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An automated solid waste bin level detection system using a gray level aura matrix

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ABSTRACT

An advanced image processing approach integrated with communication technologies and a camera for waste bin level detection has been presented. The proposed system is developed to address environmental concerns associated with waste bins and the variety of waste being disposed in them. A gray level aura matrix (GLAM) approach is proposed to extract the bin image texture. GLAM parameters, such as neighboring systems, are investigated to determine their optimal values. To evaluate the performance of the system, the extracted image is trained and tested using multi-layer perceptions (MLPs) and K-nearest neighbor (KNN) classifiers. The results have shown that the accuracy of bin level classification reach acceptable performance levels for class and grade classification with rates of 98.98% and 90.19% using the MLP classifier and 96.91% and 89.14% using the KNN classifier, respectively. The results demonstrated that the system performance is robust and can be applied to a variety of waste and waste bin level detection under various conditions.

1. Introduction

Solid waste management (SWM) is an important environmental health service and integral part of basic urban services (Ahmed and Ali, 2004). Since the earliest primitive human society, there have been attempts to safely collect and dispose of solid waste. It is considered one of the basic services currently receiving widespread attention in many developing countries (Seik, 1997). The challenges of SWM increase with the rapid urbanization of developing countries (Ahmed and Ali, 2004; Budzianowski, 2011). A traditional SWM system consists of trucks, bins and a landfill. Due to the growing issues associated with landfill disposal, many studies are investigating waste diversion methods through an integrated SWM system (Johansson, 2006; Begum et al., 2009). The economic and demographic growth of cities is posing serious challenges to local authorities and solid waste management companies due to the increasing of waste generation and inefficient collection (Laurence et al., 2011). The solid waste planning, monitoring and management require comprehensive, reliable data and information on solid waste. However, the solid waste database in Malaysia is limited because the data are managed by individual local authorities or waste contractors (Maher et al., 2010). In order to deal with this great demand for data management, advanced information technologies, such as radio frequency identification (RFID), general packet radio systems (GPRSs), global positioning systems (GPSs) and geographical information systems (GISs), must be utilized (Hannan et al., 2011; MHLG, 1999).

The solid waste collection process can be improved by using a system that can monitor trucks and bins in real-time. Real-time information about bin level status, bin position based on their situation and status and truck data can be optimized using an advanced SWM monitoring system. Improper disposal of waste and overflowing waste bins is a serious problem in cities and requires close monitoring, which was our motivation for developing a system for real-time monitoring of bin status and waste level. Few researchers have studied bin level detection, and previous research on liquid waste tank levels is not applicable for bin level detection. The major problem in solid waste monitoring is the variety of waste that is disposed inside the bin and the environmental conditions around the bin.

Solid waste collection is the most important part of a solid waste management system. In Sweden, 3300 recycling bins have been equipped with infrared LED level sensors and wireless communication equipment to estimate the level inside the container (Johansson, 2006). The system sends an alarm signal when three of the four sensors are obstructed, which provides real-time information on the status of each bin. The system also studied the effectiveness of different scheduling and routing policies based on real-time bin data from recycling stations in Malmoe, Sweden. It was concluded that bins equipped with level sensors improved the collection process, dynamic scheduling and routing policies and operating costs and reduced the collection time as compared to static collection

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with fixed routes based on bin information. Fuchs et al. (2008) proposed a capacitive sensor principle to determine the moisture content of the bin for combustion in a furnace and analyzed possible cross sensitivities of the sensor. Reverter et al. (2003) developed a point-level capacitive sensor for bins, which was built from low-cost adhesive metallic tape and can easily be tailored to any bin. The capacitive sensors were so sensitive to humidity that they did not work well for volume measurements and were not suited for all types of systems. Patrícia et al. (2010) proposed an optical sensor for bin level detection that works despite some amount of sensor contamination, but this method required regular bin cleanings.

Thus far, little research has been presented that utilizes image processing techniques to estimate bin levels. Politecnico di Milano and the Shanghai Jiao Tong University developed an automated bin collection system by using a set of sensors mounted onto the bin. Here, the bin level was calculated based on a combination of image processing and digital distance sensors (Rovetta et al., 2009). Motion detection using image processing was used to compare a current image of bin content with a previous image in order to differentially examine the newest garbage disposed in the bin (Vicentini et al., 2009.). Subtracting two images from each other is a simple image processing technique but is limited by several drawbacks. For example, bin contamination can affect image quality, and bin weights are difficult to estimate if the images are obscured. For these reasons, new methods must be developed to achieve high efficiency waste level detection.

