combining different sensor types, was built. A picture of the device is shown in Figure 1. The development of methods to extract the relevant information from the sensor data is the topic of ongoing research. The technology will allow to optimize existing and to develop new recycling processes, and assess secondary raw material quality, based on accurate, representative and objective data.

Figure 1: The characterisation device under development. A feeding chute is situated on the left that delivers the material on the conveyor belt. The conveyor belt transports the material through the sensor zone equipped with X-Ray, 3D and RGB sensors. At the right the material is collected into a container at the bottom (not shown).

Current sensor techniques in waste characterization mainly focus on surface properties, e.g. near-infrared, colour, hyperspectral or X-ray fluorescence. However waste material is often dirty and the surface properties are not representative for the bulk of the material. To overcome this limitation, a technology that sees “through” the material was adopted: X-ray Transmission (XRT). By measuring at two energy levels, called Dual Energy (DE-XRT), it is possible to determine material properties such as the average atom number and density. DE-XRT is based on the fact that the X-ray attenuation of a given material varies with the X-ray energy. Apart from the well-known examples in the medical sector and airport security, XRT is used in the food industry to recognise contaminants and in the mining industry to remove impurities from coal. In the waste industry XRT is already used for RDF purification or in combination with colour detection for sorting of construction and demolition waste, applying a binary (accept/reject) logic. To accurately interpret the information gathered by DE-XRT, extra information such as the 3D volume of the object is employed. This is measured by 3D laser triangulation (3DLT). 3DLT is a well-known technology in the industry that can measure the geometry of object at high resolution (sub-mm) using a laser and a camera. The combination of these technologies allows to fully characterise a waste stream on the level of individual particles with respect to volume, mass, shape and composition. These are also the primary properties on which the majority of (mechanical) sorting or processing techniques are based. In addition, the material and shape measurement is complemented by an RGB detector, bringing in additional information which can be used to better differentiate the materials using image processing and machine learning algorithms.

The investigated model streams originate from three residue streams from different waste processing plants:

- Shredder fluff (wind sifter light fraction) from a scrap recycling plant
- Wind sifter light fraction of construction and demolition waste sorting plant
- Residue plastic fraction from a sensor-based PMD sorting plant

These streams were manually analysed into a plethora of homogeneous material fractions: e.g. wood (hard, plywood, fibreboard), cardboard, paper, textile, stones, ceramics, glass, metals (stainless steel, copper, aluminium, iron, brass, zinc, tin, lead), electrical wires, plastics (foils, soft plastics, hard plastics, PE, PP, PET, PVC, …), insulation materials, entangled fractions etc. A selection of pictures of the manually analysed material fractions is shown in Figure 2.

Figure 2: Selection of manually analysed material fractions (15-35 mm) from the fluff (wind sifter light) fraction of a scrap recycling plant that will be used to train the machine to identify different materials. From left to right: top row: rubber, insulation, plastic foils, stones, hard plastics – bottom row: wood, entangled, stainless steel, wires, printed circuit boards.

The above material fractions are fed to the characterization device to be used as a training set. In the first stage the device parameters are optimized for an optimal discrimination of the materials present in the described waste streams. Subsequently detector response ranges can be attributed to specific material fractions. When different materials should have similar X-ray responses, information about the thickness, provided by 3DLT, can assist the differentiation. The characterisation device provides material and shape information on individual particle level and calculates tailor-made statistics on stream level. The results are compared to manual separation. In a later stage RGB information, shape analysis and object recognition techniques are considered to further enhance the material identification.