The main problems associated with the existing solid waste collection and bin level detection system are as follows (Chandravathani, 2006; Ping and Yang, 2006; Thomas, 2003; Maher et al., 2011).

- There is no system can estimate bin levels that contain different kinds of materials.
- Monitoring and tracking trucks and trash bins needs to be done in real-time.
- There is no advanced image processing technique that can estimate the amount of solid waste inside and surrounding trash bins.

However, it is difficult to monitor all of these problems in real-time using the existing system. Solid waste monitoring and management requires accurate information, which requires an effective and robust monitoring system. Currently, the solid waste management companies aim to minimize the total cost of routing a multiple number of trucks from a depot to the collection areas. Utilizing the real time data that is received by the server, good dynamic schedule and efficient routing policy can be implemented easily to lower the operating costs, shorten the collection and reduce the labor hours. To stimulate all these facilities, an effective and robust system is needed.

To achieve the above requirements, this paper proposed gray level aura matrix (GLAM) approach to extract bin image features. The extracted features are trained, tested and classified using multilayer perceptions (MLPs) and K-nearest neighbor (KNN) for solid waste bin level detection. A decision algorithm is developed based on bin level detection to classify the bin class and grade of the solid waste. The proposed automated solid waste bin level detection system is robust to analyze the solid waste features and estimates the amount of waste level. This potential approach can be used for solid waste segregation and recycling purpose for city corporation or municipalities. For example, different kinds, colors and situations of municipal solid wastes are collected for database development. The decision algorithm and feature extraction of the proposed approach could classify and detects the class, grade, amount and the level of municipal solid wastes for segregation purpose. The segregated wastes are then sorted for recycling purpose. Thus, the classification and identification of the municipal waste for recycle purpose could also be investigated using the proposed approach.

2. Solid waste scenario in Malaysia

In Malaysia, solid waste problem is one of the most controversial environmental issues due to inadequate management practices and indiscriminate dumping of wastes (The World Bank, 1993; Bell and Stukhart, 1986). Moreover, rapid development, growing population and changes in consumption pattern directly resulted in the generation of enormous amount of waste. However, with vision 2020, Malaysia to be a developed country, therefore, a lot of improvements have to be done in solid waste monitoring and management.

The amount of solid waste generated in Malaysia is steadily increasing (JICA, 2010). So far, less than 5% of the waste is being recycled. Despite the massive amount and complexity of waste produced, the standards of waste management in Malaysia are still poor. However, the government is currently focusing on methods to approach the challenge. Table 1 shows the total waste generation in Malaysia projected up to 2010 (JICA, 2010). It is seen that due to the growing population and increasing consumption, the amount of solid waste generated in Malaysia went up from 18,494 tons per day in 2002 to 26,419 tons in 2007. Currently, over 30,000 tons of waste is produced each day in Malaysia (JICA, 2010). This resulted in an increase amount of the national average waste generated at 0.5–0.8 kg/person/day, but in the cities the figures have escalated to 1.7 kg/person.

The availability of solid waste database in Malaysia is limited and most of these data are kept as hardcopies and not compiled or synthesized for further usage (Ping and Yang, 2006). Today, there is no existing system dedicated by the government of Malaysia to standardize, compile, verify, store, manage and update solid waste data using a single database system for future planning and management. Thus, a significant prediction tools is needed for the estimation of produced waste, routing optimization and monitoring trucks and bins to support future planning.

Based on the current situation of the waste management that described above, the authorities in Malaysia established the requirements of efficient solid waste collection. The bin level detection, monitoring and tracking can provide and obtain the related information to the waste collection and generation. The information can be summarized as follows:

- The amount of produced waste.
- The detection of the bin's level during the collection.
- The knowledge and the awareness of the level and waste situation at the bins to be used in optimizing truck routing during the collection and redistribute the bin point.

The main objective of the paper was to provide quantitative data referring to level of the bin that being collected in order to allow the implementation of organizational activities such as resource planning (number of bins and trucks needed in every zone). Moreover, the establishing of appropriate waste management policies, such as encouraging the overall reduction of Municipal solid waste using data related to specific locations, may also be facilitated. With the proposed system, the information of solid waste during the collection is updated in real time and keeps the information in the system database which starts from waste generation to its final destination.

3. Method and system

The method used in the proposed system is developed using RFID, GIS and GPRS interfaced with a low cost camera. RFID is designed to enable readers to capture data from tags and transmit it to the system without any physical connection. The data transmission range is depending based on the radio frequency level. GIS